The ESP-r: cookbook

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February 10 2006

Introduction 1

Tactical approaches to simulation 2

Initial tactics: 2
The client specification: 3
Design questions: 3
Model planning: 4
Model Coordinates: 4
How the building is used: 5
Environmental controls: 6
Model composition: 6

Building a model 7

Review of climate patterns and databases 7
Locating constructions for our model 10
Zone composition tactics 11
Model topology 19

Geometry revisited 21

To the keyboard then 21
Lets start clicking 23
Clicking on a bitmap 27
Which approach to take 28

Schedules 31

Scheduled air flows 33
Importing operation schedules 34

Climate data 35

Importing climate data 35
Defining seasons and typical periods 37
Climatelist entries 39

Plant 40

First exercise – using a component network to represent mechanical ventilation. 40
Defining containments 43
Finishing off the model and testing 44
Moving from ideal demands to thermal zone demands 46
Links to zones and controls 47

Introduction

Learning how to use ESP-r for design decision support and for research has tended to follow three paths - the mentor path, the workshop path and the *there-be-dragons* path. The mentor path works exceedingly well and is an efficient, if not particularly inexpensive way of gaining the skills and tactics needed to apply simulation to real-time projects. Workshops are another successful approach to simulation training. Two or three days of initial sessions, supplemented by advanced topic workshops and the occasional email allow many practitioners to productively use simulation in their practices. Both of these approaches rely on personal contact with an expert and iterations of demonstration followed hands-on experience and dialog for skills acquisition.

What you are reading now is addressed at those who are taking the other path. Perhaps you have downloaded the source distribution from the ESRU web page <http://www.esru.strath.ac.uk> or acquired an ISO image of one of the run-time distributions. Instructions for getting a working distribution can be found on the download page.

The download page does not really tell you much about what to do once you have ESP-r on your computer. Of course there are web based tutorials and exercises on the site. These date from the days when it was *believed* that web based tutorials would supplant mentoring and workshops. For many people, web pages seem less capable of supporting the acquisition of the skills needed for serious simulation use than the mentor/workshop paths.

The ESP-r distribution comes with a range of example models of two broad types – abstract models which are composed to illustrate semantics and syntax or models derived from consulting projects which focus on specific building performance design issues. The first type is often used by novices to get used to ESP-r, the second type for those who are looking for examples of best practice models.

Example models contain a wealth of information for those who know what they are looking for, for those who are persistent or for those who are using them as reference materials within the context of a workshop or in mentor based training as:

- a mechanism for exploring the tool (e.g. where do I find out information about environmental controls, the composition of walls)
- to explore the sequence of tasks required to run an assessment and recover specific performance metrics
- to explore incremental changes in the description of the model and the performance implications of such changes

Creating a model from scratch under close supervision and with commentary on the approach taken does reduce the frequency of *encounters-with-dragons* which so often frustrate those who take the third path. What you are currently reading expands on the workshop material, and to some extent recasts it for the resolution of the printed page. Its goal is not simply to act as a dictionary or reference but as a guide to how to approach realistic design decision support in real time, delivering real information and, perhaps, still having time for a cup of coffee at the end of the day.

The cookbook is based on the premiss that those contemplating the use of simulation will already have an evolved intuition about the physics of buildings and environmental systems. A future revision is planned for those who are less opinionated.

Tactical approaches to simulation

Getting acquainted with ESP-r is best done in the context of creating a model. So grab a notepad and some sketch paper. The following sections explore how you can use ESP-r to arrive at a working simulation model and a growing set of simulation skills.

Lets begin by sorting out what sort of model we are going to make and then planning the work so that this model will add value to the design process without exhausting us in the process. This is a tactical approach to simulation which concentrates on the art of making concise models.

Initial tactics:

Design Questions	*Simulation questions*
What do I want to know about this design?	What are the questions that need to be addressed by this simulation model?
How do I know if my design works?	What can the model measure (*performance metrics*) that might inform my judgments? What level of detail (*granularity*) is required to produce these metrics?
How might my design fail?	What boundary conditions and operating regimes would act as reasonable tests of the design?
How do I match the information I have with the requirements of the tool?	What is the essence of the design in term of form, composition, operation and control? What are the essential interactions which need to be represented in the model? What simulation facilities need to be employed and what skills are needed to use them properly?
Is my approach appropriate?	Can I sketch out my model and explain it to others?
How do I assure the quality of the model as it evolves and the predictions generated?	What assessments need to be undertaken to gain confidence in the model? Who can I get to review (QA) the model? What would be expected of a *best practice* design of this type? How might the design and the model evolve during the design process?
How can I deliver the most value for my client?	What else could I do that would clarify how the design works so I can better communicate this with others? What would I do now to make it easier to work with this model if, in four months time, the client asks for a new design variant?

Without a tactical approach to simulation, we might not answer the clients questions or might only do so after the answer has any value. Without tactics we will struggle to use this model to support follow-up work. Without tactics we will miss out on the value-added aspects of simulation which cost us little to implement but which deliver substantial benefit to others in the design process. A tactical approach to simulation keeps you in charge of the simulation tool.

In the next section the clients specification and design questions are presented. Then we decide what type of model the specification implies as well as the assessments that need to be done to understand its performance well enough to answer the clients questions.

The client specification:

The following figures are the specification of our first project. Figure 1 shows a plan, section (looking from the east), wireframe perspective view (looking from the south-west) and a colour image (looking from the north-east). This is a portion of a general practitioner's office. There are two rooms, an L shaped reception room and an examination room which has a sloped ceiling.

There are two people in the examination room during the hours of 9h00 to 16h00 on weekdays (200W sensible, 100W latent). In the reception occupant sensible gains are 80W from 7h-8h, 240W from 8h-9h and 12h-14h and 400W from 9h-12h and 14h-17h. Occupant latent loads in the reception are assumed to be half the sensible loads. Lighting in the reception is 150W during the hours of 8h00 to 19h00 and there are no small power loads in either room for purposes of this model. The heating set point is 20ºC and the cooling set point is 23ºC between 9h00 and 17h00 on weekdays. Both heating and cooling are assumed to be delivered convectively (i.e. we are going to delay making a decision on the specific system until we find out the demand profile). There is 0.5 ac/hr infiltration at all hours.

Design questions:

The client wants to know what the typical demands for heating, heating capacity, thermal comfort in the winter and summer, whether it is likely to overheat and if the daylight distribution is ok.

To answer these questions we require a model which represents the general form, composition and use as shown in Figure 1 and described

