DEPLOYMENT OF SIMULATION WITHIN DESIGN PRACTICE

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ABSTRACT

Addressing the complexity underlying design questions does not appear to be sufficient reason for simulation to be widely deployed in design practice. Useful insights must be delivered within the context of the time and resource constraints of the design process. This paper reports on recent work which addresses this issue through a computer-based project management environment.

Keywords:Integrated building simulation, use in practice, project management.

INTRODUCTION

The integration of simulation within real design projects is as much about the coordination of project information and clear views of how to approach assessment tasks as it is about efficient numerical schemes or tool ease-of-use. Work at the Energy Systems Research Unit (ESRU) has focused on the implementation of project management facilities which coordinate all aspects of the modelling process (e.g. project registration and documentation; database management; form, composition and use specification; technical systems definitions; invocation of integrated assessments and the recovery of performance metrics).

This paper describes the Project Manager (Figure 1), whose features support geographically distributed work groups and respond to the practitioner's need to shift attention between projects and evolve models as the design progresses. The underlying data model has been extended to include project documentation, images, fuel-to-emissions conversion factors and additional technical data to support the modelling of air movement, electrical power flow, mould growth and illuminance distribution. The Project Manager supports quality assurance tasks and assists simulation to alter its focus to track the needs of the design process.

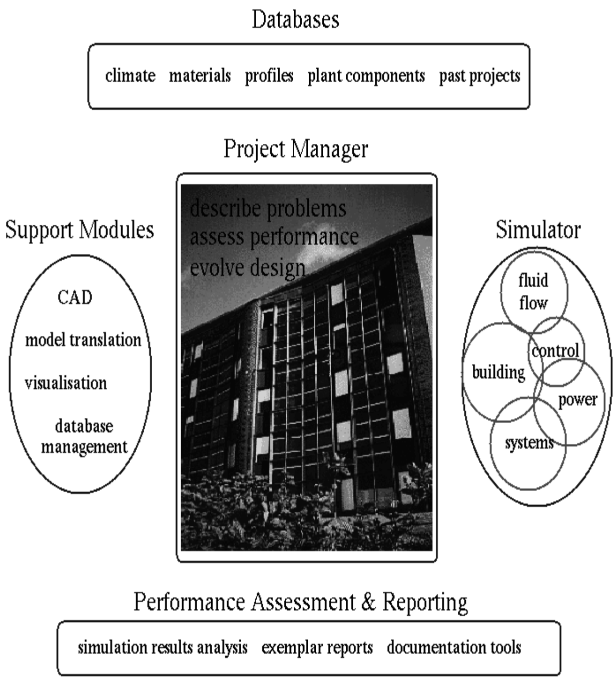

Figure 1: The Project Manager.

Simulation based design decision support places exceptional demands on practitioners. How one chooses to use simulation and how projects are managed is a critical deployment issue. Many simulation tools tend to focus the practitioner on model details, arcane data conventions and keyboard interactions. These tools tend to be regarded as repositories of numbers rather than the full range of project information required to clearly imagine future realities. Such factors isolate the practitioner and the tool from the design process, constrain deliverables and reduce the efficiency of simulation teams.

For a score of years, the simulation community has written about the importance of methodologies and the *a priori* setting of performance metrics for the project. But in the rush to service a project, how many practitioners have a clear view of the methods they use? How many managers put in place working practices which ensure that issues identified in the planning phase are followed through when computations are underway? Or that decision makers have access to a full range of performance patterns? How many groups keep an active journal of the resources they use and the actual tasks which they undertake within a project? How many practitioners approach quality assurance in an *ad hoc* manner?

Simulation support for the design process is characterised by directed searches in response to a sequence of "what if" questions. As a result, evolution of the project model and working procedures are bespoke responses to the current project problems and opportunities. Typically, simulation based projects proceed in phases, with time for the design teams to explore how new performance evidence might influence the design (hence the intermittent nature of simulation work). Such use stresses the interactive and investigative facilities of a simulation tool. The Project Manager supports interactive changes to a model in response to "what if" questions, incremental refinements in model resolution in support of directed searches, records a formal description of project evaluation metrics and then maintains a journal of user decisions, model evolutions, assessments undertaken and facilities invoked.

