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Dave BLOOMFIELD, Building Research Establishment, England
Yi JIANG, Tsinghua University, Beijing, P.R. China

A PROGRAM DOCUMENTATION SYSTEM AND THE WORK OF IEA ANNEX 21

ABSTRACT

Much software has been developed for analysing the thermal performance of buildings, and additional complexity is being added all the time. The simulation of the building is being linked not only to HVAC systems, but also to increasingly complex models of air flow, lighting and visualisation. The software available is beginning to approach the complexity that is present in the real world and the likelihood of software being used improperly, either due to misunderstandings or due to unwise approximations or errors, is increasing rapidly. This problem can be addressed partially by the design of much better human computer interfaces and by a greater level of integration of analysis tools which share common central databases. In addition, it becomes increasingly necessary to explain and document the basis of the algorithms that are being incorporated into the software. No practical building's performance can be modelled exactly, either with the current level of modelling, or with any conceivable developments in the future; this is because:

(i) Some of the physical processes such as turbulence, are not completely understood
(ii) the building, its surroundings, its internal contents and occupant controlled features can not be known in advance, and
(iii) some aspects of the building's description can never be known exactly.

It follows therefore that both the program developer and the user of the program are forced to accept compromises and make judgements about the level of accuracy required in building performance analysis work. It is argued that further development of building simulation software of ever increasing complexity should only be undertaken within the framework of a sound basic understanding of these essential constraints. No such framework has been developed to date.

This paper describes the approach being adopted to address the above issues in an International Energy Agency collaborative project - Calculation of Energy and Environmental Performance of Buildings (IEA Annex 21 of the Buildings & Community Systems Implementing Agreement). A description is given of a recent development to allow the systematic documentation of the theoretical basis of building analysis software using a prototype expert system - the MIS. An important feature of this system is the ability it provides for the investigation of assumptions embodied in common algorithms and programs on a consistent and rational basis.

The work in developing and using this system has highlighted the need for a much greater level of agreement between researchers and program developers on the definition of many terms in common parlance in this field.

INTRODUCTION

Methods 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. Increasingly complex software packages (**PROGRAMs**) have been developed and used within the research community. They are now finding their way into the construction industry and are beginning to be used to address real world problems. Initiatives from local authorities and from the UK Government and the European Community [1,2] are encouraging their use both for design and retrofit applications. As the user base becomes wider, it is inevitable that the average level of user expertise and understanding of building physics and simulation techniques becomes lower. There is therefore an increasing chance that a program will be used improperly or outside the range of applicability dictated by the assumptions and approximations within the program. Options are often provided within a single program to allow the user a choice between different **MODELs**, each having differing levels of modelling detail. This further complicates the task of the non-expert user. It is against this background that organisations like the European Community [3] and the International Energy Agency [4,5] organised workshops to discuss the state of the art within this field and to plan future main requirements. The views of the experts attending these three separate workshops showed a surprisingly high level of unanimity as to the main needs in this field. Three important new projects have been initiated since the workshops:

(i) IEA Annex 21 (Building & Community Systems Programme)
(ii) IEA Task 12 (Solar Heating & Cooling Programme)
(iii) CEC JOULE/COMBINE Project

(i) and (ii) share many objectives while (iii), starting 1990, will concentrate on developing common data structures to allow the integration of different programs to aid in building design, commissioning, operation and retrofit [6]. This paper describes the objectives and some of the ongoing work of IEA Annex 21 (part of which is conducted jointly with IEA Task 12). The overall theme of this paper is the need for, and the techniques being developed to aid in, the documentation of various aspects of modelling which vil be of use in all of the three projects (i)-(iii).

IEA Annex 21 - CALCULATION OF ENERGY & ENVIRONMENTAL PERFORMANCE OF BUILDINGS

This project started in October 1989 and is due to be completed by October 1992; 8 countries are participating fully with other countries having Observer status.

The objectives of the Annex are:

(i) to develop quality assurance procedures for calculating the energy and environmental performance of buildings by providing guidance on:

program and modelling assumptions
appropriate use of programs for a range of applications
evaluation of programs

(ii) to establish requirements and market needs in building and environmental services design

(iii) to propose policy and strategic direction for the development of calculation procedures

(iv) to propose means to effect technology transfer of calculation procedures into the building and environmental services design profession.