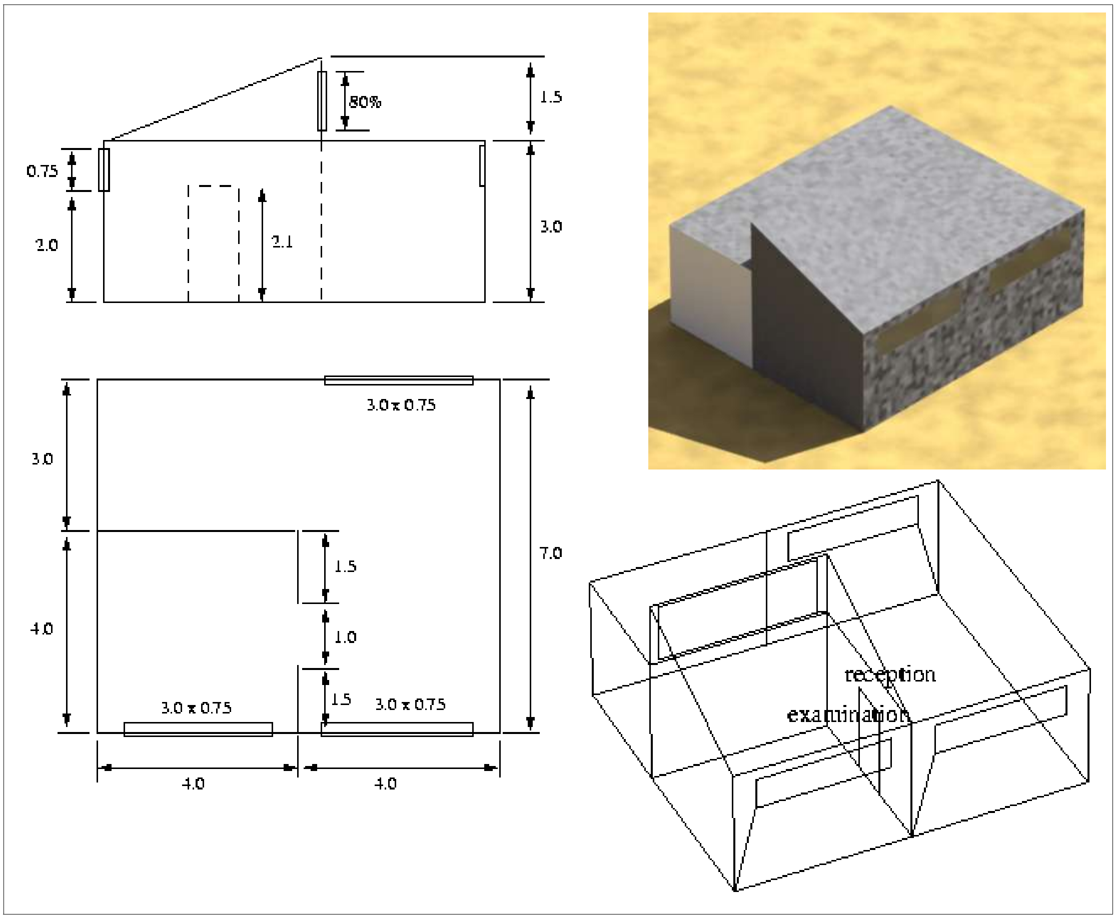


Figure 1: Plan, section and perspective of general practitioner office.

in the client specification. The model need not be particularly detailed and so as long as we maintain the volume of the spaces as well as the orientation, area, massing and general shape of the room surfaces.

What sort of assessments will address the question of typical heating and cooling demands, capacity and comfort? If we weren't thinking tactically we might run an annual simulation and then get bogged down in scanning the predictions for useful information.

A tactical approach will focus first on typical seasonal patterns. A typical week or fortnight in winter and summer has a good chance of answering our questions. If it doesn't we can expand the scope of our assessments. The point is to limit the quantity of information we have to deal so both the model and its performance is easier to understand and the QA burden is reduced.

Value added: The client did not ask for it, but it takes little extra effort to check for typical spring and autumn performance might provide useful feedback to the design team.

Another tactic is to define performance metrics early in the process. We will use some metric to help our understanding and others for reporting to others. ESP-r has a range of interactive performance assessment facilities which we can use, but we need to consider the format of metrics we pass on to others.

The metric for heating and cooling demands is kWhr (integrated) over the week and for capacity the metric is diversified kW (the peak capacity required for this portion of the building). Just to be sure that the pattern of demand is reasonable we will want to graph this. In addition to a table of demands and capacity we might include the graph in our report if it proves of interest.

Resultant temperature is a commonly used comfort metric. A frequency bin of resultant temperatures during the occupied periods would inform the client about the distribution of comfort. For our own use, we also want to check the number of hours over 24ºC and graph the temperatures, we might include these in our report if they prove interesting.

To answer the question about daylighting we can look at daylight factors across a grid in each of the rooms. To build a model that will answer questions of thermal and lighting performance we need to decide how much geometric resolution if required. In the case of daylight factors the level of detail needed for the thermal assessment should suffice. If glare was to be assessed the model would need to include additional visual geometric details. Later on we will consider tactics that anticipate probable future design performance questions.

QA tip: Write down these decisions, we will want to refer back to this as the project progresses to make sure we are working to-the-plan.

Model planning:

Tactically, pre-processing information and sketching the composition of our model will limit the chance of error and make it easier for others to understand what we intend to create, and, after we have made it, to help *check that it is correct*. This rule applies whether we are going to import CAD data or use the in-built CAD functions of ESP-r.

It saves time and removes a major source of error if we convert the important horizontal and vertical dimensions (such as those shown in Figure 1) to model coordinates and include them in our planning sketches. This critical data is then available for QA tasks and we avoid jumping between a keyboard and a calculator while we are defining the model.

Model Coordinates:

The X axis in ESP-r is towards the East and the Y axis is towards the North. Most users find it convenient to keep their model in positive coordinates and to define their model using cardinal orientations and later rotate and transform the model to reflect conditions at the site.

Figure 2 shows critical coordinates (X,Y) derived from Figure 1. To simplify our task let us assume that the origin of the model is at the lower left corner of the examination room. The critical vertical points are 0.0 (ground), 2.0 (window sill), 3.0 (ceiling), 4.5 (top of sloped roof).

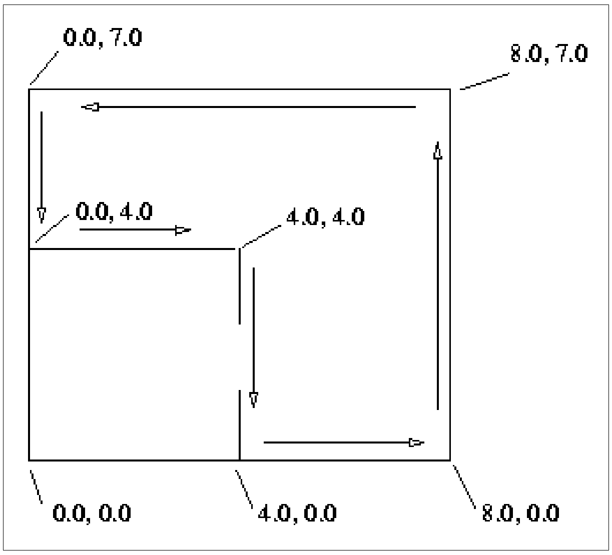


Figure 2: Model coordinates sketch.

How the building is used:

Our next stage in the planning process is to deal with how the building is used (schedules of occupants, lighting, small power). The client specification must be transformed into schedules. The examination room has a simple schedule of occupancy, but the reception has a profile of occupancy. Figure 3 is a graph of the schedules for the reception and Figure 5 for the examination room.

ESP-r represents internal (casual) gains as a schedule which applies to weekdays, Saturdays and Sundays (there is an option to define two other days as the weekend but we will stick to the default definition). You can lump all casual gains together for definition and reporting purposes or use op to three separate types of casual gains. Typically the first type is for occupants, the second is for lights and the third is for small power.

Each of the days has one or more periods associated with each type of casual gains. Periods must not overlap and should cover the entire period of the day (0h00 to 24h00. Each period has a sensible load (W), a latent load (W) as well as the fraction of the sensible load which is radiant and convective.

