INTERNATIONAL ENERGY AGENCY

CALCULATION OF ENERGY AND ENVIRONMENTAL PERFORMANCE OF BUILDINGS

Subtask B

Appropriate use of Programs

Volume 1

ENERGY CONSERVATION IN BUILDINGS AND COMMUNITY SYSTEMS PROGRAM

Preface

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the twenty-one IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources and energy research development and demonstration (RD&D). This is achieved in part through a programme of collaborative RD&D consisting of forty-two implementing Agreements, containing a total of over eighty separate energy RD&D projects. This publication forms one element of this programme.

Energy Conservation in Buildings and Community Systems

The IEA sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is sponsoring various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programs, building monitoring, comparison of calculation methods, as well as air quality and studies of occupancy. Seventeen countries have elected to participate in this area and have designated contracting parties to the Implementing Agreement covering collaborative research in this area. The designation by governments of a number of private organisations, as well as universities and government laboratories, as contracting parties, has provided a broader range of expertise to tackle the projects in the different technology areas than would have been the case if participation was restricted to governments. The importance of associating industry with government sponsored energy research and development is recognised in the IEA, and every effort is made to encourage this trend.

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects, but identifies new areas where collaborative effort may be beneficial. The Executive Committee ensures that all projects fit into a pre-determined strategy, without unnecessary overlap or duplication, but with effective liaison and communications. The Executive Committee has initiated the following projects to date (completed projects are identified by*)

Annex 1.	Load energy determination of Buildings (*)
Annex 2:	Ekistics & advanced community energy systems (*)
Annex 3:	Energy conservation in residential buildings (*)
Annex 4:	Glasgow commercial building monitoring (*)
Annex 5:	Air infiltration and ventilation center
Annex 6:	Energy systems and design of communities (*)
Annex 7:	Local government energy planning (*)
Annex 8:	Inhabitants behaviour with regard to ventilation (*)
Annex 9:	Minimum ventilation rates (*)
Annex 10:	Building HVAC system simulation (*)

Annex 11: Energy auditing (*)
Annex 12: Windows and fenestration (*)
Annex 13: Energy management in hospitals (*)
Annex 14 Condensation and energy (*)
Annex 15 Energy efficiency in schools (*)
Annex 16: BEMS 1 - User interfaces and system integration
Annex 17: BEMS 2 - Evaluation and emulation techniques
Annex 18: Demand controlled ventilating systems
Annex 19: Low slope roofs systems
Annex 20: Air flow patterns within buildings
Annex 21 Calculation of energy & environmental performance in buildings
Annex 22: Energy efficient communities
Annex 23 Multizone air flow modelling
Annex 24: Heat, air & moisture transport in new and retrofitted insulation envelope parts
Annex 25: Real time simulation of HVAC systems and fault detection
Annex 26: Energy-efficient ventilation of large enclosures
Annex 27 Evaluation and demonstration of domestic ventilation systems
Annex 28: Low-energy cooling systems

EXECUTIVE SUMMARY

APPROPRIATE USE OF PROGRAMS

IEA Annex 21 began in October 1989 with eight countries being fully involved and others having observer status. The objectives of the Annex were :

- To develop quality assurance procedures for calculating the energy and environmental performance of buildings by providing guidance on program and modelling assumptions, the appropriate use of programs for a range of applications and the evaluation of programs.
- To establish requirements and market needs in building and environmental services design.
- To propose policy and strategic direction for the development of calculation procedures.
- To propose means to effect technology transfer of calculation procedures into the building and environmental sevices design profession.

The Annex was broken down into four Subtasks.

- SubtaskA Documentation of existing methods.
- **Subtask B Appropriate use of programs.**
- Subtask C Reference cases and evaluation procedures.
- Subtask D Design support environment.

Subtask B, dealing with the appropriate use of programs, had as its objectives:

- the provision of guidance on how to select an appropriate program and data for specific applications

and,

- the provision of guidance on how programs and data are used in specific applications.

Quality Assurance (QA) is the main theme underlying the four Subtasks of this Annex. These Subtasks deal with various aspects of the quality of software used in building energy and environmental performance assessment. To map these tasks onto their QA context it was necessary to consider the sources of errors in the use of software.

Users are a major source of error in the use of software in an assessment process. One study showed predictions for a commercial building, by 21 users of the same program that varied over a range of 4 to 1 [20, Jones, 1979].

Users can misinterpret the approximations within physical models. Furthermore, because of the generality of physical models, the user is always forced to make further assumptions in order to translate the specific problem, e.g. a large office building, into the input requirements of the calculation method. Most probably mistakes will also be made in the entry of such data into the calculation method.

Unfortunately there are no specific standard guidelines or procedures available on the use of calculation methods. This source of error was the focus of the studies undertaken in Subtask B.

The Subtask was not concerned with the internal workings of programs, only with the ways in which they are used and applied, it being implicitly assumed that programs were 'correct'. 'Correctness' was investigated separately in Subtask C.

Before any serious attempt could be made to address the objectives it was necessary to develop a logical approach based on a clear idea of the extent of the problem. The overall methodological process of carrying out a performance assessment needed to be defined and its components subjected to analysis.

It was evident that information was needed regarding how those concerned with building performance assessment actually used simulation programs in practice. It was necessary firstly to ask 'what is a performance assessment?' then 'how does one carry it out?' and finally 'how can it be made into a consistent, repeatable operation?'.

The definition of a performance assessment method (PAM) may be simply stated as 'a way of determining a desired set of data indicative of a particular aspect of building performance using a predictive computer program'. Since, however, we are concerned in many cases with using the results to inform design decisions the above simple definition has been extended to incorporate the interpretation of results in design or other terms.

The definition then becomes; 'a way of determining a desired set of data corresponding to a particular aspect of building performance using a predictive computer program and interpreting the results.'

A PAM is therefore a combination of PURPOSE, PROGRAM and its METHOD of use encompassing all aspects.

PAM = PURPOSE +PROGRAM+ METHOD

A series of 'benchmark' tests was performed on a simple 'standard' building module to establish whether compatible answers would be produced by the different programs when used to perform a simple assessment of energy use using the same weather data. Initially the results showed fairly large differences which were subsequently identified as being largely due to user input errors. A repetition of the excercise produced a higher level of agreement, the remaining divergence being an indication of the different assumptions and approximations made in the programs.

The benchmark tests established that, although there were differences between programs, the differences in the results produced were considerably influenced by the way the programs were used, the assumptions made by the user and how the results were interpreted.

The solution to this problem was seen as providing documented information to the user which would enable repeatable results to be obtained when using a particular program to provide a particular set of information; a documented performance assessment method, or PAMDOC.

The objectives of the documentation were to:-

- provide a recorded description of the process of carrying out a performance assessment so as to facilitate repeatability.
- provide guidance and advice on all aspects of the program input data requirements.
- provide guidance on program configuration and sub-model selection.
- provide advice on the presentation and interpretation of the program output.

- provide a documentation archive containing advice on PAM and program selection for a particular application.

From the point of view of authors/developers documentation would:-

- facilitate PAM analysis and further development.
- facilitate the further documentation of PAMs by making available a data base of developed methods.

In order to provide documentation to fulfill the above requirements, guidance was given to the expert PAM users participating in the Sub-task to enable them to produce a range of documented PAMs, (or PAMDOCs), in a structured manner. This was accomplished by designing a proforma known as the SHELL. The completed PAMDOCs could then be incorporated into an accessible database or library.

The SHELL enables anyone to document their own PAMs in a structured manner and instructions for doing this together with a 'worked example' are available in Volume 2 Section 1.

A total of 28 PAMDOCs were produced for 9 different programs during the period of the Subtask. They deal mainly with the assessment of overheating risk as this has important implications for energy use, comfort and design decisions such as whether to install air conditioning. It is also thought to be the performance assessment most frequently carried out in practice using simulation programs.

To ensure that the set of documented PAMs were reliable, fit for their purpose and as up-to-date as possible some evaluation was undertaken. The process of evaluation, by virtue of the approach adopted, was also useful as it shed considerable light on PAM development requirements. The PAMs, produced by different authors, were evaluated by subjecting them to peer reviews, cross comparisons and by applying them to standardised case study situations using a building specification developed for this purpose. Part of the case study work involved a number of different users carrying out performance assessments both with and without the assistance of the PAMDOC. The results of these 2-stage user tests confirmed that the use of the PAMDOCs reduced the number of user errors and would have resulted in different design decisions being made.

It must be stressed here that the work carried out by the Subtask represents a 'snapshot' in the life of a PAM since the PAMs themselves will be subject to an evolutionary process of change. Each evolutionary step will, or should, require evaluation.

Some of the more important development issues identified were investigated further resulting in a number of papers being produced covering the following topics:

- Zoning
- Windows/glazing
- Ventilation
- Light switching
- Overheating definition
- Suspended ceilings

Some of the information produced in these papers is of direct use to users of PAMs but in other cases the investigations have highlighted the need for further work.

The documented PAMs represent a considerable body of knowledge and a means whereby this knowledge could be disseminated to a wider audience had to be determined to ensure that it would be readily available for use. Dissemination and availability for use also imply that the knowledge needs to be easily accessible. There are two basic types of user of the information produced. The first type would be the *user* whose objective would be to carry out performance assessments of buildings whilst the second type, the *developer*, would be more concerned with the development and documentation of performance assessment methods.

For this to happen it was necessary to place the PAMDOCs in a structured library or other data base to enable the information embodied in them to be readily accessed and related to other documents such as program input data files.

A computer-based Management Information System (MIS) to document assumptions made within programs for predicting the performance of buildings was developed in Subtask A. Although the MIS is a relatively sophisticated system and is capable of meeting all the requirements both of user and developer its development time was judged to be too long to enable it to be used for PAM development within the Subtask time scale. As an interim measure, work was put in hand to develop a simpler system. This system, Dynalink, enables a user, when providing the program input, to generate dynamic links (interactive cross referencing) between the input files, the program manual and the relevant PAMDOCs in order to access the information embodied in these files.

This sort of approach, which uses a readily available, and well used, word processing package, offers promise for the future. Some further development may be necessary if the PAMDOCs are to be used for serious commercial purposes.

Guidance on program selection is provided in terms of those features a potential user should take into account when selecting a program. No attempt has been made to say whether any one program is better than another.

The PAMDOCs themselves embody guidance on the selection and use of data as well as on appropriate QA measures to employ when carrying out building performance assessments.

The use of the PAMDOCs is facilitated by Dynalink which has been developed to provide a cross reference between the program input data files, the program manual and the PAMDOC.

Guidance has been provided on how to document PAMs using the SHELL so that organisations may be able to write and develop their own PAMDOCs in house if required.

In addition to the stated objectives a number of papers have been written relating to particular PAM development issues.

Volume 1 of this report describes the work carried out in the Subtask and comprises seven chapters:-

- Chapter 1 Introduction
- Chapter 2 Quality Assurance
- Chapter 3 Documentation of PAMs
- Chapter 4 Evaluation and development of PAMs
- Chapter 5 Information Management

- Chapter 6 Guidance on the use of PAMDOCs.
- Chapter 7 Conclusions

In Volume 2 the main outputs of the Subtask are presented:-

- Section 1 PAM Documentation Guidance
- Section 2 Documented Performance Assessment Methods
- Section 3 Interactive Cross Referencing
- Section 4 Collected Development Papers

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INTRODUCTION TO VOLUME 1

This Volume contains a description of the work carried out in Subtask B of IEA Annex 21. The broad aim of the Subtask was to document, test and develop a range of building performance assessment methods so that guidance could be given on their selection, application and method of use. Each chapter describes a particular aspect of the work and this volume may be read without reference to Volume 2 to which the reader is referred where more detail may be required. Volume 2 contains the major outputs of the Subtask comprising guidance on how to document performance assessment methods (PAMs), the documented PAMs, an interactive cross referencing system and a collection of papers concerned with particular PAM development issues. Reference is made, in this Volume and, where appropriate, in each chapter, to the publication reference numbers of reports produced during the work of the Subtask which provide the major source of information for this report.

Chapter 1

An introduction to the work carried out for IEA Annex 21 Subtask B

1.0 INTRODUCTION

1.1 Context

In the building industry and its associated research fields the need often exists to assess various aspects of building performance in order to determine the consequences of design decisions or to provide information upon which decisions may be based. There is no unique way of carrying out an assessment task and, in general, each method involves the use of different assumptions and data appropriate to the task, inevitably leading to different results.

The combination of type of assessment and the way it is performed is known as a Performance Assessment Method (PAM). It is clear that the number of possible PAMs is very large given the multiplicity of objectives and ways of attaining them. Even what appears to be a simple and frequently performed assessment, such as the annual heating energy consumption of a house, may be carried out using a variety of assumptions and a variety of computer programs. In an ideal situation any person carrying out a particular assessment using the same program should obtain the same results as any other person. This is not the case in practice because they do not share the same information, make the same assumptions, nor apply the same quality assurance procedures. When people are using *different* programs for the same assessment task the problem is compounded because of differences between programs.

Procedures for calculating the energy and environmental performance of buildings have been in existence for a considerable time and a great deal of research and development has taken place. Complex software packages and programs have been developed and used within the research community. They are now finding their way into the construction industry and are being used to address real world problems.

Initiatives from a number of European governments are encouraging the use of assessment programs for both design and retrofit applications but their use is not without problems.

A study carried out at Ispra by the Joint Research Centre of the European Community (1) has confirmed that major problems can arise. Four companies contracted to carry out energy audits of the same set of buildings, using a variety of methods, produced widely different results which resulted in big differences between the conclusions drawn. The discrepancies were found to stem from causes such as different user assumptions and differences in the level of program detail. This shows that there is a need to document not only the process of carrying out a performance assessment in all its stages but also to provide guidance on the assumptions to be made and the input data to be used. In other words quality assurance is needed to ensure that assessment tasks are carried out in a consistent and repeatable way.

As the user base becomes wider it is inevitable that the average level of user expertise and the understanding of building physics and simulation techniques will decrease. This increases the chance that a program may be used inappropriately, as a consequence of which inappropriate design decisions may be made.

It is evident that the problems associated with performance assessment methods need to be examined and proposals and methodologies for their solution developed if the current state of affairs is to be improved.

The international collaborative project, IEA Annex 21, was set up to address these problems.

1.2 Scope

Very little information exists on the different types of performance assessment methods in use and the extent to which they are used. Surveys have been carried out in North America (2) and in the UK (3). A North American survey, of energy analysis programs, showed that engineering consultants were the main users and that a relatively small number of programs dominated the market. Programs were used either because their use was mandated or in order to compare options and evaluate trade-offs.

Characteristics of programs most frequently mentioned by respondents as having influenced their purchase were ease of use and adequate documentation in a good manual. The UK survey suggests that the most common performance assessments carried out using computer programs are Building Regulations checking, condensation risk, plant sizing, temperature and humidity levels, and annual energy use. Programs are used mainly by building services consultants and local authorities with architects making the least use.

To address the problems associated with all these performance assessments would be a task of formidable proportions and it was therefore agreed that the work within Annex 21 be limited to annual energy use and overheating risk, the areas of most concern to the participating countries.

The major problems associated with the inconsistencies and errors currently observed in building performance assessment were identified as being related to the following:

- A clear statement of the assumptions and simplifications made in the program is seldom available.
- Well documented, reliable input data are hard to find.
- Guidance on how to translate a real building into the simplified form required by the program is almost totally lacking.
- Rules for the selection of climatic, occupancy and other user data are not available.
- Guidance on the type and form of program output data and its interpretation is not given.
- User interfaces need improvement to make them more appropriate to the type of user and to reduce data input errors.
- Reliable and accepted methods for assessing the accuracy and adequacy of programs are needed if issues such as professional indemnity are to be satisfactorily addressed.

If further progress to improve the assessment of building performance is to be made, the issues outlined above need urgent consideration.

1.3 Objectives of IEA 21

The project began in October 1989 with eight countries being fully involved and others having observer status.

The objectives of the Annex were :

- To develop quality assurance procedures for calculating the energy and environmental performance of buildings by providing guidance on program and modelling assumptions, the appropriate use of programs for a range of applications and the evaluation of programs.
- To establish requirements and market needs in building and environmental services design.
- To propose policy and strategic direction for the development of calculation procedures.

- To propose means to effect technology transfer of calculation procedures into the building and environmental sevices design profession.

The major theme running through the Annex was that of the need to improve quality assurance.
The annex was broken down into four Subtasks.

- SubtaskA Documentation of existing methods.
- Subtask B Appropriate use of programs.
- Subtask C Reference cases and evaluation procedures.
- Subtask D Design support environment.

Subtask B, dealing with the appropriate use of programs, has as its objectives:

- the provision of guidance on how to select an appropriate program and data for a specific application and,
- the provision of guidance on how programs and data are used in specific applications.

The Subtask was not concerned with the internal workings of programs, only with the ways in which they are used and applied. In terms of applying quality assurance to the use and application of PAMs, it was implicitly assumed that programs were 'correct' although it should be noted that a user can define the way in which they operate by, for example, setting up user-defined operational conditions or choosing between alternative sub-models. Such choices form an integral part of the methodology of performance assessment.

1.4 Approach

1.4.1 Problem definition

Before any serious attempt could be made to address the objectives it was necessary to develop a logical approach based on a clear idea of the extent of the problem. The overall methodological process of carrying out a performance assessment needed to be defined and its components subjected to analysis. It was necessary firstly to say 'what is a performance assessment?' then 'how does one carry it out?'and finally 'how can it be made into a consistent, repeatable operation?'.
How one carries out a performance assessment was largely unknown at the start of the project. Although information exists describing programs, a description of how people use them was not available. For example no documentation was available describing how a user selects the zones to be assessed, how input data are generated or how the outputs are interpreted. For any real progress to be made towards solving the problem the entire process of program selection, input data selection, decisions on program-specific modelling issues, output data specification and the interpretation process needed to be examined.
A series of 'benchmark' tests was performed on a simple 'standard' building module to establish whether compatible answers would be produced by the different programs when used to perform a simple assessment of energy use using the same weather data. Initially the results showed fairly large differences which were subsequently identified as being largely due to user input errors. A repetition of the exercise produced a higher level of agreement, the remaining divergence being an indication of the different assumptions and approximations made in the programs.

The benchmark tests established that although there were differences between programs the differences in the results produced were considerably influenced by the way the programs were used, the assumptions made by the user and how the results were interpreted.
The solution to this problem was seen as providing documented information to the user which would enable repeatable results to be obtained when using a particular program to provide a particular set of information; a documented performance assessment method, or PAMDOC.

1.4.2 Definition of performance assessment method.(PAM)

The definition of a PAM may be simply stated as 'a way of determining a desired set of data indicative of a particular aspect of building performance using a predictive computer program'. Since, however, we are concerned in many cases with using the results to inform design decisions, the above simple definition has been extended to incorporate the interpretation of results in design or other terms.
The definition then becomes; 'a way of determining a desired set of data corresponding to a particular aspect of building performance using a predictive computer program and interpreting the results.'
A PAM is therefore a combination of PURPOSE, PROGRAM and its METHOD of use encompassing all aspects.

PAM = PURPOSE +PROGRAM+ METHOD

This may be clarified by reference to Figure 1.1 which illustrates the basic components of a performance assessment process; with the exception of the program, all components are effectively user-controlled.
Subtask B has been concerned with the total process a user adopts to supply all appropriate information to the program and to organise and interpret the output information.

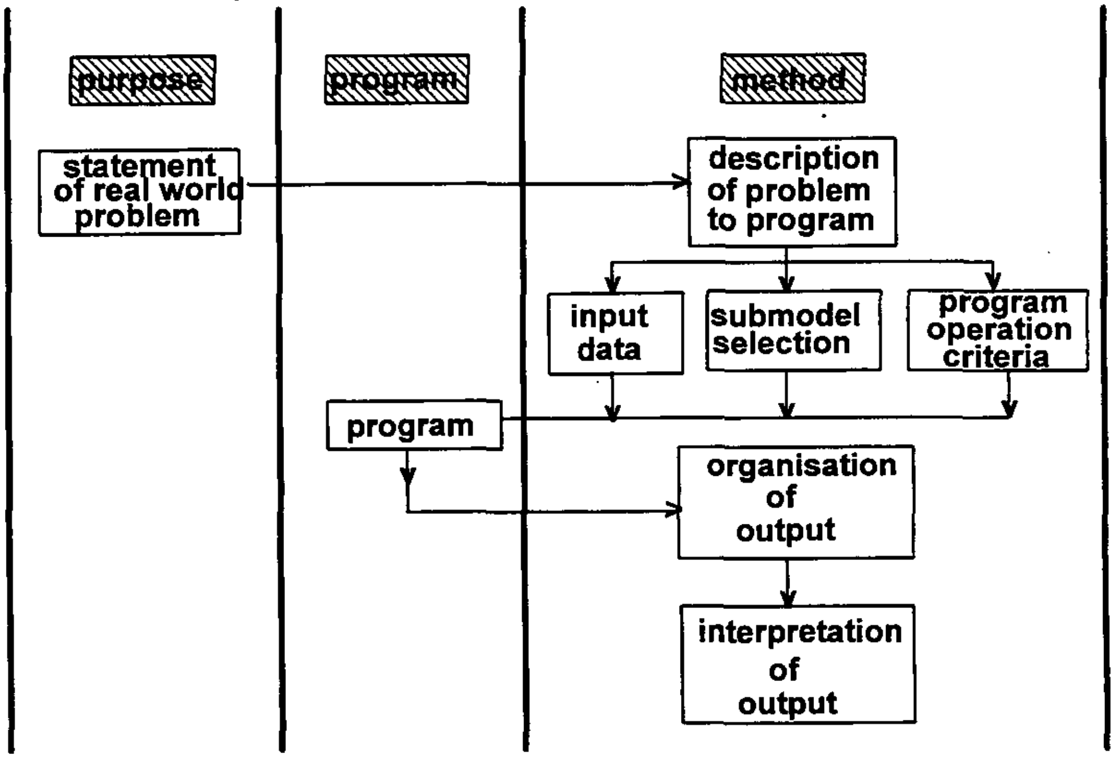

Fig.1.1 The basic components of a Performance Assessment Method

1.4.3 Documentation requirements

In order to document a particular performance assessment method there are two basic requirements:

(1) A source of knowledge; an 'expert' conversant with a particular program and the experience of using that program to carry out a performance assessment. The 'experts' were drawn from the members of the Subtask.

(2) A framework, or 'Shell', document to ensure that the documentation would be carried out in a structured manner and incorporate all the information necessary.

1.4.4 The Shell

A 'Shell' was developed, described in *Chapter 3*, which enabled a selected range of PAMs to be documented in detail. Once a set of PAMs had been documented it was possible to compare the various methodologies used, identify the differences, carry out development work and provide advice to potential PAM users.

1.4.5 PAM Evaluation

The documented PAMs (or PAMDOCs), were themselves subjected to evaluation which consisted of a quality assurance process to ensure that they were fit for the purpose for which they had been developed. This evaluation addressed issues such as:-

- How do we know a PAM is good enough?
- Is its scientific basis correct?
- Is its implementation correct?
- Does it consistently produce plausible results?
- Is it economical in use of resources?
- Will it produce repeatable results with different users?
- Is it applicable to a wide range of building descriptions?
- Does it produce 'credible' answers?.

The above questions were interpreted as meaning that a PAM should meet the following general criteria:

- It should be technically sound; the methods employed, together with any assumptions and data, should stand up to criticism on the basis of currently accepted technical practice.
- It should be free from user uncertainty; users should be able to implement the PAM in a consistent and unequivocable manner.
- It should be applicable; its suitability for application to different building types or conditions of use should be well defined.
- It should be credible to its users; they should have confidence in the results obtained.

A process was devised to enable individual PAMs to be evaluated under the above headings; a fuller description is given in *Chapter 4*.

PAMDOCs were subjected to a process of:

- peer review
- cross-comparison
- user tests
- application to case studies.

These procedures enabled problems to be identified and rectified as well as ensuring that the PAMDOCs were suitable for their intended use. The evaluation process was repeated until the documentation was judged to be complete and satisfied the criteria stated above. Although the procedures outlined above were primarily intended as evaluation tools they served the additional function of identifying important areas for PAM development.

1.4.6 PAM Development

In addition to the work outlined above, which was essentially concerned with evaluation, a number of issues were identified where it was felt that further investigation was required either to clarify the particular methodologies used or to propose alternative agreed methodologies for dealing with particular problems.
The following development issues were selected for further study:

- Selection of zones for assessment
- Treatment of window systems
- Treatment of suspended ceilings
- Overheating criteria
- Treatment of ventilation
- Light switching and blinds.

A description of this work is given in *Chapter 4* and the separate reports produced are presented in *Volume 2.*

1.4.7 Information handling

It was realised at an early stage that some form of computerised documentation handling system would be necessary as an aid to PAM analysis and development. In addition, a system had to be available whereby a potential user would be able to access PAMDOCs, evaluate them for use and obtain the necessary information to enable a given performance assessment to be run in a consistent and 'approved' manner.
From the developer's point of view it should be possible to access and edit the contents of a PAMDOC, to compare and analyse the contents of different PAMDOCs and to have the ability to create new PAMDOCs using existing documentation.
From a user's point of view it would be desirable to provide a computer link between the program input data requirements and the corresponding information provided by the PAMDOC.
Accordingly work was put in hand to investigate the use of a 'Management of Information System' (MIS), developed for Subtask A, which would act as a repository for all the PAMDOCs produced and facilitate their access and manipulation.
A simplified system for documentation management, Dynalink, was also developed to meet the more immediate needs of PAM users and developers and to provide user guidance. *Chapter 6* describes the work carried out on information management.

1.4.8 Quality assurance and user guidance.

Since the major objectives of the Annex are driven by the need to provide quality assurance, a substantial amount of effort has been devoted to QA issues which run as a thread throughout the Annex. *Chapter 2* deals with all quality assurance aspects.
Chapter 5 provides a description of the work carried out to provide guidance on PAM selection

Although the main work areas in the Subtask have been described above as essentially a linear process, much of the work has been carried out in parallel for practical reasons.
The overall approach to the Subtask is illustrated in Fig 1.2

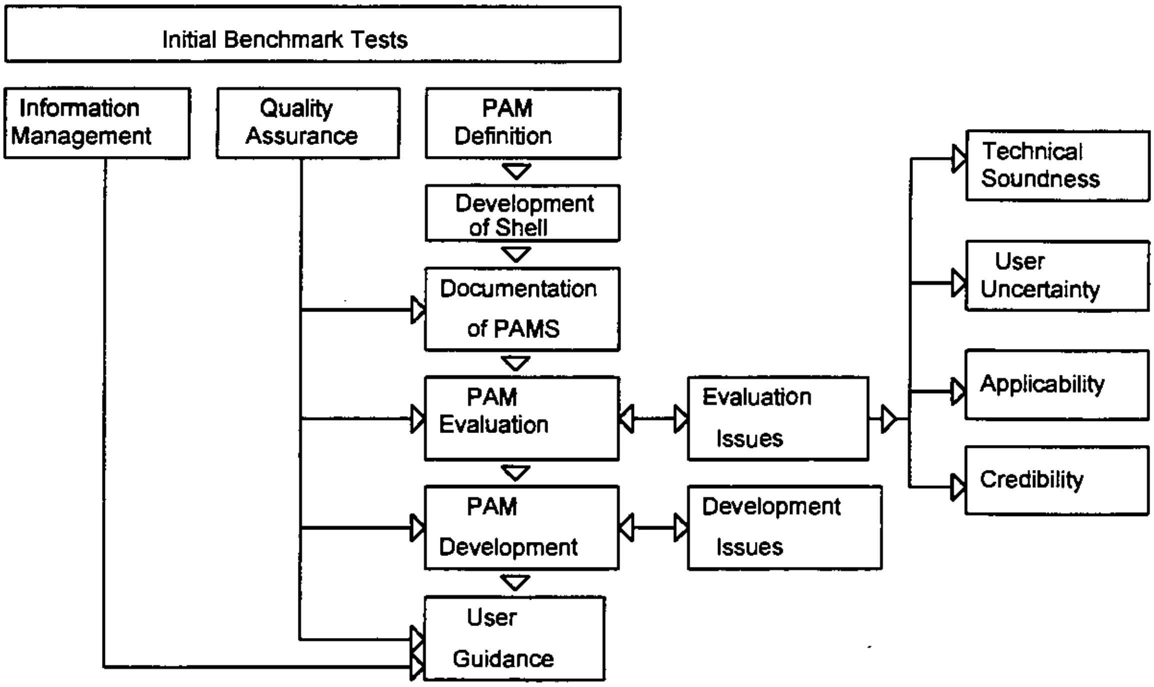

Fig 1.2 Schematic work arrangement for Subtask B

Chapter 2

Quality Assurance
IEA Annex 21 Subtask B

2.1 Introduction: Need for Quality Assurance

Reports published by BRE and other bodies have conclusively demonstrated that 90% of all building failures have their origin in faults in design and construction (design faults being responsible for 50% of all failures), Fig. 2.1, [1, PSA, 1986].

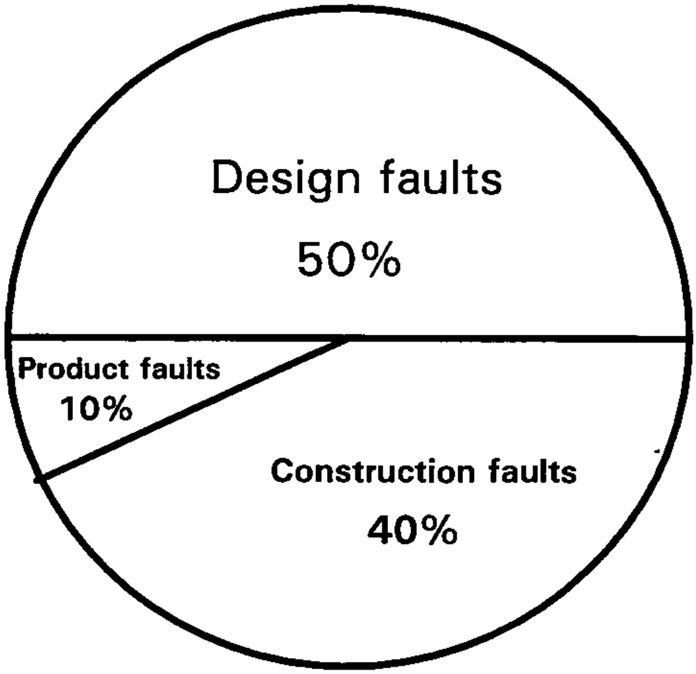

Fig. 2.1- Breakdown of building failures on basis of their origin

Quality must be designed into a product before manufacturing it. Buildings are no exception. During the design phase simple errors of judgement or failure to take full account of environmental conditions can have far reaching consequences. Faults in building are often noticed at a later stage of its life, usually when the building is finished and used. In manufacturing, the faults are noticed earlier. A fault or error in manufacturing is usually recognised at a stage where perhaps only 10% of production is affected.

The reasons that quality faults in the buildings' design and construction processes are more prevalent than in product manufacture stem from some significant differences:

i- almost all building design and construction projects are unique;
ii- the life cycle of a building is longer than the individual products used in it; and the use of a building is likely to change during its life time;
iii- established procedures exist to evaluate the quality of manufactured products whereas there are no such standards for design purposes;
iv- participants in both the design and construction of a building are likely to change from project to project; and
v- any feedback to the design and construction activities is likely to occur long after these stages have been completed.

When a computer program is used as a design aid many more reasons have to be added to the list above, the most significant are:

- vi- the appropriate boundary conditions for some of the processes involved is not well established (e.g. climate behaviour) or the user of the program may lack a detailed knowledge of data such as air leakage paths, local wind speed etc.;
- vii- these processes are idealised, generalised or simplified in order to create a mathematical model of reality suitable for implementation in computer programs;
- viii- because of (vii) and the cost involved in performing detailed modelling, a large number of assumptions and approximations are made in such programs;
- ix- the validity of these assumptions and the interaction between different algorithms is not always checked and in most cases the user may not be aware of some of these assumptions;
- x- in almost all cases the user has to make assumptions in order to fit the building and its environment into a format acceptable to the program;
- xi- tens and sometimes hundreds of data inputs are needed to describe a building and its environment; and
- xii- computers are prone to unchecked changes in the software, data and breaches of security.