Reasons for using performance calculation methods

The potential advantages of using programs include the following:

- saving time
- exploring more options prior to building than would be possible with manual methods
- assessing building performance under a variety of different types of use and climatic conditions
- investigating performance and comfort using novel materials, designs, equipment etc.
- exploring interactions between, and dynamics of, building fabric, plant and control systems
- assessing stability of plant/control systems
- increasing flexibility in Building Controls/Regulations
- setting energy targets and providing checks as part of building operating and maintenance procedures
- enhancing understanding - through training, in the design practice, in maintenance of plant.

Obstacles preventing widespread use of performance calculation methods

Despite these advantages, there are some serious obstacles to the use of prediction programs; these include:

(i) a clear statement of the assumptions and simplifications made in the program is seldom available

(ii) well-documented, reliable data are hard to find

(iii) guidance on how to translate a real building description into the simplified form required by the program is almost totally lacking

(iv) rules for the selection of climatic, occupancy and other user data are needed

(v) guidance is needed on the choice of performance parameters to be output from the program and their interpretation for particular applications

(vi) much improved user interfaces are needed; these should be matched to the type of program user and have facilities to help trap errors

(vii) reliable and accepted methods for judging the adequacy and accuracy of programs are needed if issues such as professional liability are to be satisfactorily addressed.

Annex 21 is addressing these obstacles; it is divided into four subtasks, each of which will be discussed briefly below. One major theme running through the Annex is the need to improve quality assurance which in turn implies the need to be able to describe aspects of modelling in a simple clear fashion i.e. these aspects must be documented.

You must be able to define in order to understand; to understand in order to be able to assess; to assess in order to be able to improve.

Accordingly, in this paper the major emphasis is laid on the documentation issues and tasks in Annex 21.

Subtask A - Documentation of Existing Methods

The objectives of Subtask A are to:

- produce documentation of existing programs and models
- develop standard methodology for documenting programs and models
- document explicit information on techniques used, assumptions, approximations made and definitions of input and output parameters
- document guidance on the range of applicability

This subtask is led by the Universite de Liege; they are concentrating on the documentation of existing models, making use of a proforma which has been under development in France and Belgium for some time [7].

BRE has been working together with Tsinghua University, Beijing to develop a prototype 'expert system' to aid with the investigation of documentation issues. This 'Management of Information System' (MIS) is being used to facilitate the collection and analysis of information relating to modelling the environmental performance of buildings. It could be used for the documentation of program assumptions, for documenting the way in which a program is used for addressing a particular problem ('**Application**') or for documenting input/output data requirements etc. So far most thought has gone into its use for documenting programs. This work is described in more detail below.

Subtask B - Appropriate use of programs

The objectives of subtask B are to provide:

- guidance on how to select an appropriate program and data for a specific application
- guidance on how to apply these to specific applications.

This subtask is led by the University of Newcastle, UK. The main outputs of the subtask will be a series of guides illustrating the proper use of an ideal program, and will include Case Studies to help quantify the importance of different assumptions and levels of modelling detail.

In order to develop this guidance it is first necessary to establish and document the procedures that are currently used. A draft proforma has been devised by the University of Newcastle, paying attention to structuring the information in a logical way. The proforma has been divided into logically separate sections and it is hoped that the contents of many of these sections will prove to be common to the Performance Assessment Methods adopted for different Applications. If this proves true, it should be possible to describe the procedure adopted in a very compact way and thus to encourage a much greater level of understanding and consistency between separate practitioners.

Subtask C - Evaluation procedures & Case Studies

The objectives of subtask C are to:

- produce and document a methodology for evaluating programs
- produce Case Studies or Reference Cases
- propose a program-independent standard description of building and operating conditions.

This subtask is being conducted jointly by Annex 21 and the IEA Solar Task 12; it is being led by the Solar Energy Research Institute. Previous work in the USA [8], UK [9] and the European Community [10] has investigated the various techniques available for evaluating performance assessment methods. IEA 21 is currently reviewing this work and the opportunities offered by Analytical tests and Empirical validation. An earlier IEA project, IEA Task 8 developed a technique of inter-program comparisons to generate target ranges within which the outputs from a program under test should lie [11]. This technique will be applied within IEA 21 to extend the existing set of tests for residential buildings and to develop a new set for commercial buildings.

Subtask D - Design Support Environment

The objective of subtask D is to carry out a feasibility study into the construction of a Design Support Environment to encourage the use of appropriate building performance evaluation tools as part of the design activity.