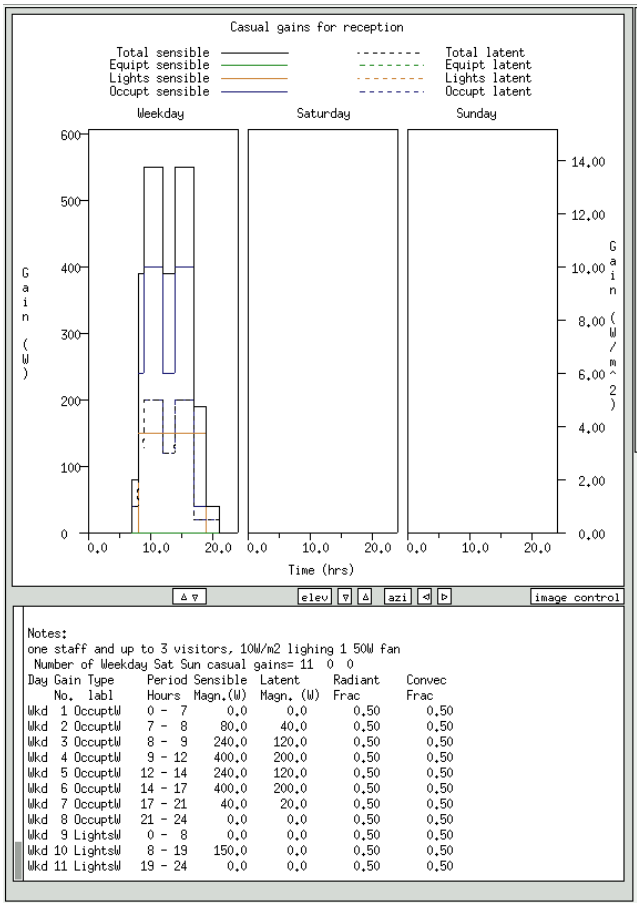


Figure 3: Occupancy profiles for the reception room

For purposes of this exercise we will treat all casual gains as having 50% convective component. In a real project you would use values appropriate to the type of occupant, light or small power device. There are occupants and lights on weekdays in the reception and nothing happens in the reception on weekends. The *notes* field gives a brief description of what is happening in the reception and can be quite important in helping users to decode the numbers within the schedules. For example the note says there are up to three people in the reception and the peak sensible gain is 400W which would be sufficient information if later on it was necessary to increase the occupancy to, say five occupants.

The examination room is also only used on weekdays, but there are fewer people and there is a computer in the room (see Figure 5).

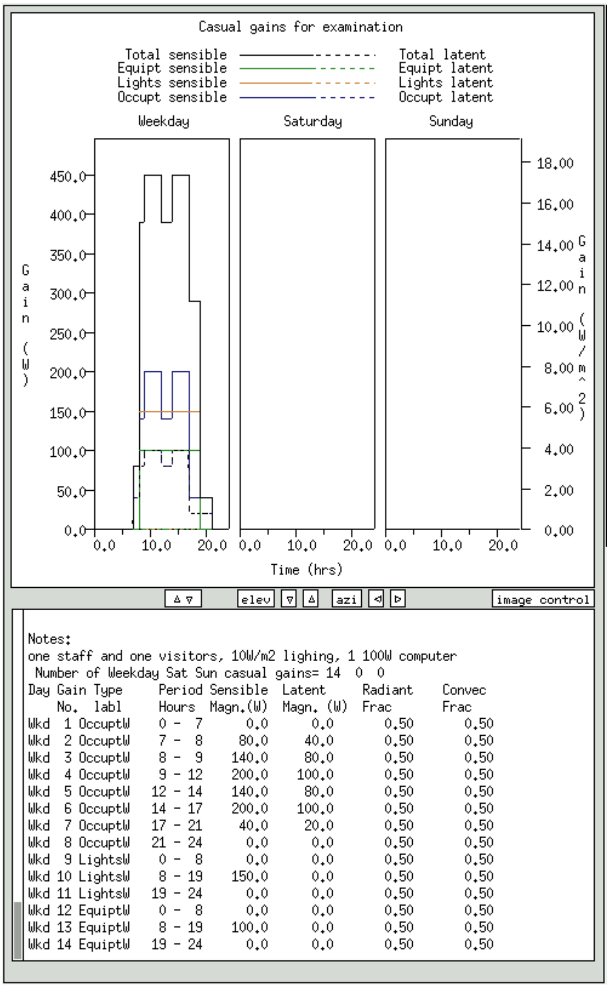


Figure 5: Schedule within the examination room

Environmental controls:

ESP-r has a number of ways of representing environmental controls. At an early design stage we are interested in the pattern of heating and cooling demands over time as well as what would happen if cooling was disabled. For purposes of this exercise an ideal zone control will characterize the response of a convective heating and cooling system to the client's set points. We do not know the capacity, so we will make an initial guess (say 4Kw heating and 4kW cooling) and see how well that matches the demands.

Model composition:

The client has not specified what the building is to be made of. We are going to have to select something typical from an existing database until such time as there is a clearer definition. So one of our initial model building tasks will be to review the current contents of the construction and materials databases.

This completes the planning phase and our next task is to use ESP-r to create a model which is fit for the requirements set out in the planning stage.

Building a model

With planning complete we can take the client's specification and our sketches and notes and begin a new project. Interactions with ESP-r and with the command line will be shown in `typewriter text`.

You should be building your model in a folder that you have control over. To ensure that this is the case, use a command window or open a new command window on your computer issue the following commands:

cd

esp-r

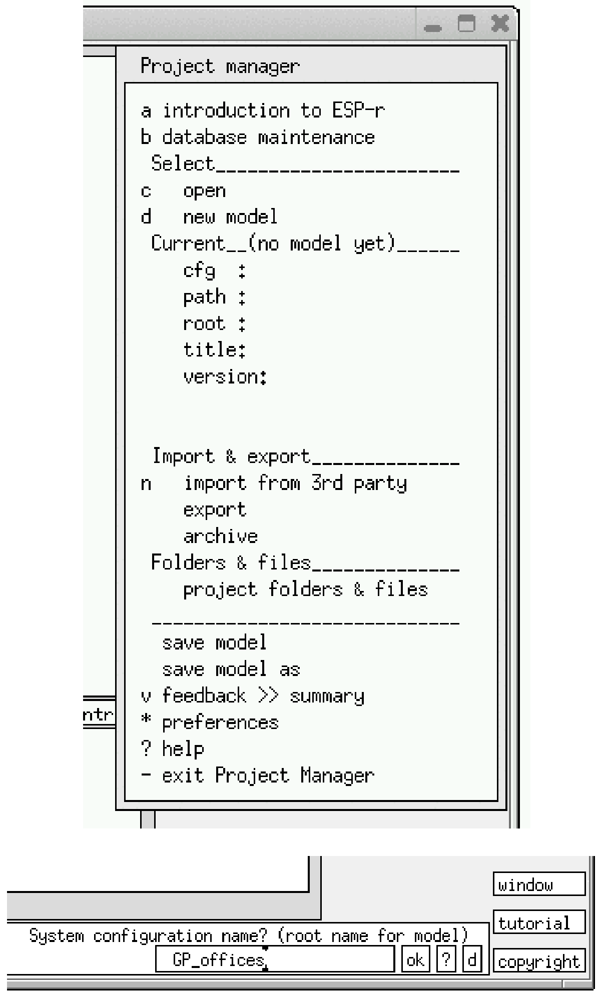


Figure 6: First steps in creating a new model

The first command returns you to your home folder and the second command will start up ESP-r project manager without an existing model.

Figure 6 illustrates the steps we are going to take. Our tasks is to create a new model so select menu option project manager -> new model. A dialog will open at the bottom of the project manager which will ask you for the system configuration name. This is the root name for the model (with no blanks) and for this exercise lets name the model GP_offices.

This root name will be used when setting up the project folders (see Figure 7) which hold the descriptive files and will be used to help name many of the files of the model.

```
Esp-r holds the model in a standard set of folders
and descriptive files.

Based on information you have supplied:

   GP_offices (project folder)
   GP_offices/cfg (system files)
   GP_offices/ctl (control files)
   GP_offices/zones (zone files)
   GP_offices/nets (networks)
   GP_offices/doc (reports and notes)
   GP_offices/temp (odds+ends)
   GP_offices/dbs (project databases)

will be created.
```

Figure 7: Folders to be created

Review of climate patterns and databases

At this point we have registered a new simulation project (the terms *project* and *model* are often used interchangeably in ESP-r). There are a number of tasks that we want to complete before we begin to define the form and composition of the general practitioners office.

- Find a climate file and typical climate periods for our assessments.
- Review construction and materials databases.

Select the menu option project manager -> database maintenance and in the options shown in Figure 8 select the climate option.

