



MORE EFFICIENT ESP-R MODELLING BY AUTOMATIC GENERATION OF INPUT FILES

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ABSTRACT

In a recent building simulation project, the significant effort required to calculate and enter casual gains and air flow data into the ESP-r modelling software was found to impede progress and increase the risk of error. A software tool, implemented as a Microsoft Excel spreadsheet using VBA, has been developed that avoids these problems by generating the required ESP-r data files automatically.

The use of the spreadsheet had a major impact on project progress. Creating the input data for a run became a matter of selecting some options and pressing a button to create the files, where it would have taken well over an hour in the past. In addition, errors were reduced and opportunities for new investigations increased.

INTRODUCTION

Computer modelling of buildings is now a common activity because of the many advantages it offers. Among other things, it allows the environmental impact of different building designs to be studied, thus allowing improvements to be made and carbon dioxide emissions to be minimized.

Detailed modelling of a building requires large amounts of information to be provided on its structure, materials and usage. In particular, the emission of heat from occupants, lighting and appliances (collectively referred to as casual gains) and the air flow in each zone of a building need to be taken into account in order for the thermal behaviour to be correctly described.

In the ESP-r building modelling tool, casual gains and air flow can take a significant amount of time and effort to calculate and enter. In modelling work carried out for the TARBASE project (Taylor et al 2009), the time and effort were increased further by the need to determine the data for two buildings, both of which contained large numbers of zones and for which many changes in casual gains and air flow were needed for the different scenarios being studied. Besides the immediate impact on the project of the preparation, calculation and input of large amounts of detailed data, there were other consequences including generation and propagation of errors and

the lack of time to explore potentially fruitful avenues of research.

This paper describes an alternative method for both calculating casual gains and air flow data and entering the values into ESP-r which was developed to avoid the problems described.

SIMULATION BACKGROUND

Hotel project

The work formed part of TARBASE, a research project supported by EPSRC and the Carbon Trust under the Carbon Vision programme. The aim of TARBASE was to investigate ways of reducing carbon dioxide emissions from existing buildings, given that they will be responsible for most of the building emissions over the next few decades. A range of building types were studied in the project, both domestic and non-domestic. The work described here concentrates on hotels because they form part of one of the highest emitting sectors of the non-domestic building stock (BRE 2002).

Two hotel types were modelled, one older and one modern. The hotels were simulated for the base year 2005 and for the target year of 2030. Several interventions expected to be available in 2030 were applied and the effects on emissions of each were determined. In most cases they involved changes in the casual gains or air flow or both and so required changes in the corresponding ESP-r input data.

The hotel models had relatively large numbers of zones: 21 for the older hotel and 29 for the newer. These large numbers were partly to allow the variations in indoor environments to be taken into account, but were also a consequence of a feature of ESP-r. The number of zones in contact with the floor or ceiling of another zone must not exceed 6. As it stood, the design adopted for the newer hotel exceeded this limit, requiring further subdivision of some zones. In order to provide a margin of safety, a decision was made early in the project to use the 48-zone version of ESP-r.

Many variations were needed in the casual gains and air flow values used in the modelling. Air flow consists of infiltration (unintended air flow) and ventilation (intended). The infiltration values were reduced at the point in the series of interventions when large-scale wall insulation and glazing changes

were made, to reflect real world experience. Ventilation was arranged such that the total air flow rate (ventilation plus infiltration) always equalled or exceeded the recommended values (CIBSE 1999, 2006), and so the ventilation values changed in response to the reduction in infiltration. The ventilation also changed for other reasons. Some zones were closed off in response to occupancy levels (again mimicking real-world practice) and so the ventilation was decreased to reduce costs. The change in occupancy also meant that the casual gains due to occupancy were changed. All ventilation levels changed between 2005 and 2030 due to new recommendations (CIBSE 2006). Finally, the ventilation values were changed in order to model a ventilation heat recovery intervention.