Real life examples of errors caused by the above factors are abundant. Errors in data entry, of type (xi), are the most common ones, invariably happening when input files are prepared for the first time. The following example, of error type (ix), that occurred in practice shows the errors that arise from misinterpreting the program assumptions. In a building description the orientation of a window was given as South. To enter the data as input to two programs a user who was expert in program A used the same data for Programs A and B with the consequence that program B assumed the window to be facing North. Despite the checking of the input files by two experienced users of these programs, this particular mistake was only discovered when the simulations were run for a different climate and comparison of the results for the two programs showed that program B was at odds with what was normally expected.
Errors can arise from housekeeping practice for computer files and programs (error of the type (xii)). The following examples show problems that have occurred in practice. A program user was obtaining unreasonable results and investigation of all apparent sources of error proved to be fruitless. Only by accident was it discovered that a colleague with access to the same program had altered the program code and compiled it for his use without informing others. A similar incident involved the alteration of a climate data base. A tight quality control on the use of machines, programs, databases etc. has to be developed to prevent such almost untraceable sources of errors.
This chapter gives a brief introduction to QA, discusses the need for QA in the use of software for assessing energy and environmental performance of buildings, identifies the main elements of establishing QA and describes methods, guidelines and procedures developed for introducing QA in both large and small organisations. First, however, an experience highlighting the need for QA is reviewed briefly.

2.2 Quality Assurance: A Case Study

Detailed simulation programs play a major role in the Passive Solar Programme (PSP) of the UK Energy Technology Support Unit (ETSU), part of the Department of the Trade and Industry. However, reliability of these programs was undermined when results of two of the programs used in the PSP suggested conflicting design advice. Figure 2.2 shows results for ESP [2, Clarke, 85] and SERI-RES [3, Palmiter, 83] predicting design trends, energy saving and absolute energy for a simple passive solar house (Linford House [4, Everett, 85]).

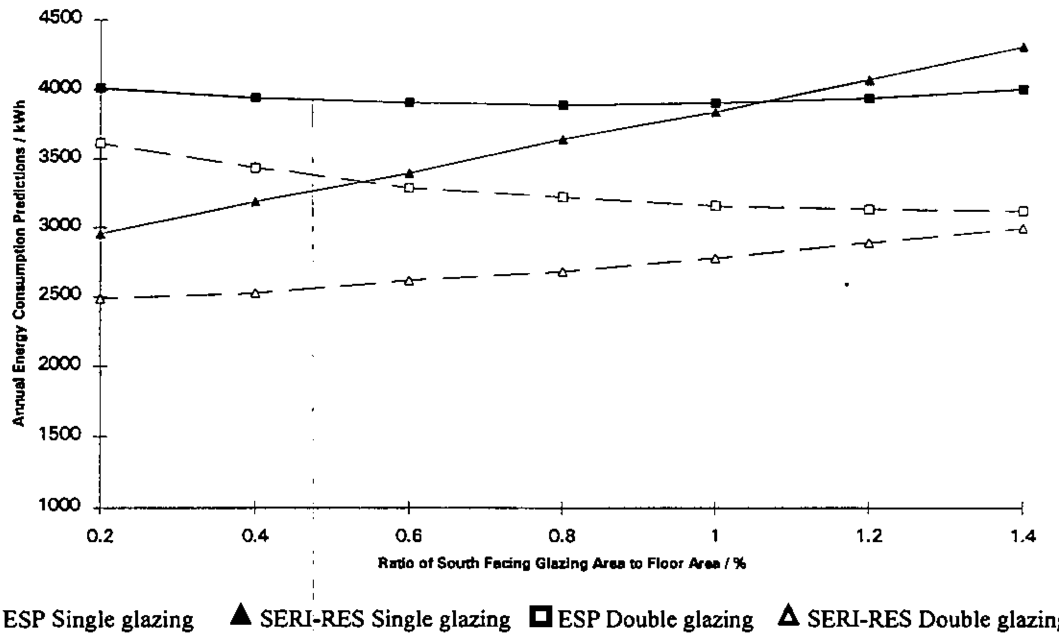

Fig. 2.2- Comparison of annual energy consumption predictions made by ESP and SERI-RES for the Linford Passive solar house. Results prior to Applicability Study

A seven man year research initiative, Applicability Study 1 (AS1), was funded by ETSU and led by De-Montfort University, UK (then Leicester Polytechnic) [5, Lomas, 92]. Some of the main aims were to identify the design problems for which detailed simulation programs can be used with confidence, estimate the inherent uncertainty in their predictions and provide guidance on the optimum method of using such programs.

From the beginning, it was recognised that a tight quality control, in particular for input data preparation, was needed to ensure the reliability of the research results.

Detailed simulation programs typically require a large number of input data. Because of the different input requirements of these programs it is difficult to derive completely consistent sets of data input. Furthermore, the output capabilities and nature of these programs are also different and require careful interpretation.

To minimise the scope for human error in input data several measures were taken. One of these measures which also aimed to develop compatible data for the three programs involved (ESP, HTB2 [6, Lewis, 85] and SERI-RES), was a data "input proforma" [7, Parand, 89]. In the proforma, values were recorded for every single input parameter required by each program. The format used allowed side-by side comparison of the data required by the different programs, for the same building feature. Omissions, discrepancies or incompatibilities in input data were therefore easily identifiable. For each base case simulation an input proforma was prepared by the project leader. The three researchers then prepared individual input files required by the program for which they were responsible. After they had been checked by their producers, these files were sent to the other two researchers to be checked. Variants of input data to reflect different designs were then produced and simulations started automatically. Figure 2.3 shows this QA process as adopted in the Applicability Study.

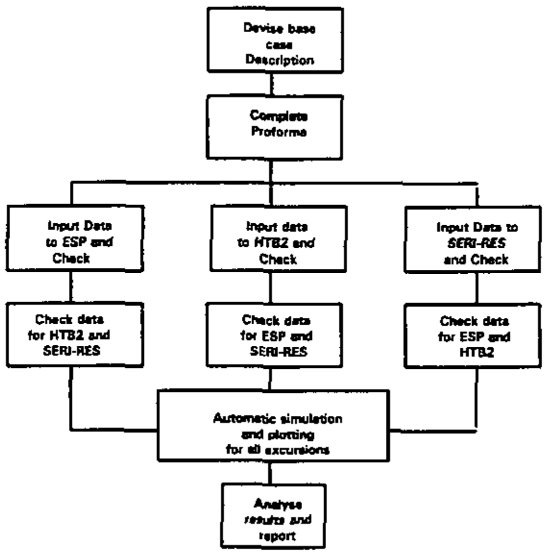

Fig. 2.3- Quality control procedure in Applicability Study 1.

Figure 2.4 shows the comparison of original energy use trends predicted by ESP and SERI-RES for the *Linford House with those obtained in* Applicability Study 1. Clearly, the design advice they produced in the AS1 was substantially the same as opposed to that of the earlier study. It was concluded that this was primarily due to improved quality control and in particular to the efforts to ensure compatibility in the building description and occupancy data supplied to the two programs.

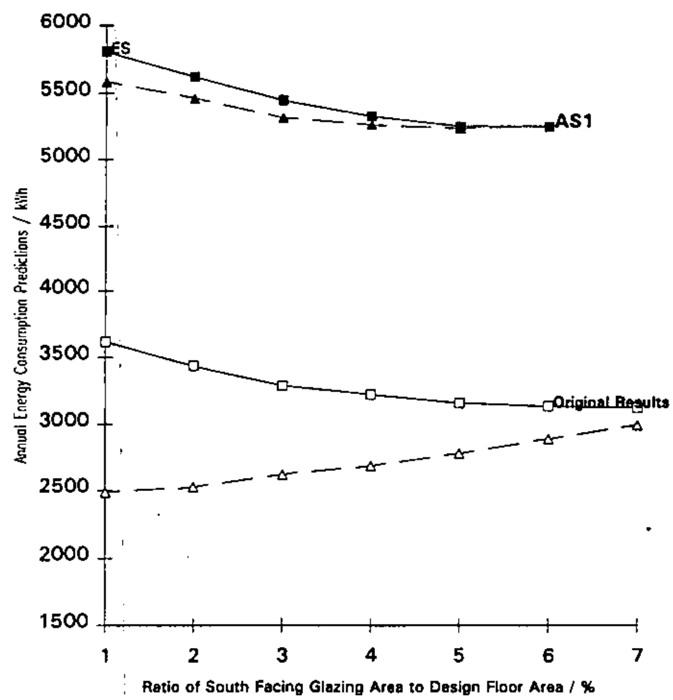

Fig .2.4- Comparison of original energy use trends predicted for the Linford house with those obtained in Applicability Study 1 (Double glazing case).

2.3 Quality Assurance: Definitions and Standards

Quality is often thought of as equivalent to excellence or a high standard attributed to a product or a service. This may have led to some confusion between quality and expense.

The Standard's definition is [8, BSI 87]: "Totality of features and characteristics of a product that bear on its ability to satisfy a given need."

Quality is, therefore, fitness for purpose; the ability to provide what a client requires.

Assurance on the other hand is a declaration given to inspire confidence in, for example, a particular organisation's capability.

Quality Assurance (QA) is a declaration given to inspire confidence that, say, a particular organisation is capable of consistently satisfying clients' needs.

The Standard's definition is:

"All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality."

It is not within the scope of this paper to define all the terms used in QA. Most of these are given in ISO 8402-8986. It is, however, necessary to introduce some of the main concepts here.

QA is often defined as an exercise that enables an organisation to "get it right first time, every time". To achieve this an organisational structure of responsibility, activities, resources and events that together provide procedures and methods of implementation of QA is needed. This is defined as a Quality System. ISO 9000 [9, ISO, 1989], and its equivalent European Standard, EN 29000 [10, CEN, 1990] and the British Standard [11, BSI, 90] lay the ground rules for a Quality System.

QA, therefore, is a management process designed to achieve stated objectives consistently. Like all management processes, QA cannot be successfully implemented unless there is a commitment to QA by the management of the organisation. This commitment and the ways and means of its enforcement form the Quality Policy of the organisation.

Once the quality policy and the quality system are in place a Quality Plan is drawn up. This consists of specific practices, resources and sequence of activities relevant to a particular product or service.

A Quality Audit is an examination of all activities, procedures and processes that is carried out to ensure that all the arrangements set out in the quality plan are implemented effectively in order to achieve the objectives.

Quality Control includes all activities that are necessary to inspect and make sure that the defined requirements are met. Inspections and checks at different stages of production, process or service are parts of quality control.

Traceability of every process and activity in the Records is vital for the successful implementation of QA.

The Quality Manual sets out and defines all elements of a Quality System and hence forms the most critical part of the QA documentation.

In simpler terms than those given above, QA can be defined as planning what to do, doing what has been planned and recording what has been done so that this can be subjected to independent checks. Implied in this definition is that management has to:

i- study and identify what is the best practice for carrying out the tasks to produce a product or to carry out a service, within the constraints of their financial and manpower resources (let us call these methodological issues);

ii- devise procedures for carrying out the identified best practice, (we call these procedural issues): and

iii- put in place an organisational structure of responsibilities, activities, resources and events that ensure that the above procedures are carried out properly, (these are Quality System issues).

As such, quality assurance cannot be prescribed for every organisation, it is up to the individual organisations to set up the quality system that suits them best. In particular, the methodological and procedural issues are very specific to the type of product and service the organisation offers. Similarly, the Quality System has to be tailored to the requirements and nature of the activity of an organisation. However, if an organisation wishes to be certified as a Certified QA firm, to benefit from the immediate credibility that certification gives, it has to abide by their national standard procedures (e.g. BS5750 in the UK, [11]). Since these standards are the results of many years of experience, research and study on the related subjects, even if one is not interested in certification per se, it is still sensible to comply with these procedures as far as possible.

To introduce QA, the three categories of issues discussed above have to be addressed according to the nature and type of activities involved. The nature of activities in organisations involved in the use of calculation methods for assessing the energy and environmental performance of buildings has been the main subject of Subtask B.

2.4. Quality Assurance and the Work of IEA Annex 21

QA has been the main theme underlying the four Subtasks of this Annex. These Subtasks deal with various aspects of the quality of software used in building energy and environmental performance assessment. To map these tasks onto their QA context it would be useful to consider the sources of errors in the use of software. The main sources of error in evaluation of the performance of a building can be traced to three main sources.

i) Physical Models
These involve translating the real world objects, buildings, walls, doors, site, sun, sky, etc., and their interactions and thermophysical processes, (conduction, radiation etc.), into data and algorithms (a model). These translations always involve simplification of the real world. These are assumptions and approximations that can be regarded as unavoidable. However, depending on the purpose for which the model is to be used and the level of accuracy required the level of approximations may vary. As a result the range of applicability of the models will vary. Detailed knowledge of these assumptions and approximations is necessary for the selection of the appropriate model or program to be used in an assessment activity. Unfortunately, user manuals and program specifications usually fail to make these assumptions clear. As far as the authors are aware, no standard exists for documentation of all the assumptions and approximations used in such software.
Subtask A addresses the issue of documentation of models and programs in a uniform, structured and unambiguous way. A great deal of effort has been expended on the design of these structures so that both the explicit and implicit assumptions are captured. Such a documentation will facilitate the selection of the appropriate models for the question in hand. Furthermore the use of a uniform format will allow researchers and model/program developers to study the differences between modelling assumptions and analyse the results obtained from them. Such studies will lead to the improvement of models and/or identifications of gaps that need to be filled by developing new models.

ii) Calculation Methods
The physical models are translated into mathematical models which in turn are modified by certain procedures to create calculation methods. Calculation methods can be manual, such as most of the UK CIBSE Guide methods [12, CIBSE, 86], or computerised. The manual methods have to be simple and easy to follow. This, however, does not mean that they are always free from errors. The computerised methods are more prone to contain errors.
For example, the wrong type of approximation or assumption could be used and mistakes can be made in the translation of mathematical models into computer (or procedural) models. The latter type can be logical (design of the procedure and or method) and/or implementational (bugs).
Analysis of software quality is very difficult. Standards have been set up for ensuring quality of software development. For example, a model procedure for quality assurance of software has been developed by the IEEE [13, IEE, 90]. BSI has also

produced a draft guideline for application of BS5750 (and its equivalent ISO 9001/2) to software products [14, BSI, 91]. ISO 90004 (89 edition), also gives guidelines on software validation. However, these Standards are of general nature and mainly address this issue at the development stage.
Subtask C addresses the issue of model/program evaluation at the specific level and aims to develop a set of techniques, e.g. comparative benchmark and empirical tests etc., to identify implementation errors as well as the applicability and validity of approximations used.

iii) Users
Users are a major source of error in the use of software in an assessment process. One study showed predictions for a commercial building, by 21 users of the same program that varied over a range of 4 to 1 [15, Jones, 1979]. The situation has not improved significantly as recent studies suggest [16, Bloomfield, 86] and [17, Chapman, 91].
Users can misinterpret the approximations within physical models. Furthermore, because of the generality of physical models the user is always forced to make further assumptions in order to translate the specific problem, e.g. a large office building, into the input requirements of the calculation method. Most probably mistakes will also be made in the entry of such data into the calculation method.
Unfortunately there are no specific standard guidelines or procedures available on the use of calculation methods. This source of error is the focus of the studies under Subtask B of IEA Annex 21. QA aspects of the use of software in building energy and environmental modelling are naturally addressed within this Subtask.
Subtask D addresses the QA issue in a different way by focusing on the requirements for a design support environment (DSE). It deals with higher level issues such as usability of the software, integration of design tools and automation of design tasks. Using such systems can reduce many of the errors introduced by users. For example, using direct entry of geometrical data from Computer Aided Drafting tools (CAD) into thermal models and/or direct entry of data on properties of materials and building components such as doors and windows, will greatly reduce the chance of accidental mistakes in data entry. Furthermore, integration will improve design consistency by allowing different design tools to work on the same objects. Similarly, conflicting solutions imposed because of different requirements in a design can be identified and avoided. For example, overheating and lighting requirements may offer conflicting solutions. This can be avoided in an integrated design support environment. Such integrated building design systems are just emerging.
The remainder of this chapter reports on the work carried out within Subtask B. In this Subtask a number of methods and procedures addressing methodological, procedural and Quality System issues have been developed. These include: a Sample Quality Plan for carrying out performance assessments; a number of routine checks for Quality Control of the assessment carried out and finally a Sample Quality Manual for introducing formal QA.

2.5. Sample Quality Plan for Using Calculation Methods

The sequence of activities normally carried out in performing an assessment, is shown in Figure 2.5.

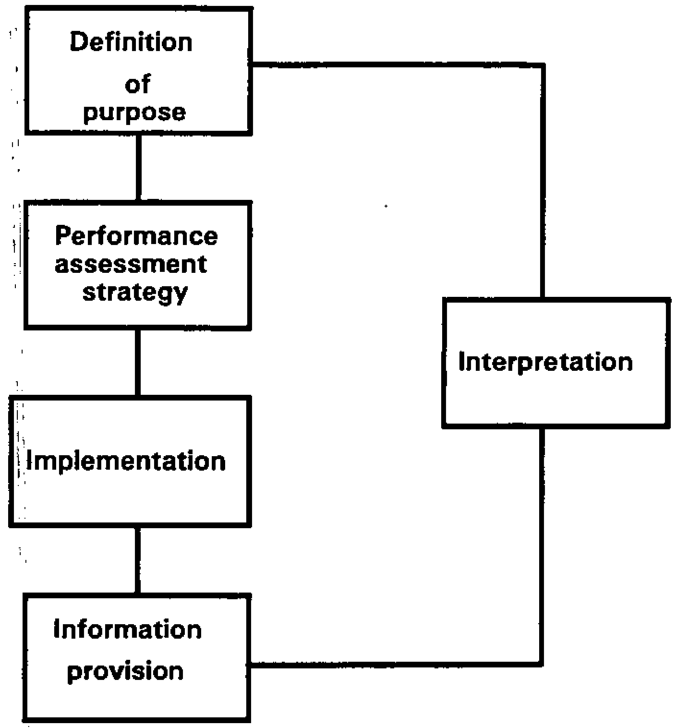

Fig. 2.5- Components of Performance Assessment Method

The components of this process are further elaborated below.
As an example, consider a consultancy office that is given the job of designing a building and its services to maintain a comfortable environment for the occupants throughout the year while minimising both the cost of installation and maintenance. Assume that the architect and the HVAC and lighting engineers decide to use a computer program to assess the performance of their various designs.

a- Definition of Purpose
The architect and/or engineer must know exactly what the building will be used for. Any special features which may influence the design or its performance (e.g. atria, pool, orientation, need for 100% fresh air ...) should be identified and agreed with the client. The level of thermal comfort is established and agreed with the client (e.g. hotel room temperatures should not go below 18 ^{o}C in winter for longer than 2 hours at a time, or higher than 26 ^{o}C in summer for more that 50 hours in total, but not on successive days, similar criteria for humidity, glare and level of lighting).
Each and every aspect of design, as defined in the brief is considered and defined (e.g. what is meant by overheating, what is the objective with respect to energy use etc.). When these aspects and the purpose of design have been clearly defined, related questions have to be formulated. For example would the building overheat as the

design stands? If the south facing glazing area was increased to 60% of the surface area, what is the consequence on annual energy use?

b- Strategy for performance assessment

Decide on a strategy for the performance assessment. This involves consideration of numerous factors including:

- the information required to answer the question,
- main features of thermal processes influencing the performance,
- criteria for the assessment of the performance,
- choice of program or calculation method,
- the rigour and depth of the performance assessment method,
- the level of representation of the building/plant and their features,
- time and resource constraints,
- risks involved and the consequences of an incorrect assessment,

It is at this stage that an appropriate performance assessment method (PAM) has to be selected based on the above decisions and information obtained at the definition stage.

c- Implementation

This involves preparing input data, making certain assumptions, preparing input files as required by the program or calculation method, performing a test run and finally the main simulations or calculations.

The major QA task occurs at this stage of the process. Here the data acquired in the definition stage is translated for use with the program chosen, in the strategy stage, to implement the PAM. Routine checks must be made at this stage to ensure that the implementation is carried out correctly.

d- Information provision

The selection of the type and form of information for presentation to the client must be addressed based on the criteria selected in the definition stage. In the present example, if the agreed criterion was the number of hours that a zone's temperature is above a certain limit, this might be shown graphically or in a table for different design alternatives.

e- Interpretation

Certain assumptions may influence the results, for example the distribution of the transmitted solar radiation could influence the wall surface temperatures, and hence, in our example, the comfort temperature. Such assumptions should be borne in mind when interpreting results.

When interpreting the results, one must make sure that the output data are clearly understood. For example definition of the time for which results are reported and, if appropriate, the way results are averaged over the reporting period must be clearly defined and understood. In our example, the number of hours must be for occupied hours only.

f- Reporting

Finally, a report giving details of what has been done, and what tests and checks have been made should be prepared. Sufficient details will be needed for the report to the client.

Each of the above components consists of several activities which have to be broken down to simple and indivisible specific activities or steps. This is shown in Figure 6. Once these steps have been defined and documented they can be used as intermediate inspection points for tracing and checking that the correct procedures have been followed. Some proposed points for checks by a second person (or Quality Assessor) are indicated in Figure 2.6.

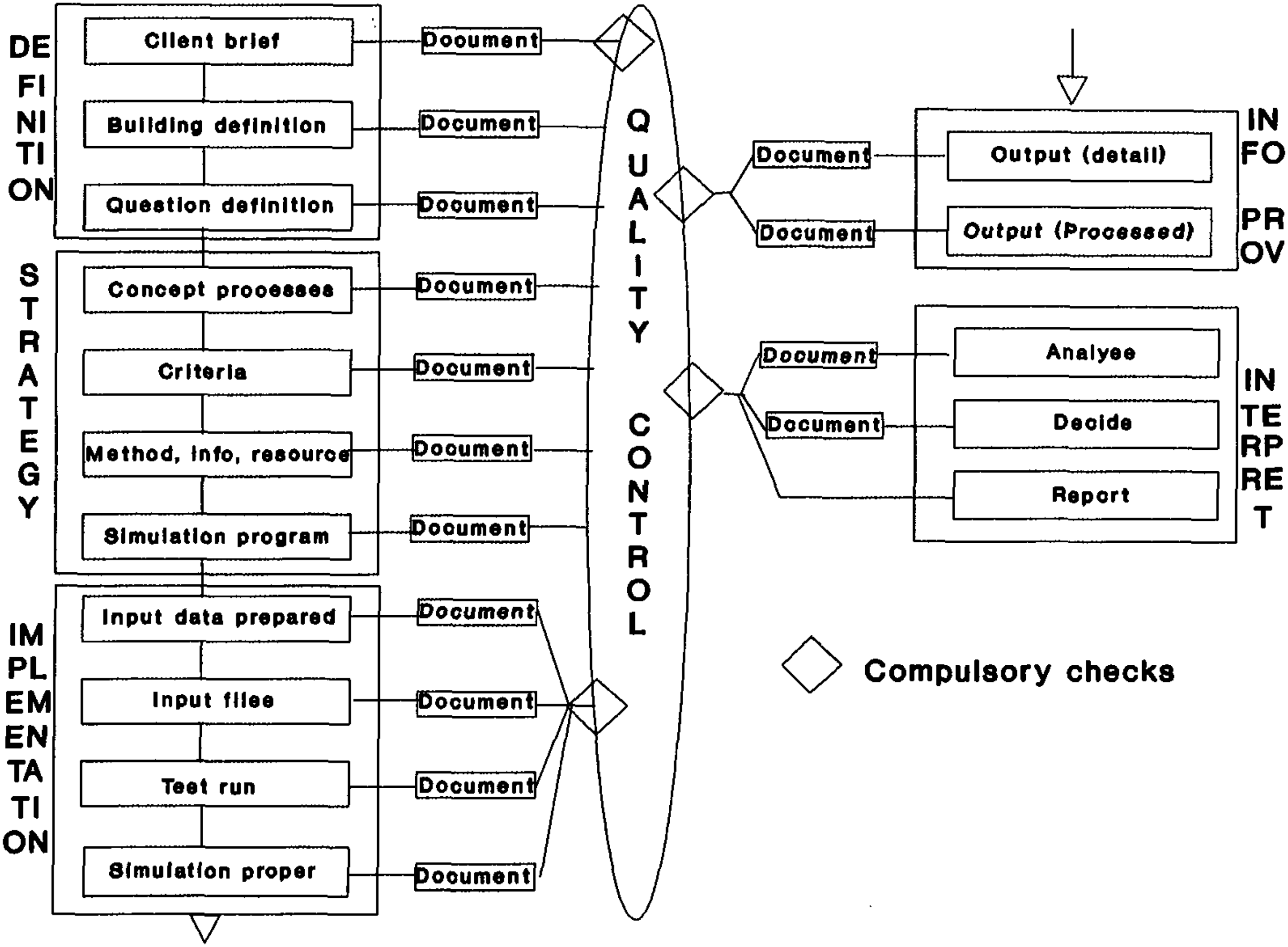

Fig. 2.6- Quality Loop in environmental performance assessment.

The breakdown of the process described above is usually referred to as a Plan of Work. QA requires a quality plan which follows the Plan of Work but also incorporates:

i- identity of the project, its location and the client,
ii- identity of the staff that carry out the work,
iii- identity of the quality assessor
iv- control procedures.

A proposed Sample Quality Plan is given in Appendix-2.A.

2.6. Quality Checks

The most important element in implementing QA is Quality Control of the product or service. Appropriate checks have to be devised and performed at appropriate points in the process of assessment. In our domain of assessing building design performance using calculation methods, a system of checking must be devised to make sure that all the information has been correctly translated into data for input to computer programs (or a manual calculation method) and, further, that this represents an "adequate" representation (as decided in the strategy stage) of the information given in the definition stage. Preferably, in addition to the person carrying out the work, a second person should always perform these checks.

If the assessment requires simulation for a year or longer it is advisable that a test run should first be conducted, for a short period. This test run, however, should include important events (e.g. shut down over weekends, closing blinds over night, etc.). The main input data supplied to the program should be checked against that reproduced by the program. For example, the following might be necessary:

- check areas, volumes, etc.,
- check that the shut down over the weekend has actually been modelled,
- check that the intended climate data has been used by the program,
- check plant size and set points,
- check the version of the program used and the date of its modifications,
- check that the input files and databases used are the intended ones (e.g. check the directory and the date of modification of files when using a computer)

Other checks should also be used, on a routine basis, for example to visualise the building geometry using the data input to the program, checking the input climate data as reproduced from the program output, if possible, investigating the relative heat sources and sinks, e.g. by visualising a Sankey Diagram, if possible, checking the time of maxima, etc. Figure 2.7 highlights some of the routine checks that are recommended to be carried out by both the modeller and the quality assessor.

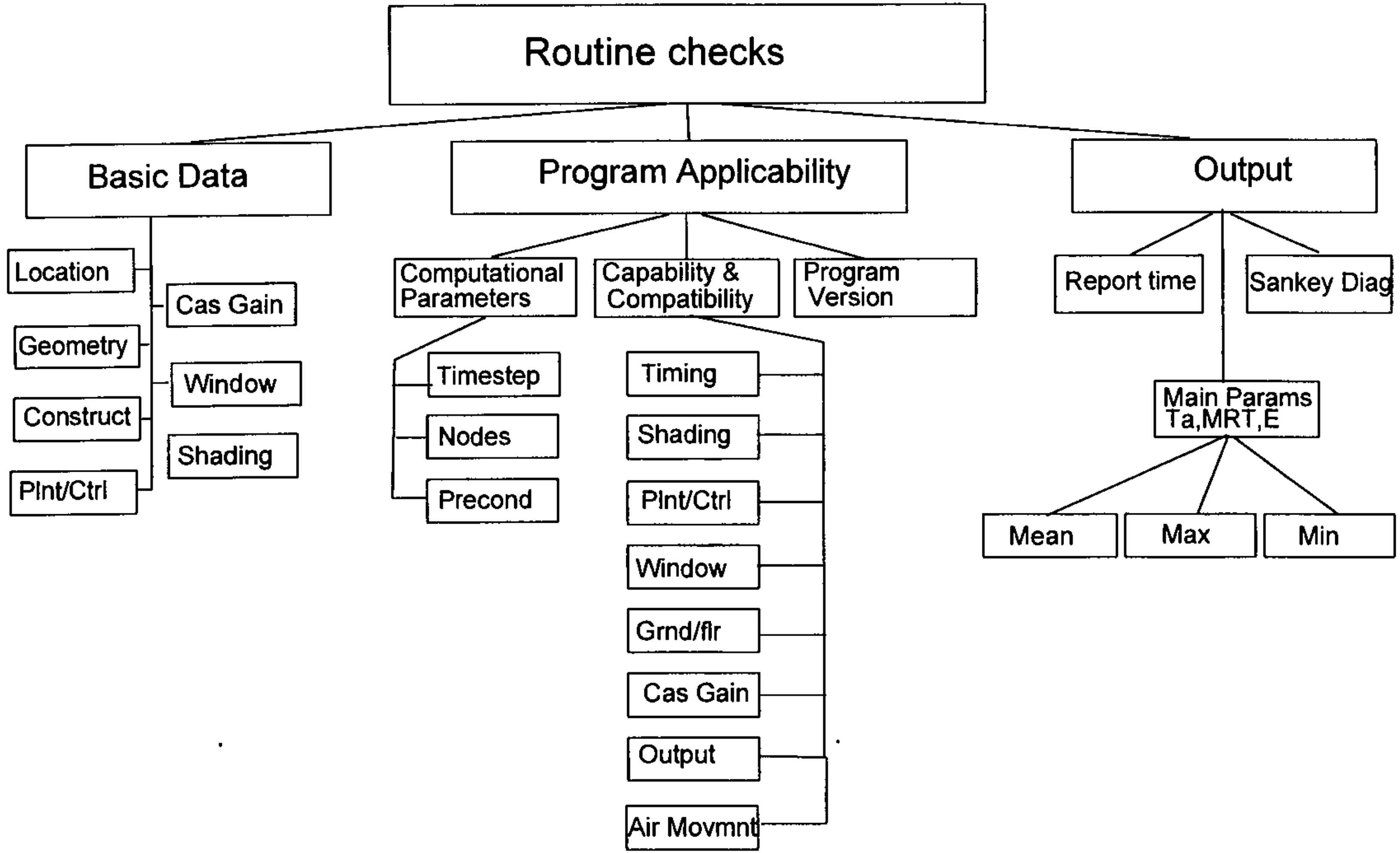

Fig. 2.7- **Aspects of basic data, program applicability and output data that require routine check.**

Errors of an order of magnitude can be trapped by using simple tests and range checking. For example, comparing the results of a steady state simplified calculation of the total heat loss of a building, with that of a dynamic program when used to emulate steady state may reveal order of magnitude errors in the input data. Similar tests can be performed for checking the thermal performance of the building, using the results of an appropriate, simplified method. The question of how to emulate the simplified method can be difficult to answer. One may be able to manipulate the input data, for example by preparing a climate input file with constant air temperature and/or no solar radiation. It might be possible to set building mass to zero. Simple range checking, for example of areas, heights, plant sizes, temperatures etc., can be used to trap large errors.
Comparison of results with those of previous similar projects would always help identify major errors. The principle of double entry, as is widely used in accounting, might also be used. For example, building floor area entered as a spereate input item could be checked against the sum of floor area of rooms within the building.
A number of such techniques have been proposed within Subtask B of IEA Annex 21 (See Working Document No IEA21RN151/90 (Jaboyedoff, 90).

2.7 Quality Manual

The above Sections report on the development of guidelines, procedures and checks to be used in carrying out a performance assessment. However, even when these guidelines and standards have been established, there is still a need for a clearly defined procedure and a system of controls to ensure that these guidelines are integrated into the process of modelling, performance assessment and design decision making. This is exactly what the Quality System is about.
To establish and maintain a Quality System for an organisation, a Quality Manual is needed which defines all the activities necessary. The main elements of a Quality Manual are:

a- the quality policy, defining the objectives of the management; the procedures for implementation of such policies and the organisational responsibilities,
b- the procedures that the management have accepted as necessary to produce products or services to the best ability of their organisation, with due consideration given to the economics of the activities,
c- the methods to check that these procedures are actually carried out and
d- the procedures for reviewing (a), (b) and (c).

Within Subtask B of IEA Annex 21 a structure for a Sample Quality Manual has been developed. Attention is focused on the use of calculation methods (with the emphasis on computerised methods) in building environmental performance assessment.
The requirements of a Quality System as set out in the ISO9000 and BS5750 have been used in producing the proposed quality manual. The Proposed Quality Manual is given in Appendix 2.B.
The proposed structure and procedures are designed to be adequate for an organisation with projects large enough to appoint a project manager, a project team and a quality assessor for a

number of such projects. When it is used for producing a manual in a specific organisation, specific information has to be added and parts that are not relevant have to be deleted.

In a small organisation the quality assessor could be a member of another project team. In an even smaller organisation where there is only one design/assessment team, or perhaps just one person, it is possible to tailor the recommendations made here to fit such circumstances. In such cases the mere concept of having a system for documentation and routine checking will improve efficiency and reliability in the results.

The proposed quality manual is designed to be used by those organisations without an existing *quality system.* Those organisations that already have one in place but need a procedure for the use of calculation methods can modify the structure and use it as a quality procedure.

Small firms that do not want to implement a full Quality System, can choose elements that are of importance to them. It is recommended that, no matter what parts they choose to implement, they should document it, clearly explaining their rationale in making each selection.