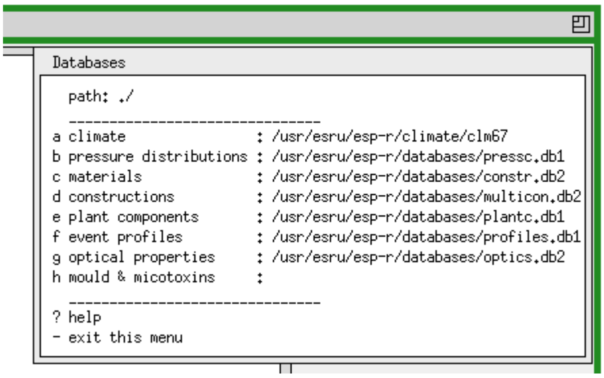


Figure 8: List of ESP-r databases

The next interface (see Figure 9) is common to all of the ESP-r databases. You can work the current file, select another file, create a new (minimal or blank) database, copy a standard database for use in this project.

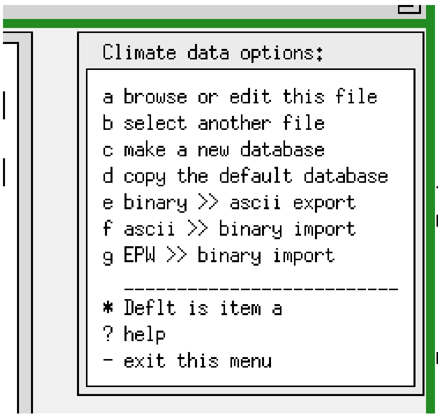


Figure 9: Climate file options

Depending on the type of database you will also be offered conversions between binary and ASCII versions. For climate databases there is also an option to convert an EnergyPlus EPW file to an ESP-r format file. For purposes of this exercise we want to select another file.

Assuming ESP-r was installed correctly, you will now be presented with a list of known climate sets. The sets that come with the standard distribution are shown in Figure 10. You can add other sets, but that is another topic for another time.

For this exercise, select the Birmingham IWEC climate, look at its documentation and then continue the climate (clm) module of ESP-r. *Clm* will be passed the name and location of the selected file. The climate module offers facilities to graph, report and analyze climate data.

Figure 10: Standard distribution climate sets.

There are a number of options under synoptic analysis (Figure 11) which are useful for finding climate patterns with which to test our building. To generate a report such as is shown in Figure 12, first select the climate data you wish to analyze (say ambient dry bulb temperature) and then the type of analysis (maximum & minimum) and then the reporting frequency (each day/week/month). Near the bottom of the options is `find typical weeks`. This facility works as follows:

- the average & total heating and cooling degree days (HDD & CDD) and solar radiation are determined for each season,
- for each week, average HDD & CDD and solar data is found and compared with the seasonal values and the week with the least deviation (using user supplied weighting factors) is re-

ported. For this climate and with the default heating and cooling base temperatures the best-fit weeks start on 27 Feb, 10 April, 19 June, 5 Oct and 4 Dec. Write these dates down and then go review these periods by graphing and/or gathering statistics about them.

- The climate module provides several ways of looking at the data so see which 'view' tells you the most!

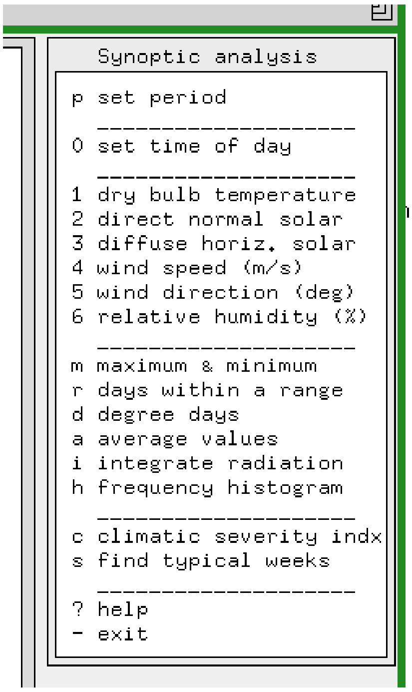


Figure 11: Synoptic analysis options

Dry bulb temp. deg.C

Week	Minimum	Time	Maximum	Time	Mean
Wk of Wed 1 Jan	-15.0	@24h00 Tue 7	6.8	@ 4h00 Wed 1	-5.2
Wk of Wed 8 Jan	-23.9	@ 7h00 Sun 12	2.8	@17h00 Fri 10	-15.3
Wk of Wed 15 Jan	-23.3	@ 1h00 Thu 16	-1.1	@14h00 Mon 20	-9.6
Wk of Wed 22 Jan	-25.0	@ 5h00 Mon 27	-5.0	@ 4h00 Thu 23	-14.4
Wk of Wed 29 Jan	-22.8	@ 8h00 Wed 29	-10.0	@18h00 Thu 30	-15.0
Wk of Wed 5 Feb	-15.8	@ 1h00 Thu 6	-3.6	@16h00 Fri 7	-10.0
Wk of Wed 12 Feb	-16.9	@ 7h00 Mon 17	-1.3	@16h00 Fri 14	-8.1
Wk of Wed 19 Feb	-14.4	@24h00 Tue 25	4.7	@14h00 Thu 20	-3.9
Wk of Wed 26 Feb	-21.1	@ 7h00 Wed 26	5.6	@14h00 Sun 2	-5.5
Wk of Wed 5 Mar	-12.2	@ 5h00 Thu 6	9.4	@10h00 Wed 5	-3.6
Wk of Wed 12 Mar	-10.6	@ 7h00 Sun 16	5.6	@23h00 Fri 14	-3.0
Wk of Wed 19 Mar	-11.7	@ 6h00 Wed 19	11.1	@17h00 Mon 24	-0.4
All period	-25.0	@ 5h00 Mon 27 Jan	11.1	@17h00 Mon 24 Mar	-7.6

Figure 12: Weekly maximum & minimum ambient temperatures

The provision of *different views* of the climate data can assist in locating patterns within the climate data and answering different questions that clients might pose.

Time spent exploring this module can provide critical clues as to patterns within a climate that may be used in the design process.

An example is the graph of temperatures over the year (Figure 13). There are a number of times when it is below freezing, but the graph indicates that these tend to be brief. This might support the use of brief performance assessments for winter heating demands and capacity. It also indicates scope for testing whether a design might be optimised to cope with brief rather than extended cold periods.

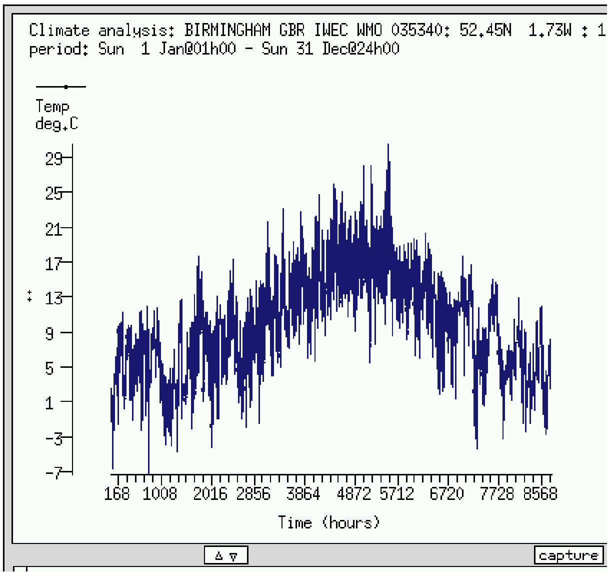


Figure 13: Climate graph (for quick check of cold days)

Another example is Figure 14 where the psychrometrics of the outside air have been plotted over the whole year for the same location.