Several projects related to this objective are underway or already planned within the member countries of the IEA. Subtask D will initially collect together information on these projects and make recommendations on how to best achieve the common objectives of these countries.

MANAGEMENT OF INFORMATION SYSTEM (MIS)

The most important point to grasp about the MIS is that it is intended to allow documentation of an object in such a way that there are no ambiguities - the terms used must have unique meanings so that the information can be stored, and subsequently analysed, by computer. One way to ensure this is to produce the documentation using a computer in the first place. Additionally, to ensure consistency between information provided by different documentors, the decision was made that it be provided in the form of choices made between a finite set of possibilities, rather than in a free format as is conventional.

The information is structured by the use of **libraries, groups and links** which influence the storage and processing processes. Facilities **Document, Edit Group and Edit Tree Structure** are provided for collection of information and procedures for automatic analysis of information stored within the MIS are also provided.

The MIS has been implemented on a PC 386 machine using Turbo Prolog. The terms used have been defined in accordance with a glossary that is being prepared within IEA Annex 17 and 21, and the UK Industry/Research Club BEPAC (Building Environmental Performance Analysis Club[12]). It is very important that strict definitions of terms are adhered to if the information is to be suitable for analysis by computer. Users of the MIS are required to add new definitions where necessary via a **"help" facility**. These definitions can then be used to improve the draft IEA glossary.

Menus, Trees, groups, links and libraries

The MIS user chooses from a **"menu"** of options corresponding to the description of some modelling features. The **menu "term"** which applies is either chosen by **"marking"** the option, or a new term can be added to the menu.

Two sorts of menu can be used - "multichoice" or "free format".
A multichoice menu is to be preferred to a free format one as this allows a very clean way of unambiguously describing information in a computer-readable format.

Consider the following **free format** example menu:

Value of internal surface coefficient:

The user can input **answers** (i.e. menu terms) in any format; answers such as:

a) 0.12 m^2K/W, or
b) 0.3 British units, or
c) It's 0.120 for vertical walls, but 0.14 for floors/ceilings.......

Fig. 1

could then be given.

This menu question has been very badly designed and the resulting responses would be very difficult to analyse by computer.

An alternative, and better, approach would be to split this into several menus and use multi-choice forms - e.g. these menus might include the following:

A1 Modelling of internal surface coefficient

[1] radiation and convection treated by use of a combined coefficient
[2] " " " are treated separately

A2 Modelling of combined radiative/convective int. surf. coeff.

[1] constant value
[2] value is dependent on temperature, time etc.

A3 Modelling of constant combined r/c int.surf.coeff.

[1] same value used for walls, floors & ceilings/roofs
[2] different values used for walls, floors & ceilings/roofs

A4 Value of constant combined r/c floor int. surf. coeff.

[1] 0.14 m^2K/W
[2] 1/(a + bT) m2K/W

etc.

Fig. 2

When the menu defines actual values used for something that is of a continuous, rather than a discrete nature, a multichoice menu can still be used by offering a choice between ranges of values e.g.:

Value of combined internal surface coefficient

[1] 0
[2] 0-0.099
[3] 0.1-0.199
[4] 0.2 or greater

Fig. 3

Subsidiary free-format menus could be linked to these terms if the exact value was very important.

'Links' also need to be specified e.g. between A2 and A1[1], A3 and A2[1], A4 and A3[2] so that the MIS user, has to supply a minimum of information, i.e. the menus displayed to the documentor will be logically dependent on the user's previous responses. The set of 'menus' and the logical 'links' between menus form a 'tree' structure (see Fig. 4).