2.8. QA in Small Organisations

The Cost of Quality

The risk of failure can be reduced by improving the quality. This helps to reduce the cost of failures. However, improving the quality of a service or a product by establishing QA will raise *initial costs.* The main objective then is to find an optimum cost benefit (Fig. 8). In general, after a few years the benefit will outweigh the cost. Hitachi of Japan have measured the cost of fixing post release errors against the total cost of the project (as a ratio). After introducing QA the cost of fixing errors improved significantly from 1.48 in 1976 to 0.08 in 1979 [18, Rathbone, 1988].

Despite such benefits the initial cost of establishing sound QA procedures may be prohibitive for smaller companies. However, it always should be possible to find an optimum point in the total cost (Fig.2 8).

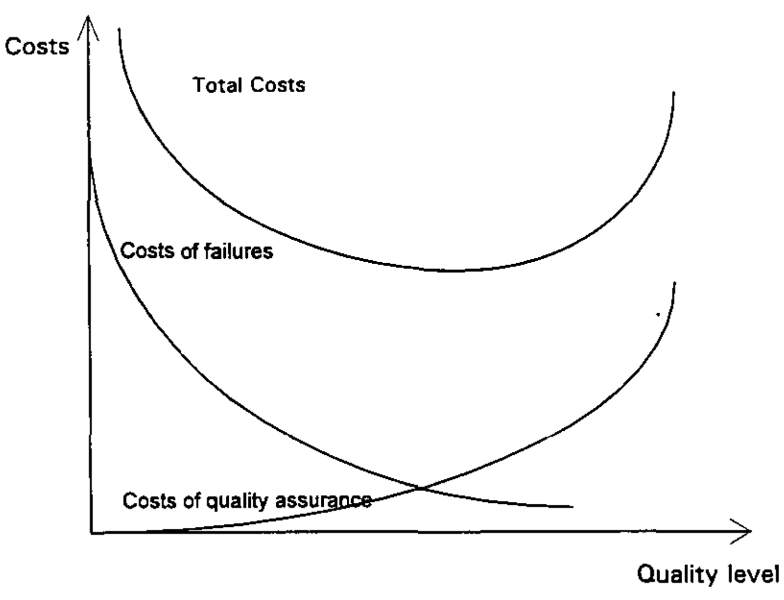

Fig. 2.8- Economics of quality assurance

The question that the management of such companies must address is what is the cost of failure and whether they can afford it? Small companies are also able to carry out such an assessment for each individual job and set a specific quality control check for jobs with high cost of failure. However, if this were to be repeated for every job the cost may be prohibitive.

Smaller companies should introduce elements of QA in stages as and when possible. Indeed, larger companies have found that the implementation of QA has to be gradual [19, Clark, 87] and [20, Hall, 90]

The first and foremost requirement in small companies is the establishment and documentation of a basic procedure for quality control of their product or service.

Minimum Requirement

In the absence of a proper QA system it is recommended that a basic system be established. Some desirable elements in such a system are:

- a- The management must decide what are the best methods, programs and techniques for carrying out performance assessment. For example they have to decide on a number of PAMs and lay out clear instructions as to when they should be used.
- b- Decide on a number of quality control checks.
- c- Document (a) and (b).
- d- Decide a simple audit system by which the management can find out whether (a) and (b) are carried out according to documented procedures (c).
- e- Review (a) to (d) at least once a year. This is necessary to update methods and the cost effectiveness of checks and controls.

In an organisation involved in the use of calculation methods for the assessment of building performance it is recommended that the following points are considered and form part of the routine procedure for the staff carrying out the assessment.

- i- The person carrying out the calculations should make sure that the input data (files) are checked thoroughly with the PAM data and building specifications. If possible choose material and building components' properties from a built-in database. Visualise building geometry and check it, if possible.
- ii- Document the errors and blunders found. Such a log book can be used in setting up some routine checks of the areas that are most prone to error. After sufficient data has been collected in such a log book, an analysis can be made and areas that need routine checks will be identified. A proposed format for an error log book is given in Appendix 2.C.
- iii- If possible, a second person should be asked to check the input data according to the PAM and building specifications and add the errors found to the log book.
- iv- A test run is carried out and all results (and not only the results that are of direct interest to the PAM) are analysed. One should always look for unexpected results. If possible produce a Sankey diagram (a diagram shown all energy sources and sinks, (Fig.2 9) and inspect it. For example by examining such a diagram and comparing the relative

magnitude of energy gains and losses associated with main building components, e.g. window roof, floor etc., it is possible to identify major possible errors.

v- If possible, carry out simple tests, comparing steady state calculations. Do the same for thermal mass tests.

vi- If the output capability of the program allows, the PAM user should check the energy balance at the air or zone node for important zones, or if possible, for the entire building.

vii- If possible, compare with examples from previous similar jobs.

viii- Make sure that the versions of the program, data files, weather files, etc. correspond to the final design and have been checked. Good housekeeping is essential.

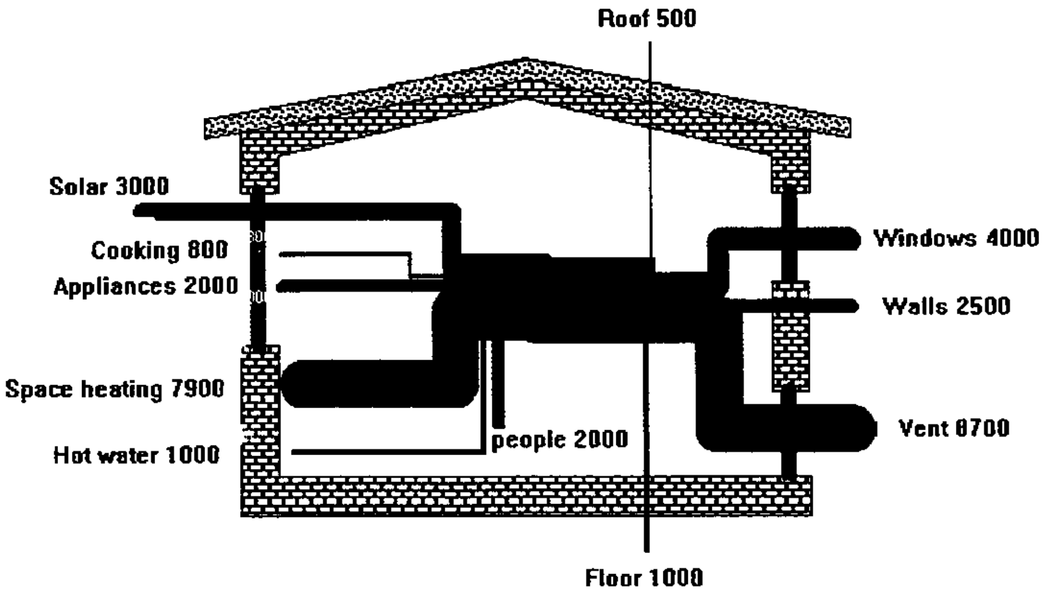

Fig. 2.9- A Sankey Diagram showing heat flows into and out of a building

2.9. Recommendations and Future work

The quality of an assessment depends on the software selected, its implementation, its range of applicability and the way it is used. It has been shown that, depending on these factors, inappropriate use of software may lead to significant errors. Researchers, software developers and users can help prevent some of these problems.

Researchers and Research Collaborations

IEA Annex 21 addresses several issues related to the quality of software and their use for building energy and environmental performance studies and assessments. The main deliverables of this collaborative research project include:

a- structured methods for documenting implicit and explicit assumptions used in programs (Subtask A);
b- techniques for testing programs, e.g. analytical, empirical and comparative tests (Subtask C);
c- desirable attributes of an integrated design support environment (Subtask D);
d- techniques for appropriate use of programs and issues directly related to introducing Quality Assurance within a consultancy practice (Subtask B);

Under Subtask B of IEA Annex 21 and the ETSU Methodology Project, a structured format for documenting Performance Assessment Methods (PAMs) has been developed. A number of such PAMs, for different purposes, have been documented (PAMDOPCs) and evaluated. A number of other methods and guidelines directly related to introducing QA have also been developed within Subtask B of IEA Annex 21. These include PAMDOCs, a number of routine Quality Checks, a Sample Quality Plan and a Sample Quality Manual. These tools and techniques have been developed for use as a starting point in implementing QA in relevant organisations. They will have to be modified and adapted according to the needs of each organisation.

Software Developers

By incorporating certain features and capabilities into their programs, developers can help to prevent some user errors, for example:

1- incorporating range checking and consistency checks and warning the program user when appropriate,
2- incorporating comprehensive output capabilities allowing the investigation of different flows and temperatures, and reproducing, as output, the input data exactly as they have been used within the program,
3- allowing visualisation of building geometry,
4- producing or facilitating the production of Sankey Diagrams and energy balances,
5- adopting a standard for user interface for data entry,
6- facilitating, the interchange of data with CAD tools,
7- incorporating material and building components databases.

Software Users

By following the methods and techniques developed within IEA Annex 21, users can improve the quality of their assessments and reduce the number of errors they make. Furthermore, they can develop and/or adopt a number of good practice principles, for example:

1- set up an error logbook, and document each and every error found
2- always check the input files thoroughly,
3- always carry out a test run and look for unexpected results; if routine checks are available use these to identify possible errors,
4- if possible, have a second person to check the work carried out,
5- create a database of results from previous projects to be used for comparison,
6- for frequently used materials and components, create databases, and
7- always perform Good Housekeeping Practice.

Introduction of QA

The introduction of QA should be tailored to the size, type of activity and resources of the practice in question. However, general recommendations can be made on certain aspects of QA. These have been outlined above.

Both small and large organisations should attempt to introduce QA on a gradual basis. Small organisations should not be frightened of the amount of documentation and procedures required for formal QA. They should develop their own criteria for what to keep and what to leave out, based on their experience and common sense. However, they should clearly document the procedures for carrying out routine assessments, and stay close to Standards as far as possible. They should decide what is the risk of failure and whether they can afford its cost. The cost of failure could be much higher than the cost of implementing QA.

2.10 References

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Chapter 3

Documentation of Performance Assessment Methods
IEA Annex 21 Subtask B

3.0 DOCUMENTATION OF PERFORMANCE ASSESSMENT METHODS

3.1 The need for Documentation.

Section 1 gave a brief discussion of the need for documentation.This is discussed in more detail here in order to lay down a firm foundation for the documentation process.
Quite apart from the understanding of the program and model options that a PAM user needs to have, the choice of what input data to use and how to make the building fit the internal description used by the program can give rise to difficulties. Many possibilities exist and different choices of e.g. climatic data, number of separate zones to be explicitly modelled, might lead to quite different results. In order to answer a particular design question, say "will the building as currently designed lead to unacceptable overheating?", even the definition of appropriate outputs to be provided by the program is far from simple.
It is clear that even if a 'perfect' program exists, the way in which that program is used and the results interpreted may still lead to inconsistent or even erroneous conclusions.
If any real progress is to be made, then the entire process of selecting a particular program, specifying the input data, making any necessary modelling decisions dictated by the program in order to represent the building, specifying the output data and deciding on rules for their interpretation needs to be examined. The ways in which programs are used must be documented. Only by doing this does it become possible to understand the complete process of performance assessment.
A wide range of PAMs exists, each having a different PURPOSE, e.g. energy auditing, overheating risk assessment, lighting level evaluation, etc.
In addition, the APPLICATION of these PAMs may not always be straightforward. A PAM suitable for domestic buildings may not, for example, be suitable for factories since its PROGRAM may not successfully deal with large single volume spaces.
Each combination of PURPOSE, APPLICATION and PROGRAM requires a separate PAM, which, if they are to be analysed in terms of their suitability to achieve the particular objectives of the user, must be documented in a structured way. It must be made clear here that analysis of the PAM is not concerned with the methodology or scientific correctness of the programs; this is dealt with by other IEA Subtasks. It is directed more at those features of input and output necessary to ensure that the user's requirements are met in a consistent and unambiguous way.
Having given some consideration as to why PAMs need to be documented, it is possible to define the uses to which the documentation may be put, which in turn influences the form the documentation should take.

3.2 Documentation Objectives

The major function of the documentation may be considered from the points of view both of PAM users and authors/developers.

From a user's point of view documentation should:-

- provide a recorded description of the process of carrying out a performance assessment so as to facilitate repeatability.
- provide guidance and advice on all aspects of the program input data requirements.
- provide guidance on program configuration and sub-model selection.
- provide advice on the presentation and interpretation of the program output.
- provide a documentation archive containing advice on PAM and program selection for a particular application.

From the point of view of authors/developers documentation should:-

- facilitate PAM analysis and further development.
- facilitate the further documentation of PAMs by making available a data base of developed methods.

In order to provide documentation to fulfill the above requirements, guidance was given to the expert PAM users participating in the Sub-task to enable them to produce a range of documented PAMs, (or PAMDOCs), in a structured manner. This was accomplished by designing a proforma known as the SHELL. The completed PAMDOCs can be incorporated into an accessible database or library.

The general process of PAMDOC production and use is illustrated in FIG.3.1

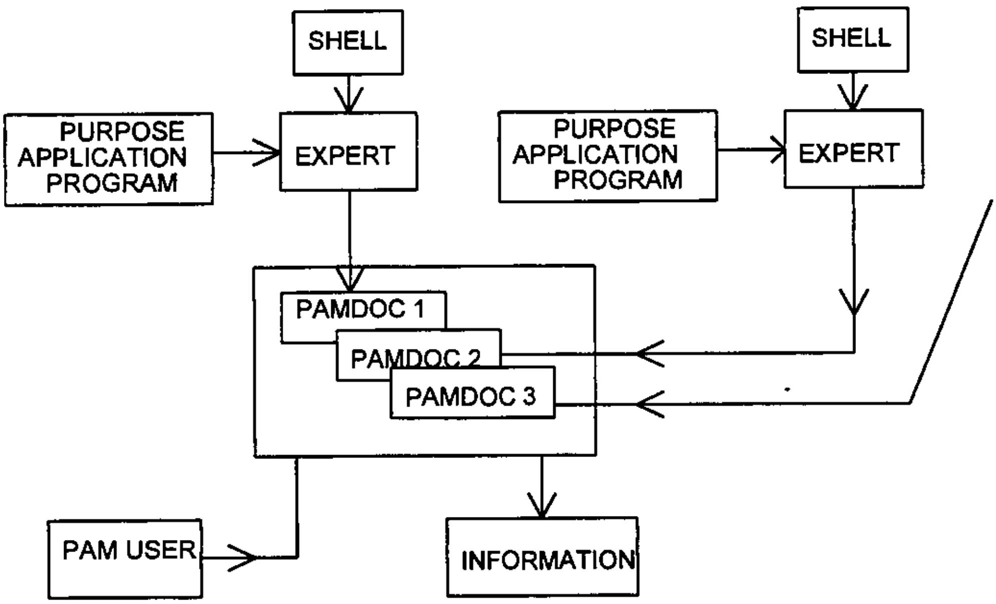


Fig. 3.1 Production and use of documentation

It is assumed that an 'expert' has a PROGRAM which may be used for a particular PURPOSE and APPLICATION. With the aid of the SHELL, which provides the necessary guidance for documentation, the PAM can be documented, i.e. a PAMDOC is produced. This is then transferred to a LIBRARY which may be accessed by a PAM user for a particular application.

3.3 Shell Development

To make this process possible, the key element was the documentation 'SHELL' since this controls the content and format of the documentation.
The features of the SHELL considered to be of importance were as follows:

- It had to be FLEXIBLE since it should be capable of dealing with all known PAMs.
- It needed to be COMPREHENSIVE in order that it may take into account all situations likely to arise when documenting a PAM.
- It had to be applicable to all the PROGRAMS likely to be dealt with and therefore to be INDEPENDENT of the program.
- It had to be EASY TO USE from the point of view of the document author.
- It had to be in a MODULAR form so that the information produced can readily be held in a computer database for rapid retrieval and analysis.

The major sections of the SHELL are shown in Table 3.1.

SECTION	CONTENTS
A	NOTES FOR GUIDANCE
0.0	PAM IDENTIFICATION
1.0	DEFINITION OF PERFORMANCE ASSESSMENT
2.0	PROCEDURE
3.0	INFORMATION DEFINITION
4.0	PROGRAM DEFINITION
5.0	CONTEXT DESCRIPTION
6.0	ZONING DESCRIPTION
7.0	BUILDING DESCRIPTION
8.0	BUILDING OPERATION DESCRIPTION

Table 3.1 Sections of SHELL on which PAMDOCs are based.

Section 0.0 PAM IDENTIFICATION is effectively the 'cover sheet' of the documentation with brief details as to the PAM's purpose, application, program used and source.
In SECTION 1.0, the PAM is defined in detail enlarging on the brief information provided in SECTION 0.0 and covering such aspects as the type of environmental control system and climatic zones for which the PAM is suitable.
A PROCEDURE section follows which describes the steps followed if one were actually using the PAM and identifies those sections of the PAMDOC containing the relevant information. The PROCEDURE section of the SHELL is the only section where the order, description and possibly number of sub-sections may be changed since PROCEDURES may vary depending on the program being used.
The remaining sections, 3.0 - 10.0, of the SHELL are concerned with providing all the information a user would require to describe his application to the program.

The documentation for different PAMs, especially if using the same PROGRAM, may have common sections which only need to be completed once for one PAM and can then be referenced by the others. This is illustrated in FIG 3.2. It is likely that, having fully documented one PAM, other PAMs dealt with by the same PROGRAM will only require a small amount of new documentation. If for example a program is capable of carrying out overheating risk and energy audit assessments then only Sections 0.0 to 3.0 will need to be changed.

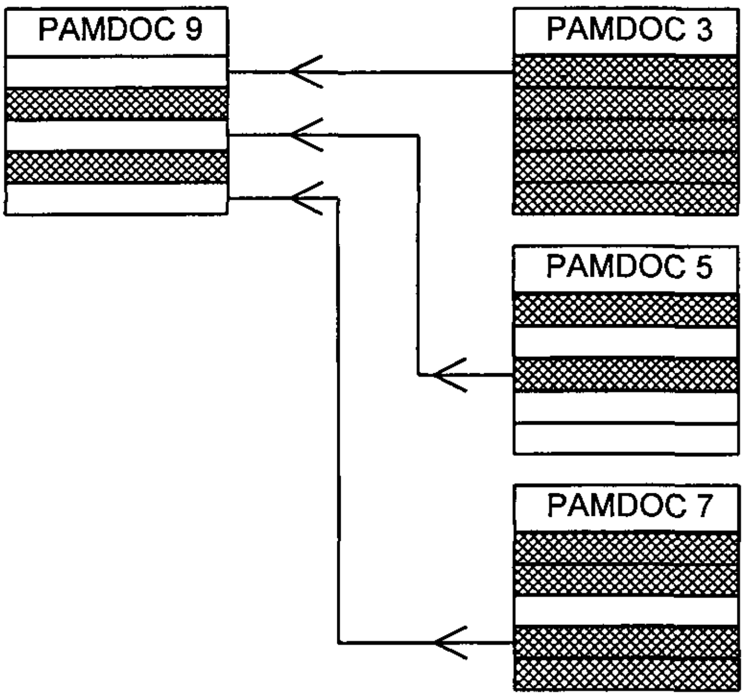


FIG 3.2
The shaded areas represent completed sections.

The major sections of the SHELL are themselves broken down into sub-sections. For example Section 6.0, ZONING DESCRIPTION, consists of Zoning Description, (6.1), and Interzonal Coupling, (6.2), which themselves break down into individual topics (see Fig.3.3). For every lower level topic the same subdivision is used (see Fig.3.4). It is these lower topic levels which contain the detailed information required.
It is important to document the rationale for doing things and the sources of information. From a user's point of view it provides the documentation with authority. From a PAM developer's point of view it enables all the different ways of doing things, and the reasoning behind them, to be open to inspection and improvement as the field of performance assessment develops.

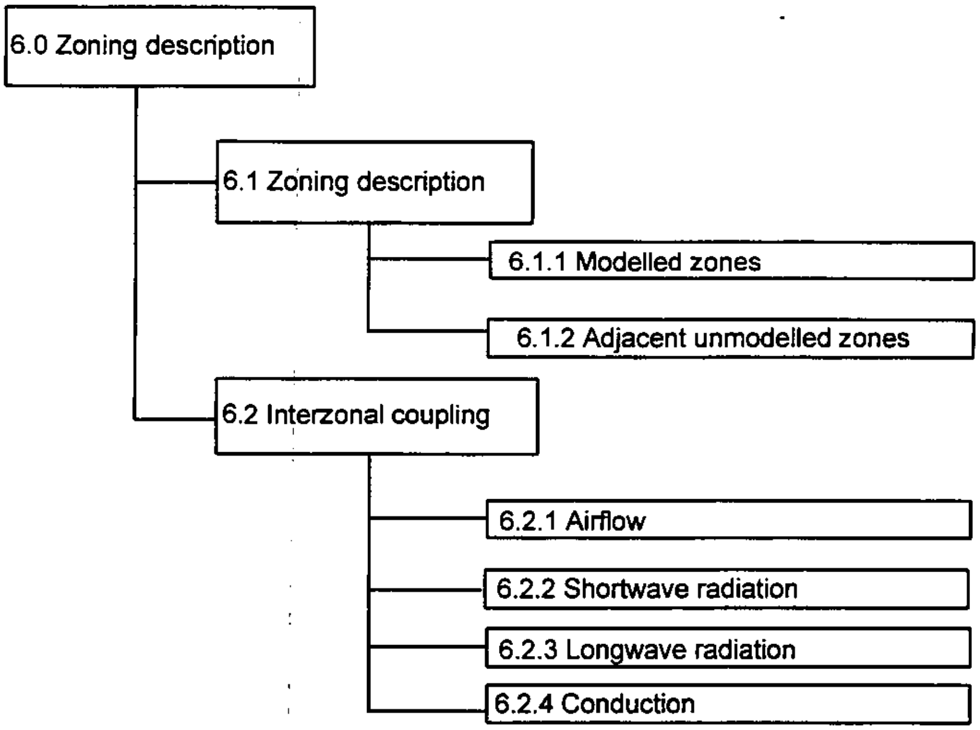


FIG 3.3 Sections, sub-sections and topics.

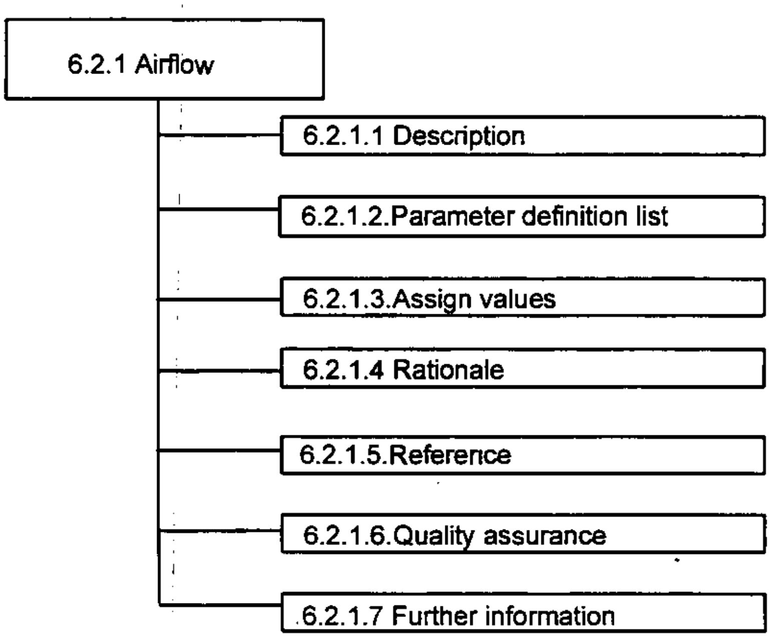


Fig. 3.4 Topic breakdown into descriptive divisions.

Quality assurance is the major theme of the work and a heading is provided to describe any methods for checking the quality and consistency of the data provided.

3.4 Documented PAMDOCS

A total of 28 PAMDOCs was produced during the life of Subtask B using 9 different programs. Table 3.2 gives a brief description of each PAMDOC. The complete hard copy of BREADMIT, SERI-RES and DOE2 PAMDOCs, as example PAMDOCs, are given in Section 2 of Volume 2. Section 3 of Volume 2 (Interactive Cross References) contains the electronic copies of all PAMDOCs.

Identifier	Purpose	Application	Program	Author(s)
BLAST001	Assessment of overheating risk	Commercial building with single room	BLAST	S. Huther
BRE 0001	Assessment of overheating risk	Evaluation at the early designs stage of small to medium buildings	BREADMIT	L. Roche, D. Bloomfield
BRE 0002	Analysis of the thermal performance of building construction elements	Conduction performance of all opaque layer constructions and of glazing	BREADMIT	L. Roche, D. Bloomfield
EMPA 0001	Assessment of overheating risk in commercial buildings	Active heating, daytime natural ventilation, natural and artificial lighting	DOE2	G. Zweifel
EMPA 0002	Assessment of overheating risk in commercial buildings	Active heating, daytime natural ventilation, nocturnal ventilation natural and artificial lighting	DOE2	G. Zweifel
EMPA 0003	Assessment of overheating risk in commercial buildings	Active heating, daytime natural ventilation, natural and artificial lighting, blinds	DOE2	G. Zweifel
EMPA 0004	Assessment of overheating risk in commercial buildings	Active heating, daytime natural ventilation, nocturnal ventilation, natural and artificial lighting, blinds	DOE2	G. Zweifel
EMPA 0005	Assessment of overheating risk in commercial buildings	Active heating, mechanical ventilation, natural and artificial lighting	DOE2	G. Zweifel
EMPA 0006	Assessment of overheating risk in commercial buildings	Active heating, mechanical ventilation, natural and artificial lighting, blinds	DOE2	G. Zweifel
ARD 0001	Assessment of overheating risk	Evaluation of design of commercial buildings of up to 50 zones	ENERGY 2	M. Holmes, P. Schild
*BDP 001	Monthly and annual energy audit	Analysis of the designs produced for Passive Solar Design Studies	ESP	A.J.A. Sluce

*BDP 002	Calculate the light switching function in a thermal zone	Provision of light switching function for input to ESPbps	MABEL	A.J.A. Sluce
*BDP 003	Over heating assessment	Non-domestic buildings	ESP	A.J.A. Sluce
*BDP 004	Performance on representative days	Non-domestic buildings	ESP	A.J.A. Sluce
*BDP 005	Calculation of annual and monthly energy consumption	Non-domestic buildings	ESP	A.J.A. Sluce
*BDP 006	Indication of the effect of solar gain on a building	Non-domestic buildings	ESP	A.J.A. Sluce
NU002V6-Com.	Overheating Risk Assessment	Office buildings	SERI-RES	J.T. Wiltshire, B.F. Warren, B. Sodagar
NU002V5	Overheating Risk Assessment	Houses	SERI-RES	J.T. Wiltshire, B.F. Warren, B. Sodagar
NU001V6	Annual "Useful" Energy Audit	Houses	SERI-RES	J.T. Wiltshire, B.F. Warren, B. Sodagar
SORANE PAMDOC1	Overheating Risk Assessment	Office buildings	TRNSYS	P. Jaboyedoff
vub-trn.010	Global PAMDOC: Overheating Risk Assessmen	Office buildings	TRNSYS	P. Verstraete
vub-trn.011	Zone air temperature and overheating integral	Office buildings	TRNSYS	P. Verstraete
vub-trn.012	Calculate the gains to each zone	Office buildings	TRNSYS	P. Verstraete
vub-trn.013	Calculate the external losses of each zone	Office buildings	TRNSYS	P. Verstraete
vub-trn.014	Calculate the capacitance of each zone	Office buildings	TRNSYS	P. Verstraete
vub-trn.015	Calculate the total losses of each zone	Office buildings	TRNSYS	P. Verstraete
TNO-BOUW-0001	Overheating Risk Assessment	Office buildings	VA114	A. Wijsman
TNO-BOUW-0002	Overheating Risk Assessment	Office buildings: with nocturnal ventilation	VA114	A. Wijsman

Table 3.2: Documented PAMDOCs

• A series of PAMDOCs were produced by Building Design Partnership (BDP) under another contract external to Subtask B and are included here for completeness.

3.5 Summary

A structured way of organising the information has been developed to facilitate analysis of the documentation produced for different PAMs. This has meant ensuring that the provision of information at each topic level follows a defined pattern. The information that needs to be set down not only describes how things are done, but also consists of the Rules for doing things and the Rationale behind these rules. This is to highlight areas of uncertainty and lack of knowledge as well as providing a measure of confidence, or lack of it, in the quality of the information.

The starting point for producing a 'library' of documented PAMs is to fully document a sample PAM for a simple application. This provides the foundation on which to base further documentation and to enable development to proceed.

The SHELL itself contains some guidance as to the content of each section but in addition to this a more comprehensive guidance document (Volume 2 Section 1), has been produced which contains information on how the SHELL is used to compile PAMDOCs, an example PAMDOC and a glossary of terms.

The completed PAMDOCs provide information in addition to that which is normally found in program manuals. Whereas the manual may provide a program user with the type of information needed for the data input files the PAMDOC more completely specifies the information needed for a particular application. As an example the manual may state that an external wall has to be specified in terms of its width and height whereas the PAMDOC will give guidance regarding from where the measurements should be taken; from the internal face of the wall, from its mid point etc as appropriate to the application as well as the reasons for doing it in a particular way. Or, again, the manual may ask for materials to be specified in terms of density, specific heat and conductivity but it will give no guidance on actual values to be used. The PAMDOC, on the other hand, will provide this type of information. Fig. 3.5 illustrates how a PAMDOC may be used, in conjunction with information given by the program manual, to specify the input file data requirements.

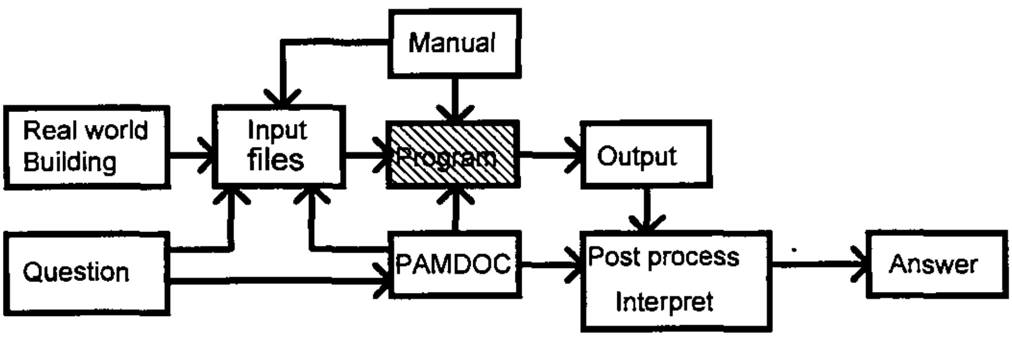


FIG 3.5 The use of the PAMDOC

Chapter 4

Evaluation and Development of Performance Assessment Methods

4.0 EVALUATION AND DEVELOPMENT OF PERFORMANCE ASSESSMENT METHODS

4.1 Introduction

To ensure that the documented PAMs were reliable, fit for their purpose and as up-to-date as possible a process of evaluation was undertaken. This also shed considerable light on PAM development requirements. It must be stressed here that the work carried out by the Subtask represents a 'snapshot' in the life of a PAM since, as knowledge in the field of building assessment increases, the PAMs themselves will be subject to an evolutionary process each step of which requires evaluation.
The evaluation of PAMs is a complex and time consuming process and it was not possible to evaluate all PAMs completely within the time framework of the Subtask. A methodological approach has, however, been developed and work has been carried out on each of the evaluation aspects described.
Whilst not all the PAMs developed have been evaluated in all aspects the evaluation methodologies themselves have all been tested. By its nature evaluation does not produce definitive results; much depends on the time available and the skills and integrity of those who perform the evaluation.
The development of the documented PAMs took place, to a large extent, as a consequence of, and in parallel with, the evaluation process which highlighted areas where development was needed. The cross comparison work was particularly useful in this respect since it enabled desirable features of particular PAMs to be identified and incorporated into other PAMs. In addition to this, certain aspects of PAM methodology were identified which were considered as deserving special attention. Separate studies were instigated to investigate strategies for dealing with the following issues in an attempt to develop common methodologies suitable for the PAMs under consideration:

- Zoning
- Windows/glazing
- Ventilation
- Light switching
- Overheating definition
- Suspended ceilings

4.2 Evaluation

A strategy for evaluation was developed at an early stage of the Subtask since evaluation was seen potentially as one of the most work intensive aspects of the program. It was determined that the evaluation process needed to address such issues as:

How do we know a PAM is good enough?
Is its scientific basis correct?
Is its implementation correct?
Does it consistently produce plausible results?
Is it economical in use of resources?
Will it produce repeatable results with different users?
Is it applicable to a wide range of building descriptions?