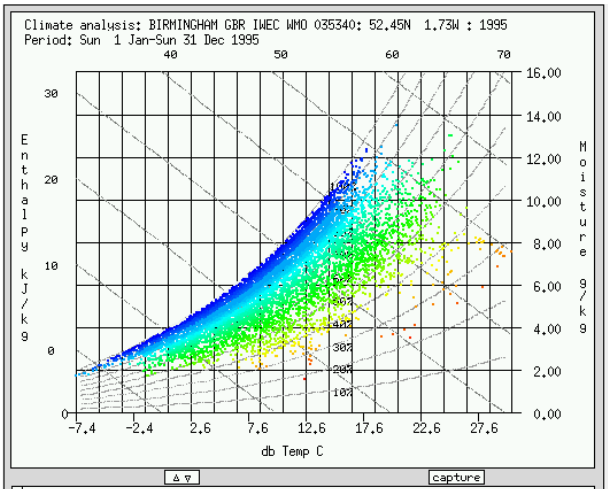


Figure 14: Psychrometrics over a year.

Most companies who regularly deploy simulation will have evolved procedures for selecting climate data for specific design assessments. The acquisition of climate data is covered in a later chapter.

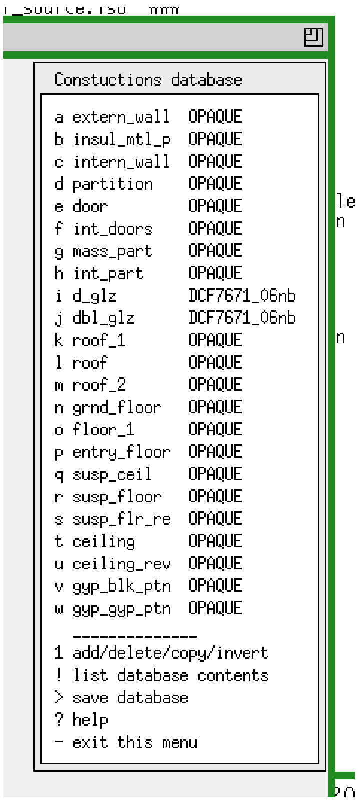


Figure 15: List of known constructions

Locating constructions for our model

Our next task is to do a quick review of available constructions so that we will be able to attribute our model as we create it. So, return to `project manager->database maintenance->constructions`, select the current database and note the list of constructions (see Figure 15) and details (see Figure 16)of those you might associate with this new model.

One tactic, if you don' t find what you are looking for, is to make a project copy of one of the standard databases and then add in *place-holder* constructions. A place-holder is a named construction which either does not have a full set of thermophysical properties or uses an approximation. This can be associated with the surfaces in the model and later, when the actual information is available it can be updated and all of the surface which use it will take on the revised properties.

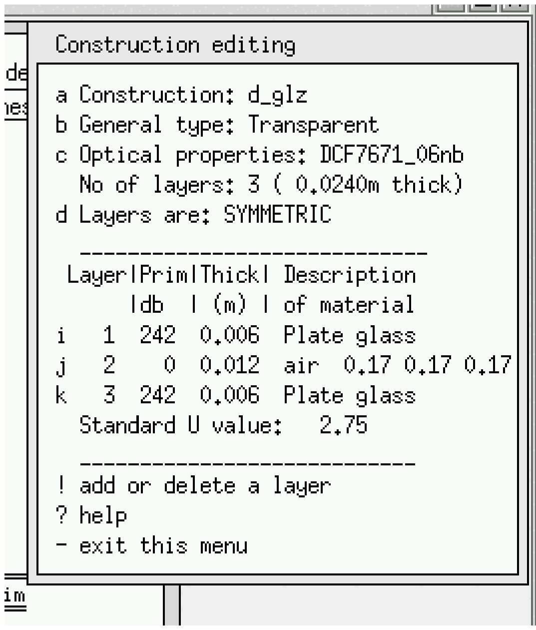


Figure 16: Construction details.

So, add to your project notes the names of the constructions which you wish to associate with walls, floors, ceilings etc. This can save lots of time and reduces a source of error!

Zone composition tactics

Before we begin defining our zones lets review tactics. For purposes of this exercise we are going to use the in-built CAD facilities. We are going to use these facilities tactically so as to minimize the number of keystrokes and avoid errors. Later on you can adapt the techniques for even greater efficiency. Here are the tactics:

- plan for maximum re-use of existing information
- use information on your planning sketches and notes
- take opportunities to embed documentation in the model
- give entities meaningful names and use attribution early-on in the processing
- learn the tool well enough to use in-built facilities to copy, edit and transform

The order we define a model can allow us to build new zones from portions of adjacent zones. In this exercise if we begin with the reception we can make use of this information when creating the examination room.

If we take the information from our planning sketches rather than improvising or using a calculator, we will make fewer errors, we will be less likely to loose track of where we are when the phone rings and we will be less likely to find we need two more surfaces than the interface allows.

ESP-r has numerous places where you can document your assumptions. Of course you would never want to use such facilities because you never loose scraps of paper and you always remember the assumptions you made about that model four months ago and your clients solicitor will never ask you to prove you followed procedures or used the correct values for that computer lab.

A surface in a simulation model is not just a polygon, it has a name, it is made of something, it has specific boundary conditions and it must conform to the (virtual) laws of physics. QA gets a lot easier if something that looks like a door in a wireframe image, is named *door* and is composed of a door type of construction. The tactic is for these attributes to reinforce each other so it is easy to notice if we get something wrong and to be able to easily focus on the correct portion of our model.

Defining the reception

To define the reception select `project manager->browse/edit/simulate->composition->geometry & attributions.` Since there are no existing zones you will be asked whether you want to 'load existing' or 'create via dimensional input'. Choose the latter and you will be asked to name the zone and in this case the name *reception* is a good choice. Next you will be asked to describe this zone so lets paraphrase of the clients definition “reception and weighting room for GP office with varying occupancy”.

The next dialog asks whether we want to start with an 'extruded rectangle', 'a floor plan extrusion', a 'polyhedra' or 'click on bitmap'. For purposes of this exercise select floor plan extrusion and gather your sketch which corresponds to Figure 10. Actually, there is one more dimension not shown in Figure 2. At X=4.0 and Y=7.0 there is a break in the wall. To the West of this point the wall is a partition which faces another portion of the building which we are not going to bother to define. To the East of this point the wall faces the outside. We need to define two walls along the north side of the reception and so the total number of walls that we are going to extrude from the floor plan is 7. The arrows shown in Figure 10 indicate the ordering of the walls. Remember this rule: when extruding a floor plan proceed anticlockwise. In this case we will start with 0.0,4.0 and then 4.0,4.0 etc. around to 0.0,7.0 (we need not repeat the initial point).

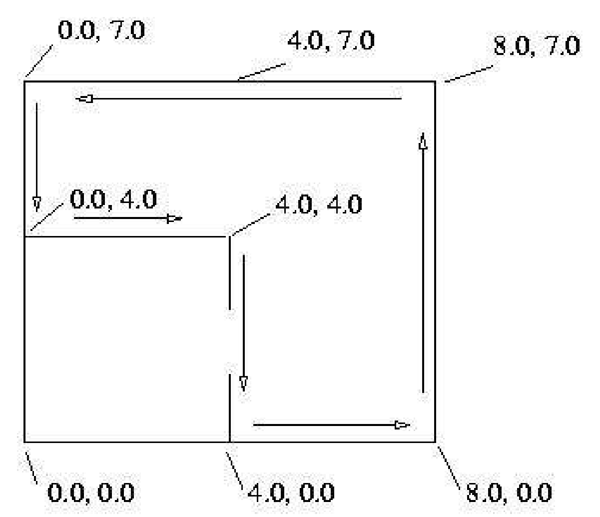


Figure 17: Sketch of layout with critical X Y points marked.

When the walls coordinates have been defined you have the option to accept them. If you are *in any way worried* about having made a mistake, say no and you will have a chance to check and edit the data. Once you accept the points the project manager display will update to what is shown in Figure 19 with a listing of the vertex associations in Figure 18 are several things to notice about the graphic feedback and the command options.