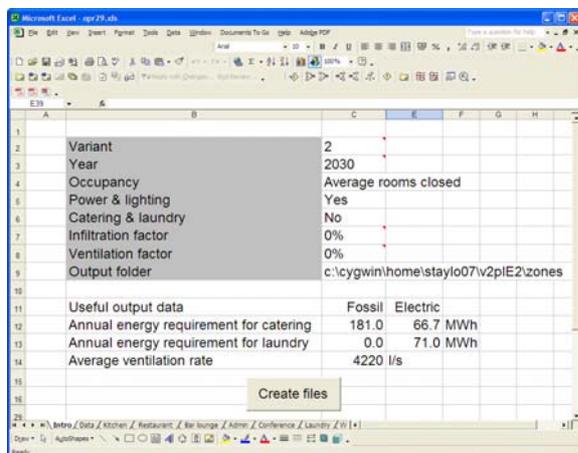


Figure 1. User entry screen

Some lighting values changed between 2005 and 2030 as a result of different recommended values of illuminance, but a more significant change was a result of a “power and lighting” intervention. Very low energy lighting using LED or some alternative technology was assumed to be available by the target year of 2030. As part of the same intervention, very many changes in appliance (small power) energy consumption, and therefore heat gains, were also made.

Use of ESP-r

The 48-zone Cygwin version of ESP-r (v. 11.4) was used for all of the work reported. Initially, casual gains and air flow data were entered using the standard method. This is done in ESP-r by entering values under four categories (occupation, lighting, small power and air flow) for three day types (weekday, Saturday and Sunday). In each case, periods are defined covering 24 hours and appropriate values for the gain are entered for each period. Additional data are needed in some cases, e.g. non-default values of the radiant and convective fraction for some small power gains.

As a result of the large amount of time taken by the calculation and input of casual gains and air flow data, attempts were made to speed up the process. A spreadsheet was developed for calculating the values corresponding to each intervention. In addition, features of ESP-r were used where possible, e.g. the ability to enter one set of data for weekdays (say) and then copy it for Saturday and Sunday. Also, use was made of the area scaling function that preserves the casual gain per unit floor area when copying between zones.

However, the length of time taken to create the required files was still longer than desired and further speeding-up methods were sought. Editing schedules were devised to minimize data entry since for certain interventions some data did not need editing and could be copied from earlier simulation input. Also, advantage was taken of the way ESP-r handles casual gains. The data are placed in .opr (operation) files, one per zone, ready for use by the simulation engine. These files are character-based and editing them directly was sometimes found to be an efficient way of making changes. This led to the recognition that creating them from scratch could provide greater productivity.

DATA DERIVATION

Spreadsheet for casual gains calculation

As described earlier, the use of a spreadsheet for casual gains calculation was an obvious initial step. It was developed using Microsoft Excel in an evolutionary fashion as the project progressed, although the basic structure remained unchanged. Descriptions provided are for the final form of the spreadsheet.

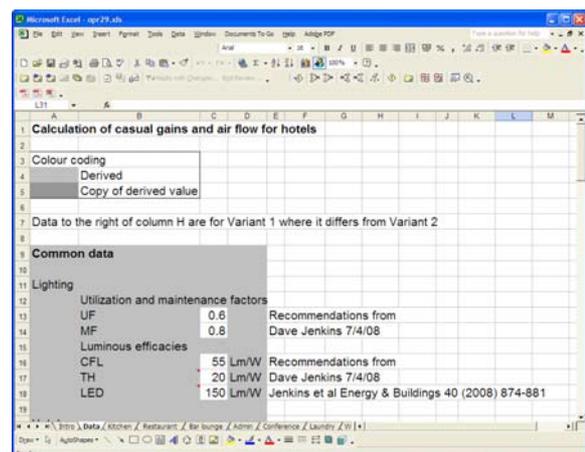


Figure 2. Common data sheet

A user entry sheet (Fig. 1) allowed automatic selection of intervention options. A common data sheet (Fig. 2) held the base data used by other sheets (e.g. recommended values of illuminance) and associated references. Each zone, or group of similar zones, was represented by its own sheet (Fig. 3). It

held data for both hotel types (since in many cases the one was derived from the other) in a standard format: general assumptions (e.g. weekday/weekend operation, daily schedules, floor areas), equipment gains (with special treatment for kitchen and laundry where some of the generated heat was lost from the building), lighting gains, occupancy gains, air flow (infiltration, ventilation and their sum) and finally the calculated data ready for entry into ESP-r.