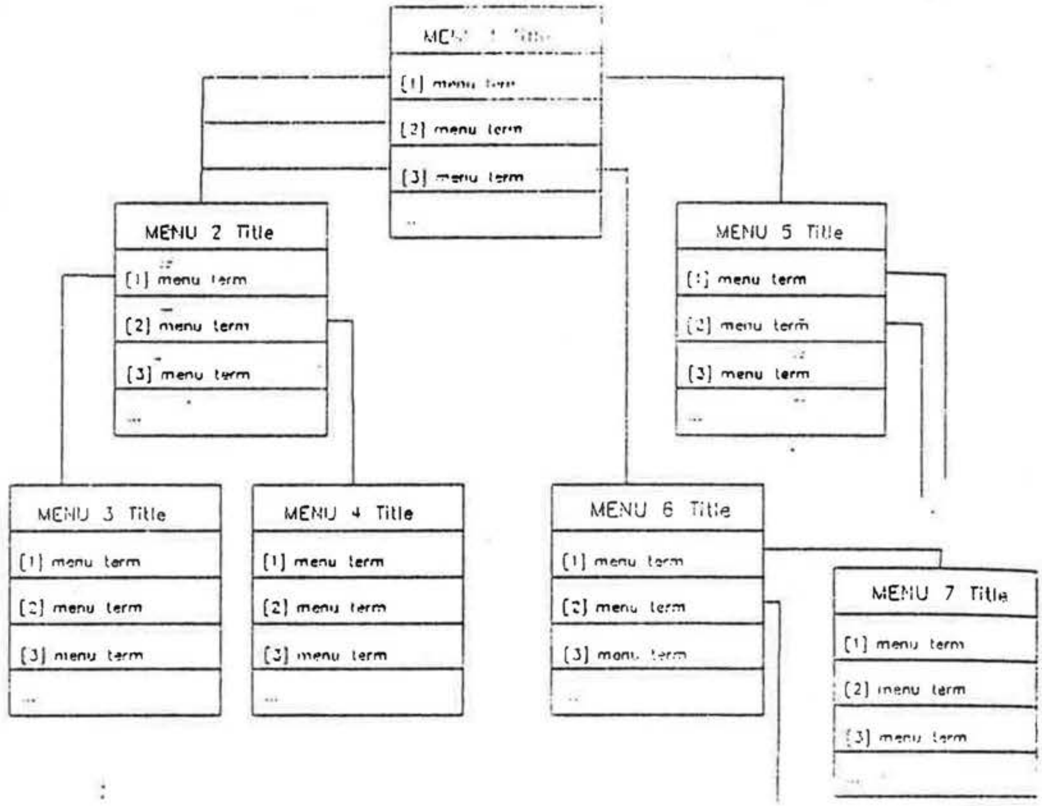

Fig. 4

A collection of such responses can be stored in a <u>'library'</u> (e.g. WALL, ZONE, MODEL, APPLICATION).

A few key rules should be followed when designing a menu structure:

Every option within a menu must be a possible response.

The text of each menu term should be as full as possible so that its meaning is clear even when it appears separately from its menu title.

Each menu term should contain a single, clearly expressed statement - any special terms should be defined in Help files.

The title of each menu should be phrased as a statement, not a question.

The multichoice menus should be designed so that, as far as possible, only one term will apply to any object to be documented.

e.g. avoid:

(A) Type of wall that can be modelled

(1) Single layer wall
(2) multi-layer wall
(3) wall with air gap
(4) wall with phase change material
(5) ...

Fig. 5

Instead, split this into separate menus:

(B1) Treatment of multi-layer walls

(1) only single walls can be modelled
(2) multi-layer walls can be modelled

(B2) Treatment of air gap

(1) ...
(2) ...

(B3) Treatment of phase change walls

(1) phase change walls are treated as normal walls
(2) ...

Fig. 6

If the menu system is well-defined, the total tree will contain many menus, for which the number of possible answers (or terms) will be small and easy to understand. In the documentation phase, such a system should lead to the expert modeller being presented with a small number of menus, each of which is very relevant to him.

In order to ease the task of the expert modeller who is going to provide information to the MIS, it was found to be convenient to group and display the menus under logically connected titles. These titles can be chosen and positioned in a nested form using the "Edit Group Structure" command - e.g.

.. WALL 2 MODEL LIBRARY

.. GENERAL INFORMATION

[1] menu

.. PHYSICAL MODEL

.. HEAT FLOW & STORAGE WITHIN FABRIC

[5] menu

[6] menu

.. MATHEMATICAL MODEL

..

[10] menu
[11] menu

.. NUMERICAL MODEL

[50] menu
[51] menu

Fig. 7

This "group structure" is intended to help the documentation process and should be useful later when analysing the information in the MIS libraries. It does not, however, affect the tree structure which is normally invisible to the expert modeller. The tree structure is defined by the links between menus - e.g. in the scheme above, menu [50] could be linked to a menu from any group (e.g. [5], [11], ...)

The group names can best be thought of as analogous to Chapter or Section titles in a book. Indeed, one of the main aims of the Subtask A MIS work is to devise such a Book - the Chapter and Section titles, together with the structure of their contents, will define a user manual for documenting program assumptions. A HELP file can be provided to contain textual information to act as an introduction to each group.