- Items in the menu which start with a character can be selected and those that start with a blank in the first column are reporting derived values (which will be updated as you modify the model).
- Under the graphic feedback area are a number of buttons for altering the viewpoint, altering the size of the graphic feedback area and controlling the image. The latter allows you to turn on and off names and vertices and the site origin. Spend a few moments exploring this.
- The text feedback (not shown in Figure 11) includes a synopsis of the geometry of the zone and a list of the attributes and derived values for each of the surfaces. This report is designed to complement the wireframe image and you will notice that the word UNKNOWN shows up many times so there is still some work to be done!
- You will notice that the surfaces have been given names like Surf-1 ... Surf-9. This is unambiguous without being at all helpful.

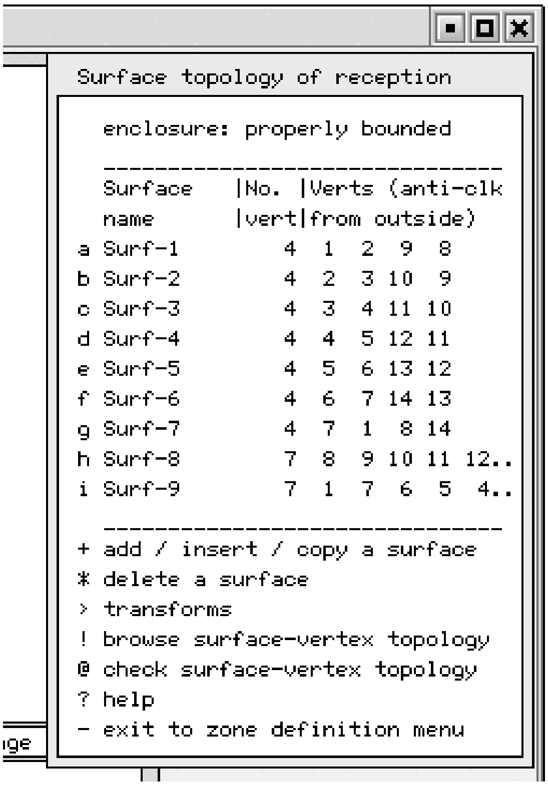


Figure 18: List of vertex-edges for each surface.

Inserting doors and windows

In ESP-r, windows and doors should be included as surfaces in a model if they are thermally important. A tactical approach also includes windows and doors if they *make it easier for others* to understand the model. The door probably falls into the latter category – we save time because we will not have to explain why we have omitted it.

Our next tasks is to insert a window into `Surf-3` and `Surf-5` and a door into `Surf-2`. The interface provides a way to make a rectangular 'hole' in an existing surface and place a new sur-

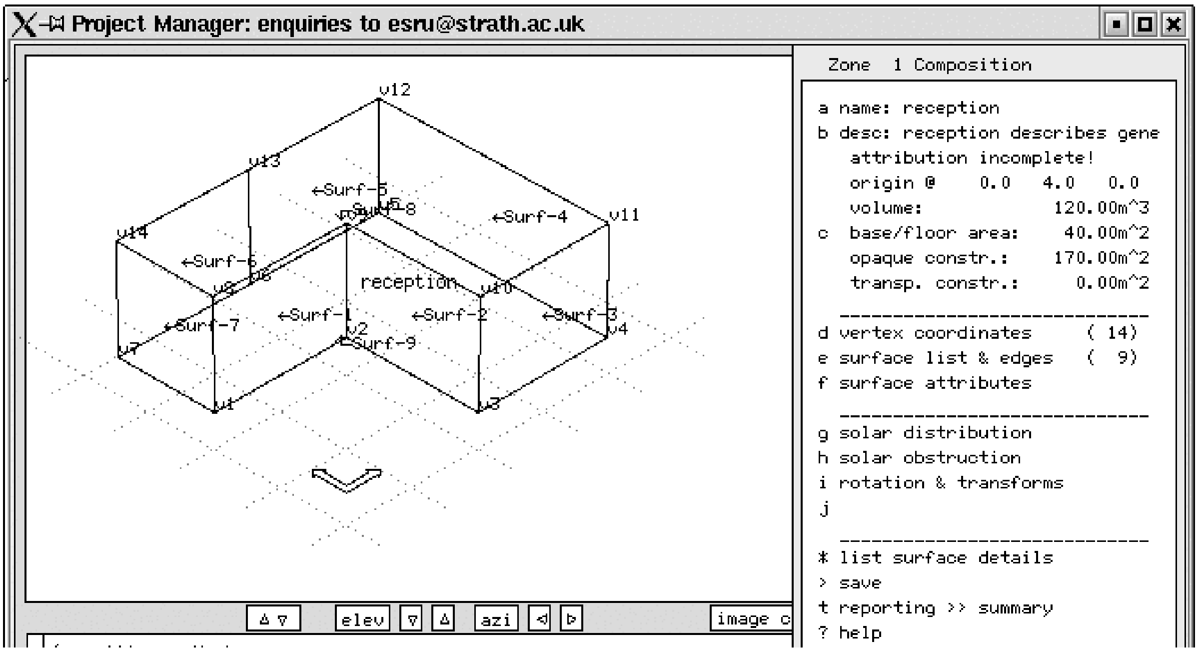


Figure 19: Interface after initial definition of floor plan points.

face into that hole. The interface also provides an option to wrap an existing surface around a door. In both cases you will be asked to provide an offset and a width and height of the rectangle to be inserted. The offset is from the lower left corner of the existing surface (looking from the outside).

According to Figure 1, the window in `Surf-3` starts 2.0m above the floor and is centered in the wall. So the offset X is 0.5m and the offset Z is 2.0m and the window size is 3.0m x 0.75m. The same offsets and size apply to the window to be inserted into `Surf-5`. The door is 1.5m from the edge of `Surf-2` and is 1.0m wide. No height is given in the specification so lets assume 2.1m.

Beginning with the window in Surf-3, select `surface list and edges->add/insert/copy a surface` and then choose `inserted into a surface->within surface`. Provide the dimensions from the paragraph above and the proposed location of the window will be shown on the wireframe. If it is not ok you can re-enter the data, otherwise a new surface will be added and the existing Surf-3 which started out with 4 edges becomes a 10 edge surface which wraps around the new surface. You will be asked to name the new surface (`south_glz` or something similar) and pick a construction for it (there is an entry `dbl_glz` in the constructions database).

Repeat this process for the window in `Surf-5`. Remember that you can rotate the wireframe viewpoint to get a better view of your work. For the door, use the `inserted into a surface->at base` option. When you have done this the display should look like Figure 20.

Completing attribution

Tactically, we would prefer that others find it easy to understand our models and if we can also reduce errors and speed QA tasks we have a winning combination. One successful pattern of model attribution is to begin with the names of the surfaces so that subsequent selection tasks and reports benefit. Of course if you want to do it the hard way...