A METHODOLOGY FOR REAL TIME DELIVERY

Observations of successful consulting projects and support of simulation consultants who have consistently delivered information within real-time projects indicate a number of successful strategies as well as specific issues which have proven difficult for practitioners.

Firstly, translating design questions into a coherent structure which identifies the metrics of performance, and generates models which quantify these metrics against an appropriate set of boundary conditions, is one of the more difficult tasks undertaken by simulationists. Inappropriate working practices and choices of metrics, and atypical boundary conditions, will each sabotage deliverables in ways which cannot be overcome by program-based checks.

Successful practitioners exhibit the following characteristics:

- they allocate time for planning and consider paper and pencil as valuable as their workstations;
- they are adept at translating design questions into concise modelling tasks;
- they design models which embody only the essential characteristics of the design and choose boundary conditions which are geared towards understanding the behaviour of the design before they undertake long term performance assessments;
- they take the time to add clarity to their models (i.e. naming a surface office_floor in preference to surface_28), document their assumptions and structure their work;
- they follow quality assurance procedures relevant to each stage of the simulation task;
- they clarify design issues and modelling tasks and then adapt their working practices to the needs of the project;
- they calibrate their models and take time to understand performance predictions—they are sceptical of automated procedures;
- and they ensure that management and simulation staff communicate regularly and work together to convey their findings to other members of the design team and the client.

Secondly, the design process is often iterative and it is necessary for those who use decision support tools to react to "what if" questions with statements like "give me 15 minutes to alter the atrium glazing and re-run a standard assessment". This has implications for the design of tools, how tool skills are acquired and how practitioners use tools:

- tool interactions and feedback must ensure that when the practitioner makes an *ad hoc* change to the model, the actions involved are unambiguous and both data and computational dependencies are resolved (i.e. quality assurance is implicit at each step);
- the simulation model must include the metrics by which the design will be judged and a definition of the intended performance assessments to guide calculations and reporting facilities;
- skills acquisition must include sufficient semantic content so that the practitioner is able to identify which tool facilities are relevant, what parts of the tool data model will be involved and if specialist knowledge is required to define and interpret that portion of the model;

- work practices must ensure that simulation tasks which evolve in response to design changes are in keeping with the goals and resources of the project, and that the design of the model anticipates future design questions;
- staff must know how to archive working models, know when to document work and know how to undertake quality assurance checks;
- staff must be given the skills to recognise where a modification might impact on a colleague's work and be able to interpret the changes in performance patterns.

Thirdly, the design process is intermittent. A project can easily become inactive for a period of weeks and then revert to crisis status with a few hours notice. At the same time, simulation based consultancies tend to have a mix of active and inactive projects which demand attention. The demands of renewing one's understanding of a project (including the assumptions embedded in earlier work) is a particular test of the efficacy of a simulation environment and its quality assurance procedures. Rapid understanding demands clarity in the underlying data model and in reports generated by the tool, as well as consistency in the user interactions.

In this context, time wasted through badly organised and documented models is expensive time indeed. Information written down on scraps of paper does not equate with intermittent and iterative tasks. Tools which restrict internal documentation or constrain geometric descriptions under the guise of saving input time complicate quality assurance tasks and are a potential source of ambiguity. In terms of simulation deployment, shortcuts will often have the effect of increasing overall project resource demands.

Observations also show that successful projects use a mix of assessment approaches as the design progresses (for example invoking more rigorous assessments, increasing the resolution of the model or even switching tools). Successful practitioners start with the essence of the design and only add complexity when this is required to support the goals of the project. Because it only takes moments to abstractly represent a typical office with an idealised control scheme or to modify an existing model, such "disposable simulations" can be used to determine general patterns of behaviour and indicate the way forward for subsequent, detailed modelling exercises. Of course, where practitioners are able to anticipate design questions, it is usually possible to plan models so that they can be quickly evolved. Importantly, it is adherence to the metrics and goals of the project which has been observed to be the critical issue.

This is in contrast to the use of simulation to support non-directed parameter excursions of scores of possible design options. Such use is predicated on automation of simulation. Practitioners rarely explore detailed performance data in order to clarify their understanding of higher level performance issues. Without such understanding it may not be possible to determine the mechanisms by which better performance (or the mitigation of poor performance) is achieved.