Does it produce 'credible' answers?

Four basic criteria emerged against which it was deemed desirable to evaluate the PAMs. These were:-

- They should be technically sound; the ways and reasons for doing things together with any assumptions, methodology employed and data provided should stand up to criticism on the basis of currently accepted technical practice.
- They should be free from user uncertainty; users should be able to implement the PAMs in a consistent and unequivocal manner.
- They should be applicable; their suitability for application to different building types or conditions of use should be well defined.
- They should be credible to their users who should have confidence in the results obtained.

The terms used in the Subtask to describe the above criteria are defined and expanded upon below.

Technically sound:

A judgement that a PAM has a sound technical basis not withstanding any reasonable approximations or assumptions that have to be made.

As the definition implies, this can only be a qualitative measure. It is not practicable to measure a PAM against an absolute 'truth' model since none are available in practice and there are no analytical tests nor field data against which comparisons can be made. In reality there can only be a series of checks, or quality assurance milestones, which a PAM should pass before it is released for use.

User uncertainty:

The uncertainty or variation in the output from a PAM generated by differences in the users' implementations of the PAM.

This has nothing to do with whether a PAM is 'correct' or not, it is related purely to the different ways in which it may be implemented by the user. Ideally, in a well written PAM, the guidance given would ensure that all users would implement it in exactly the same way. That is, the PAM is understandable, comprehensive and applicable and consistently produces repeatable results.The extent to which this is not the case may be construed as user uncertainty caused by such factors as misunderstanding the documentation, too much freedom of interpretation or the limited applicability of the PAM.

Applicability:

The determination of the scope of a PAM.

Applicability is concerned with determining the limits or, viewed more positively, the scope of application of a PAM - the range of conditions within which the PAM produces acceptable performance. Any given PAM will have what can be called a 'performance envelope' within which it produces acceptable results and which has a 'boundary' defined by its acceptable limits of operating conditions. This strictly only applies to PAMs having simple single purpose applications, where one would expect to have a simple performance envelope. PAMs may, however, have more complex purposes, the components of which may have their own distinctive limits to performance. A PAM, may, in reality, have more than one performance envelope, each of which may correspond to a particular aspect of

PURPOSE. Each envelope would have its own performance boundary which may or may not be coincident with those of other envelopes. Determining the limits of application at which a PAM becomes unacceptable is a simple problem in theory, but presents extreme difficulties in practice. By limiting PAMs to those having simple, single purposes the practical difficulties are considerably reduced, although the task is still far from easy. To a certain extent the bounds of operation of a PAM will be determined by the author of the PAMDOC who will have incorporated limitations when dealing with particular features. As an example there could be a statement which says "this PAM is only suitable for external temperatures between 0°C and 30°C" which then defines a range of climatic conditions within which the PAM may be applied without serious problems. In this particular example the temperature range may have been determined from the experience of the author in his use of the method, it could be a limitation related to algorithms or fixed data bases within the PROGRAM of which the PAM author is aware or it could have been derived by performing sensitivity studies.
Within the framework of the Subtask the approach to the problems posed by 'applicability' was firstly to rely on the expertise and judgement of the PAMDOC authors and secondly to carry out appropriate sensitivity studies and inter-PAM comparisons so as to detect whether exposure of the PAM to a wider range of operating conditions produced an unacceptable change in its behaviour.

Credibility:
The PAM produces results which their users believe and upon which they are prepared to base design decisions.
A PAM might be viewed by its author as being technically sound, free from user uncertainty and of demonstrated applicability. However there is no guarantee that practitioners in design offices will adopt a PAM unless it has been demonstrated to their satisfaction that it can be successfully used to solve real world problems. Verification in use is required to ensure that results agree with accepted practice or, at the very least, are explicable in terms of current design knowledge.
Evidence for the credibility of PAMs might be:

- they produce consistent design advice
- their results agree with or can be explained in terms of best current practice
- the risks associated with using them are acceptable.

Methodologies then had to be determined which could be used in a practical manner to test the PAMs against the above criteria. Because of the nature of the criteria and the PAMs themselves there are no tests which give absolute results. Two basic approaches to this problem emerged: rigorous examination of the PAMDOCs and their application to well defined test cases. The particular methods adopted are described below.

4.3 Evaluation methodology

4.3.1 Benchmark tests

The computer software packages being used within the Performance Assessment Methods (PAMs) were tested and compared, using the Cases 9 to 12 'benchmarks' developed in IEA Solar Task VIII [4.1]. These cases include both simple lightweight and heavyweight constructions, with mechanical heating and cooling and free-float conditions. The main aim of this exercise was to quantify the differences between the programs used within the documented Performance Assessment Methods (PAMDOCs) so as to aid in interpreting the comparison of results from different PAMs. Five countries took part: Belgium, Germany, The Netherlands, Switzerland and the United Kingdom. Nine computer packages were used: BLAST, BREADMIT, ENERGY2, ESP, SERI-RES, TAS, TRNSYS, VA114 and a code written in-house by a BRE contractor from Tsinghua University, China. Some packages were run by more than one participant, giving an insight into the effect of variations in personal interpretation of input data. Details of special features and problems found when running each package are documented. Comparative results have been plotted and are discussed.

Sixteen sets of results were obtained. These showed clear variations between users for ESP, SERI-RES, TAS and TRNSYS and indicates the difficulties of interpretation even for a clearly defined simple building. This user effect can cause greater differences in results than that of using different programs.
Typical results for annual heating loads have a range of 7988 to 9403 kWh for the lightweight building, while cooling loads have a wide range from 411 to 1299 see Figure 4.1. The range of results is smaller for the heavyweight case. Many programs predicted loads outside the target ranges established within IEA Task VIII. For the lightweight building annual heating loads, 6 results were above the maximum and 3 below the minimum of Task VIII; for cooling loads, none was above the maximum but 9 were below the minimum. For the heavyweight building heating loads, 8 results were above the maximum and 5 below the minimum of Task VIII; only one cooling load was above the Task VIII maximum but 11 out of the 16 were below the minimum.

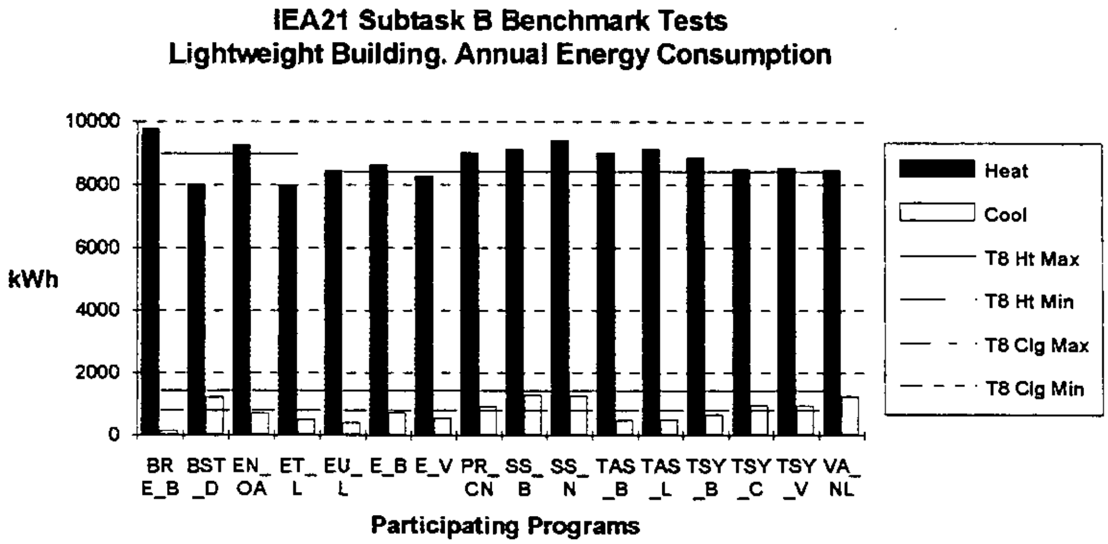


Fig 4.1

An important indicator of the consistency with which design decisions can be made was obtained by comparing the programs' ability to predict the effects of a change in the building design, e.g. in thermal weight. Differences in loads between the light and heavyweight buildings have a range of 596 to 1310 kWh, even for detailed programs having a similar level of modelling complexity. This does not give much confidence and reinforces the need for careful studies to evaluate the programs. Such work is being conducted within IEA Annex 21 Subtask C.

It was found useful to compare intermediate energy flows, where the codes allow this to be done. For example, with one exception, infiltration loads were all very close. However, a comparison of daily profiles of incident solar radiation clearly showed the difference in the modelling by one program compared to that of the other programs. The incident solar radiation on the South surface had a range of 3098 to 4008 kWh for May 30 and 2502 to 3857 kWh for May 31. These show the differences in calculated incident solar radiation between programs, which may account for much of the differences in heating and cooling loads, free-float maximum temperatures and number of hours of overheating.

In view of the work within Subtask B to develop PAMDOCs for assessing overheating, it is of importance to see how closely the programs predict maximum temperatures and cooling loads when applied in a controlled way to simple buildings such as those used for the 'benchmark' tests. For the lightweight building there is a high variation in maximum cooling loads predicted.

The predicted maximum free-float temperatures for the lightweight building vary between programs from 28.5^{o}C to 37.7^{o}C. Few of the programs predicted results lying within the target range established in the original IEA VIII work. See Fig. 4.2

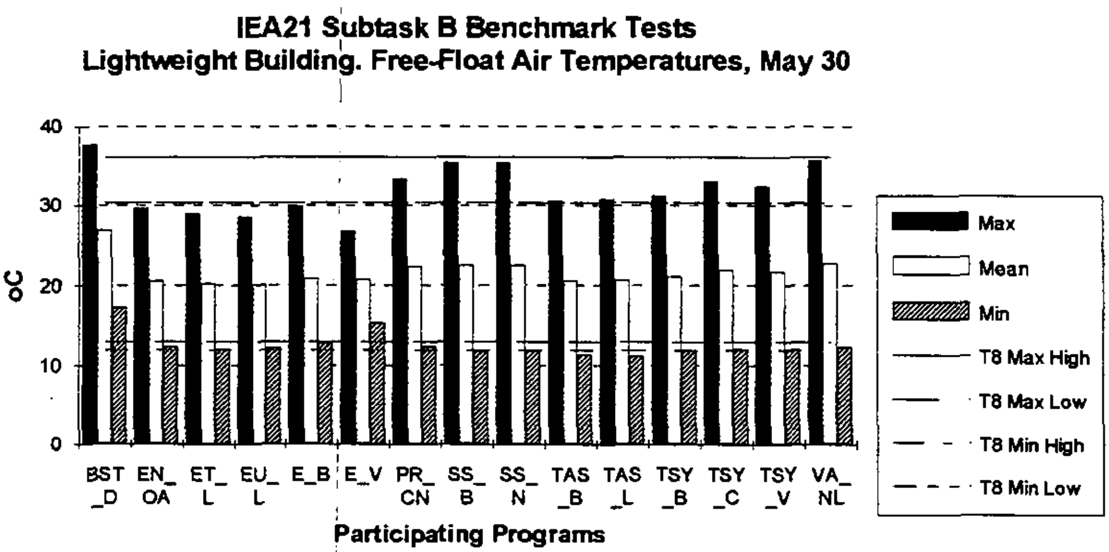


Fig. 4.2

A good indicator of how a program treats the thermal mass, or storage of the building, can be gained by looking at the predicted range in temperature over a day. Most of the programs gave similar results but with a few outliers, at least one of which seemed likely to be due to user rather than program errors.

As some of the PAMs use the accumulated frequency of temperature as a criterion for overheating, this parameter was calculated. The predicted number of hours for which a temperature was exceeded varied widely between programs. For example, 25^{o}C was exceeded between approximately 100 and 180 hours for the lgiMÁ¿;LTSP2PE=<EÚgiMÁ¿;LTSP2PE 4.3.

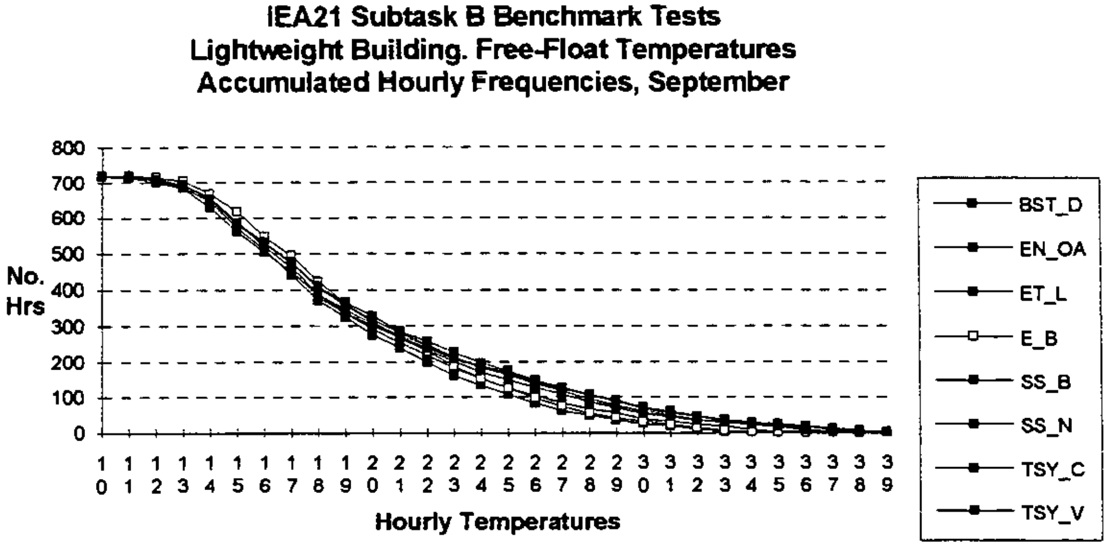


Fig. 4.3

It should be stressed that the purpose of this study was to gain an impression of the effect of the combination of program and user for predicting the main performance measures with simple test buildings. It would be expected that the range in results obtained between PAMDOCs executed for more realistic conditions would be much larger. The main aim of this exercise was to quantify the differences between the programs used within the PAMDOCs so as to aid in interpreting the comparison of results from different PAMs. The benchmark tests compare across programs and do show fairly substantial differences. When individual assessments were made, with and without PAMDOCs, those runs with the PAMDOCs showed definite improvements. It can therefore be concluded that both the programs and the methods of use contribute to uncertainties in the predicted building performance. This exercise was very worthwhile in establishing a common understanding of modelling issues and in clarifying major differences between programs. The need for a common terminology and for very well documented building specifications was apparent. The influence of the user and the ease with which user errors can be introduced was also clear. Some recommendations which follow from this work were:

- need for careful and detailed evaluation studies to be devised and performed on the programs
- need for agreed standard definitions of modelling terms
- need for exemplars of how to document building and operating conditions
- need for good quality assurance procedures to be used in any modelling studies
- need for care to be taken in defining outputs.

4.3.2 Peer Review

Each PAMDOC was examined by designated members of the team. Usually this was done by each author meeting with at least one other author to discuss their own PAMDOCs. This examination addressed the main issues of completeness, technical acceptability and comprehension by a potential user.

In all cases the peer review procedure led to amendment and improvement of the documentation as well as highlighting areas where further development work was needed.

4.3.3 Cross Comparison

Each PAMDOC was compared on the basis of corresponding sections. Since the documentation was prepared using a standard format, the SHELL, corresponding sections of each PAMDOC should contain the same type of information. The procedure adopted was that designated team members were each allocated a number of sections each of which was examined for all the PAMDOCs produced. This 'horizontal' examination provided a second check on the issues addressed in the Peer Review and identified any information which was out of context relevant to the appropriate section. In addition differences between the PAMDOCs in the treatment of particular issues were identified enabling rationalisation of content to be considered as well as highlighting issues where further investigation and development could usefully take place. An interesting example of the latter was that 'overheating' was defined in a number of different ways leading to different interpretations of simulation results and, probably, to different design decisions being taken; clearly a case for rationalisation.

As an example a few subsections of Section 3 (Information Definition) of PAMDOCs are reproduced here. The remarks of the team member(s) responsible for the exercise are recorded in the last column of the table. The usefulness of this evaluation and development tool was demonstrated by consequential revision of PAMDOCs. The PAMDOCs given in Volume 2 Section 2 have been revised to take account of the review comments.

HEADINGS	SHELL	PAM1 SERI-RES	PAM2 BREADMIT	PAM3 TRNSYS-PJ	PAM4 DOE.2	PAM5 VABI	PAM6 BLAST	PAM7 TRNSYS-PV	REMARKS
3.1.1 Description	General description of information required	Assessment of overheating risk	O/Heating risk assessed by predicting dry resultant temp in each selected zone	For each simulated case results should be: Zone environmental temp and outdoor temp plotted hourly during summer Zone air temp plotted hourly for hottest week of year Classified zone air temp during summer period (hours per K)	Overheating in a particular zone occurs if thezone air temp in a representative module exceeds an outdoor comfort level by a certain of hours and degrees during a defined period	Assessment of overheating risk	Overheating in a commercial building occurs if thermal comfort conditions (Fanger) of particular zones exceeded certain threshold values during occupancy time.	Simulation (over a period of 10 days) are run to assess the overheating problems for selected zones.	Varying descriptions: (2)says howit is done (3)gives results required (4) and (6) define what is meant by overheating NOTE;Should say 'what are we trying to do?' Most of information provided here should be in 3.1.2

HEADINGS	SHELL	PAM1 SERI-RES	PAM2 BREADMIT	PAM3 TRNSYS-PJ	PAM4 DOE.2	PAM5 VABI	PAM6 BLAST	PAM7 TRNSYS-PV	REMARKS
3.1.3 Assign Values	May cover, for exampleHow individual rooms or zones are selected for assessment Rules for generation of ParametersHow particular values are assigned	T_z=27^{0}C Sum of consecutive time periods for T_z>=27^{0}C is risk based on user experience	Dry resultant temp is selected for output.Zones selected as section 6. Breadmit single zone model.User select zones most likely to overheat.Carry out run for each likely zone.	Overheating if product of temp above admissible temp and number of hours is greater than 30(k*hrs) Overheating hours calculated during working hours and from 1 May to 30 September	Upper comfort level is a function of daily max ambient temp Tamaxas follows: Tamax <=12 Tcom = 25 12<Tamax<=20 25<Tcom<28 20<Tamax<=30 tcom = 28 tamax>30 Tcom no limit	The summer period;154 days starting April 27,1964 The hot sumer day:August 26,1964 Two levels are important: TOVERTH(1) = 25 ^{o}C TOVERH(2) = 28^{o}C TCOMF=0.5* TVN+0.5*TMR (a = 0.5)	PMV = 0.5 (corresponds to PPD of 10%)	None	(1) incomplete, nothing on zone selection (2)reference to section 6 which is concerned with criterion for treating spaces as separate zones.Nothing relating to temperature which defines overheating (3)what is 'admissible temperature'? (4) Good

HEADINGS	SHELL	PAM1 SERI-RES	PAM2 BREADMIT	PAM3 TRNSYS-PJ	PAM4 DOE.2	PAM5 VABI	PAM6 BLAST	PAM7 TRNSYS-PV	REMARKS
3.4.2 Interpretation	How are the results interpreted?	If zone temp exceeds a given value for more than a particular priod of time it is said to overheat	see 3.4.1	Different levels 1 Sinple pass rule 2 Comprison between different options	No further interpretation needed	1)Figure Temp v Time of the day during hot summer day 2)Figure 'Daily max/min temp during summer 3).......similar info 4).......similar info	Maximum number of hours with maximum acceptable PMV	The results are compared with: - a selected temperature which should not be exceeded. - a selected temperature interval where the results should not be situated in for more than a given length of time.	(2) and (3) appear to be saying that 'interpretation' is the same as 'description'. If this is the case it would be better to repeat the description if it is the interpretation (5) Much of this is about the things you can find out not about interpreta-tion

4.3.4 Case Studies

The peer review and cross comparison procedures were essential first steps in evaluation and they resulted in a set of thoroughly examined and improved PAMDOCs. However they were only partially able to address the four basic evaluation criteria. In order to more fully examine the problems a user might face it was necessary to put the PAMs into practice. This provided an additional test of whether the PAMs were technically sound and free from user uncertainty as well as allowing aspects of applicability and credibility to be examined. To provide a vehicle for the practical tests a specification for a simple office building and its operational requirements was defined. This was intended to represent the information a designer might be expected to possess at an early design stage. It allowed the PAMs to be tested not only in areas where information was tightly defined, but also where assumptions had to be made with respect to incomplete information.

Tests were carried out on the PAMs for overheating risk assessment as most of the PAMs had been developed for this application.

Assessments were initially performed with the offices ventilated during the day (the occupied period) by outside air to a level chosen to satisfy the occupants' requirements in terms of acceptable air quality. During the night (unoccupied) a nominal fixed ventilation rate of 0.2 air changes per hour was assumed to take place.

This initial assessment, the base case, enabled the quality of the PAMDOCs and how they were applied to be examined on the basis of actual figures produced.

A second set of assessments was then carried out similar to the first but this time with office windows opened by a specified amount during the night to provide an element of night time cooling. This test enabled the PAMs to be examined regarding the methodology used to deal with opening windows. Both sets of tests resulted in a variety of discrepancies being discovered which then had to be rectified and the tests repeated. A more detailed discussion of the case studies and their results now follows.

4.3.4.1 Office Case Study

The Office Case Study was undertaken as an aid to development of the PAMDOCs. It had to be 'realistic' in the sense that problems that would normally be encountered when carrying out a performance assessment, at an early design stage, would be taken into account. It was desirable to establish a link with the realities of practice.

4.3.4.1.1 Description

In order to provide the realism required the following points were taken into account:-

- a whole building was considered in order to be able to address such problems, for example, as how to divide the building into zones for simulation. For the tests considered it would have been unrealistic to use a 'shoebox' type of building.
- the building information provided was what would normally be expected in practice at an early design stage. It was purposely not provided in great detail to ensure that assumptions would have to be made concerning some of the required simulation program input data.

Although providing a link to practice implies taking a real existing building, the approach adopted was to draw up a specification for a simple prototype office building which would embody those features which frequently occur in real buildings. This approach avoids the problem of having to deal with a real building which usually has some unique features when compared with other buildings. The specification can be considered as incorporating those elements which would address the general modelling problems most frequently encountered.

The specification for the construction of the case study building was one which, from experience, would mean that any summertime overheating problems could be dealt with by the application of relatively simple measures such as solar protection or night ventilation.

The full description of the building is given in Appendix 4 its main features being as follows.

It is a cube consisting of 5 identical floors orientated with facades facing the cardinal points. Offices are arranged around the perimeter of each floor which has a central circulation/ancillary area. Each floor has four identical corner offices and a further twelve standard offices equally distributed three per facade.This arrangement enables a central office on a facade to be modelled as being surrounded by identical spaces.

The corner offices have exactly double the floor area of the standard offices, which means double the internal gains, and double the number of windows as the standard offices, but on two different orientations. All windows are of the same type and size. This arrangement enables the performance of a corner office to be readily assessed with respect to a standard office. The basic floor plan is illustrated in Figure 4.4.

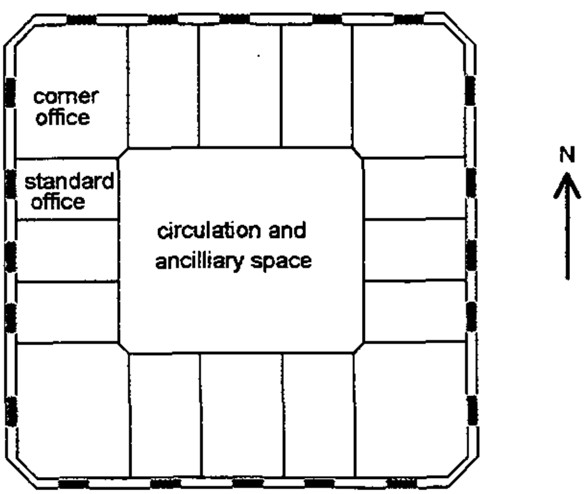


Fig. 4.4 Basic floor plan.

Other building information was provided at a level expected to be the case in practice as follows:-

- layers of materials with thicknesses, but without thermophysical properties
- glazing description with basic characteristic data, but no detailed description of physical properties which is not normally available.
- type, level and time schedules for occupation and equipment to enable values for internal gains to be determined, but no radiative/convective split
- verbal description of lighting system and its control
- verbal description of ventilation strategy

This leads to the necessity for the users to make assumptions on data which is not available from the building description nor from the program manual. Information obtained from the PAMDOCs is supposed to fill the gaps.

The users were asked to calculate 2 cases:

- -A base case with a minimum hygienic ventilation rate provided through open windows during occupancy time and infiltration only during non-occupied periods.
- -A 'night ventilation' case, with enhanced window ventilation for cooling purposes during non-occupied periods with information being provided by a sketch of the window opening pattern.

Some of the participants also considered measures such as blinds for solar protection.
The problem description was initially supplied to the prospective users for comment. The comments received from the participants after the first distribution of the specification almost exactly addressed items where incomplete information had been intentionally given and where assumptions would normally have had to be made. These should have been available from the PAMDOCs. They asked for radiative/convective splits, detailed glazing descriptions, thermophysical properties etc.

4.3.4.1.2 Results

Some of the results from 4 participants using the latest versions of their PAMDOCs are shown in tables 4.1 to 4.3.

		User:	TNO	Newcastle	Sorane	EMPA
Room	Case	Program:	VA114	SERI-RES	TRNSYS	DOE-2
south center	Base case		1060	1493	1089	1068
	with blinds		692		788	38
	open windows night, no blinds		849	706	200	507
	open windows night, with blinds		36		4	34
south-east corner	Base case		1060	1480		1248
	with blinds					36
	open windows night, no blinds			688		782
	open windows night, with blinds					34

Table 4.1: Number of hours with room temperatures > 25 °C (occupancy time only)

		User:	TNO	Newcastle	Sorane	EMPA
Room	Case	Program:	VA114	SERI-RES	TRNSYS	DOE-2
south center	Base case		1037	1447	1089	913
	with blinds		182		210	0
	open windows night, no blinds		394	290	14	94
	open windows night, with blinds		0		0	0
south-east corner	Base case		969	1451		919
	with blinds					0
	open windows night, no blinds			328		156
	open windows night, with blinds					0

Table 4.2: Number of hours with room temperatures > 28 °C (occupancy time only)

		User:	TNO	Newcastle	Sorane	EMPA
Room	Case	Program:	VA114	SERI-RES	TRNSYS	DOE-2
south center	Base case		41.6	45.4	<= 41	38.6
	with blinds		30.8		<= 31	26.2
	open windows night, no blinds		35.7	34.5	<= 29	31.0
	open windows night, with blinds		26.2		<= 29	26.1
south-east corner	Base case		39.2	44.2		37.7
	with blinds					26.1
	open windows night, no blinds			33.8		30.9
	open windows night, with blinds					26.1

Table 4.3: Maximum calculated room temperatures during run period, °C (occupied period only)

Since the PAMDOCs do not require the results to be presented in the same way some agreement was necessary in this respect. Also, in order to present a short and compact comparison table not all the results have been included. Daily curves are not presented here. The information given in Tables 4.1 and 4.2 follows the Dutch requirement. In addition, the maximum predicted room temperatures are given in Table 4.3.
The results still show a substantial disagreement in some cases. There is quite a good agreement in the overheating hours for the base case, although the peak temperatures are considerably different. Some of the different hour numbers are due to different occupancy schedules used. The effects of the use of blinds as well as window ventilation at night are obviously considered in different ways by the different participants. The results from SORANE and TNO agree regarding the effect of blinds, whereas those from EMPA show a much stronger effect. On the other hand, the effect of window ventilation at night is the strongest for SORANE, followed by EMPA and with a rather good agreement between TNO and Newcastle.
Concerning these effects the task is not only how to model correctly the presence of blinds or an open window, but also to define how they are used. This means that the differences can be due to different *strategies* or due to *different ways of modelling* these strategies in a program. Development of the PAMDOCs is mainly concerned with the latter situation, although users may also need help for the strategies themselves.

4.3.4.1.3 Conclusions

The case study satisfied two major requirements; firstly it enabled PAMDOCs to be used in a realistic situation and so forced the users to ensure that their PAMDOCs were complete especially with regard to guidance on the assumptions that would normally have to be made when considering an incomplete building specification. Secondly the results could be used to assess the differences between the ways that different PAMDOCs treated common building operational aspects such as the need to control blinds and ventilation.through windows.

Regarding the users' first reactions to the specification, it can be said that it has positively influenced the understanding of the purpose and therefore of the quality of the PAMDOCs and ensured that they were complete enough to be used in a real situation.
There are still differences in the results, stemming from the different ways of considering blinds and night-time window ventilation. The PAMDOCs used do not necessarily contain unified strategies for these problems, but should advise the users to correctly handle a strategy. There is the implication however that further work is needed to unify strategies if consistent results are to be obtained.

4.3.5 Multiple User Tests

The case studies were an important element of the evaluation process and were useful in terms of PAM improvement. However, as they were carried out by the PAM authors, who had a special knowledge of the problem, a full investigation of the problems of user uncertainty that different PAMs were likely to encounter was not possible. It was agreed therefore that one of the case studies, the base case, be carried out with each PAMDOC being applied by several users who would have some experience of the different programs but no experience of the guidance contained in the PAMDOCS. It was not possible however to apply this procedure to all the PAMs due to the practical difficulties of finding appropriate users.

4.3.5.1 Summary of work carried out by A Wijsman (IEA21RN313/93) and G Zweifel (IEA21RN280/92)

4.3.5.2 Method

In the Netherlands 4 users were asked to do calculations on the IEA Annex 21 'Base Case' with the Dutch simulation program VA114 in 2 stages: without and with the use of the VA114 related PAM developed by TNO-Bouw.
To obtain maximum information from this test some extra work was done:
Before the 4 users started with stage 1 they were asked to provide information about how they would do the zoning and about how they would present the results. After they had delivered this information stage 1 was started with a prescribed way of zoning and a prescribed way of presenting the results.
After the 4 users had completed the simulations a fifth user studied their input and output files. This was done to search for errors, differences in assumptions made, differences in input data, differences in modelling. This fifth user also carried out the BaseCase simulation.
In this way important information for PAM development was collected.
In Switzerland, 3 users with different knowledge levels: highly experienced, medium experienced and a beginner, were selected from the community of the companies equipped with the simulation program DOE-2. They were asked to perform an overheating risk assessment on the IEA Annex 21 case study building for 4 different cases with blinds and different assumptions for internal heat gains and ventilation. This was done the first time without any aids, according to the practice of the respective company, and a second time with the tool developed in the framework of this project. This was *not* the PAMDOC, nor any other paperwork, but a standard DOE-2-input for this application, formed by a transformation of the PAMDOC content. The users were unaware of the differences.
An important aspect of this test was that the level of information provided was **not** in such detail as would be necessary to achieve very close results. It's intention was to provide as much information as would be expected in a practical case at the stage of a project where the question of overheating has to be treated, and which is usually available for the

products in use. No information was given on the zones to be selected, except that for comparison reasons they were asked to treat *at least* the center office module in the south and the west facade. The location of the building was given and the users were asked to follow the regional requirements and to provide *at least* any results to meet these.

4.3.5.3 Results

The Dutch work resulted in:

- completed questionnaires about the way of zoning
- completed questionnaires about the way of presenting the results
- list with findings from checking the input files and a documented print out of the input values.
- influence of the use of a PAM (together with a check by a second person).

Figure 4.5 gives the results without the use of a PAM and without check by a second person, Figure 4.6 gives the results with the use of a PAM and with a check by a second person. The check by a second person was shown to be essential.