In the `surface attributes` menu there is an `*attribute many` option. First attribute names (see Figure 22) and then attribute constructions (use the list of useful constructions you wrote down when you were reviewing the databases). Where several surfaces have the same construction

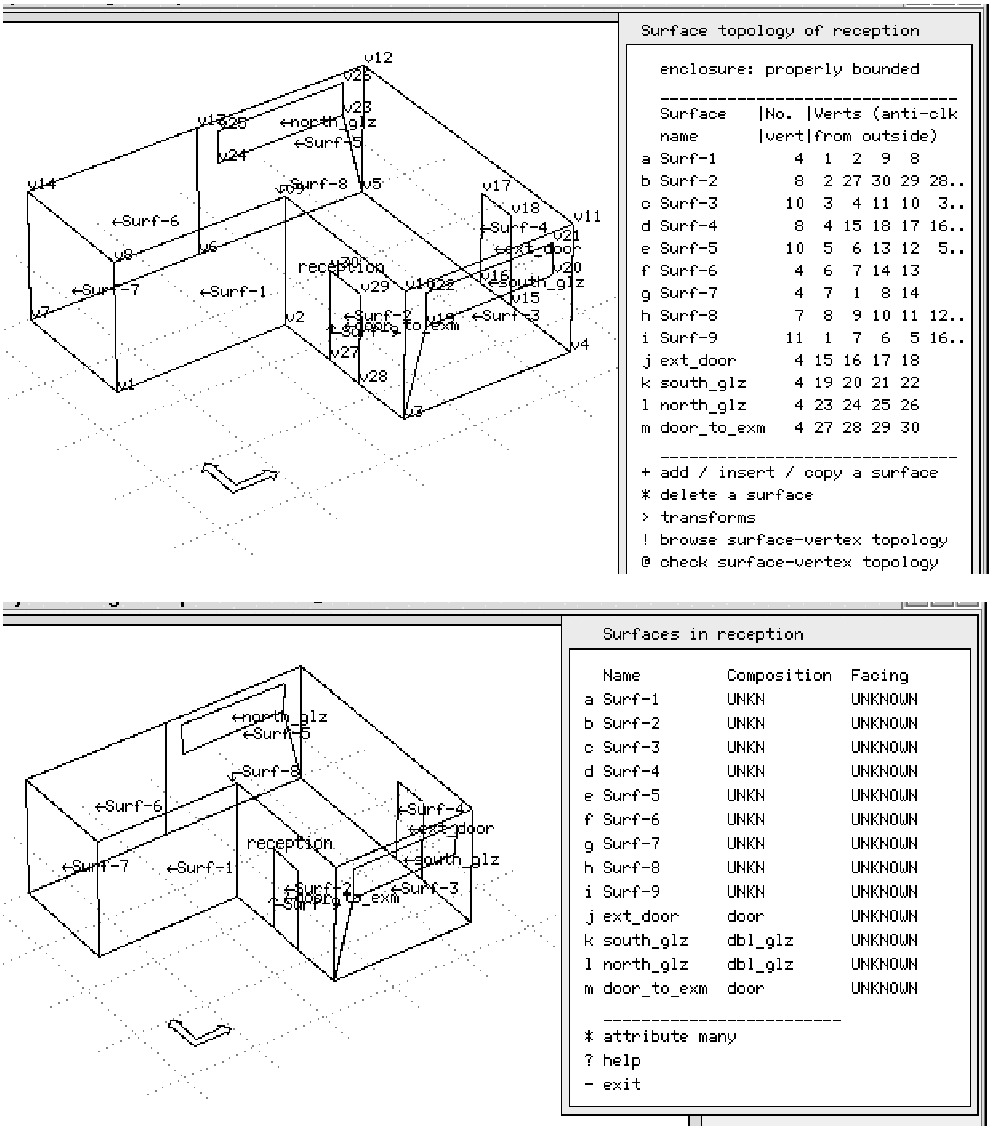


Figure 20: Reception after the addition of windows and doors.

use the `*attribute many` option. Otherwise select the surface you wish to attribute as in Figure 21. All of the attributes of the surface are reported on and are available for editing.

Skip boundary conditions for the moment – there is an automatic process to assign this attribute later in the process.

The point of careful attribution is that the combination of the graphic image and surface attribution ensures that the model is correct. If something called door is composed of concrete and you see it as a horizontal in the image someone is likely to notice!

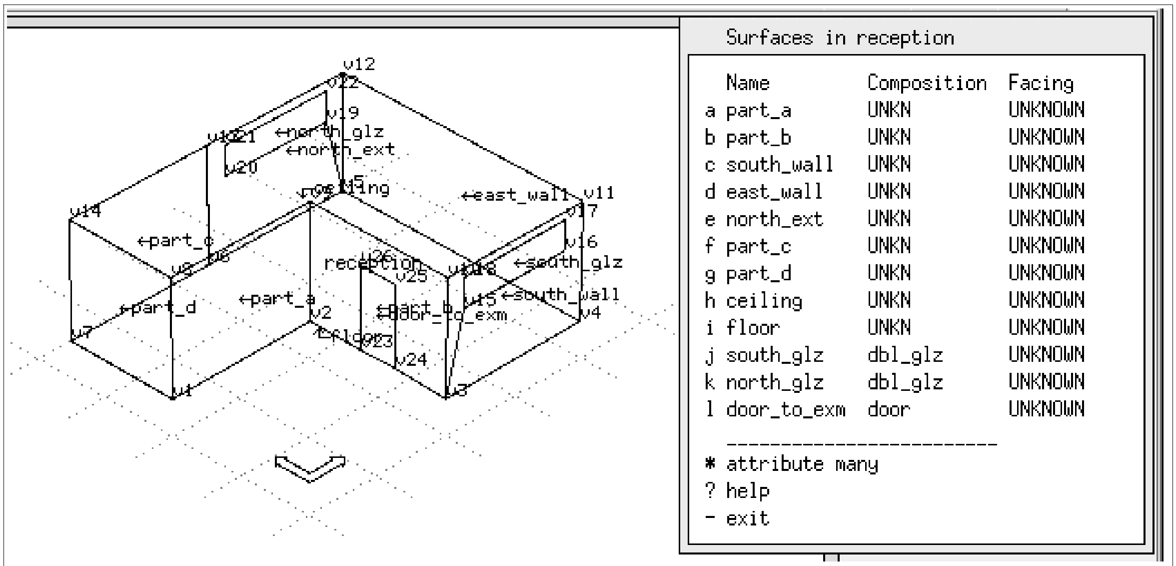


Figure 22: After surfaces have been named.

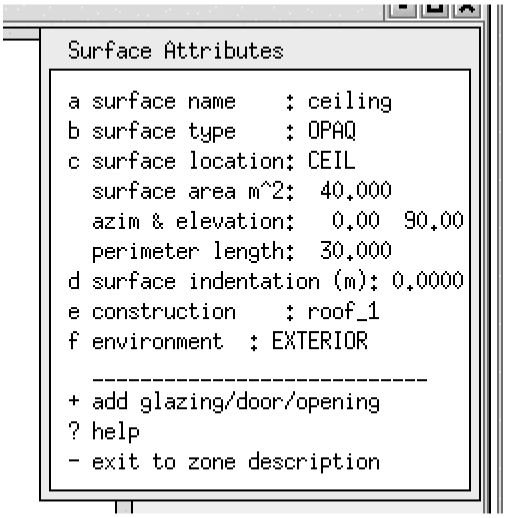


Figure 21: All the attributes of a surface.

Adding the examination room

The examination room is rectangular in plan, but has a sloped roof and it shares partitions with the reception. There are a number of approaches to creating this zone:

- start with a simple shape and evolve it
- start with the coordinates of a complex shape and link them together to form the zone

For purposes of this exercise we are going to start with a simple shape (a box) and transform it into the final shape. The transformation is going to involve changing two coordinates to elevate the roof, deleting a couple of surfaces and then copying surfaces from the reception. For purposes of this exercise it is an efficient approach and it will give you a chance to work with a range of transformation facilities. Referring back to Figure 2 the initial box has an origin of 0.0, 0.0, 0.0 and a width of 4m (East along the X axis) and depth of 4m (North along the Y axis) and is 3m high.