The screenshot shows an Excel spreadsheet with the following sections:

- Admin**
- Calculations and assumptions**
 - 1. General assumptions
 - Weekdays, Saturdays and Sundays have identical schedules
 - Periods considered

Hours	Operational?
0	24
	Yes
 - Number of people present at any one time: 2
 - 2. Equipment gains
 - 2.1 Equipment used before P & L intervention

Equipment	Rated power/W	Usage Factor Fu	No.	Total av. power/W	No.	Total av. power/W
PC	66	0.587	4	155	3	116
Monitor	33	0.715	4	94	3	71
Printer	54	0.280	3	45	3	45

Figure 3. Example of a zone sheet

DATA TRANSFER

Treatment of casual gains and air flow by ESP-r

Since ESP-r transfers casual gains and air flow data to the simulation engine by means of character-based .opr files, it became clear that the possibility existed for a separate input process, bypassing manual data entry in ESP-r altogether.

The approach used by ESP-r is straightforward. There is an .opr file for each zone in the building with a simple naming convention, and all the files are stored in the model's "zones" folder so that they can be used at simulation time. So the requirement for an alternative approach was to create the files by another route and then put them in the zones folder before initiating a run.

Automatic .opr file generation

It was clear that the greatest productivity would be obtained by linking automatic .opr file generation to the automatic calculation of casual gains and air flow described above. Various tools were considered for the job, including Fortran, Matlab/Octave and VBA (Visual Basic for Applications). The last of these was selected because the framework for using it already existed in the Excel casual gains and air flow calculation spreadsheet. If VBA could be used to create .opr files that were readable by ESP-r, a suitable tool could be built.

The feasibility of the approach was tested by creating an .opr file using VBA. The file was created by writing text strings copied from an existing .opr file

to a new one. A simulation was then attempted using the newly created file. It ran successfully, showing that automatic file creation could be used for data transfer.

Development

An evolutionary development approach was adopted in which the fixed text created for the feasibility check was gradually replaced with variables. The fixed format of the .opr files created by ESP-r was reproduced precisely to ensure compatibility.

The implementation made use of a mixture of Excel and VBA. Selection options were provided on the main page (see Fig. 1), mainly in the form of simple pull-down menus implemented using the Excel Data Validation functionality. These options corresponded to the interventions and other changes that needed to be made to the casual gains and air flow to carry out the required simulations, along with the path for the folder where the resulting .opr files were to be created.

The data sheet of the spreadsheet (Fig. 2), which held common values used in other parts of the calculations, was also used to hold addressing data for the VBA code. This consisted of row and column numbers that enabled the VBA code to pick up the correct results from the spreadsheet for each zone and option.

A "Create Files" button on the main page triggered the operation of the VBA code. The result was the creation in the designated folder of all of the .opr files needed for the simulation of interest: 21 for the older hotel or 28 for the newer. The 29th zone in the newer hotel represented the roof space for which no changes in casual gains and air flow were needed. It was therefore excluded from the automatic calculation and copied separately into the destination folder.

Simple error checking was included. The VBA code was used to display a message box on the screen at run time indicating the number of files created. The code included logic to check whether data were being read from the correct position, and error statements were displayed in message boxes if a text header was incorrect, for example. Also, the Excel code included logic to enter "-999" in various cells if an incorrect logical choice was made.

The system was designed to document the run automatically by providing a record of the options chosen. This was done in two ways. First, the comment line in the .opr file was automatically populated with information about the run options, date and software version. Second, the information on the main page was arranged in such a way that it could all be copied in a single operation, to allow the details of the run to be recorded in a project progress file.

As the evolutionary development continued, the system was made to match more closely the

modelling work being carried out. Additions to the spreadsheet included calculation of the total ventilation rate (to allow the energy used for mechanical ventilation to be determined) and the energy used (both electricity and gas) by laundry and catering, to facilitate calculation of carbon dioxide emissions. These additions were included in the main page display for easy copying, resulting in the final design shown in Fig. 1.

Testing

Initial testing concentrated on feasibility by establishing whether the automatically-produced files could be read successfully into ESP-r and listed out, and whether a successful simulation could be performed. The focus was thus on the machine-readability and syntax of the files.