Interfaces and reporting facilities which are optimised for automating step-wise changes to models and delivering standard reports may not provide the multiple views of model entities and exploratory facilities needed to support the understanding of models. The all too common case of practitioners bypassing tool interactions and contiguity checks and directly manipulating (i.e. hacking) the model data store further complicates quality assurance and can easily result in unresolved data and computational dependencies.

THE PROJECT MANAGER

The Project Manager's task is to coordinate all aspects of the building performance assessment, enable access to relevant tool functionality and maintain the coherency of the underlying data model. Although optimised for the ESP-r system, the Project Manager is model independent—it has links to the COMBINE Integrated Data Model [Augenbroe 1992], TSBI3 [Johnsen et al 1994], AutoCAD [Autodesk 1989] and RADIANCE [Ward-Larson and Shakespeare 1998]. It supports *ad hoc* modifications to a model, provides access to performance data at several levels of granularity and links computational behaviour to the current level of descriptive detail in the model. Figure 2 shows an interface which brings together images, reports and user supplied entity names and attributes to limit ambiguity. Treating model entities as objects in the user's domain and giving easy access to all attributes and dependencies (Figure 3) is one step in support of real time simulation use.

Tool developers must move on from traditional views about what constitutes a simulation model, the points at which the design team might wish to use simulation and the nature of the design questions which simulation supports. The aim should be to integrate modelling within the design process.

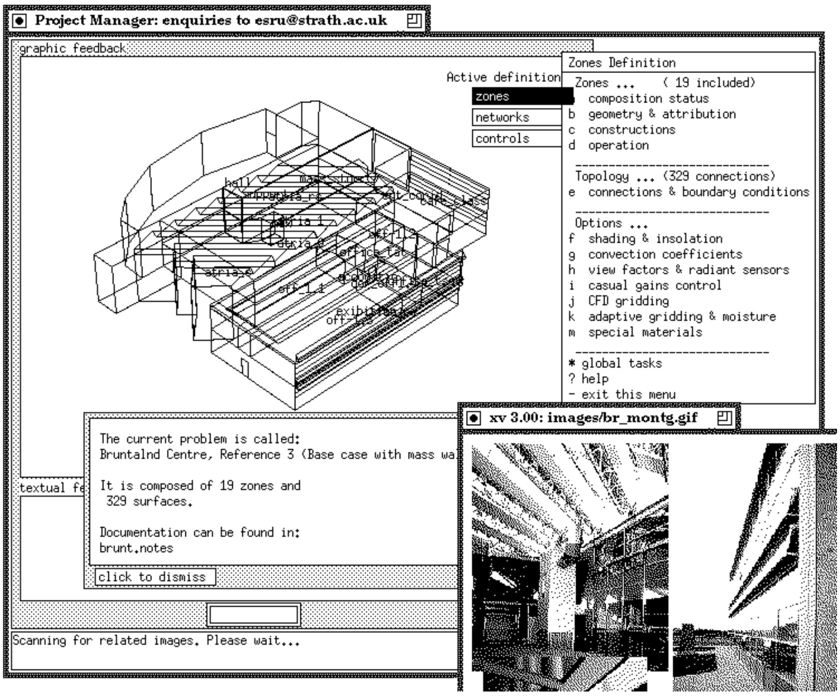

Figure 2: ESP-r Project Manager interface.

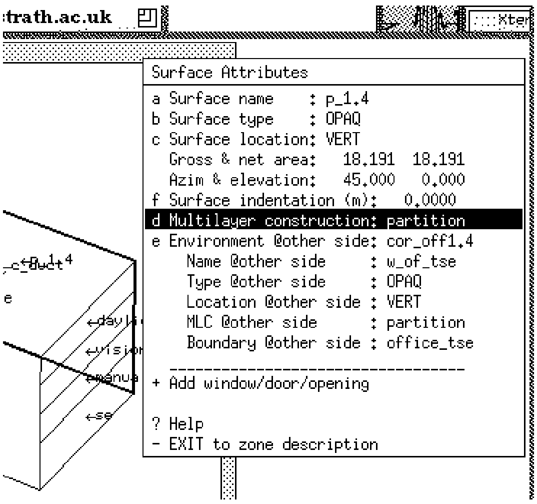

Figure 3: Object treatment of surface attribution.