From the Swiss work, information was obtained on:

- which zones are chosen by different users
- assumptions made by different users in areas where information was lacking.
- the impact of these assumptions on the results
- how the users try to meet requirements without having the corresponding tools
- what major mistakes are made

		1st Stage				**2nd Stage**			
Zone	**Case**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
South	**User 1**	1147.2	960.4	*17.2*	398.8	*0.2*	*18.0*	*0.0*	75.4
	User 2	82.2	82.2	*6.3*	*0.0*	33.4	33.4	*0.0*	101.9
	User 3	71.1	60.7	*24.7*	960.2	*3.5*	*5.0*	*0.0*	*16.6*
West	**User 1**	*0.0*	*0.0*	*0.0*	*0.0*	---	---	---	---
	User 2	216.7	216.7	33.7	*0.0*	102.3	102.3	*0.2*	219.8
	User 3	38.9	31.6	*15.0*	893.4	82.5	94.5	*0.0*	139.0
East *	**User 1**	2735.0	2641.0	103.0	1727.0	1572.7	---	50.7	---
Corner SW	**User 2**	67.0	67.0	*4.0*	*0.0*	*2.2*	*2.2*	*0.0*	*14.5*

Table 4.4: Results of the Swiss user test, in the form of overheating Degree-hours (Kh)
* Own assumptions from stage 1 partly kept in stage 2 to show differences.
Italics: No overheating

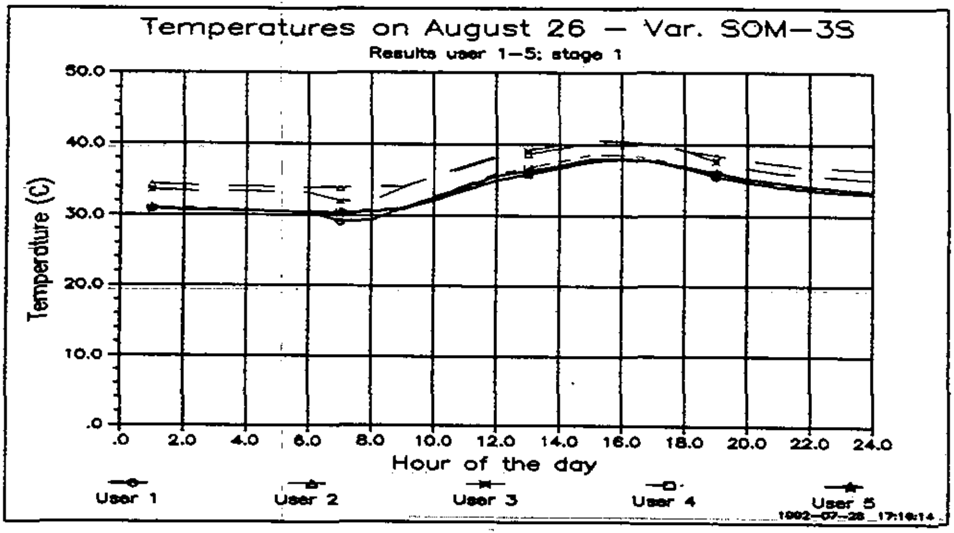


Fig.4.5(a)

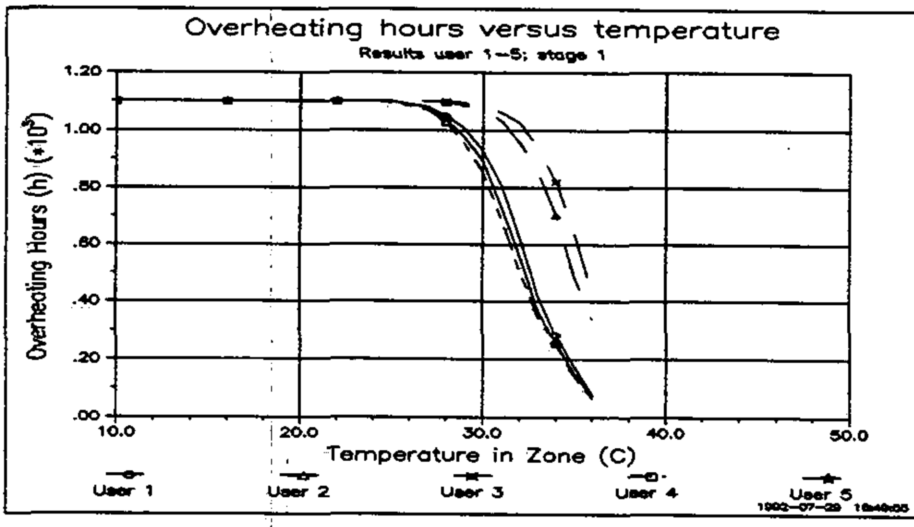


Fig.4.5(b)

Figure 4.5a and b: Results after stage 1
(without PAM and without check by second person)

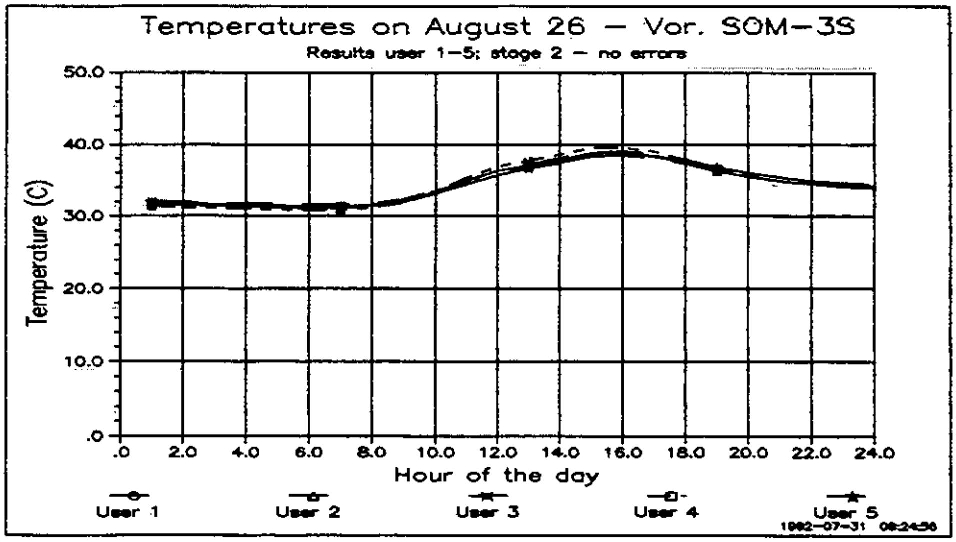


Fig. 4.6(a)

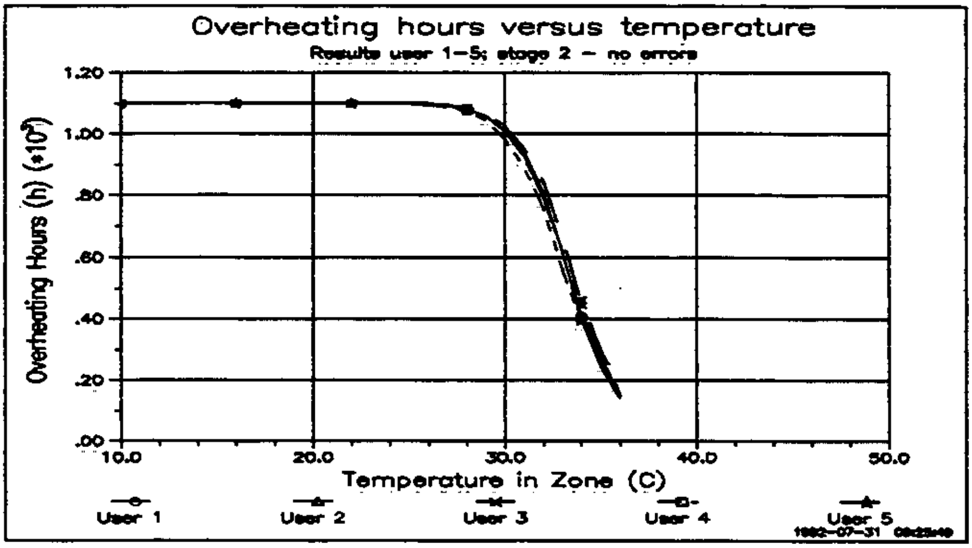


Fig. 4.6(b)

Figure 4.6a and b: Results after stage 2
(with PAM and with check by second person)

4.3.5.4 Conclusions

The two-stage user tests resulted in the following observations:
There is some agreement on how to choose zones for modelling. The information gathered is a first step in the direction of development of criteria/rules for zoning.
There is no uniform way of presenting the results. The proposal in the PAM is a first step in the right direction. In Switzerland this is solved by specifying legal or standardised requirements.
Without the use of a PAM the calculation results show considerable differences. Serious mistakes are made even by experienced users, which stresses the need for quality assurance.
Major sources of differences are due to different assumptions in 3 major areas:

- Internal loads (including 'realistic' user behaviour by defining probabilities).
- Window and solar protection definition .

- Ventilation.

Use of a PAM gives much closer results. However, the use of a PAM only makes real sense after a second person has checked the input files.
The tool developed in Switzerland can bring a substantial improvement in the results, reducing the range in prediction of hours of overheating (Kelvin-hours) by a factor of 10.
Each application requires a separate PAM. It is expected that carrying out user tests for other applications will identify other shortcomings in the PAMs and lead to their improvement.

4.4 Development

During the evaluation a number of issues were identified for further development work which resulted in the production of a number of papers. The summarised results of this work are presented here and the complete papers form Section 4 of Volume 2 of this final report.

4.4.1 Selection of zones for assessment; Investigation summary

B. Warren and B Sodagar

4.4.1.1 Introduction

One of the objectives of Subtask B is to ensure, by the application of quality assurance techniques, that a measure of consistency is achieved between workers carrying out the same assessment task. This cannot be achieved if different people carrying out the same task choose different zones upon which to operate. Different results will be obtained leading possibly to different design decisions. This is particularly relevant to assessments of the type where a zone, or selection of zones, is taken as typical of the whole building performance, or perhaps representative of the worst case, in order to reach a design decision without having to assess the whole building performance.

4.4.1.2 Objectives

a) To determine whether, for the same purpose and building, different people select different zones for overheating assessment.

b) To determine the methodologies used for zone selection with the aim of making recommendations.

4.4.1.3 Method

The method of investigation was to invite designers to select the zone or zones they would use when carrying out an overheating assessment on a specified office design. The building specification used was developed within Subtask B for PAM evaluation. Initially the survey was conducted amongst colleagues of Subtask B participants but was later extended to personnel in a selection of consultant's offices.
The results of the survey were compared with the results of simulations using SERI-RES.

4.4.1.4 Results

The results of the surveys confirmed that identification of zones for assessment may be very different from user to user and that the basis for selection is user experience. The minimum number of zones selected by a particular user was 2 and the maximum 15. The zone attracting the most votes from all the respondents was the South facing centre room on the middle floor. The simulation results indicated that the worst zone for overheating was the East facing centre room on the middle floor which was also confirmed by other members of the Subtask using different programs. This was probably due to high solar radiation gained in the morning (East gives the highest daily mean in June), stored due to the heavyweight nature of the building, and combined with the internal gains in the afternoon. Only five out of the seventeen survey respondents selected a range of zones which included this worst case.

4.4.1.5 Conclusions

Unless very obvious cases exist, e.g. S facing highly glazed 'lightweight' spaces with high internal gains, or that the zones to be assessed are to answer specific questions, eg is the kitchen likely to overheat?, then users' selections of zones for assessment vary widely both in terms of the number selected and their position and orientation. It is likely that the overall performance of the respondents would have been better if the building had been thermally lightweight. Accumulated experience needs to be obtained and 'handed down', and simple selection techniques need to be developed possibly based on a range of simulated cases. Until this has been done only experienced users should carry out assessments or all zones should be modelled.

4.4.2 Windows/glazing; Investigation summary

A. Wijsman

4.4.2.1 Introduction

Overheating risk in buildings is assessed using computer programs that describe the thermal behaviour of the building. An important aspect is the translation from practical building to input data for the Building Simulation Program. One detail in this process is the translation from a practical window system to input data.

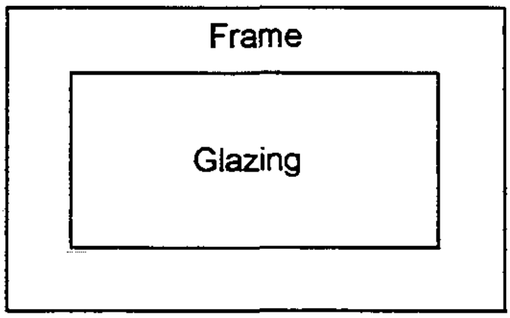


Figure 4.7 Window system

In a PAM (Performance Assessment Method) guidelines are given on how to handle several aspects of buildings. The treatment of the window system is one of these aspects.

4.4.2.2 Objectives

The aim of this paper is to give some more background information about window system modelling with the aim of improving the PAMs concerning the treatment of the window system.

4.4.2.3 Method

First a review is given of different methods of treating practical window systems. Then the influence of these methods of treatment on overheating results was determined using the Dutch Building Simulation Program VA114. The office module used was a South facing module on the third floor of the specified IEA-21 Standard Office Building. The Dutch Base Case PAM was followed for all other aspects.

4.4.2.4 Results obtained

- Methods of modelling the window system
- Influence of modelling method on overheating hours
- How to handle in case a part of the window system information is missing.
- Information about window system treatment in the PAMs of the several participants.

Moreover in appendices information is given about:

- Rules to derive the characteristics of a window system from the characteristics of glazing and frame.
- Practical values for glazing-to-window area ratio
- Necessity of using the CF-value.(Solar heat is transferred to the zone by direct radiation, by convection and by longwave radiation. CF is the convective fraction)
- Treatment of window system and self shading. (i.e shading by other parts of the same building).

4.4.2.5 Conclusions

In principle, the various different ways of modelling the window system glazing and frame (separate or combined, resistance network or U-, SF-(Solar Factor), CF-value characterisation) give the same results. Only the effect of self shading when the window system lies deep in the facade will give different results.

However it is important that the CF-value is used, as well as the U- and SF-value, especially for window systems with blinds, etc.and that the area and characterisation of the total window system is known.
For the latter the right rules should be used to determine the characteristics of the total window system from area and characteristics of both glazing and frame.
If no information about the glazing-to-window area ration is available then guidelines (for instance a rule of thumb) should be available in the PAM.
If no characteristics of the frame are available then guidelines (for instance: assume frame has same properties as the wall) should be available in the PAM.
If such guidelines are not given in the PAM big deviations in the results can be expected (see Figures 4.7 and 4.8). Fixed quantitative requirements on overheating hours (for instance the Dutch requirements: number of overheating hours above 28 C should not exceed 20 hours) are then without much sense.
Finally, some of the PAMs developed in the framework of IEA-21 still contain insufficient detailed information for glazing system treatment. The PAMs should be extended with this information.

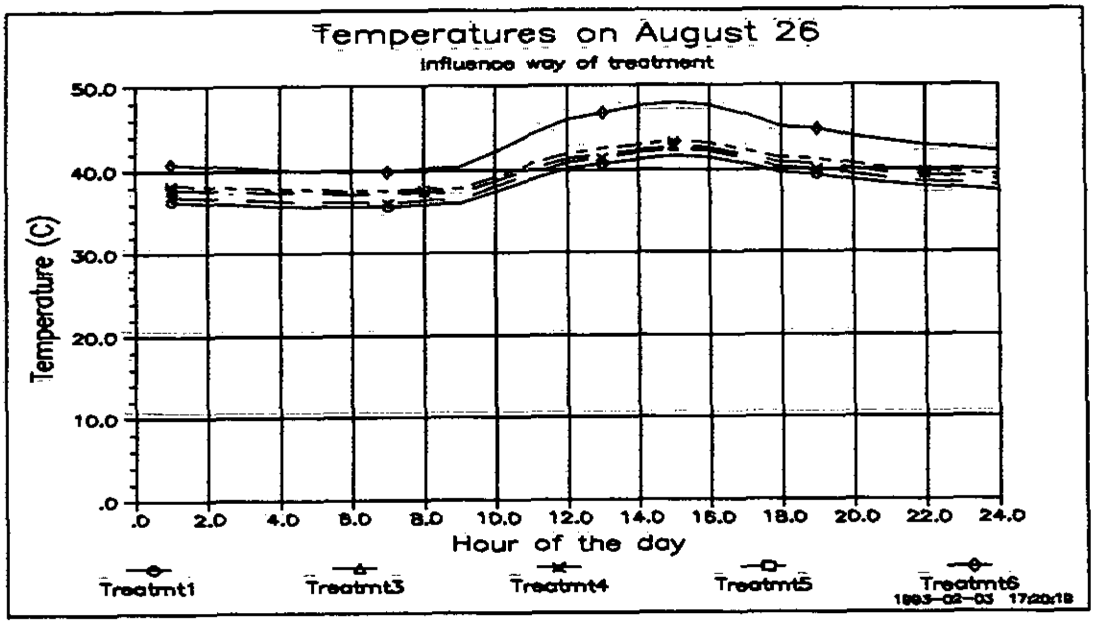


Figure 4.7: Air temperature on August 26, the hot summer day.
Influence of way of treatment.
Window system: double glazing - no blinds

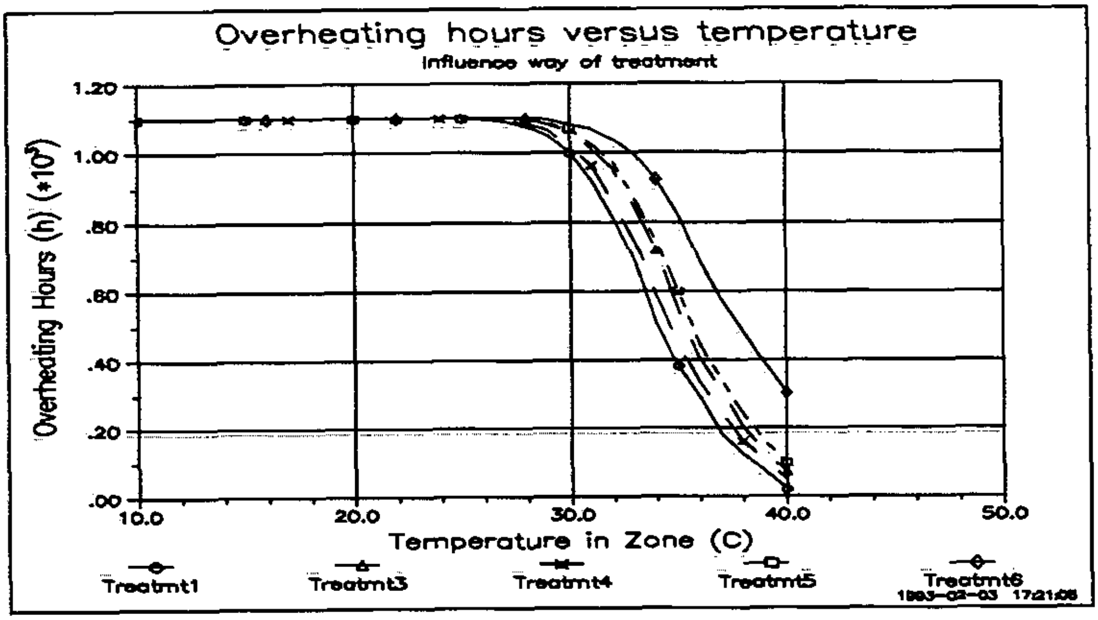


Figure 4.8: Number of overheating hours during the entire summer period versus air temperature.
Influence of way of treatment.
Window system: double glazing - no blinds

4.4.3 Ventilation; Investigation summary

P. Jaboyedoff, C. Prudhomme

One of the techniques used to avoid overheating in buildings consists of providing ventilation by opening windows. The effect of window opening on the indoor temperature is due to additional air exchange with the outside. The results obtained by simulation of such a process are influenced by such parameters as:

- window opening strategy
- air change rate model
- related models for overheating control (blinds, ...)

This study aims to show how different user's hypotheses regarding model selection can affect the results obtained by simulation for overheating assessment.

For comparison purposes the analysis has been performed for office building modules under two different climates, Copenhagen and Rome, and for various assumptions. The building description corresponds to the base-case study performed by the Subtask participants.

In order to perform this study, to compare different strategies and models for window opening, specific models have been developed and integrated in TRNSYS. This enables air-change by window opening to be modelled, taking into account different assumptions.

- Modes of opening can be:
  1) day only.
  2) day+night.
  3) night only at users discretion.
  4) night only as per schedule.
- The window opening by simulated user can be either on/off or progressive.
- The air-change with window open can be either a constant value given as input, or computed by a discharge coefficient method (N=f(DT) where DT is the temperature difference between zone and outdoor conditions)

As an example of the impact of assumptions made by users when using simulation tools, two different simulations of building office modules located at Copenhagen are presented in Table 4.1(see Copenhagen run n°1 and Copenhagen run n°3).

The differences in the assumptions are:

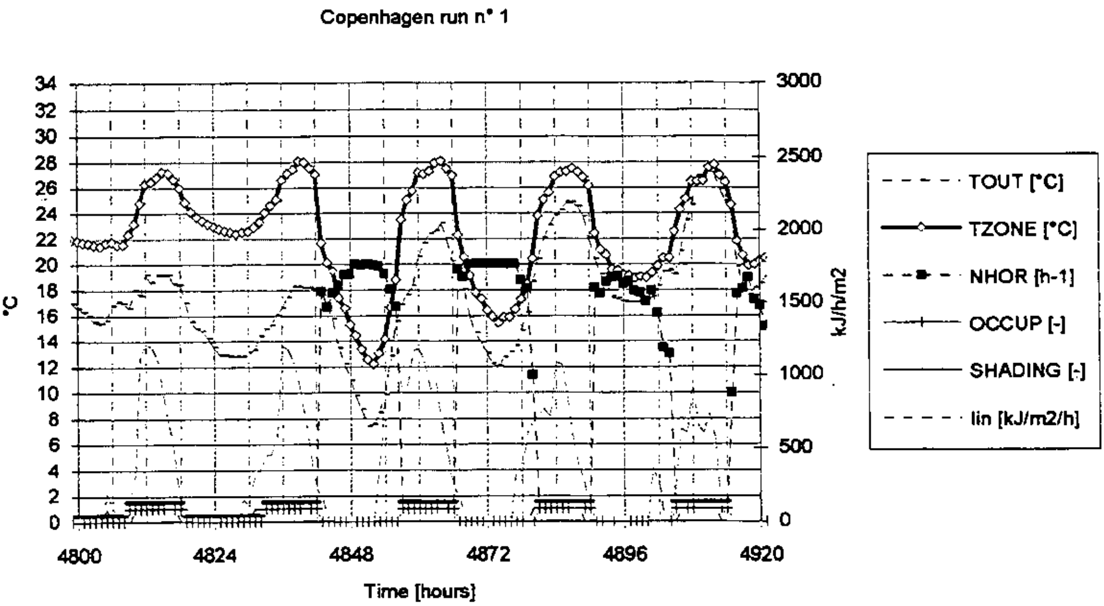
	Run 1	Run 3
Run conditions		
(see explanations on table 4.2)		
Opening strategy (MODE)	3	4
Opening operation	2	2
Calculation of airchange (N)	2	2
Min temp. for night opening	26	every night
N airchange as input	-	-
Max air change rate	20	20
Blind shading coeff.	0.5	0.5
Window shading coeff.	0.87	0.87
Min solar rad for blinds	360	360
Discharge coeff. day time	0.6	0.6
Discharge coeff. night time	0.25	0.25
Attenuation by blinds [%]	30	30

Table 4.1

		Run conditions	
1	MODE (1=Day, 2=Day+night as 3, 3=Night if, 4=Night	Opening strategy (MODE)	3
2	OPEN (1=on/off, 2=progressive)	OPENING operation	2
3	CALCUL (1=N input, 2=N=f(Tzone-Tout)	Calculation of airchange (N	2
4	TNIG (min temp. at end of day for night opening as in	Min temp. for night openin	26
5	NHORIN (N value as input, as in OPEN = 1)	N airchange as input	-
6	NHORMX (max airchange rate)	Max air change rate	20
7	SHADBL (blind shading coefficient)	Blind shading coeff.	0.5
8	SHADWI (window shading coefficient)	Window shading coeff.	0.87
9	LIMSO (Min It level for blinds down [kJ/hr/m2])	Min solar rad for blinds	360
10	C1 (discharge coefficient daytime)	Discharge coeff. day time	0.6
11	C2 (discharge coefficient night time)	Discharge coeff. night time	0.25
12	ATTC (attenuation of discharge coefficient when blind	Attenuation by blinds [%]	30
13	HIN (kJ/m2/K)	Inside convective coeff. (k	10.8

Table 4.2: Conditions for the base case simulation

In the first run, the opening strategy consists of user simulated behaviour that opens the window if the zone temperature is greater than 26 °C. The convective coefficient between the air and inner walls is 10.8 kJ/h/m2/K. Run 3 uses a different strategy with the window being opened every night and the convective coefficient between the air and inner walls is 20 kJ/h/m2/K. These differences significantly change the results obtained as is seen from Figs. 4.9 and 4.10.



Run conditions (see explanations on table 4.2)	
Opening strategy (MODE)	3
Opening operation	2
Calculation of airchange (N)	2
Min temp. for night opening	26
N airchange as input	-
Max air change rate	20
Blind shading coeff.	0.5
Window shading coeff.	0.87
Min solar rad for blinds	360
Discharge coeff. day time	0.6
Discharge coeff. night time	0.25
Attenuation by blinds [%]	30
Inside convective coeff. (kJ/	10.8

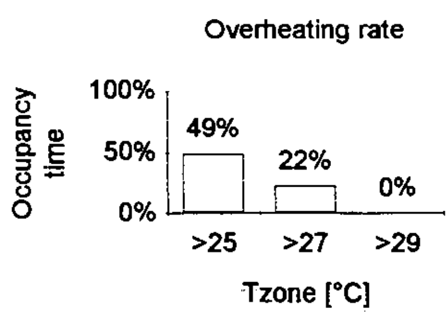


Figure 4.9 Results from Run 1

other parameters kept constant, building characteristics, blinds, etc., variation of the order of 50 to 100 % may still occur in the overheating assessment.
The results are mainly affected by the following:

- Inner wall convection coefficient values with window opened (further research is needed in this area)
- The simulation of users' behaviour.
- The window opening air-change model.

The results obtained in this study confirm that the program user's influence on the results is as important as the physical quality of the programs.

4.4.4 Light Switching. Investigation Summary

Gerhard Zweifel

4.4.4.1 Description of Lighting Systems

Types

The different existing lighting systems can be distinguished by several qualities: Lighting type (Incandescent, fluorescent etc.), Fixing (Suspended, recessed, task lights etc.), Integration in ventilation system (non-vented, vented to return air, vented to supply and return air etc.)

Control

There are different ways for controlling the artificial lighting in a room: Automatic or manual control; on/off switching, stepwise or continuous dimming; different criteria for automatic control (e.g. illumination, occupancy); partition of a zone into subzones for control (e.g. perimeter and core).

4.4.4.2 Modelling

Types

For modelling in building simulation, artificial lighting systems are essentially a heat gain in the room or zone with a couple of parameters needed to describe the qualities mentioned above. A part of these parameters are difficult to get information about, because they are not design parameters for the lighting manufacturers and therefore are not measured and/or calculated. Default values given in certain programs are helpful, but the user has little possibility to judge these and therefore has to trust them.

Control

It is sensible to avoid unnecessary loads before cooling is provided in a building. One possibility for this is to switch off or reduce artificial lighting in a room when daylight provides enough illumination. Therefore it is essential for building simulation applications such as overheating risk assessment, that the corresponding strategies can be calculated by the program being used.
There are different levels of modelling lighting control. The simplest one requires the user to define, e.g. by a schedule, when the lights are switched on and off. A stepwise control could be simulated in this way, too.
A correct simulation of any automatic control taking into account the illumination level requires a parallel daylight calculation. This is neither a simple nor an easy task, nor is it included in all programs. No further details about such a calculation are given here.
In the programs DOE-2 [4.2], SERI RES UK version 1.2 [4.3] and VA 114 [4.4] the control can be calculated in similar ways: A zone can be partitioned into 1-2 daylit and 1 non-daylit subzones. For each daylit subzone, a reference point is assumed or can be specified and assigned an illumination level setpoint and a control type. The program will calculate the illumination level at the reference points due to daylighting, and determine the electric power of the artificial light in each subzone such that the illumination level is never below the setpoint level. In VA 114 the natural illumination level is estimated as a function of the solar radiation and the window properties.
The correct simulation of manually controlled lights is more complicated. The two extreme cases of a very unaware user and an ideal user can be covered by the methods for

automatic control described above. In some programs there is an additional possibility for defining a control probability in order to model a non-ideal user. Although this may lead to estimates closer to the practice, there are two reasons for a recommendation not to use these possibilities e.g. in an overheating risk assessment:
- The results will not be the same for different runs with equal input parameters
- Non-ideal behaviour of the occupants should result in discomfort rather than in increased energy consumption.
Simplified methods have to be used in programs without daylighting possibilities. e.g. it can be assumed, that on sunny days with a reasonable operation of the shading devices (e.g. avoid penetration of direct radiation.), no artificial lighting will be needed in a perimeter zone of e.g. 5 m from the exterior wall.

4.4.4.3 Connection to Window and Shading Devices

The Problem

With a daylighting calculation, there is a connection to the treatment of windows and especially of shading devices due to the fact that these may have an effect on the illumination and therefore on the use of artificial lights.
There are some important parameters describing exterior blinds:

- the criterion, when the blinds are to be closed
- a visible transmission value for the blinds, possibly time dependent.

The latter depends on the type of blind as well as on the operation (e.g. slat angle which can be varied) and very few data are available. Some reasonable data, based on measurements, could be provided for this by a study carried out in the frame of IEA Annex 21 in Switzerland.

Studies Performed

The influence of the illumination level for the control of the artificial lights on the lighting energy use and on the indoor temperatures was analysed for the Office Case Study of Annex 21 and is reported in [4.5].
The aim of the Swiss study [4.6] was to estimate the values to be used in the visible transmission schedules for DOE-2 when simulating blinds of different types and with slats at different angles. Parametric runs with DOE-2.1D with variable blind transmission factors were compared to results from measurements [4.7] and with results from the daylighting program SUPERLITE. In this study the strategy was that no direct sunlight can enter the space and that only diffuse and reflected sunlight from the slats reaches the interior. The solar angles determine the required blind slat angles to prevent direct radiation from penetrating into the space. The most general way of description was found by defining a function which describes the visible blind transmission factor as a function of the solar angle δ, which is defined according to Figure 4.11.
The function is:

$$T = 0.08952 + 0.2158 \cdot \tan\delta + 0.2031 \cdot (\tan\delta)^2$$

It is shown in Figure 4.12 and was built into DOE-2 in the form of a 'functional input'.

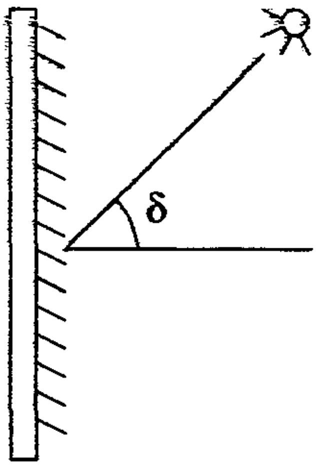


Fig. 4.11: Definition of the solar angle δ

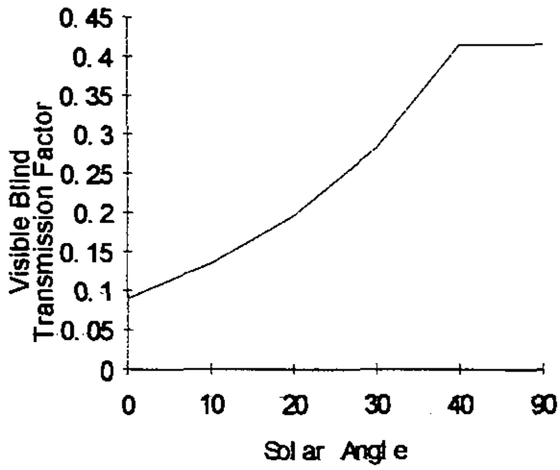


Fig. 4.12: Blind transmission factor as a function of the solar angle δ

4.4.4.4 Need for Further Studies

Similar illuminance measurements with blinds should be made under clear sky conditions. The reflection of sunlight on the blind slats is a rather complicated procedure and should be studied in more detail.

Additional studies could perhaps lead to rules of thumb for use with programs without daylighting capabilities, giving, for example, information on the need for artificial lighting in the perimeter zone depending on the solar radiation on the window, the transmission factor and the needed illumination level.

4.4.5 Overheating definition. Investigation summary.

B. Warren

4.4.5.1 Introduction

It was found during the cross comparisons of the documented overheating performance assessment methods that different program users interpret what is meant by overheating in different ways.This results in the use of a number of different overheating criteria against which simulation program outputs are compared to determine whether or not a problem exists. Since, even when using the same input data, different programs produce different numerical results the application of different ways of interpreting these results is likely to confuse the issue even further. A total of five different criteria were identified from the PAMDOCs produced in the work of Subtask B but it is likely that others are also used. It is also likely that different criteria are used for different building types;

4.4.5.2 Objectives

1) To document the different criteria used for assessing overheating as determined from the work of Subtask B.
2) To demonstrate that the use of different criteria could lead to different design decisions being made.
3) To propose further work in this area.

4.4.5.3 Method

The sources for the investigation were taken from work by others as follows:

1) R. R. Cohen, D. K. Munro and P. A. Ruyssevelt ; Halcrow Gilbert Associates Ltd., Burderop Park, Swindon SN4 0QD, UK :'Overheating Criteria for Non Air Conditioned Buildings'; CIBSE National Conference 1993.
2) H. Eppel and K. J. Lomas ; 'Comparison of Alternative Criteria for Assessing Overheating in Buildings'. An IEA working paper.
3) B. H. Bland; 'Proposed Method for Calculating Thermal Discomfort'.An IEA working paper.