In more detailed testing, the .opr files were compared character-by-character with equivalent files produced by the conventional ESP-r method in order to test the ability of the spreadsheet tool to calculate the correct data values. In the main, the agreement was good. Occasionally, however, differences were found. It is interesting to note that in most cases the file produced by the new, automatic method was correct, and the errors were in the manually produced file. The usual reason was that an error had been introduced in an earlier run due to a bug in the previous calculation method. The error had either remained or had been propagated as a result of the techniques described earlier to reduce manual data entry.

DISCUSSION AND ANALYSIS

Costs and benefits

The software described delivered benefits but also entailed costs in the form of time spent on its development. The time spent was not great (of the order of 10 person days), but it was significant against the background of a project with tight timescales.

The benefits were that speed and accuracy increased significantly, repaying the development effort many times over. The ease of running a simulation for arbitrary conditions also meant that it was worthwhile to try new options that would not have been considered previously.

Working method for simulations

A working method was adopted in tandem with the spreadsheet development that made the interventions straightforward to simulate. Each intervention was a combination of three influences: climate, physical building structure and casual gains & air flow, with an additional effect due to standards for illumination and ventilation changing between base and target years.

The climate was set directly within ESP-r to either 2005 or 2030 according to the schedule shown in

Table 1, and the year that defined the standards used was set to the same value.

Physical models of the hotels were set up for the four variants studied: za (all zones available), zc (some zones closed), zci (zones closed + insulation) and zcig (zones closed + insulation + glazing). The za intervention made use of all of the zones while the others allowed for a defined group of bedrooms that were unheated and minimally ventilated.

Casual gains were then selected for each case as shown in Table 1. "Occ" stands for occupancy, for which the options were full, average with all zones open (as) and average with some zones closed (cz). P&L (power and lighting) covers all the available power and lighting improvements for simplicity, although in reality additional options were available. The percentages listed for Vent(ilation) and Inf(iltration) are the changes from the base value.

Table 1
Schedule of simulations

Run	Intervention	Physical model	Casual gains & air flow				Climate
			Occ	P&L	Vent	Inf	
1	Hotel full	za	full	n	0%	0%	2005
2	Average occ, spread out		as	n	0%	0%	
3	Average occ, closed zones	zc	cz	n	0%	0%	
4	2030 climate	zci	cz	n	0%	0%	2030
5	Ventilation heat recovery		cz	n	-70%	0%	
6	Reduced infiltration		cz	n	-70%	-50%	
7	Wall Insulation						
8	Glazing	zcig	cz	y	-70%	-50%	
	Condensing boiler						
9	Power & lighting Solar thermal hot water						

A separate spreadsheet was used to post-process the modelling predictions and derive the main results. It combined a separate calculation of hot water usage with the simulated heating energy consumption. By taking into account heating system efficiency and type of fuel used (electricity or gas) by the heating system and laundry and catering appliances, it calculated the total energy and carbon dioxide emissions for the different intervention stages.

It is worth pointing out that while runs 1 to 7 in Table 1 each correspond to a single intervention, both runs 8 and 9 correspond to two. This is because the second intervention in each case (condensing boiler and solar thermal hot water) could be derived without further simulation: the outcomes depend on external calculations. For the condensing boiler, this was a change in the heating system's efficiency and, for the newer electrically-heated hotel, fuel. For the solar thermal hot water it was a change in the hot water calculation.

Limitations of system

The main limitation of the system for automatic generation of .opr files is that it was designed for the current project and so lacks the flexibility for general use. In particular, it was set up for a particular range of interventions for the specific equipment and usage periods appropriate to a hotel.

However, the design is not complicated and it would be a fairly simple matter to redesign it to apply to a different set of circumstances.

CONCLUSIONS

- A software tool has been designed to calculate casual gains and air flow for building simulation, and to transfer the resulting data into the ESP-r simulation engine automatically.
- The tool provided significant value in a project where many changes in the casual gains and air flow data were needed for building models containing large numbers of zones.
- The development effort was repaid many times over by speed and accuracy improvements
- The use of the system led to the development of an efficient working method
- The evolved system lacks flexibility because it was customized for the project, but it would be straightforward to adapt it to different circumstances.

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