In the current work several approaches have been explored:

- the introduction of *registration phase* simulation models which have no geometry but which contain site data and project documentation (text, images, hypertext links, etc.);
- a formal description of the metrics of the project to guide performance reporting;
- the use of "Integrated Performance Views" to identify the implications of design decisions across a range of performance criteria (e.g. plant capacity, energy use, atmospheric emissions, visual and thermal comfort);
- embedding knowledge of possible *useful computations* which become available as the description of the design evolves;
- a consistency manager which monitors changes in a model and resolves data and computational dependencies as in the example of Figure 4;

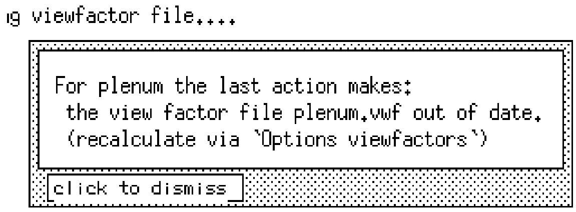

Figure 4: Consistency manager giving feedback to a user.

- extensions to the underlying data model in support of user documentation and technical systems description and *a priori* project metric definition.

The Project Manager supports the corporate use of simulation. For example, in Figure 5 a manager has added a list of current projects to a database and can browse the current state of each project.

As tools grow in complexity and data models are extended, the implicit connections between data model entities grows. The consequences of a user action must be reflected not only in the interface, but throughout the data model and the assessments which are dependent on these data. This is difficult to accomplish if the "front end" is substantially decoupled from the data model or only relates to a sub-set of the underlying tool functionality.

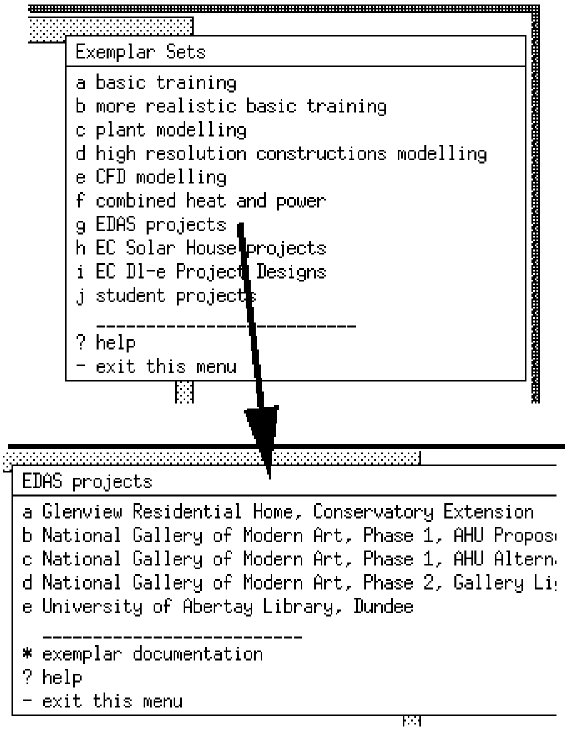

Figure 5: Access to active projects.

The task is made more difficult if quality assurance is less than ubiquitous. Reports [Donn 1997] that a majority of practitioners surveyed have no formal training in quality assurance procedures are no less disturbing than anecdotal evidence that some practitioners devote excessive project resources to the task. Both extremes imply that practitioners are not getting the information they need in a form which helps them determine that their models and their assessments are appropriate. Clearly, quality assurance is a critical aspect of simulation deployment. It should take no more than a few moments to generate a comprehensive review of the current model or to identify the nature of the differences between a base case model and a variant (see Figure 6).

Not only must program developers deliver the "buttons" which practitioners have come to associate with tool interfaces, they must also find ways to resolve data model dependencies which may be both subtle and only tenuously linked. To address this, ESRU has focused on extending the coupling between the interface and underlying data model [Hand 1998] to ensure that the Project Manager is able to access models for all possible assessment domains, and knows the dependencies implicit in a user action and the actions to take to resolve these dependencies.

In real-time deployment of simulation, observations indicate that limiting ambiguity is more important than speed of interaction. An automated facility which must be followed up by extensive manual cross checking is of questionable value, so the Project Manager informs the user of the implications of an action and asks for confirmation during automated tasks.