The Documentation Process

A library must first be selected - this could be e.g. a WALL library, a library containing information about PLANT modelling, or one containing methods of assessing OVERHEATING.

The documentor is requested to describe the program, model, application etc by 'marking' each option that applies in the current menu which is displayed on the screen. If none of the menu options applies then a new term can be added, the new term marked and the Help file edited to explain the new term if necessary.

If the whole menu (M) is inapplicable, the existing links (i.e. logical conditions which determined that the menu should be presented to the documentor must be incorrect. The user can correct this, i.e. improve the system, by selecting 'Refuse to answer' from the pop-up menu. A sequence of menus will then be displayed (working back up the tree which led to the current position) and the user requested to select a menu (F10) which contains the reason why the menu M was not applicable. Further, a particular term within the menu should be marked e.g. menu M. In this way, the MIS allows information to be gathered from the modelling experts who use the system to document an object and, at the same time, 'learns' how to improve the information collection process.

Evolution of MIS structure

Initially, when an MIS user creates a new library no structure exists - at most there will be one introductory menu. After the library has been used for some time to document several different objects a tree structure will exist and the MIS user documenting a new object within this library will be presented with one of the menus created by previous users who have documented similar objects.

Rather than allowing the structure to evolve in this way, it is possible and, indeed, advisable to impose greater order by using the Edit Group Structure pop-up menu option directly after creating a new library. This allows the menus to be displayed on the screen or printer as belonging to user-defined, logically connected groups. Figure 7 shows an example for a library of wall models.

New menus can also be created, positioned and linked using this option. This is the quickest way to create a basically sound structure for a library. Adherence to the Rules explained in this note is important, and it is expected that this option will be used mainly by the more expert MIS user. The normal modelling expert who uses the system will usually be working with existing libraries where a basic structure has already been created.

Another option exists for the expert MIS user - 'Edit tree'; this allows links to be changed by direct editing, but should be used with caution.

One purpose of the MIS is to document assumptions in programs. One of the major outputs will be the development of a manual structure for future programs. By concentrating on programs, rather than models, it is in principle possible to preserve information about the links that exist within programs between the many models implemented.

The IEA 21 working procedure is to:

a) provide a basic, logically sound structure for component parts of programs, developed separately in "COMPONENT" libraries (e.g. WALL, ZONE, WINDOW).

b) use this to document actual programs (still using component libraries) - to test the basic structure and to add/improve it as more programs are documented.

c) merge the libraries so as to form complete documentation of program assumptions.

d) use this structure to define a user manual.

There are certain important differences of principle between documenting programs rather than models. When documenting programs, the menus, or questions to be answered by the documentor, should deal with what the program as implemented actually assumes e.g. including actual values of parameters that are encoded, or are provided as defaults. For programs which allow the user to select from several options (e.g. windows modelled as a simple conductances or as a transparent zone surface) all options should be documented, thus leading to several terms being marked in a single menu. When documenting models, the actual values may be of less importance as the same basic model can be used with different values. In some cases, a simple change in value can change the physical model substantially (e.g. value of surface coefficient). For both cases it is useful to describe any limitations on values (max, min)

At this stage in the work, we are seeking ways to make the objects involved in the environmental modelling of buildings understandable by computer i.e. to develop a database. After this database has been developed different analyses can be performed depending on the purpose for which it is to be used.

The MIS could be used to deal with several purposes additional to the main one described above i.e. designing a program user manual structure. For example:

i) documentation of program
ii) selection of a suitable program via analysis facilities & program libraries
iii) specification of design for a new program
iv) as for (i)-(iii), but for model not program
v) documentation of Application
vi) documentation of data input to program
vii) documentation of output data (options)
viii) documentation of procedure adopted in a particular modelling (case) study.

In principle, analysis routines could be added to perform matching between available programs/models and applications requirements.

Purposes (ii) & (iii) are really part of the more general purpose (i) - they contain an implied body of information. When selecting a program, clearly one needs to know the program assumptions i.e. purpose (i), but what criteria would be used in performing this selection? Again, when specifying the basis of a new program - one could select (i.e. mark) the most appropriate assumptions - but based upon what criteria?

It is hoped that some rules will be developed during the course of IEA21, but much of the necessary information does not exist yet. For this reason the more general purposes - (i), (iv)-(vii) have been made priorities. This implies that structuring should be dictated primarily by objective, physical principles.