4.4.5.4 Results

The results of the work carried out by Eppel and Lomas and Cohen, Munro and Ruyssevelt clearly demonstrate that the use of different criteria to define overheating can lead to different design decisions being made. SERI-RES was used to determine the allowable window area for a house which would avoid overheating. The interpretation of the program output using the five different overheating criteria led to considerable variation in the final result. As an example, when SERI-RES is used, window areas based on the UK Passive Solar Programme criterion could be over 50% larger than those based on criteria used in The Netherlands.

4.4.5.5 Conclusions

For a given application different design decisions may be made, or different levels of comfort achieved, depending on the combinations of program and overheating criteria used. On the assumption that different programs will continue to be used amongst the international design community then, at least, some rationalisation of criteria is required to ensure consistency of use for different applications. It is proposed that initially a programme of work be carried out to thoroughly document the different criteria and test their use for different applications taking into account the implications for thermal comfort and energy use. This would enable designers to choose, from a range of criteria, those best suited to the solution of particular design problems.

4.4.6 Suspended ceilings. Investigation summary.

A. Wijsman

4.4.6.1 Introduction

The study of overheating risk in buildings is carried out using simulation programs that describe the thermal behaviour of the building. An important aspect of their use is the translation of information from the actual building to input data for the Building Simulation Program. Of particular interest is the treatment of suspended ceilings.

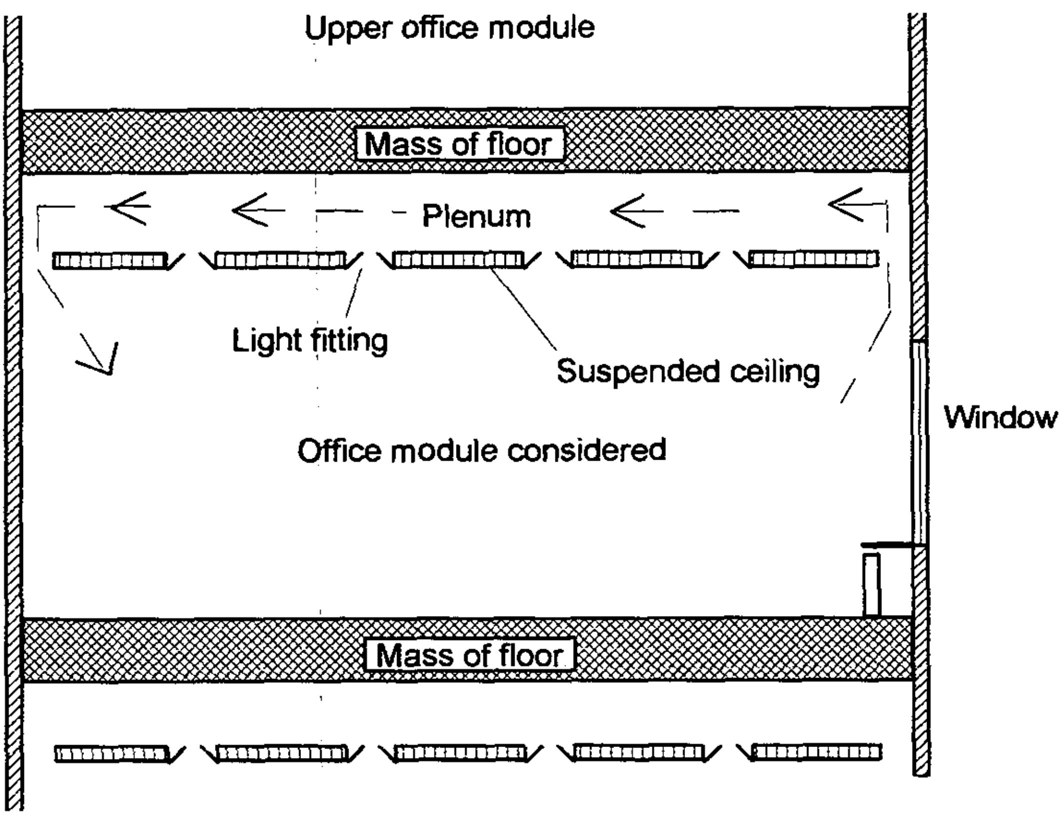


Figure 4.13:Office Modules with suspended ceiling

In a PAM (Performance Assessment Method) guidelines are given on how to treat different aspects of the building. The treatment of the suspended ceiling is one of these aspects.

4.4.6.2 Objectives

The aim of this paper is to provide more background information about suspended ceiling modelling and to provide guidelines for the improvement of the PAMs concerning this aspect.

4.4.6.3 Description of suspended ceiling

The ceiling of a room (e.g. an office module) and the floor of the room above is often basically formed by one and the same construction, e.g. a concrete slab. For visual and acoustic reasons an extra lightweight construction layer is generally provided beneath this

construction. Between the concrete slab and this extra layer there is usually an air gap (the plenum). This construction is called a suspended ceiling.
A disadvantage of such a suspended ceiling is the shielding of the mass of the concrete slab. During summer time this leads to higher zone temperatures or to higher peak cooling loads.
In practice this disadvantage can be avoided by making the suspended ceiling partly open (15-20% open). Air exchange between zone and plenum couples the zone to the mass. The visual and acoustic advantages are maintained using this construction.
Artificial lighting devices may be part of the suspended ceiling.
In practice there are several possibilities for airflow through the plenum:

1. Suspended ceiling is closed; there is no airflow
2. Suspended ceiling is partly open; there is only airflow by buoyancy when the zone air temperature is higher than the temperature in the plenum.
3. As 2., but there may also be a continuous airflow caused by other air movement patterns within the zone.
4. Exhaust ventilation air is removed mechanically through the plenum.
5. The plenum is ventilated with ambient air (operation at night for cooling).

The airflow through the plenum is not usually controlled. In practice, combinations of the above mentioned cases can occur and may also depend on the control of the mechanical ventilation system.

4.4.6.4 Simulation of the suspended ceiling

For simulation purposes information is required concerning:

- the airflow that occurs in the cases 2 and 3 above.
- the proportional split of the lighting heat dissipation between the plenum and the zone
- the convective heat transfer in the plenum.
- the infiltration rate of the plenum.
- etc.

There is no control of the airflow through the plenum. However the airflow can change because of mechanical ventilation control. It is important to know how this situation is handled by the program.

One- or two-zones approach

Many building thermal performance programs work with 'Center of Wall-to-Center of Wall' dimensions for the zone geometry and with constructions that have 'zero-thickness'. The suspended ceiling construction can have a thickness of up to 0.5 m, so cannot be neglected.
Two approaches are possible:

A. Treat the office module including the suspended ceiling as 1 zone; the suspended ceiling with floor above being treated as a single ventilated construction.
B. Treat the office module with suspended ceiling as 2 zones; the plenum is treated as a second zone.

Approach by the different programs

The report [4.8] gives information about the capability of programs to handle the one- or two-zone approach. Programs considered are DOE2, SERI-RES, ESP and VA114.

4.4.6.5 Studies performed on suspended ceiling.
At TNO-Bouw a study was performed on the influence of the suspended ceiling on the overheating of an office module [4.9] and some preliminary work was carried out on the one-zone and two-zone approach [4.8].

4.4.6.6 Need for further studies
The one-zone and two-zone methods of treating different cases are described. The resulting effects of these methods should be investigated for all the cases.
An investigation of the effect of a known airflow through the plenum as well as calculated airflow is also necessary.
The results will contribute to guidelines regarding how to simulate the influence of suspended ceilings in an appropriate way.

4.5 REFERENCES

4.1 IEA Solar Heating and Cooling Programme Task 8: Passive and hybrid solar low energy buildings - United States
4.2 DOE-2.1D Supplement
4.3 Contribution from Behzad Sodagar, University of Newcastle upon Tyne
4.4 Contribution from Aad Wijsman, TNO-BOUW, Delft
4.5 Aad Wijsman: 'Influence of Some Assumptions Made During Implementation of the Base Case' (IEA21RN223/92)
4.6 Nicole Hopkirk: 'Estimation of Illumination Reduction Factors for Simulation of Blinds with DOE-2' (IEA21RN234/92)
4.7 W. Geiger et al: 'Untersuchungen über wärme-, licht- wind- und schalltechnisches Verhalten von Sonnen- und Wetterschutzanlagen', 1979
4.8 A. Wijsman: 'Simulation Aspects of Suspended Ceiling', December 1993.
4.9 A. Wijsman and W. Plokker: 'Gevoeligheidsstudie Thermisch Open plafond (Sensitivity study on the thermal effect of open suspended ceilings.)', June 1990.

Chapter 5

Information Management
IEA Annex 21 Subtask B

5.0 INTRODUCTION

5.1.General

Any research activity has as its objective the furtherance of knowledge and unless that knowledge is disseminated its usefulness is lost. Furthermore, it is essential that the knowledge is used in practice. The use of knowledge ensures that it is constantly under review and that development is likely to take place as part of a natural process. This is illustrated in Fig 5.1.

Two important aspects of the knowledge cycle which have to be considered are the time lag from creation to utilisation and the comprehensiveness of dissemination and utilisation. Efficient knowledge transfer demands the dissemination of knowledge amongst the widest possible audience with the shortest time delay.

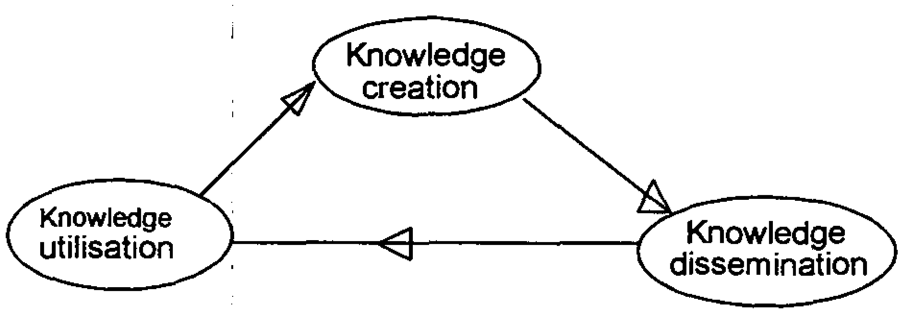


Fig 5.1 The Knowledge Cycle

5.2 The requirements of Subtask B

In the context of Subtask B work was carried out as part of the knowledge creation process and an approach had to be determined whereby this knowledge could be disseminated to a wider audience to ensure that it would be readily available for use. Dissemination and availability for use also imply that the knowledge would be easily accessible. It was envisaged that there would be two basic types of user of the information produced. The first type would be the user whose objective would be to carry out performance assessments of buildings whilst the second type would be more concerned with the development and documentation of performance assessment methods. For convenience we can call these types the *client* and the *developer*.

From the point of view of the *client* a system had to be available whereby a potential user would be able to access PAMDOCs, evaluate them for use and obtain the necessary information to enable a given performance assessment to be run in a consistent and 'approved' manner. The *developer* should not only be able to access and edit the contents of a PAMDOC but should also have the ability to create new PAMDOCs using existing documentation. The *client* is concerned with PAM utilisation and the *developer* with PAMDOC creation and development. For this to happen it is necessary that the PAMDOCs are placed in a structured library or other data base to enable the information embodied in them to be readily accessed. The diagram in Fig 5.2 illustrates this.

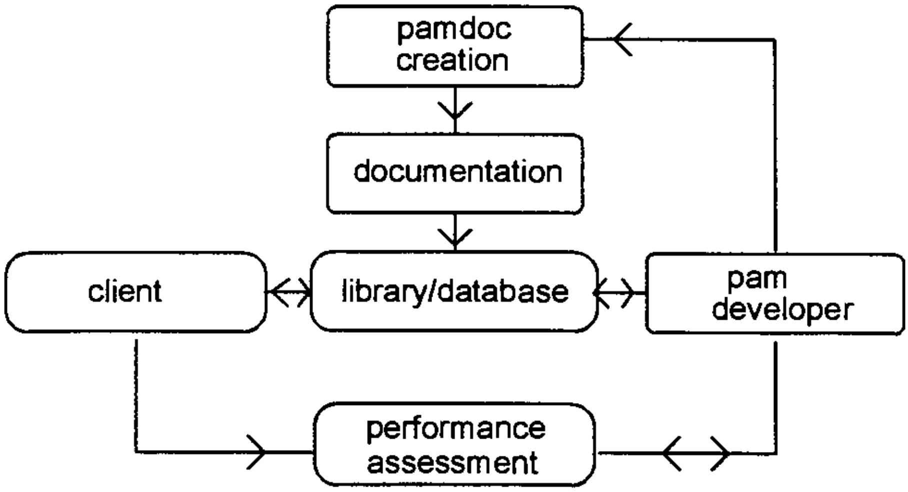


Fig 5.2 Use of PAM knowledge

The need to produce an easily accessible body of information to meet the needs of both user types and with the capabilities for future expansion and international use made the choice of a computerised database inevitable. Although the client type of user would only need to access the information and follow it's recommendations a paper based library would hardly be suitable and it would be far too cumbersome for a developer.

5.3 The Management Information System (MIS)

A computer-based system to document assumptions made within programs for predicting the performance of buildings was developed in Subtask A. The main aim was that the documentation should be:

- complete - all assumptions and approximations should be documented
- consistent - agreed definitions of all terms should be used
- standard - thus enabling comparisons between programs to be made easily
- understandable by computer - thus enabling information to be 'managed' easily
- extendable - so that new methods can be added.

The program was written in PROLOG and runs on a PC. The key principle adopted was the use of a series of multi-choice 'menus' to obtain answers to specific questions about the assumptions made. The consequent avoidance of free format text brings advantages in speed with which an object can be documented and ease of retrieval and analysis. A typical menu might look like the example below:

Menu n

Convection and longwave radiation at internal surface

[1] are considered separately

[2] are considered as combined

[3] only convection is considered

Once one of these options has been selected, logical links within an overall tree structure of menus present the next logically relevant menu to the documentor e.g.
menu m (linked to term [2] of the above)

Definition of combined convection & radiation coefficient
[1]
[2]
...

Sets of menus are collected together into 'libraries', each library dealing with a specific topic (e.g. a WINDOW library); this can help in re-using commonly occurring aspects and can reduce the time needed for documenting a program.

In order to help the user of the system, sets of menus are also collected together into Groups, where each Group is analogous to a Chapter of a book.

Another key feature of the MIS is its extendibility - if the object being documented has a feature which is not adequately covered in the existing MIS tree structure, the documentor can simply add a new term to the appropriate menu, or even add a complete new menu. The system, therefore, can 'learn' as more objects are documented by experts such as those in IEA Annex21.

This software system has been developed and tested and a User manual has been produced. Although it has been used mostly for the purposes of Subtask A, in principle it could also be used to document PAMs and to aid in the storage and retrieval of the PAMDOCs. For example the Purpose section of the SHELL might become

menu n

Purpose
[1] overheating
[2] energy
[3] plant sizing
...

with subsidiary menus being linked to each term to specify e.g. domain of applicability (building type - house, office, factory, ...), period of time for which assessment is carried out (year, month, day, ...) etc.

The process of creating PAMDOCs could then be reduced to simply 'marking' the appropriate menu terms. The documentation process would then lead to a database of PAMDOCs and the MIS could provide the storage, retrieval and analysis facilities needed by the end user.

The modular nature of the PAMs would fit very well with the MIS concept. New PAMs could be produced by selecting from libraries of PAMDOC sections. Although there appears to be no reason why this approach should not work, it has not been tested in practice to any great extent. The experience of using MIS for documenting programs suggests that the development of a suitable library structure with the MIS may be quite time consuming. It is a possible area for future research.

If the MIS were to be used to document both programs and PAMs, it would be possible to envisage the combined database forming an intelligent knowledge-based tool that could be used to ask the user about his application and purpose (through the PAMDOC libraries) and for the implied requirements in terms of level of program assumptions needed to be matched to the actual programs documented. The user may therefore be given guidance on what program(s) can be used and what data would be required. Much of the code required to perform this matching already exists in the MIS, but a lot of work would be needed to establish the rules that would need to be implemented.

5.4 The Dynalink system

Although the MIS is a relatively sophisticated system and is capable of meeting all the requirements both of client and developer, its development time was judged to be too long to enable it to be of use for PAM development within the Subtask time scale. As an interim measure work was put in hand to develop a simpler system which, although not having the capabilities of the MIS, could be used by Subtask members before the end of the project. Two simple systems were developed in parallel at Newcastle, UK and Sorane, Switzerland. Both systems were based on Word for Windows which, being in extensive use, had the advantage of making them readily accessible to a wide audience. After demonstration of both systems it was decided that the Swiss version, Dynalink, would be adopted and tested by Subtask members.(See Appendix 5 B for software user guide etc.)

5.4.1 General description of Dynalink

Within Subtask B of Annex 21 a number of performance assessment methods have been documented (PAMDOCs). The content of these PAMDOCs is strongly related to the manuals and input files of existing programs and provides complementary information for users of programs when carrying out performance assessments. To cross refer between these documents, both for obtaining information and for carrying out quality control checks, would be a cumbersome and time consuming process for program user and PAMDOC developer alike if only hard copies of the documents were available. Fig 5.3 illustrates the relationship between the three main documents to which a PAM user would refer.

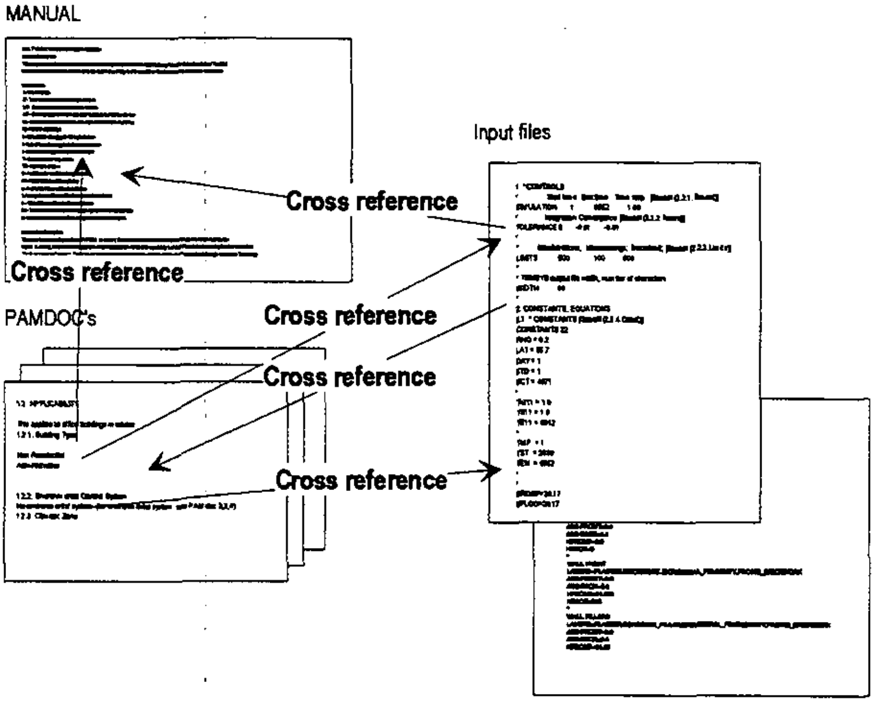


Fig. 5.3 Relationships between the three main user documents.

While developing these documents, it was realised that these interactions could be better handled at development level and later at a user level if the PAMDOCs, reference input files, the already existing manual, and any specific quality assurance documents could be interactively related.
User tests have shown that PAMDOCs have little chance of being routinely used if they are not integrated within an interactive environment. The best solution would be to have the PAMDOCs integrated into the program's manual which should then be related to an interactive input and output system. However, this is impossible to achieve in an international IEA Annex as such systems do not exist for most of the programs and, if they do already exist, the access to such an evironment is only available to the program's developer. Therefore an intermediate solution using a program independent environment was chosen. This program provides people, willing to actually use the PAMDOC's, with a tool to help them in their day to day tasks.
As a word processor is the best tool with which to work on documentation development, the application which generates interactive links between different documents has been developed under this environment using Word Basic Language.
Dynalink is an application developed under Microsoft Word for Windows to generate and use dynamic links (active cross-reference) between the different files that are used to perform an assessment with a simulation program.
The user of Dynalink, when providing the program input, is able to generate dynamic links (interactive cross referencing) between the input files, the program manual and the relevant PAMDOCs in order to access the information embodied in these files. See Fig 5.4.

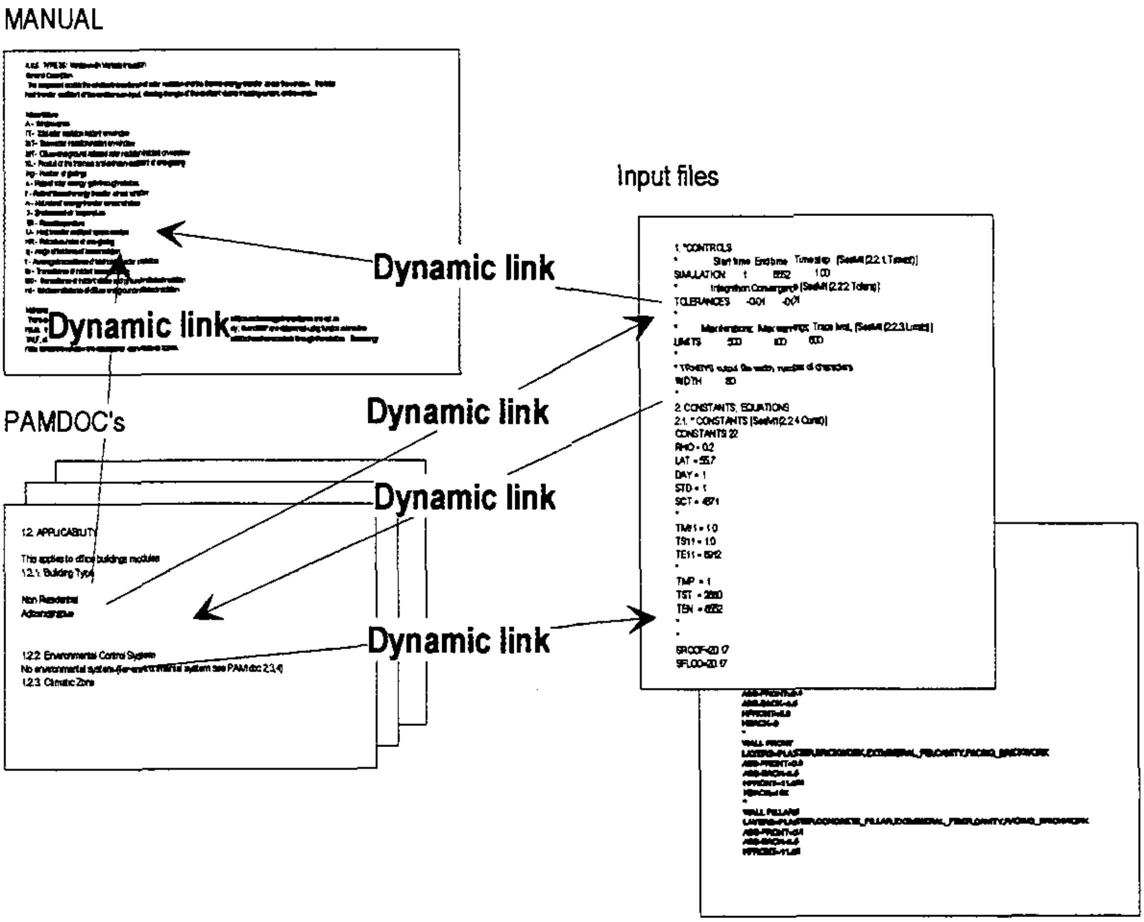


Fig. 5.4 Dynamic link relationships.

It allows simulation program users to generate dynamic links (or interactive cross-references) between the PAMDOCs, some reference input files, the program's manual (embedded in the system for TRNSYS) and any other documentation.
The cross-references are marked in the text of the documents so that hardcopies also show these cross-references.

Chapter 6

Guidance on the use of PAMDOCS
IEA Annex 21 Subtask B

6.0 Guidance on the use of PAMDOCS

6.1.Introduction

Simulation programs are currently widely used during the building design process either for predicting the behaviour of a building under different operation scenarios or to compare its performance with design alternatives. Two of the most common uses of simulation programs are to assess thermal comfort conditions and energy consumption.
To determine any aspect of the performance of a building implies the use of a performance assessment method or PAM. The designer requires to know what he/she requires; there must be a PURPOSE, a PROGRAM has to be available and there must be a METHOD of using the program in that information has to be supplied and assumptions have to be made. A PAM may be defined as PURPOSE + PROGRAM + METHOD. There is currently little or no guidance on the selection of programs appropriate for a given purpose nor any consistent methodologies for their use. Different users will have their own approaches with the consequence that there is little consistency between them and poor correspondence between the results of their performance assessments.
When no guidance is available the results from simulations may incorporate errors resulting from:-

- inappropriate use of the program for the particular application
- inappropriate program configuration
- the use of the wrong input parameters
- errors in entering the input data
- the use of different assumptions regarding input data which have not been clearly defined.
- incorrect interpretation of results.

All of the above may ultimately lead to making the wrong design decision.
Problems and subsequent errors may be considerably reduced by using consistent information and assumptions and by the application of quality assurance methods.

This chapter summarises the following:-

- the use of the SHELL structure.
- the use of PAMDOCS.
- the possible use of an interactive documentation cross referencing system.
- ways to extend the scope of use of existing PAMDOCs.

6.2.Aids to PAM use and selection

To assist users of simulation programs in improving the quality of their work, the following aids have been developed within Subtask B:-

- a SHELL document which enables users to document their own PAMs in a consistent way. The SHELL comes complete with guidance for its use and an example PAMDOC.
- a set of documented PAMs, (PAMDOCs) which may be used to provide the appropriate guidance in a limited number of cases.

- an interactive cross reference tool, DYNALINK, enables PAMDOCs and program input files to be electronically cross referenced.

6.2.1.The use of the SHELL

The SHELL is a framework for the documentation of performance assessment methods which may be used to provide a detailed record of the way they are carried out within an organisation as an aid to achieving consistent and quality assured results.
In many organisations performance assessments are carried out on an *ad hoc* basis insofar that the program user is free to select the program and the information required to produce the desired output. The only documentation providing any form of guidance is usually the program manual which is often of limited use. The result of this type of operation is that if two people in the same office are given the same assessment task to perform they almost invariably produce different answers. By using the SHELL to document PAMs a record (PAMDOC) is created containing all the information required to carry out a particular assessment task including quality assurance checks. The PAMDOC becomes an important QA document which can be related to the program input data files to ensure consistent use and selection of the appropriate data whilst, in addition, ensuring that the program output is presented in a consistent manner so facilitating comparison with other outputs.
A general description of the SHELL and how it is used is given in Chapter 3 and the complete SHELL, Guidance notes, example PAMDOC and Glossary of terms form Section 1 of Volume 2 of this final report. Reproduced below are SHELL section headings showing the scope of its coverage.

SECTION	CONTENTS
A	NOTES FOR GUIDANCE
0.0	PAM IDENTIFICATION
1.0	DEFINITION OF PERFORMANCE ASSESSMENT
2.0	PROCEDURE
3.0	INFORMATION DEFINITION
4.0	PROGRAM DEFINITION
5.0	CONTEXT DESCRIPTION
6.0	ZONING DESCRIPTION
7.0	BUILDING DESCRIPTION
8.0	BUILDING OPERATION DESCRIPTION

The main advantages of producing PAMDOCs may be summarised as follows:-

- Their use ensures that programs are only used for appropriate applications; programs are not used to perform simulations for purposes outside their scope.
- The information required from a performance assessment is clearly defined as are the program outputs, any post processing requirements, and the interpretation of results.
- Programs are set up for operation in a consistent manner using the same procedures, initialization and computational parameters.
- The methodology for description of context, zoning, building geometry and building operation is specified in a consistent manner and guidance is provided

on values to use and assumptions that have to be made with their appropriate sources of reference.

- Quality assurance checks may be built in to the PAMDOC.

It has been demonstrated, in the work of the Subtask, that the use of PAMDOCS considerably reduces the variation between the results when different users carry out the same simulation task.

6.2.2.The use of the PAMDOCs

A list of the PAMDOCs produced by contributors to Subtask B is included in Chapter 3. These cover a variety of topics and commonly used programs. The emphasis has been on assessment of overheating which is a common requirement during the early stages of building design and on which design decisions regarding both building and air conditioning are often based. Other topics covered include annual and monthly energy audits, light switching and the performance of constructional elements.
Using these PAMDOCs confers the same advantages as those which may be produced by organisations 'in house' with the added bonus that they can be used as an aid to selecting programs for performing particular tasks.
Regular users of PAMDOCs should already be familiar with the use of simulation programs in general and with the simulation programs for which the PAMDOCs have been written in particular. Reading the program's manual is a prerequisite.
In addition to being used for carrying out performance assessments, the PAMDOCs are also useful as a teaching aid for newcomers to building simulation.
When a particular aspect of building performance has to be assessed the first action required is to *define the problem.* This defines the PURPOSE of the PAM and the type of assessment required to fulfil this PURPOSE. For example, it may be found necessary to carry out an overheating risk assessment.
The next thing to do is to examine existing PAMDOCs to determine the one which most nearly meets the purpose of the assessment defined in Section 1. The selected PAMDOC should be carefully studied to ensure its suitability for the task in hand. The procedure described in section 2 and related actions in other parts are a good guide to this activity. The structure of the PAMDOC and its reference links with the program input files can be examined by using the DYNALINK environment.
It may be that a suitable PAMDOC is not available in which case a new one has to be written.

6.2.3.Example of use of sets of PAMDOC

Depending on the assessment that has to be carried out it may be desirable to use a set of PAMDOCs rather than a single document. An overall performance assessment may require that a number of subsidiary assessments are undertaken. Instead of providing several complete PAMDOCs a basic version may be produced, containing common data for each subsidiary assessment, with other, shorter, PAMDOCs containing the particular information for each subsidiary assessment. An example design process, based on minimal needs to satisfy the requirements of thermal comfort in an office module, is given here to illustrate the use of a set of PAMDOCs. The flow chart, Fig 6.1 shows a possible simplified approach to such a study.

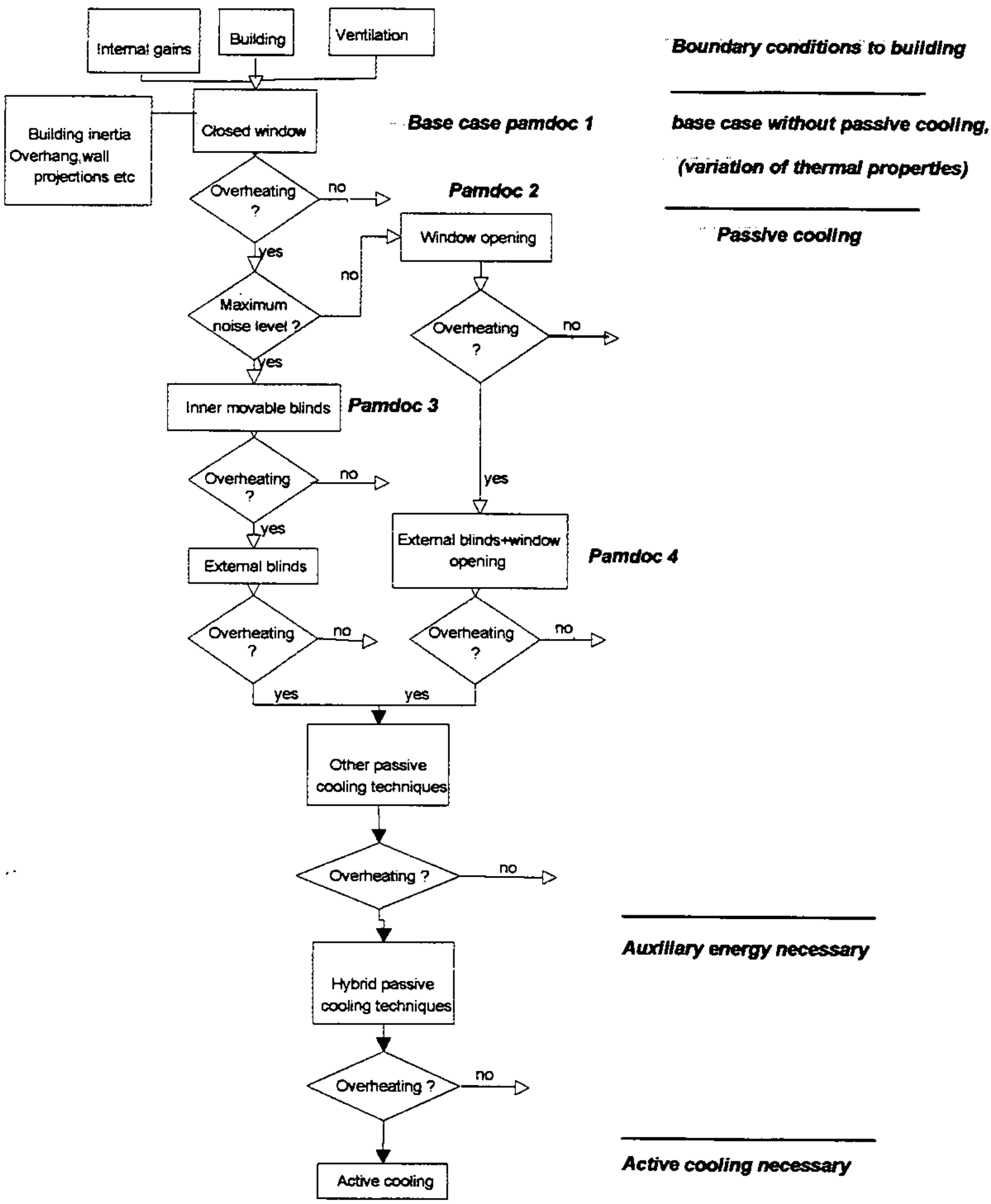


Fig. 6.1 Notional assessment flow diagram.