In real-time simulation, what is presented to a user is often more critical than how it is presented. A selection list that includes items which are inappropriate in the current context, or which uses abstract rather than user defined entity names, places a needless burden on the user. A report which forces a user to decode combinations of indices or which omits critical attributes and relationships only serves to delay the identification of errors.

APPLICATION COORDINATION

Observations of real-time use of simulation show that early performance indicators are critical and that simulation is capable of responding to this need. Materials and constructions databases often provide performance indicators which can be used prior to a full assessment. Climate assessments can provide indicators of sensitivity to changes in boundary conditions. An early indication of the distribution of solar radiation can be accomplished by changing the viewpoint to that of the sun at various times of the day and year instead of undertaking explicit insolation calculations.

Later in the design it often becomes necessary to assess the interaction between domains, such as heat and air flow in natural ventilation studies or heat and light flow in lighting studies. Such cases demand high quality performance data and practitioners assume that this implies significant resources. Such perceptions do have some basis in fact, but much of this is related to practitioners opting for over specified computations, e.g. using CFD where bulk network flow is more appropriate, or attempting to generate photo-realistic renderings inside a building when point illuminance prediction would suffice.

Figure 7, for example, shows ESP-r’s module [Hand et al. 1999] for integrated thermal and lighting assessment based on the RADIANCE system [Ward-Larson and Shakespeare 1998]. This ensures that the thermal and visual models are

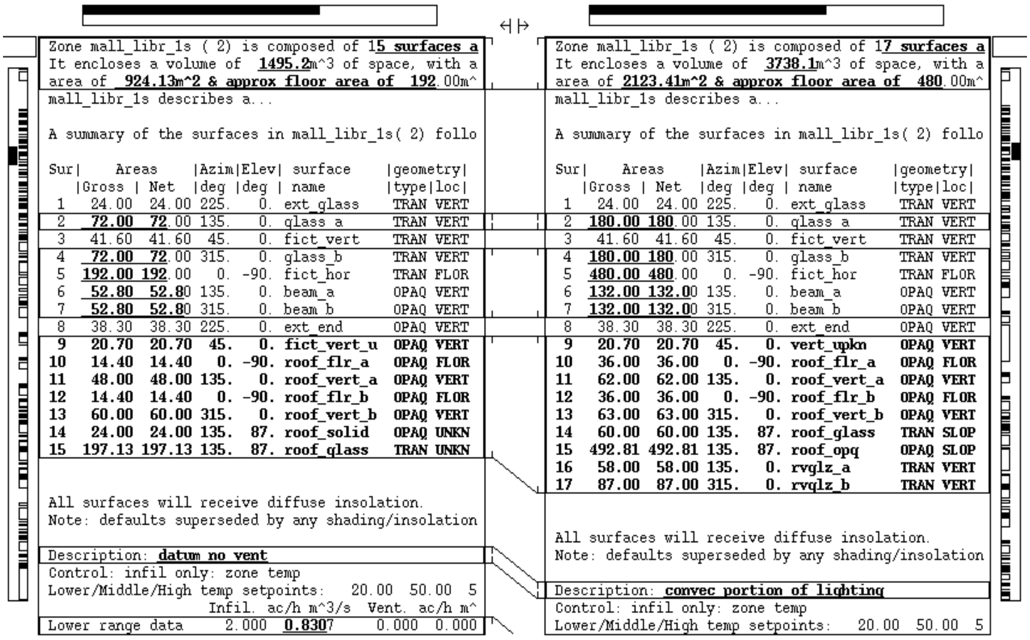

Figure 6: Using a visual difference tool to compare model variants.