Purpose (viii) - documentation of the entire procedure adopted in a particular modelling Case Study is of great importance, especially so when the quality of the results need to be carefully assessed, or when comparing results (from different programs or users). The MIS could be used to record in great detail all of the assumptions made in a particular simulation - these would include those particular to the program used and those arising from the way in which the program was used. Here, the specific input values and the actual options selected within the program would be included.

The MIS may be used in this way to record the procedure adopted in the Case Studies conducted within IEA 21. Analysis facilities could then be used to enable automatic comparison of assumptions both between different programs (e.g. SERIRES, TRNSYS..) and between different users (program ESP - as used by BRE, Tsinghua, ..). In previous comparative studies the lack of such quality control has seriously limited the value of the results. The comprehensive procedures adopted in the UK Applicability Analysis Study [13] demonstrated the value of such an approach. In an original study undertaken as part of the UK Dept. Energy's Pasive Solar Programme, comparisons were made using detailed simulation programs of the effect of different glazing areas on energy consumption of a passive solar house. These showed very significant differences (Fig 8).

The study was repeated under the Applicability study with good quality control and led to much better agreement between the programs (Fig 9). The original discrepancies were due more to the program users and the additional assumptions made than to any inherent differences in the predictive capabilities of the programs.

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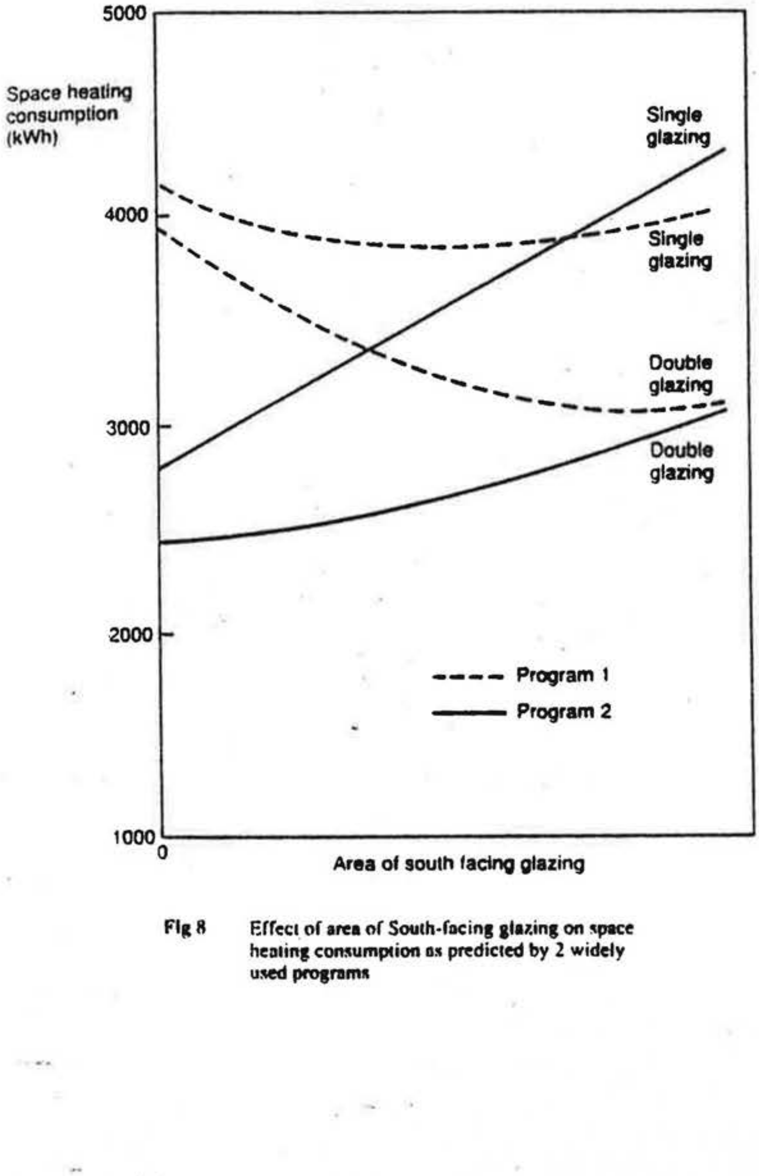

Fig 8 Effect of area of South-facing glazing on space heating consumption as predicted by 2 widely used programs