Figure 6.1 illustrates the procedure for a design in order to keep the indoor conditions of a building within thermal comfort limits (i.e. no overheating) with the minimum complexity and possibly without active cooling system.
For each specific design situation suitable PAMDOCs have been developed, a base case PAMDOC (PAMDOC 1), in which all basic data are contained, and other, so called satellite, PAMDOCs which provide information additional to the base case. Referring to Fig. 6.1:-

- PAMDOC 1 Base case : used to investigate building inertia, glazing type, static shading, etc.
- PAMDOC 2 Used to investigate passive ventilation cooling action by window opening at night and/or night and day.
- PAMDOC 3 For investigation of passive cooling action using moveable blinds (internal or external)
- PAMDOC 4 To investigate passive cooling using a combination of window opening and movable blinds.

Such a flow chart could be extended and related satellite PAMDOCs added; for example, more passive cooling techniques (ventilation by thermal buoyancy in a central atrium, cross ventilation, ...) or hybrid techniques (hollow concrete slabs with internal air circulation, cooling by a water system only or by using a cooling tower) or active mechanical cooling as developed for some programs.

6.2.4. Cross referencing with input data files.

One of the major uses of the PAMDOCs, which applies both to those produced within Subtask B or to any produced 'in house', is that they may be cross referenced with the input data tables. This enables a user to easily access those sections of the PAMDOC relating to corresponding sections in the input data tables for the purpose of supplying information additional to that contained in the program manual. A document relating the input file parameters for SERI-RES to a PAMDOC for overheating risk assessment was produced in the early days of the Subtask and a section is reproduced here as an example (Table 6.1).
Although this type of cross referencing is useful there is clearly the practical problem of using cumbersome look-up documents. A better approach is to use some form of on-line computer cross referencing system whereby a user would have rapid access to the appropriate information contained in the PAMDOCs during the data input process. To facilitate this the Dynalink software has been developed.

SERI-RES Data Table : Runs
Table headers and sample entries.

RUN LABEL	STATION NAME	GROUND REFL	GROUND TEMP	'START' MON DAY	'STOP' MON DAY	SKYLINE PROFILE	PAR TYPE
		.(FRAC)	(C)	(DATE)	(DATE)		
AAAAAAAAA AAAAAAA	AAAAAAA AAA	S.SSSS	SSS.SS	AAA XX	AAA XX	AAAAAA	AAAAAA
HDS/BAR/SE/1	KEW	0.2	TEMP G	OCT 1	SEP 30	SKY	NORMAL

Parameter Name	PAMDOC reference		Definition
	Section	**Page**	
Run Label	0.0	2	A string of up to 16 characters which labels the simulation.
Station name	5.2	22	A string of up to 10 characters which identifies the weather station and data used in the run (must be defined in the STATION section)
Ground reflectance	5.1.3	20	A fraction which represents the proportion of solar radiation reflected by the ground.
Ground Temperature	5.1.4	21	A constant or the name of a schedule. (TEMPG is the standard name for the schedule) defining the ground temperature.
Start/Stop days	4.4.3	17	The first and last days in the calendar over which the simulation is to be run.
Skyline profile	5.1.5	22	An arbitrary string of up to 6 characters identifying the type of skyline.(must be defined in the SKYLINE TYPES data section.)
Par Type	4.3	10	A string of up to 6 characters identifying the set of run control parameters. It must be defined in the PARAMETERS input section unless the default <none> is used.

Table 6.1 Example of cross referencing of data tables with a PAMDOC

6.2.5.Using DYNALINK as a tool to learn the PAMDOC approach

DYNALINK is an application developed under Microsoft Word for Windows to generate and use dynamic links (active cross-reference) between the different files that are used to perform a building performance assessment using a simulation program.
The user of DYNALINK, when providing the program input, is able to generate dynamic links (interactive cross referencing) between the input files, the program manual and the relevant PAMDOCS in order to access the information embodied in these files.

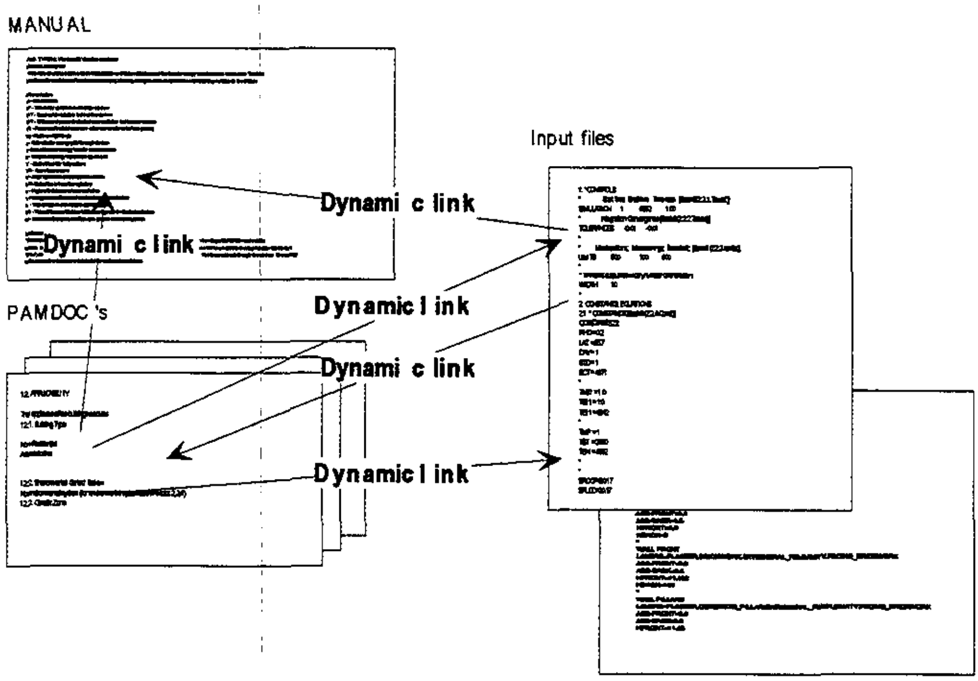


Fig. 6.2

Once the philosophy and structure of the PAMDOCS is understood, the way they are used can be demonstrated by using the DYNALINK environment. Two approaches can be made:-

a) Follow the PAMDOC procedure. By following the PAMDOC in a linear sequence, as per the PROCEDURE in Section 2, and by relating it to the reference program input files, using DYNALINK, the relationship of the PAMDOCs to the actual program's use is easily shown.

b) One may also follow a reference input file from beginning to end, and then use the dynamic reference to the PAMDOCS and program's manual to see how the PAMDOCs may help the program's user to make the correct input file entries. This approach, although not completely following the PAMDOC structure, is a good way to see how an input file is related to the PAMDOC.

6.3.Modify, extend PAMDOCs for more general use.

During the project there were not enough resources to develop a full set of PAMDOCs for all possible applications using different programs; the available set consists mainly of PAMDOCs for overheating risk assessment. Therefore existing PAMDOCs may not cover users' needs.
Thanks to their modular structure, the PAMDOCs can be extended to other uses quite easily.
Some parts of the PAMDOCs are generic for all kinds of assessment, other parts are very dependent on the problem addressed, but can be adapted for other purposes.
The goal of this section is to explain how to extend the scope of application of PAMDOCs while using the existing set as a basis.

When using simulation programs for performance assessment, one can identify two major areas where the scope of application of a PAMDOC may need to be extended.:

1. The building/zone type changes, for example from an office to a computer suite, so that the applicablity of already developed PAMDOCs is no longer relevant.
2. A different assessment has to be carried out, for example a change from overheating risk to annual heating energy demand, so that the kind of information required is different

In both cases, an analysis of the differences between new and old purpose must be performed in order to show the differences

6.3.1. Change of building type

In this case, the purpose of the performance assessment is the same, i.e. overheating risk, but the building type differs from the previously developed PAMDOCs.
The first check is to look at the ability of the program to model the new building/zone type. One has to examine the particular features of the new building/zone type in comparison with the already documented one. This has to be done by following the PAMDOC structure including the satellite PAMDOCs in the analysis, and concurrently using the program's manual.
As an illustrative example, we shall assume that a PAMDOC dealing with the overheating risk assessment of an office building module exists, and that this needs to be modified/extended so as to be suitable for a factory building. This example considers some of the main questions that have to be raised to tackle this type of problem.

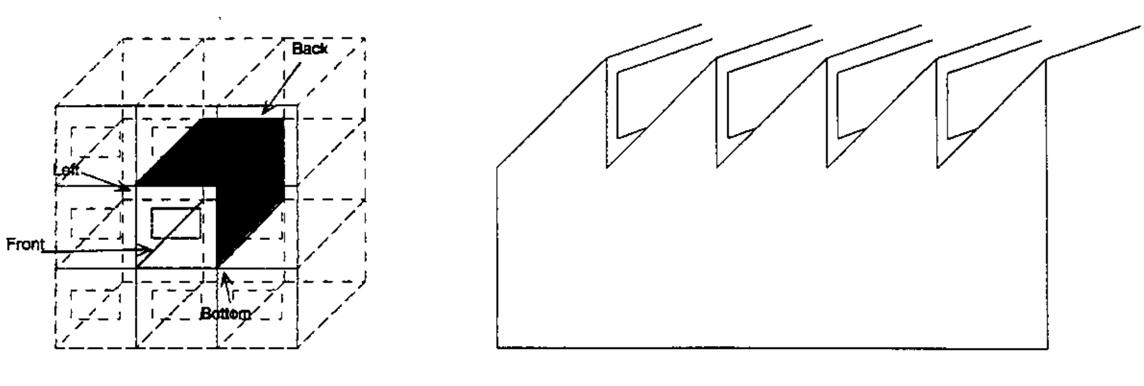


Fig. 6.3

Figure 6.3 illustrates the two building types considered.
By following the PAMDOC's structure in an appropriate order, one can identify differences, and then modify the PAMDOCs in order to fit the new application. A logical path through the PAMDOC structure, which differs from the procedure described in Section 2, is proposed. For each section of the PAMDOC the differences between the existing version and the proposed version may be tabulated as shown in the following tables.

Section 1, Definition, describes the assessment to be carried out, the building type and environmental system type.

PAMDOC sections	PAMDOC sub-sections	Existing PAMDOC:Office building module	New PAMDOC: Industrial assembly hall	Differences	Implications on modelling, program	Implications on PAMDOC
1. Definition of PAM	Purpose	Assessment of Overheating risk in Office Buildings	Assessment of Overheating risk in an industrial assembly hall	Not only comfort for human being, but also conditions for machines		Change in description, ->Section 3, information requirement

In Section 3 (Information definition), the information required and its interpretation are described. This is where the additional, or more specific required variables are defined.

PAMDOC sections	PAMDOC sub-sections	Existing PAMDOC:Office building module	New PAMDOC: Industrial assembly hall	Differences	Implications on modelling, program	Implications on PAMDOC
3. Information definition	Information requirement, variable definitions	Temperature in zone	Temperature at 1.5 meter above ground, air velocity,...	Temperature uniformity in zone ?	Stratification taken into account ?	More variables to be defined, additional calculation to be performed

The stratification that may occur in an industrial building has to be taken into account, the consequences are that a given program may not be able to deal with this phenomenon, or additional calculations should be performed before a PAMDOC can be developed.

In Section 8 (Building operation description), the conditions of operation and environmental control are defined.
Differences in the ventilation rates, occupancy, heat, and lighting gains, with their time schedules are defined.

PAMDOC sections	PAMDOC sub-sections	Existing PAMDOC:Office building module	New PAMDOC: Industrial assembly hall	Differences	Implications on modelling, program	Implications on PAMDOC
8. Building operation description	Ventilation	Ventilation by opening	Ventilation by - venting on top - venting on top and bottom	Other ventilation models required	Has the program the capabilities ??	Add new description, and sub models in section 4

In Section 4 (Program definition), sub model selection is performed. At this stage, one must consider the modelling issues.

- check to see if sub-models already incorporated in the PAMDOCs are suitable, and,
- if not, check in program's manual what modelling possibilities exist.

An example of the type of modelling problem that may arise is the stratification that can occur in big industrial buildings, and the difference in the natural ventilation mechanism, such as roof openings instead of window openings in façades for offices.
At this stage, the limitations of a given program to satisfactorily simulate some specific features is examined.

PAMDOC sections	PAMDOC sub-sections	Existing PAMDOC:Office building module	New PAMDOC: Industrial assembly hall	Differences	Implications on modelling, program	Implications on PAMDOC
4. Program definition	Sub model 1: ventilation by openings	Ventilation by window opening	Ventilation by - venting on top of sheds - venting on top (sheds) and bottom doors	Other ventilation models required	Has the program the capabilities ?? One must assess it	Documentation of these sub-models if available
	Sub model 2: ground reflectance for sheds	As specified for ground reflectance in section 5 under ground reflectivity	Reflectance for sheds glazings from roof	Needs a geometrical model to calculate ground reflectance	Has the program the capabilities ?? One must assess it	Documentation of these sub-models if available
	Sub model xx:					

The foregoing procedure can be used to determine differences in zoning strategy, Section 6, and building fabric description, Section 7.
Specific items such as furniture specifications in office modules must be changed to take into account industrial equipment instead.

6.3.2. Different assessments

In this case it is necessary to determine the differences between the required variables as defined in Section 3 of the PAMDOC, as well as changes that may occur at other PAMDOC sections such as other modelling needs, other building operation conditions, etc....
The procedure to follow would again be to tabulate the differences as in the previous example. Examples of particular differences that would have to be taken into account are:-

- in an office building module, the required variables may differ depending on the assessment to perform: for overheating risk, basically zone air temperature, or comfort temperature is sufficient. When looking at annual energy consumption, with mechanically ventilated buildings, a number of variables may be required . One needs to know the annual gross and net energy requirement, which in turn means that systems must be modelled by the program.
- in an industrial building, in Summer, the air temperature stratification is favourable for comfort, but in the heating period, it is not, as factory roofs do not usually have an insulation level as good as the walls.

6.4 Program selection

When selecting an appropriate program for performance asessment purposes the following considerations should be taken into account.

- Program documentation. A good user manual is essential. Poorly documented programs lead to time wasted, the need to make assumptions which may not be correct and a long learning curve.
- Ease of use; is it easy to input data etc?; is it user friendly?
- Compatibility with other packages; for example CAD, preprocessors; output processors.
- Flexibility; does it have a modular structure?
- Available support; on line; specific news?
- The existence of user clubs for exchange of experiences.
- The validity of the program; how does it perform against benchmarks and other programs?
- Use approval; is it approved or recommended by government authorities for testing compliance with regulations?
- The existence of examples of applications similar to those for which it is required?
- Guidance for its use when carrying out specific performance assessments.

Although the existing PAMDOCs do not contain all of the above information they do provide the guidance for use indicated in the last point above and in addition should enable a user to perform cross comparisons between programs as an aid to program selection.

When a program has to be chosen to carry out a particular task it is often useful to check the capabilities of a number of programs against the requirements of the building assessment that has to be carried out. As an example one may need to know whether an overheating problem exists in a design and what is the most effective way of controlling it. A flow chart representing the design steps to be considered may be as shown in Fig 6.4.

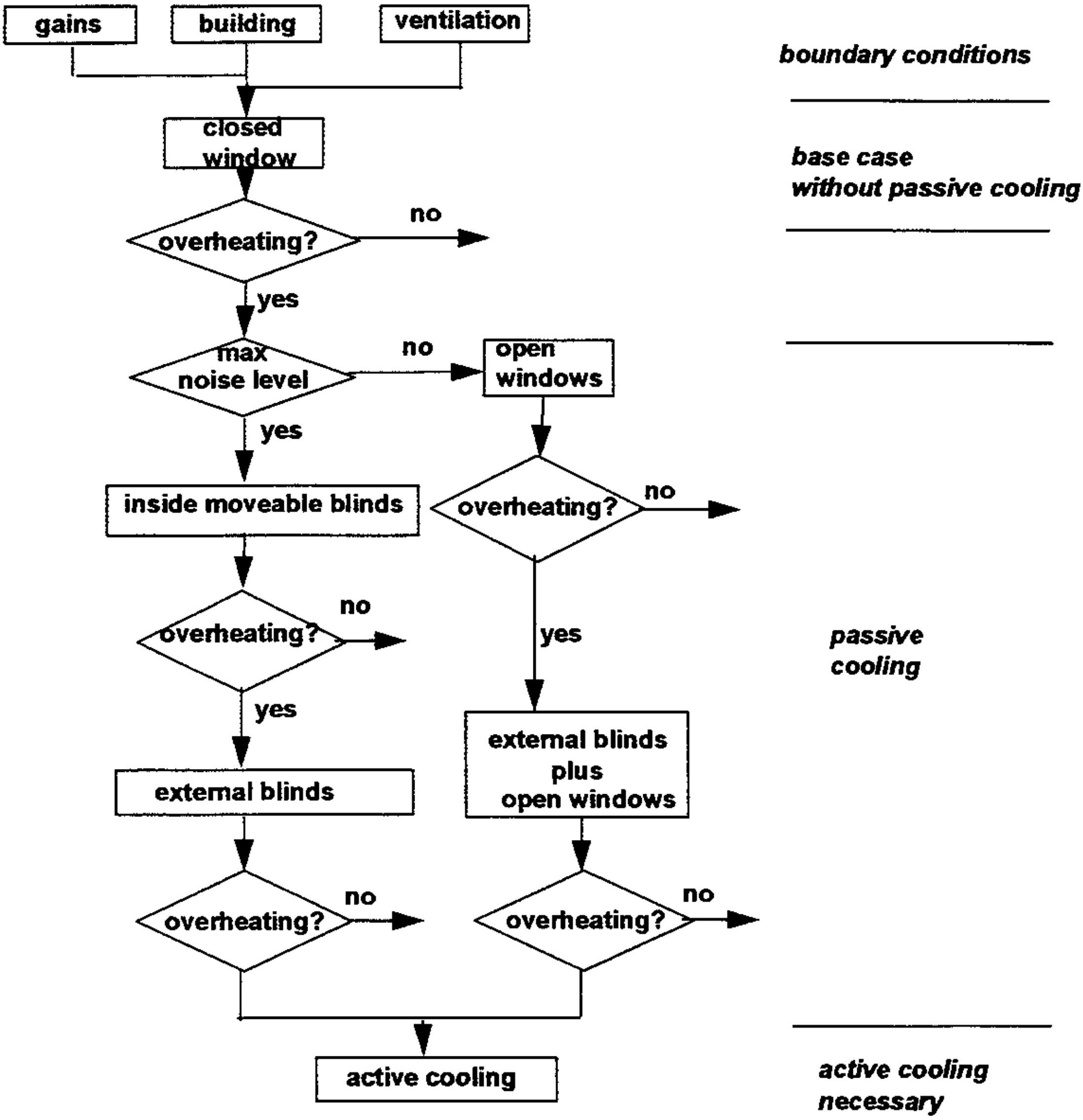


Fig. 6.4 Notional design flow diagram

By considering the requirements of a program to carry out the above design process a matrix can be set up which relates these requirements to the capabilities of the different programs to handle them. This information is contained in the PAMDOCs. An example of such a matrix is shown in Table 6.2.

Modelling capability	**Program A**	**Program B**	**Program C**	**Program D**	**Program E**
Multi layer glazing	***	**			
Blinds (inside, outside, control schedule etc.)	**				
Natural ventilation (opening, control schedule etc.)	****				
Mechanical systems (in zones)	*				
Systems (distribution, heat recovery etc.)	***				
Plant (Mechanical cooling)					

Table 6.2 Example of program capability matrix
* Capability rating

Chapter 7

Conclusions from IEA Annex 21 Subtask B

7.1 Introduction

Performance Assessment Methods (PAMs) have been developed and documented (PAMDOCs) for some applications of importance to the Construction Industry in the participating countries, Belgium (B), Germany (D), The Netherlands (NL), Switzerland (CH) and the United Kingdom (UK). PAMDOCs contain information on how to translate a practical building into the input data necessary for analysis by a building thermal performance computer program and on how to use the resulting outputs from that program to answer the questions of importance for a particular real world application. Once experts have recorded the detailed information on how to conduct such assessments in a PAMDOC, it becomes possible to transfer this information to other, less experienced, users. The PAMDOCs produced in Subtask B of IEA Annex 21 represent the current state of the art as practised by experienced users from the participating countries. It will be necessary to update these in the future as the body of knowledge and experience grows. Prior to this work there was no basis for accessing and building upon the best current knowledge - each practitioner has had to start from scratch and learn by experience.

The documentation of Performance Assessment Methods has been found to be exceptionally useful for reasons discussed below.

- PAMDOCs encourage disciplined thought about how to address building design problems. For example, in the process of setting out how to assess the risk of overheating all of the national experts, even those working for leading practices, found that there were some aspects that could be improved upon in the procedures that they have operated in their own countries. The discipline imposed by having to state clearly the purpose of the performance assessment was found to be particularly useful.
- They encourage the development of a consistent performance assessment process and identify areas where quality control procedures need to be developed. Some of the main recommendations made by Subtask B have already been implemented by the Nl, UK groups (checklists and independent input data checks).
- They provide evidence of good working procedures which can be helpful where professional indemnity is involved.
- They facilitate training of new staff, providing a way to pass on expertise gained from practice and to protect, as well as extend, the corporate knowledge base.

Whether the PAMDOCs can successfully be adopted by practitioners and used beyond the training phase, for everyday work, has yet to be determined. It is likely that their use will be seen as difficult by some unless a successful computer-based implementation can be devised. It can be expected that there will be a range of opinions within Industry, depending to a large extent on past experience and degree of willingness to adopt new, computer-based ways of working. Acceptance will, to a large extent, depend on how the concept is presented and promoted to the Industry.

The work performed has led the participants to the view that it is essential that appropriate and reliable procedures be used and that the procedures currently in use are not yet adequate. It is essential to redress this situation.

The process of documenting and subjecting PAMs from several countries to a peer review process has led to :

- improvements in some national procedures
- rationalisation of some modelling issues that were examined in detail (window treatment, selection of which zones need to be simulated, treatment of suspended ceilings, the need for databases of standard material properties, ventilation by window opening, modelling of blinds)
- identification of areas which still need further research.

7.2 PAMDOCs For Overheating

In order to document Performance Assessment methods it was first necessary to develop a documentation structure or 'SHELL'. This was tested by using it to document several different applications deemed to be of importance by the participants to the Subtask. The assessment of overheating risk was chosen as being of most practical importance and each group prepared a national PAMDOC using the SHELL. The main reasons dictating this choice of application were:

- There are large capital and running cost implications associated with the need for air conditioning, which is usually determined from the results of overheating risk assessments.
- There is an increasing pressure to introduce the use of models into Building Regulations. This has already happened in Switzerland and, although not mandatory, is increasingly being demanded within the Netherlands (e.g. RGD demands that calculations be performed and places a limit on the resulting number of overheating hours permitted) .
- Research conducted in the seventies and eighties (e.g. McIntyre, Jokl) showed that the thermal state of the body affects the performance of physical and mental work. It is not yet possible to quantify this effect with respect to overheating and the relationships may well be complex, with changes in temperature regimes providing a positive source of stimulation. It does seem very likely that overheating can lead to decreases in the efficiency with which people work and thus can have a very large effect on overall costs of an organisation - possibly much larger than the effects of energy.
- Overheating entails consideration of larger dynamic effects than energy estimation; it therefore provides a more severe test of the capabilities of simulation programs. Also the definition of this risk-related problem poses more difficulties for the practitioner e.g. on choice of weather, zoning etc; it is therefore felt that the PAMDOCs should be of most use for this particular purpose.
- A proper assessment of overheating is likely to have a direct influence on the design of a building through architectural issues such as thermal mass, shading, window size etc. These early design features are of crucial importance as they are hard to change at later stages of design and can also have a substantial effect on total energy use, capital and running costs. It should be noted that even if the early design is well done and this leads to a 'passive' building, the predicted performance will only be achieved in practice if the later stages of design are also carefully performed.

7.3 PAMDOCs For Other Purposes

Most of the effort has had to be devoted to the development and testing of the 'SHELL' - the framework for documenting performance assessment methods. The majority of the testing has been performed for overheating assessment as this was the priority interest of most of the Subtask participants. It is also important to check that the SHELL is also suitable for purposes other than overheating. Accordingly, some PAMs dealing with energy retrofit were documented. It was found that the SHELL structure was suitable and this gives confidence that it can be used as a general tool for the future with little or no modification. Further development is needed for full consideration of heating and cooling systems.
It is seen as particularly important that such procedures be developed for energy assessment as moves are made towards the use of energy targets and rating within the European Community and other countries. By its nature, the use of models in a regulatory framework makes it essential to specify all the assumptions and modelling procedures so that consistency can be achieved.

7.4 Factors Affecting The Proper Use Of Programs

The effect of the user of the program is very important - this has been shown in past work where results obtained by different users of the same program have differed dramatically. This effect has again been demonstrated within Annex 21. Several comparative exercises were undertaken - firstly to aid in the development of a common understanding of terminology etc and secondly to measure the effectiveness of the documented PAMs in reducing user effects. The first exercise was conducted mainly for the former purpose (common understanding). Benchmark tests were used which had been developed in a previous IEA project (Solar Task 8). The second exercise addressed the latter purpose (effectiveness). It was carried out both in Switzerland and the Netherlands; it was divided into two stages, in which several users were asked to assess the performance of a given building, firstly with no special instructions and then, subsequently, with the aid of the documented PAMs for overheating. The results demonstrated clearly the value of the PAMs, leading to much greater consistency in results. The spread between users in the number of hours of overheating predicted for a year decreased significantly. This exercise served to demonstrate that even within one organisation quite different results could be obtained without the use of a documented PAM. Quality assurance is of paramount importance - it is considered further in Section 5.

Several technical issues of importance were investigated and their impact on overheating assessments quantified.

7.4.1 The definition and selection of zones within the building that need to be simulated

It appears that there is little generally applicable guidance available. A survey was conducted in which experienced users were invited to select zones within a particular office building which they judged would be suitable for assessing the risk of overheating. The responses obtained covered a wide range in both number of zones (from 2 to 15), and in their location. Simulations for this building subsequently showed that the zone that was worst affected by overheating had only been chosen for simulation by 5 out of the 17 survey respondents. It should be noted that the choice of zone may also depend on the type of problem; it may be different for overheating risk assessments depending on whether they are carried out for economic reasons or to satisfy regulation requirements. Some useful information was produced within Annex 21 but there remains a need for additional research and for robust guidance to be developed from experience and from further Case studies.

7.4.2 The criterion used to define what is meant by Overheating

Five different criteria were found to be in use and these were documented within the PAMDOCs developed by participants. Simulations were conducted for an example building and the overheating risk assessed according to these criteria. It was found that the effect of these definitions alone could lead to a 50% difference in allowable window area. It is important to note that this follows entirely from this single aspect of modelling methodology and is quite independent of the program used and the many other methodological decisions which have to be taken by practitioners.

7.4.3 The treatment of windows and glazing

Different ways of translating practical window systems into data that are required by current simulation programs were reviewed and their adequacy investigated by conducting simulations for an office building Case Study. A common source of confusion was found to be the separate treatments of frame and glazing. Some practical rules were developed and it was concluded that these should form part of the PAMDOCs if large errors are to be avoided.

7.4.4 The treatment of ventilation using opening windows.

A study was carried out to investigate the effects of user assumptions on overheating risk assessment when ventilation through open windows is used as a temperature control technique. It was found that apart from the physical description of the models, the user's assumption are also very important and can significantly affect the results obtained. Decisions for active or passive cooling techniques may be taken on the wrong basis purely because the user's assumptions are inappropriate. This study shows that with all other parameters kept constant, building characteristics, blinds, etc., variation of the order of 50 to 100 % may occur in the overheating assessment.
The results are mainly affected by the chosen convective heat transfer coefficients, the simulation of window opening schedule and the window opening air change model.
The results obtained in this study confirm that the program user's influence on the results is as important as the physical quality of the programs.

7.4.5 The treatment of light switching behaviour

It is sensible to reduce unnecessary loads before cooling is provided in a building. One possibility for this is to switch off or reduce artificial lighting in a room when daylight provides enough illumination. The design and treatment of windows and shading devices are related to the illumination provided and subsequently to the use of artificial lighting. Therefore it is essential for building simulation applications such as the overheating risk assessment, that the different strategies for this can be simulated. The aim of this study was to summarise the aspects of artificial lighting systems, in combination with operation and properties of blinds, to be taken into account in building performance simulation. Additional studies could perhaps lead to rules of thumb for use with programs without daylighting capabilities, giving, for example, information on the need for artificial lighting in the perimeter zone depending on the solar radiation on the window, the transmission factor and the needed illumination level.

7.4.6 The treatment of suspended ceilings

One of the aims of this paper was to provide more background information about suspended ceiling modelling and to provide guidelines for the improvement of the PAMs concerning this aspect. Suspended ceilings, commonly installed in many buildings, come in a variety of different configurations and may be simulated in several different ways. A study of different simulation approaches for several ceiling configurations was made to determine the effect on simulation of building overheating risk.

It was found that peak temperature and hours of overheating are considerably influenced by the ceiling configuration and simulation approach. Further studies are needed but it is anticipated that the results from these further studies will lead to guidelines as to how to simulate the suspended ceiling in an appropriate way which may then be incorporated into PAMS.

7.5 Quality Assurance

Work elsewhere and the direct experience of the participants in Annex 21 demonstrates very clearly the need for Quality Assurance (QA) in performance assessment and in particular in modelling. The interfaces in currently available programs and the low quality of many of the data sources are such that it is very easy for mistakes to be made. These can be at several different levels - typographical errors, incorrect assumptions about input data, approximations to the real world building, zoning, interpretation of results etc. The use of PAMDOCs is only one part of an overall QA strategy.

The results of the two-stage user tests demonstrated that a check of all input data files by a second person is very important. Such checks also proved extremely useful in identifying the areas in the PAMDOCs that were unclear or insufficiently detailed.

A set of recommendations has been devised on how to implement QA in practices both large and small. Actual QA tests have been included in the PAMs where possible

and these have been tested in practice. A sample Quality Plan and Manual has also been produced. Other subtasks of Annex 21 have addressed different aspects of quality related to the use of programs for predicting performance. Subtask A has developed methods for documenting assumptions within programs, Subtask C has developed techniques for testing programs and Subtask D has detailed desirable attributes of an integrated design support environment containing performance prediction programs.
It has been found by some participants that the introduction of QA can actually save time as well as increase the quality of the design process and hence the completed building and services. This is likely to be true for large projects where the consequences of errors are serious and where quality checks are essential. Although, for small projects, there may not be a time saving the consequences of errors may still be important and warrant the need for QA.

7.6 Application In Practice

Although several of the participants of Subtask B are practitioners, there is a need to test the acceptability of QA techniques more widely in a range of national consultancy organisations. There is compelling evidence that a system which allows control of quality is needed. The lack of an effective feedback loop to allow the consequences of design failures to become apparent means that there may be resistance to the adoption of such a system by practices. Although much more work could profitably be done to develop the PAMDOCs and QA plans further, it is felt sensible that the concepts should first be introduced to industry and tested. An appreciation of the benefits that will follow from adopting QA needs to be gained by actual experience. The current and proposed future plans for implementation are summarised below.

This work has contributed to the procedure that forms part of a new Standard in Switzerland and is mandatory in some regions if air conditioning is to be allowed in buildings of a certain size. Many of the recommended data will be fixed within a standardised input for the US program DOE-2, which leads to:

- considerably fewer user errors
- substantial time benefits
- much better uniformity and transparency of the procedure
- increased ease for authorities to check and control compliance.

This standardised input is currently in the process of being declared mandatory for use with DOE-2.