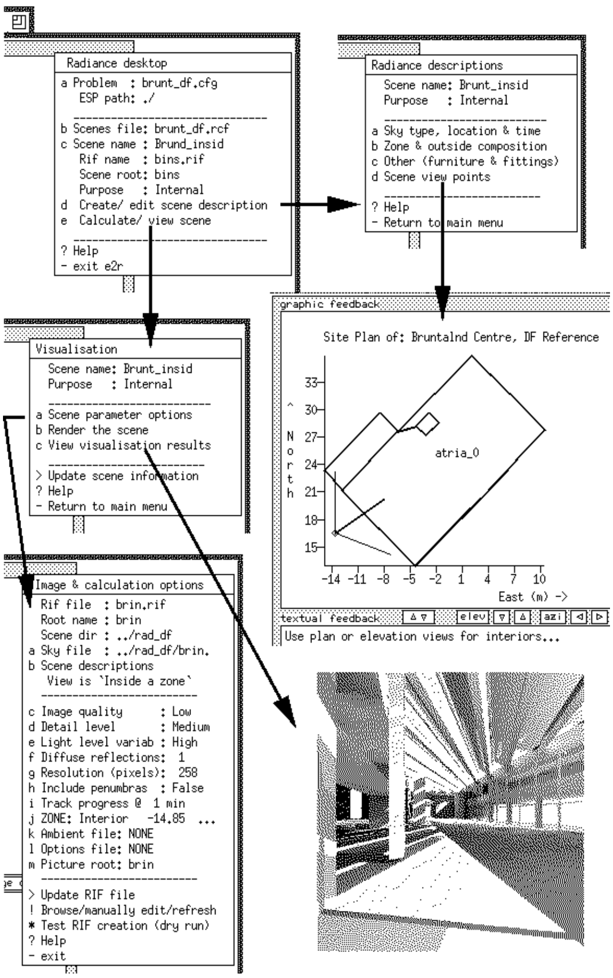

Figure 7: Visual desktop command structure.

equivalenced and coordinates RADIANCE to undertake visual assessment tasks at reasonable resolutions (e.g. internal illuminance distribution and glare).

While long term research addresses issues of integrated data models, tool developers can help the deployment of simulation by a number of near-term enhancements. .LP First, the concept of functionality following description could be clearly expressed in the interface by signalling when new assessment functionality becomes available as new information is provided. Next, tools can enhance their quality assurance and reporting facilities by including derived steady-state and simplified performance indices prior to detailed assessments. Because energy simulation requires a superset data model, it is able to export partial data models to other applications.

UNDERSTANDING PERFORMANCE PREDICTIONS

To many practitioners, the demands of real-time projects imply that they have no option but to resort to standard assessments and generate standard reports. Clearly there is a risk associated with judging performance by a limited set of metrics and in ignoring underlying patterns.

In real-time simulation the benefits of offering different views of performance must be balanced against the need to ensure that the costs and benefits of a design decision are viewed in the context of a range of issues. Taking into account the iterative and intermittent use of simulation, what is required is a mechanism that ensures that appropriate assessments are run and relevant performance metrics are extracted in a form that also identifies where more detailed study may be required.

The formal definition which underpins ESP-r's Integrated Performance View (IPV; Figure 8) [Clarke et al 1998] is such a mechanism. It allows the benefits of standard working procedures and reporting conventions to be applied to bespoke project work and then embodied in the workings of the assessment tool. Not only does it remove a considerable quality assurance burden, it provides an early identification of design problems and supports a compact view of the performance implications of design changes. By embedding the definition within the model it is also possible to replicate a particular assessment at a later date.

PRACTITIONER SUPPORT

Tool design only addresses some of the risks related to the delivery of inappropriate information to the design process. It is difficult to over-emphasise the importance of training. ESRU have used hypertext based instructional materials [ESRU 1999] in both introductory workshops and formal tutorials with increasing success. It is, however, a pleasant fiction that standard two or three day vendor workshops provide the practitioner with any more than a subset of the skills and attitudes needed to respond to realistic design projects. It is an altogether perverse fiction that managers can remain aloof from the process of simulation and that technical staff need only concern themselves with keyboard skills. Poor teamworking inevitably lead to overly complex models and missed deadlines.

Another limitation of workshops, is their tendency to deal with models that are highly abstracted or which are geared for instruction on syntax and thus are an inappropriate platform for the advanced skills needed to cope with the pace and demands of real-time design. At the other extreme, highly complex models used to impress potential users or clients may be acquired without realising the resources needed to generate and maintain such models. Simply stated, a tool developer who is not active in real-time consulting will not be well placed to give advice on working practices and methodologies.