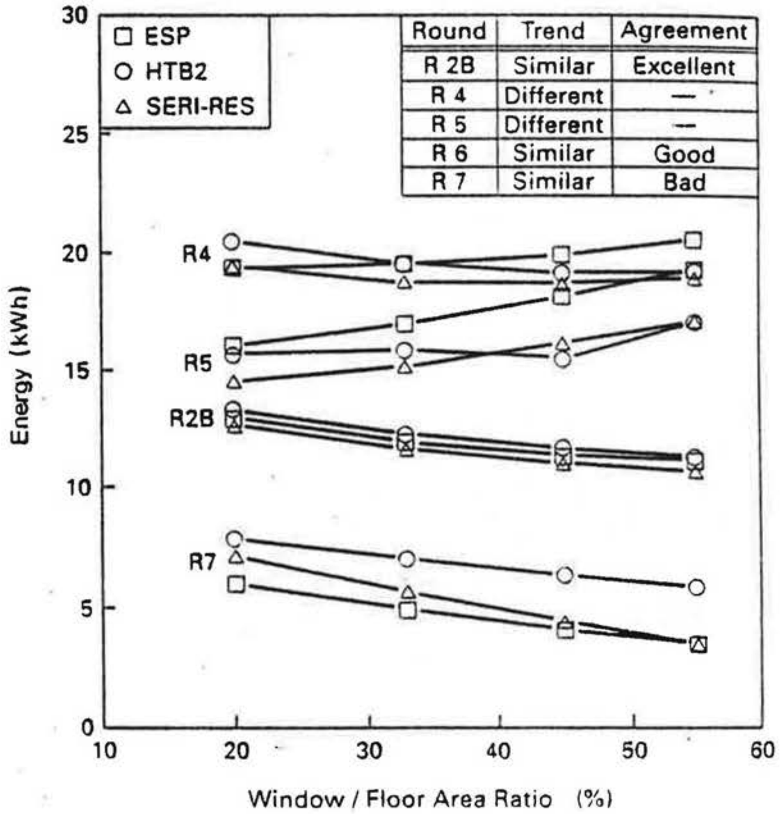

Figure 9 Comparisons of predictions obtained with detailed simulation programs in UK Applicability Analysis project.

CONCLUSIONS

Quality assurance is of paramount importance in the field of building performance prediction. This implies a need for documentation of various aspects of modelling.

The assumptions made in a performance prediction program must be clearly stated and available for inspection, if not by every program user, at least by a qualified expert capable of certifying the program. This is necessary in order to cope with the issue of professional liability. It is the reponsibility of the professional designer or engineer to select appropriate tools, although they may, in turn, rely upon the expert certifying body.

Even if a suitable program has been selected, the way in which it is used, together with the data selected and the interpretation of the outputs, is all important. This performance assessment method also needs to be documented, evaluated and be open to inspection by a quality assurance manager.

International Energy Agency Annex 21 is addressing this need for documentation by developing proformas and by the use of a prototype expert system.

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DISCUSSION

NGENDAKUMANA P. (Belgium)

Could you explain a little more what you mean by "accuracy" of programs ? Do you mean comparisons between programs or comparisons between program results and experimental data ?

ANSWER :

A program may not need to be terribly accurate for it to be adequate for its intended purpose.

PEDERSEN C. (USA)

What is the current status ? How far have you progressed on the grand scheme ?

ANSWER :

The software of the MIS has been developed to about 70% ≈ 80% . It will be finished by the middle of next year, but the interface still needs to be improved a lot. However, the meaning of the software is only a software, not much knowledge (or information) inside just something like an empty box. A lot of work has to be done to fill the box. This is one of the IEA Annex 21 subtasks. We hope after the Annex 21 is finished (end of 1991), we can present the whole system including frame and knowledge, and it will be used by normal software users and building design consultants.

UNKNOWN

MIS deals with a sharing database. What is data processing system which allows the experts to fill this database, especially the term glossary and the hypothesis database.

ANSWER :

The information is presented in MIS in the way of multi-choice menus. Every menu and every term in the menu has a note to describe it in details. Then, during the documentation process, the documentor can only select one of the terms from the multi-choice menu, or add a new term. MIS records the number of the menu and the number of the term that the documentor has selected. During the analysis procedure, MIS just analyzes the numbers (search, match, etc). In side of MIS, only the number of the menu and term works. The text only works when the MIS produces the final presentation to the -er.