A computerised system has been developed in Switzerland to allow linking of the program manual and the documented PAM together with an editor that enables the production of input data files for the program. This on-line Help facility has hypertext features and promises to substantially improve the efficiency and quality of modelling.

The work conducted has led to knowledge about what differences in predicted overheating would be obtained without the use of a PAMDOC and without QA checks by a second person. The results of the specific investigations on windows, zoning and suspended ceilings will lead to beneficial changes within the 100 strong user community of VABI. Introducing the use of PAMDOCs to all VABI users is regarded as the most important next step to take.

It is intended that the use of PAMs will be promoted within companies in Belgium in order to help explain and make explicit the assumptions which have been made and to increase quality. In the UK discussions are underway with the Chartered Institution of Building Services Engineers (CIBSE) with a view to including PAMs within an Application Guide and in the relevant sections of the widely used CIBSE Guides. The organisation of courses which qualify for CPD (Continued Professional Development), offered through the Building Environmental Performance Analysis Club (BEPAC), a joint Industry/Research activity, are also being considered. The PAM concept is being tested by two firms of consulting engineers who are using the SHELL to document their own in-house procedures for overheating risk assessment and plant sizing applications. In the longer term it is expected that the move towards a rating or targeting approach within the various national Regulations and European Community Standards will increase the need for the values of various modelling parameters etc to be tightly specified and the use of PAMs will facilitate this. For example, the need to define the criterion for overheating assessment is very important - it is essential for correct interpretation of results.

7.7 Future Needs

The work completed within Subtask B has been successful in developing a methodology together with some examples. The value of the approach has been demonstrated very clearly. This has shown that more work is needed in the areas described below.

- Implementation in practices and improvement of PAMs using feedback gained - this should be done nationally, with a workshop to exchange experiences in 1 year's time. Work is currently underway in Netherlands, Switzerland and the United Kingdom.

- Prepare PAMs for other purposes - this could be done nationally with peer reviewing by other members of Subtask B who retain an interest in developments; the practicality of this should be discussed at the workshop referred to above. In Switzerland an extension of the standardised inputs concept is being discussed. In addition to the scheme developed for overheating, additional applications are being considered - cooling load calculation and energy consumption of ventilation systems. This might well be best implemented by first preparing Performance Assessment Method documentation using the PAM SHELL.

- More research needs to be carried out on several of the modelling issues discussed during Annex 21. The topics in which interest has been expressed are listed below together with the interested countries:

➢ robust and appropriate zoning strategies for a given purpose (UK)
➢ ventilation due to window opening (NL)

- ➢ displacement ventilation (CH)
- ➢ solar gain and distribution for large window areas, atria (NL)
- ➢ solar shading (NL)
- ➢ non-uniform air temperature in a zone (NL)
- ➢ passive cooling (CH)
- ➢ hybrid systems (CH)
- ➢ heating and cooling systems and controls (CH)

7.8 Recommendations

1. Set up national workshops etc to explain and promote the use of overheating PAMDOCs
2. Test and improve existing PAMDOCs through use in practice and feedback.
3. Further develop PAMDOCs by extending to real world issues especially Systems and Controls.
4. Develop improved models, in particular to address some of the issues which are currently left to the program user to resolve (e.g. zoning) and to improve the user interface.
5. Organise an international workshop to discuss progress and national developments and exchange experiences.

References

Jokl M V, The effect of the environment on human performance, Applied Ergonomics, 13(4), p269-280, 1982

Mcintyre D A, Indoor Climate, Applied Science Publishers, 1980.

APPENDICES

Note that the numbers of the Appendices refere to the Chapters to which they relate.

Appendix 2.A
Sample Quality Plan for carrying out Performance Assessment

1 Definition

1.1 Identities

1.1.1- Project name.
1.1.2- Location name.
1.1.3- Client name.
1.1.4- Identities of the Project Manager (**PM**), Project Team (**PT**) and Quality Assessor (**QR**).

1.2 Need/Purpose Definition

1.2.1- Discuss the client brief and document. (carried out by PM)
1.2.2- Define aims and objectives, make a clear list of needs/purposes and document.(PM)
1.2.3- Identify special features or requirements and document. (PM)
1.2.4- Discuss constraints (time, finance etc.) and document. (PM)
1.2.5- Agree (1.2.1) to (1.2.4) with the client and Document.(PM)

1.3 Need/Purpose Evaluation

1.3.1- Analyse needs/purposes (1.2.2) and define the specific questions on each aspect and document. (e.g. What is and What if questions) (Carried out by PM/PT)
1.3.2- Identify main physical and environmental and operational features of the building, the equipment used, etc. that influence the design or performance of the building (e.g. geometry, construction, sunspace, pool, site shading, plant location) and document. (PM/PT)
1.3.3- Identify main thermal and environmental processes influencing the performance (e.g. Long Wave, Convection, Heat storage, plant size, ...) and document. (PM/PT)
1.3.4- Assess the need for performing calculations and identify the performance assessment methods (PAMs) that can be used for each purpose (these are the pre-defined assessment methods that have been tested and adopted by the organisation, e.g. PAM-10, PAM-34 and PAM-200). (PM/PT)
1.3.5- Identify, for each purpose, features (1.3.2) or processes (1.3.3) that cannot be handled by the PAMs identified in (1.3.4) and document. (PM/PT)

2 Strategy:

2.1 Risk analysis

2.1.1- Assess the possibility, and consequences (and the level of risk) of drawing wrong conclusions on the basis of the purpose and the information available, assess the level of the risk (e.g. the level of risk and consequences of a performance analysis carried out for deriving a government policy is very different from that of sizing plant for a single family dwelling) and document. (PT)

2.2 The level of representation

2.2.1- Assess the level of detail required to answer the questions and satisfy the needs/purposes and document. (PM/PT)
2.2.2- Assess the effect of the main assumptions in representing physical features and processes as identified in (1.3.2) and (1.3.3) and document (e.g. one dimensional conduction, window modelled as a resistance, air temperature the same as environmental temperature, etc.). (PM/PT)
2.2.3- Assess and identify the input requirements for the level of detail decided above and document. (PM/PT)
2.2.4- Consider the uncertainty in input data (e.g. materials property or occupancy schedules etc.). Decide the strategy of using an upper, lower or intermediate value in the possible range of values and document. (PM/PT)
2.2.5- Establish or define the criteria for assessing the answers to the questions in (1.3.1) and document. (PM/PT)
2.2.6- Assess and identify the output requirements for analyses and evaluation and decide on the form of data presentation for analysis and document. (PM/PT)
2.2.7- Decide on the nature and form of output for presenting to the client. (e.g. tabular, graphical, etc..) and document. (PM/PT)

2.3 Method selection

2.3.1- Select the performance assessment method for each purpose, from among those identified in (1.3.4) and document. (PM/PT)
2.3.2- Identify the need for using a new method if none of those available is appropriate to answer the problem, and document. Refer to Quality Procedure number, say, QP#xxx. (PM)
2.3.3- Decide on the necessary simulations to be carried out and document. (PM/PT)

2.4 Resource planning

2.3.1- Assess the availability of staff, expertise, equipment and finance, estimate the cost and document. (PM)

2.5 Client approval

2.6.1- Discuss the results so far with the client, e.g. the cost, time, level of uncertainty etc. and obtain approval and document. (PM)

3 Implementation

3.1 Prepare input data

3.1.1- Study the PAM selected from the proforma. Its modelling assumptions, input data, procedure for carrying out assessment, make observations and document. (PT)
3.1.2- Prepare input data following the PAM proforma (use a blank PAM proforma for documenting the data used) and create input files. Use data, where possible, from standard databases (e.g. CIBSE, BRE, ASHRAE etc.). Consider uncertainty in input data, decide and document. (PT)
3.1.3- Check thoroughly input files according to procedures and guidance in the PAM proforma. Modify as necessary, produce the final input file, destroy any redundant file, print out and store on different media and document the location of the original and stored input files (giving the path of the directory where appropriate). (PT)

3.2 Quality control

3.2.1- Test run (a short period run or calculation) and check key data as echoed by the program, according to instructions for quality checks in the PAM used, and document observations. Keep a record of the number of test runs and the observations. Do not destroy the results for previous test runs. (PT)
3.2.2- Modify input files, if necessary, according to Quality Procedure number, say, QP#yyy and Document. Do not destroy old data, identify as 'old' data and keep a register and a note of changes made. Repeat previous step (3.2.1). (PT)
3.2.3- Quality Assessor to check operations and documentation so far and Record. If modification needed start from the point that needs modification and repeat all appropriate steps thereafter including this one. Use the instruction given for quality checks in the PAMs use. (Carried out by quality assessor, QR)

3.3 Perform Calculations

3.3.1- Carry out calculations (simulations). (PT)
3.3.2- Check outputs for unexpected results according to the appropriate checking procedure in the PAMs used and document. (PM/PT)
3.3.3- Modify input files, if necessary, according to the quality procedure number, say, QP#yyy and document, then start from step (3.2.1). (PT)

4 Information provision

4.1 Prepare output

4.1.1- Prepare output in the form required for analysis as set out in step (2.2.6). (PT)
4.1.2- Prepare output in the form required for presentation as set out in step (2.2.7). (PT)
4.1.2- Check and compare the output as presented in the two forms in the two previous steps. (PT)
4.1.3- Carry out modifications, if necessary, and start from the point necessary and repeat steps if appropriate. (PT)

5 Interpretation

5.1 Analysis output

5.1.1- Analyse the results and document observations and conclusions. (PM/PT)

5.2 Decision making

5.2.2- Make design decision or performance evaluation and document. (PM)

5.3 Report

5.3.1- Write report according to quality procedure number QP#xxx. (PM)

6 Final Quality Control

6.1 Quality assessor

6.1.1- Quality Assessor to carry out check and control operations and documentation from step 3.3.1. (QR)
6.1.2- Quality Assessor to review his controls for all steps above from (1) to (5). (QR)
6.1.3- Quality Assessor to prepare report of quality control. (QR)

7 Completion

7.1 Management report

7.1.1- Submit reports (5.3.1) and (6.1.3) to the management. (PM)
7.1.2- Quality manager, or an assigned representative to decide whether the job is complete or is to be returned for modifications. (Management)
7.1.3- Send report to client. (PM)

Appendix 2.B
A Sample Quality Manual Structure

1 Quality Policy
This is a statement by the management giving its commitment to establish, document and maintain an effective and economical quality system to ensure that the products and services conform to specified requirements.

2 Organisation
The responsibilities of the personnel whose activities affect quality has to be clearly defined here. Management has to appoint one of its members, who is not directly involved in production (design/assessment) or sales, as quality manager to oversee and be responsible for all quality activities.

3 Review of the Quality System
The quality system must be reviewed periodically. The quality manual specifies this period, responsibilities and the arrangements for such reviews.

4 Planning
At an early stage of any project a quality plan must be drawn up. Here a specific procedure has to be specified. For example, Appendix-A can be used as a template for a quality plan.

5 Work instructions
Instructions for carrying out specific tasks in a project. For example instructions given to the quality assessor for carrying out inspections or testing, or instructions given for archiving documents, etc. In our example the PAM Shell is a template for work instructions, to the project team, in using calculation methods. Other work instructions have to be prepared for the use of machines and other resources.

6 Records
Records are the objective evidence that the methods used and procedures carried out comply with the specified requirements (or standards if appropriate). Records procedure refers to the list of all procedures, work instructions, forms, etc. and defines the location of the documentation and the period of their retention and other information. The organisation must devise their system of records keeping. In carrying out performance assessment, clear instructions should be prepared for methods and conventions for archiving the results of an assessment on computer readable media and if appropriate in paper form.

7 Corrective action
Procedures should be established for a continuous analysis of defects and mistakes made. Such findings should be documented and prompt and effective action taken (for example by changing the calculation method or the PAM used).

8 Design control (Performance assessment control)

Procedures should be established for reviewing the methods used in the assessment of building performance and introduction of new methods. For example:

a- produce a design or an assessment method development program if appropriate,
b- investigate new methods of assessment,
c- devise procedures for preparing and maintaining drawings, calculation sheets, quality procedures and work instructions.
d- carry out regular design and/or assessment reviews, the objective of which is to ensure that:
  - the design/assessment meets the requirements,
  - other viable paths/methods have been considered,
  - statutory requirements are complied with,
  - adequate supporting documentation to define the design or the assessment is prepared,
  - alternative calculations are made to verify the correctness of original calculations, where appropriate and possible.
e- use of defect data feedback from previous design or assessments.

9 Documentation and change control

This is a procedure for producing and maintaining documents on all activities carried out. This includes procedures, work instruction, documents essential to design/assessment, drawings, audits, controls etc. These are incorporated in the Work Plan (See Appendix A) and the PAM Document. There should exist a clear procedure for keeping a record of changes made to the documentation. For example for calculations:

- Keep old documents (e.g. input files) and mark as 'old' with date, note the reason and put the name of the person making the changes. If the changes are minor, cross out the old ones (do not delete), add new ones, make a note of changes, date and name.

10 Control of inspections, measuring and test equipment

Not applicable.

11 Control of purchased material and services

Refers to procedures for the assessment and purchase of software, calculation methods, data, consultancy and inspections services, etc. Also refer to procedures for the purchase of storage materials or media (tapes, disks, etc.) and other materials and consumable that are essential for the design, documentation and control purposes.
The most important aspect, here, is the selection and purchase of programs and calculation methods. These should always be selected from among those that have been tested and/or accredited by a third party, if possible.

12 Manufacturing control

Not applicable

13 Purchaser supplied material
This is the material supplied by the client, which has to be kept in a safe place, its quantity and quality inspected regularly and ensured that complied with the specification.

14 Completed item inspection and test
procedures for final inspections and checks. As set out in section 6 and 7 of Appendix A.

15 Sampling procedures
When appropriate, the quality manager or his representative should issue work instructions for sampling procedures. It might be decided that projects with values less than a certain amount, need to be selected on a random basis for carrying out some special tests and not all tests.

16 Control of non-conforming material
Not applicable

17 Indication of inspection status
Not applicable

18 Protection and preservation of product quality Procedures for storage, material or document handling
Due regard should be given to the computer archiving media.

19 Training
Procedures for identifying the need for training of new staff or for staff in the sue of a new method, technique, software or hardware etc.

Appendix 2.C
A Sample Error Log Book

Page No.: Name:

Date	Error Description	Error Category	Program used & version number	Building type	Purpose	PAM Used	Who found	When found	Checks before	Results before	Results after
		Geometry *		School	Overheating		Self	Before run	Test run	main values	main values
		Construction		Hospital	Energy use		Second Person	After test run	steady state		
		Order of layers		House	Optimum energy			Before checks	Thermal mass		
		Rad/conv split		Factory	Improve comfort			After checks	Weather tests		
		Plant size		Flats	Improve air qlty.			etc.	Comp. previous		
		Weather file		office	Building Regs .				etc.		
		setpoint		etc.	Condensation						
		Schedules			Plant sizing						
		start time									
		time step									
		Solar processes									
		windows									
		infiltration									
		etc.									

* Categories of different nature in above table are included as a reminder only. Users are required to describe as fully as possible the error its source, type etc.

However, using the keywords will make the analysis easier. Users are also encouraged to add their categories and use them subsequently.

A Base Case

1. Building

1.1 Layout

Since the zoning procedure is part of the PAM docs (or at least of the shell), not only a module, but a whole building is proposed.
The building under consideration is a 5 storey office building with offices of the same type within the whole building on all four sides, except at the corners. The standard floor plan, showing the orientation of the building is shown in fig. 1, and its facade view in fig. 2.
It is in general a heavy weight construction type, with the exception of the internal walls, which are light weight according to widely used practise. There are no special features like glazing in the roof for the core zone etc.

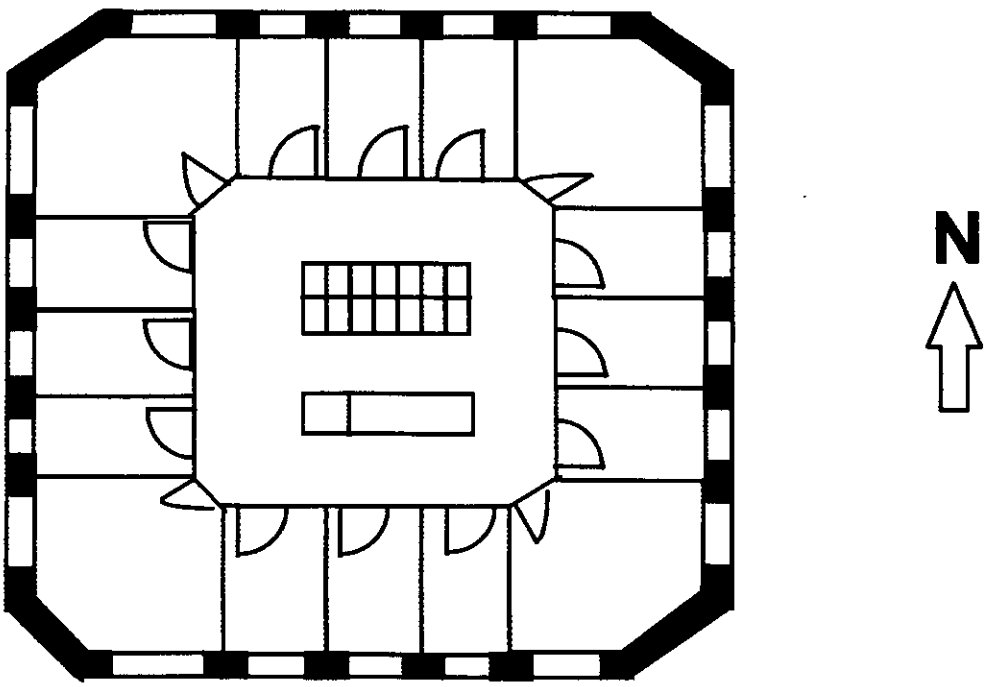


Fig. 1: Building floor plan (not exactly to scale)

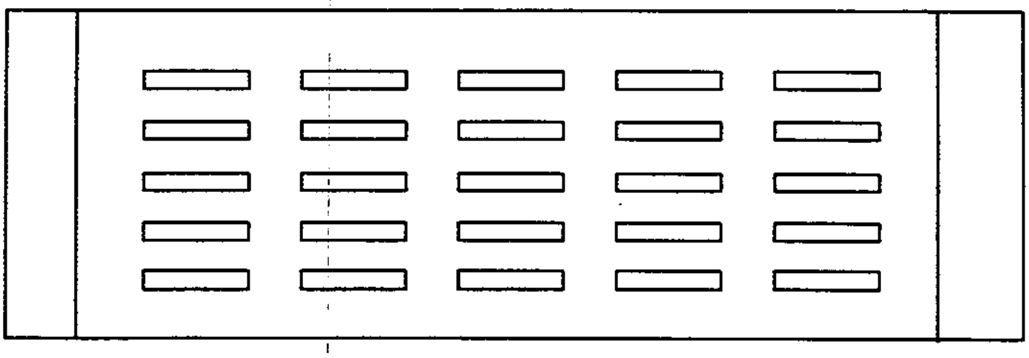


Fig. 2: Facade view (not exactly in scale)

<u>**1.2 Site**</u>
The building stands in an industrial area with loosely scattered buildings of a similar type in **Copenhagen** (since we are using Copenhagen weather data).
There are buildings in a distance of 25 m exactly centered in front of all 4 major facades of the building, with dimensions (facing facade) of 25 m (width) and 10 m (highth).

2. The Offices

The floor plan and cross section of a single office is shown in fig. 3 or 4, respectively.
The corner offices have exactly double the area of the standard ones, and have two windows of the same dimensions on two different orientations (see fig. 5).

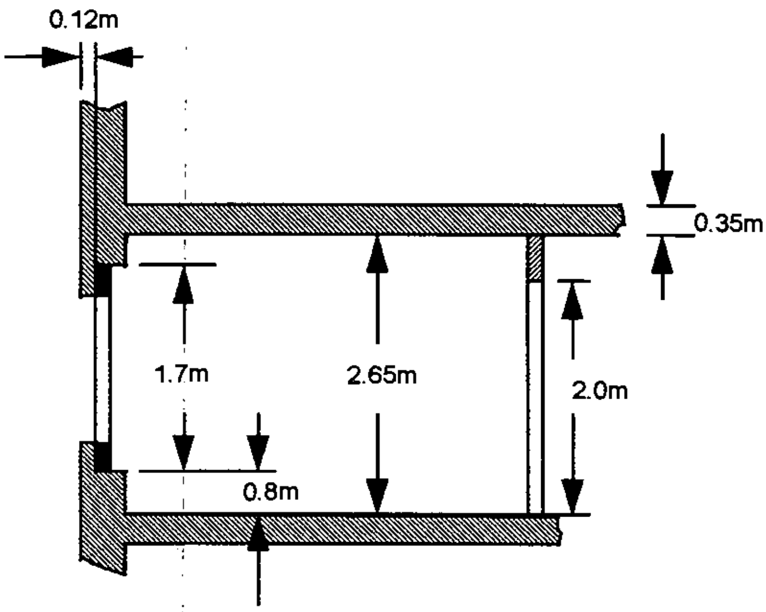


Fig. 3: Standard office cross section

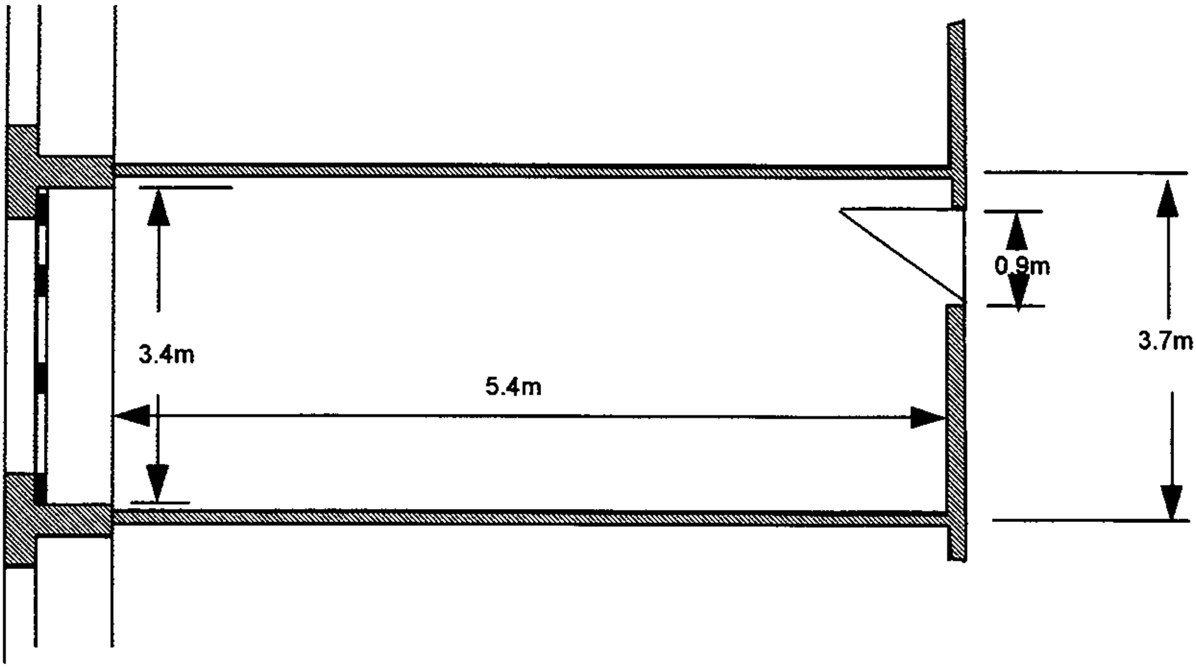


Fig. 4: Standard office floor plan

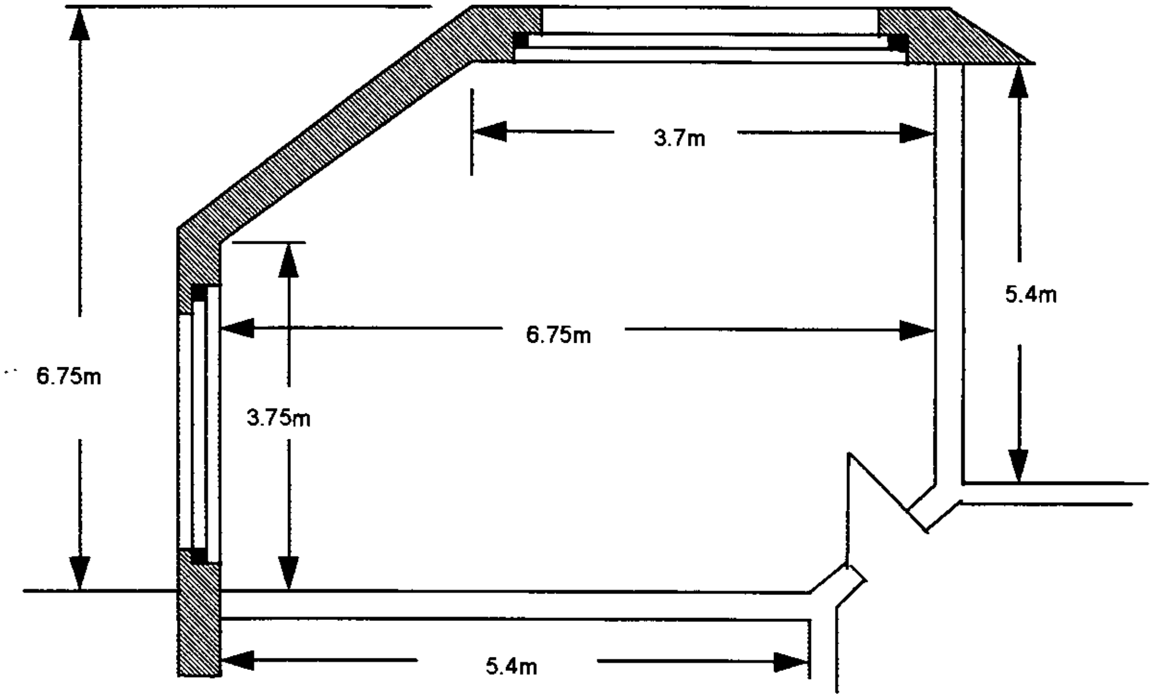


Fig. 5: Corner Office floor plan; all missing dimensions are the same as in the standard office.

3. Constructions

3.1 Roof

top	
Gravel	6 cm
Polystyrene extruded	12 cm
In-situ concrete	25 cm
matt beige paint cover	
bottom	

3.2 Floors

top	
PVC felt, gray of medium brightness	0.5 cm
Cement floor	8 cm
Mineral fiber plate 80 kg/m^3	1.5 cm
In-situ concrete	25 cm
bottom	

3.3 Exterior Walls

3.3.1 Parapets and Windowless 45 ° Walls

outside	
Facing brickwork	12 cm
Cavity	7 cm
Mineral fiber plate 60 kg/m^3	8 cm
Brickwork	15 cm
Plaster finish	
matt beige paint cover	
inside	

3.3.2 Pillars

outside	
Facing brickwork	12 cm
Cavity	7 cm
Mineral fiber plate 60 kg/m^3	8 cm
In-situ concrete	20 cm
Plaster finish	
matt beige paint cover	
inside	

3.4 Windows

3.4.1 Dimensions

Gross area see fig. 3 and 4.

Pure glass area: 3 pieces of 1.43 m x .93 m.

3.4.2 Properties

Uncoated sealed double glazing with a pane thickness of 4 mm and an air gap of 12 mm, with air filling. Frame in wood or wood/metal. (This would probably be what you might get from a client.)

More specifically:

Number of panes:	2;
Glass transmission (total spectrum):	0.71
Glass reflection (total spectrum):	0.14;
Glass transmission (visible only):	0.81;
Total window U-value (frame included):	2.6 W/m^2K.
U-value of glass only:	3.1 W/m^2K.

The given glass properties are for normal incidence.

The U-values are calculated with surface coefficients of 8 W/m^2K (inside) and 20 W/m^2K (outside).

3.5 Interior Walls

matt beige paint cover	
Plasterboard	1.5 cm
Mineral fiber	7 cm
Plasterboard	1.5 cm
matt beige paint cover	

3.6 Doors

matt beige paint cover	
Massive fir wood	4 cm
matt beige paint cover	

3.7 Furniture

Amount present:	25 kg/m^2 floor area;
Density:	650 kg/m^3
Part of floor area covered by furniture:	30 %.

4. Building Operation

4.1 Occupancy

Number of people per office: 2 (corner office: 4);

Presence:

Monday to Friday:	00:00 - 08:00	none;
	08:00 - 12:00	100 %;
	12:00 - 14:00	50%;
	14:00 - 18:00	100 %;
	18:00 - 24:00	none.
Saturday, Sunday		None.

4.2 Equipment

1 PC (125 W) per person, operation schedule:.

Monday to Friday:	00:00 - 08:00	none;
	08:00 - 12:00	50 %;
	12:00 - 14:00	25%;
	14:00 - 18:00	50 %;
	18:00 - 24:00	none.
Saturday, Sunday		None.

1 printer (150 W) per office, operation schedule:

		Standard office	Corner office:
Monday to Friday:	00:00 - 08:00	none	none
	08:00 - 12:00	33 %	67 %;
	12:00 - 14:00	none	none;
	14:00 - 18:00	33 %	67 %;
	18:00 - 24:00	none	none.
Saturday, Sunday		None.	None

4.3 Lighting

Suspended fluorescent lighting devices with an installed power consumption of 10 W/m^2. Operated by occupants through on/off switch according to needs, i.e. off when natural lighting sufficient.

4.4 Ventilation

Adventitious: Air exchange rate of 0.2 h^{-1} (non-occupancy time).

Fresh air according to minimum fresh air requirements of occupants provided through open windows during occupancy time.

For the adventitious as well as for the user defined ventilation it shall be assumed that the door to the corridor is closed.

4.5 Heating

Heating is provided by low temperature water convectors equipped with thermostatic valves with a proportional band of 2 K (setpoint +/- 1 K).

Setpoint:		
Mon - Fri:	00:00 - 06:00	16 °C;
	06:00 - 18:00	20 °C;
	18:00 - 24:00	16 °C.
Weekends:	always	16 °C.

5. Results to be produced

Since there may be differences in zoning and required results between the different PAMDOCs, produced results have to be coordinated in both respects in order to have comparable results.

5.1 Zones to be Chosen

In addition to what you have to chose according to your PAMDOC, everybody should calculate at the same time the module in the center of the south and of the west facade.

5.2 Required Data and Presentation

In addition to what your PAMDOC says, the results as set out in section 3 of PAMDOC EMPA 0001 (IEA21RN158/91) should be produced.

5.3 Conflicts

In case of conflicts between definitions given in this specification and recommendations in your PAMDOCs, the specification has priority. These cases should be reported together wit the results.

B night ventilation Case

To make the difference clearer I would call this "enforced natural ventilation for night cooling through open windows". It is defined as follows:
Occupancy time:
Same ventilation as for base case, i.e. minimum required fresh air for occupants, provided through windows (windows cannot be open longer during occupancy because of noise problems).
Non-occupancy time:
Assume that the windows are open according to fig. 6. Assume that for fire protection reasons the doors to the corridor are closed during non-occupancy time.

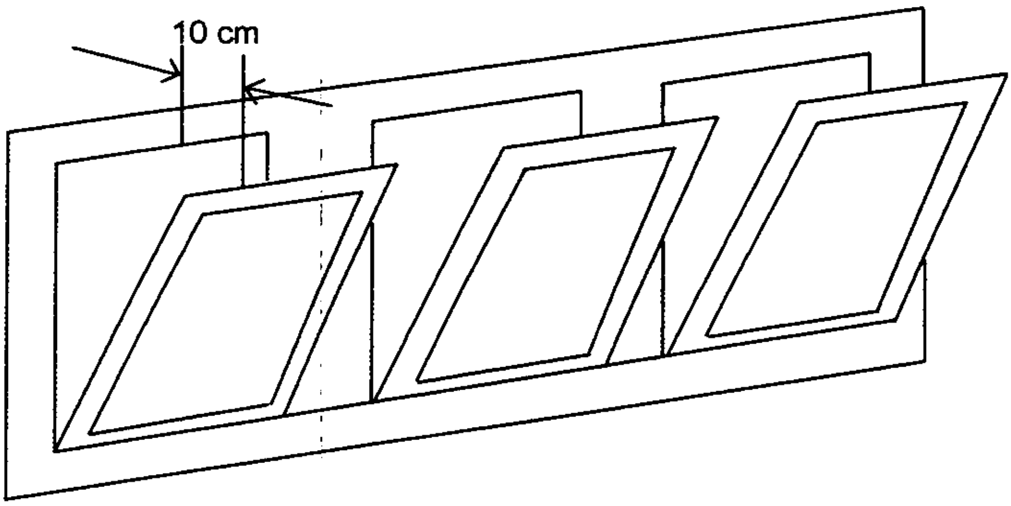


Fig. 6: Window opening scheme

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