What does work is to follow an initial workshop with mentor based training within the context of active projects. Here the issues are real, supporting information is a mix of sparse or dense, chaotic or well ordered and the need for a mix of pragmatism and inspiration in order to deliver useful information within the constraints of the project is clear. Access to a mentor clarifies how to match resources and project demands as well as working techniques and working practices.

One pattern which has proved successful is to begin with a practitioner observing the mentor undertaking the bulk of the simulation work based on a jointly defined project plan. Subsequently, the practitioner works under the direction of the mentor and finally makes use of the mentor for strategic planning, quality assurance and technical support. Practitioners who emerge from this extended mentoring have been observed to adopt work practices which are efficient and which deliver added value to their clients.

CONCLUSION

For simulation to become commonly used and integrated into the design process, new capabilities within simulation programs and a new approach to practitioner support are required. In particular simulation tools must address support for interactive and intermittent use and report performance metrics in a comprehensive way. This paper has described one implementation of these ideas.

In scores of real-time projects, the approach has been seen to provide design decision support within the constraints of consulting practice. Currently, this requires considerable effort and motivation on the part of the practitioner. However, several practioners have seen the benefits, judging by their use of simulation in further projects. In addition, improvements in the user interface and simulation capabilities have resulted from observation of simulation use in practice. This, together with enhanced practitioner skills and procedures, should lead to further integration of simulation within the design process.

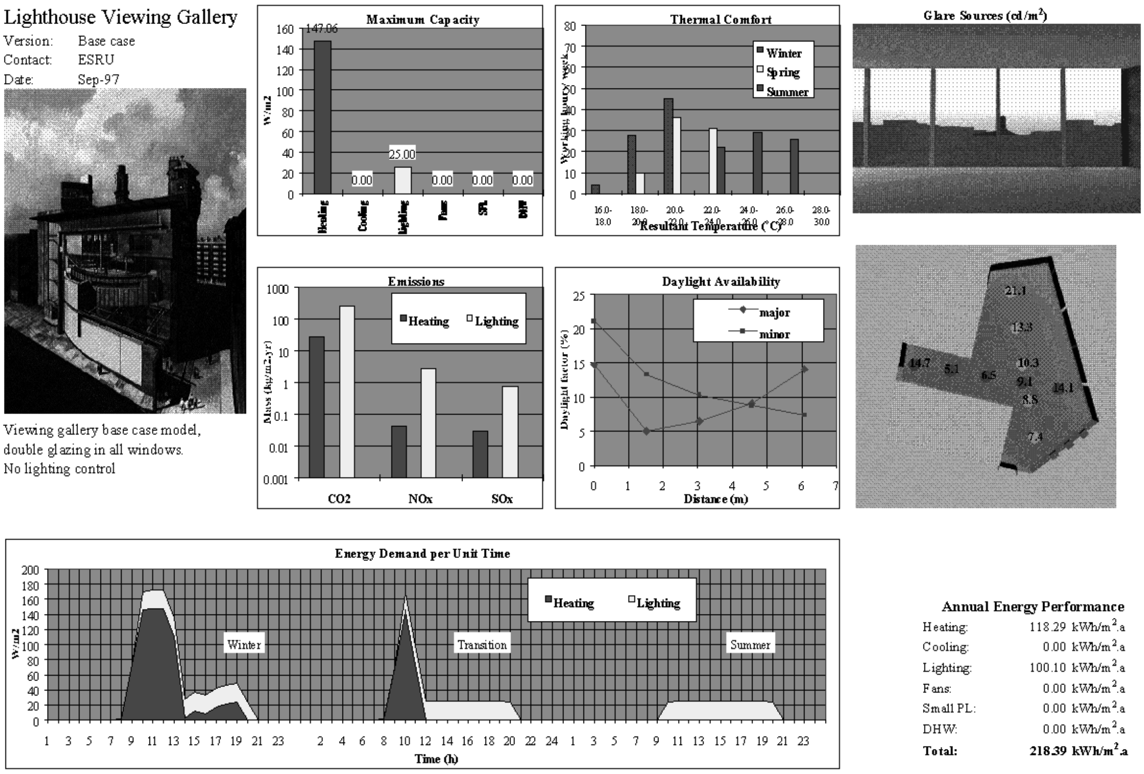

Figure 8: Integrated Performance View report.

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