So return to `project manager->browse/edit/simulate->composition->geometry & attributions.` Select the option to add a zone. Again you will be asked for a name (say examination) and a description (say something like *examination room with GP and one patient during office hours*). You will be offered a choice of initial form and this time choose `extruded rectangle`. You will be asked for the origin (0.0 0.0 0.0) and dimensions (4.0 4.0 3.0) and the result is shown in Figure 23

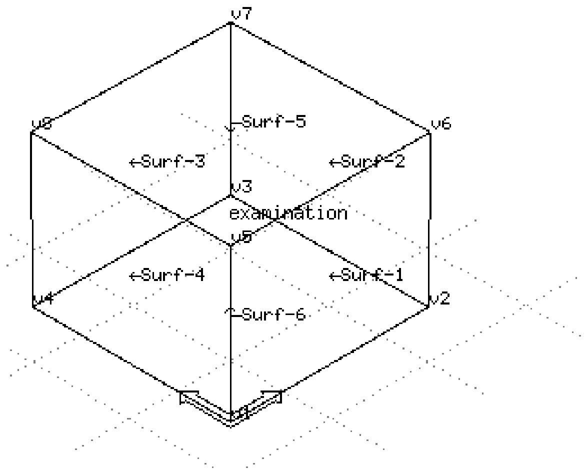
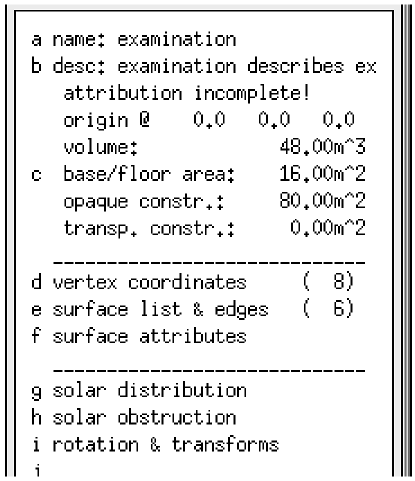


Figure 23: Initial box shape of examination room.



To make the roof sloped we need to alter the Z value of vertex 7 and 8 to 4.5m. To do this select the `vertex coordinates` menu option and pick each vertex in turn and change the Z value. As you do this the wireframe image will be updated (see Figure 24).

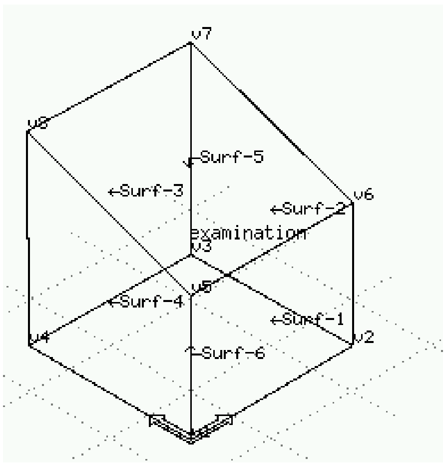


Figure 24: After editing vertices.

ESP-r has a rule: every surface has one boundary condition. So what is the boundary condition for surf-2 and surf-3 in and how does this compare to the initial sketch in Figure 1? The examination room has partitions adjacent to the reception zone as well as external walls and clearstory glazing. We make this transform by first deleting both `surf-2` and `surf-3`. The place to do this is the `surface list & edges->add/delete/copy` option. After you delete these surfaces the wireframe image will look like Figure 25.

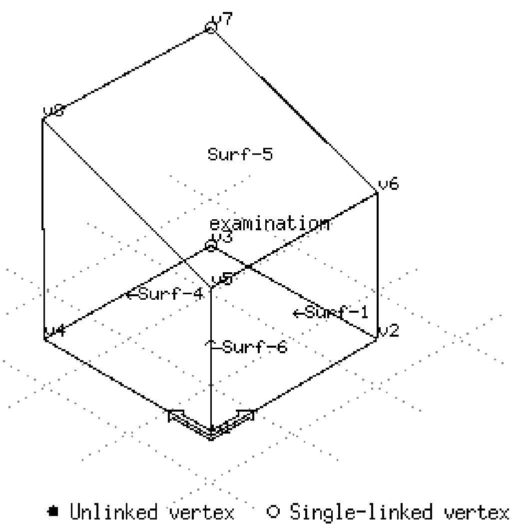


Figure 25: After deleting surfaces 2 and 3.

Our next task is to add surfaces to the zone by copying the relevant surfaces from the reception zone. Figure 26 shows the available options. We will be using several of these as we progress, first select `copy surface from another zone`. A list of known zones is presented (select reception) and then select surfaces `part_a` `part_b` and `door_to_exam`.

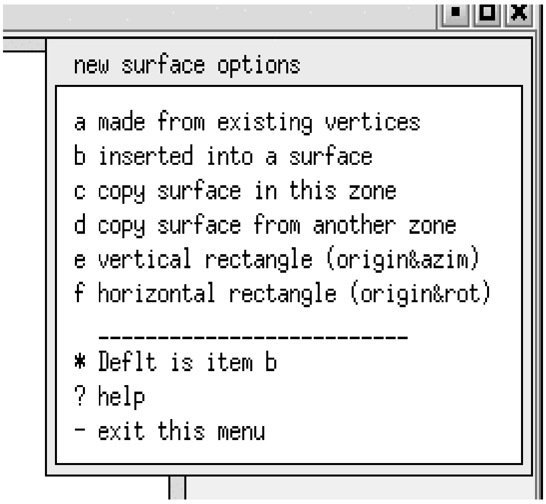


Figure 26: copy options.

You are then presented with a set of transform options for these copied surfaces (see Figure 28). These options allow you to re-use existing surfaces in many ways without having to get out a calculator. There is a rule in ESP-r that

the order the edges of a surface are defined in tells ESP-r which is the outer face of the surface.

For example, part_a in reception had an azimuth of 180º. We need to reverse this and we select the `invert` option. You will be asked to confirm this choice for the other two surfaces that you copied. You will also be asked if it is ok to update the edges of some of the existing surfaces to take account of the new vertices that have been included (say yes).

After copying the surfaces your model should look like Figure 27.

Our next task is to fill in the upper external portion of examination. We already have most of the information we need. One of the surface addition options is `from existing vertices`. When we select this we get a dialog box with a `via mouse` option as in Figure 29. We could type in the vertices for the triangular shaped surface on the East side of examination. Another ESP-r rule is:

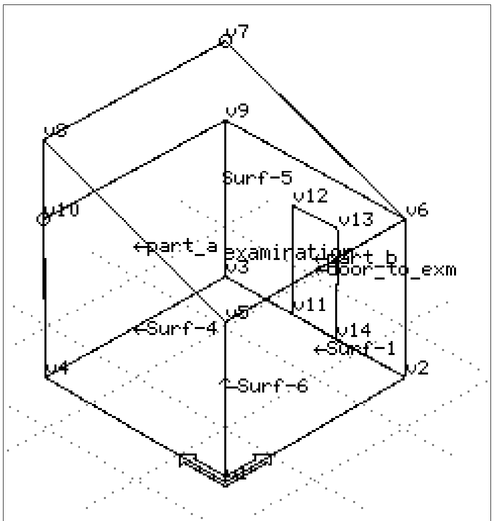


Figure 27: Examinations room after partitions and door have been copied.

If you see the outside face of a surface in the wireframe define the edges anticlockwise *from the lower left corner. If you see the inside face of the surface in the wireframe then define the edges clockwise.*

From this rule we would either type in 6 9 7 or we would click on the via mouse button and then click over each of these vertices in the same order and then type the character 'e' to end the process (you are given an option to further edit these points just in case you made a mistake.

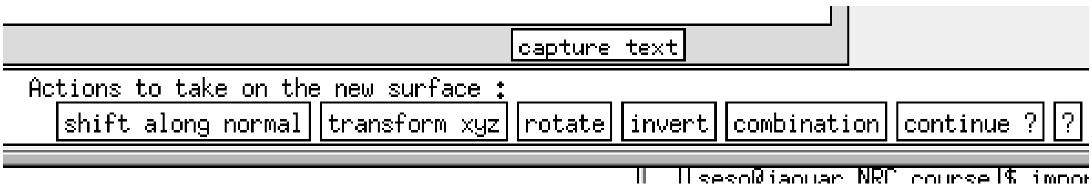


Figure 28: Transform options for copied surfaces.

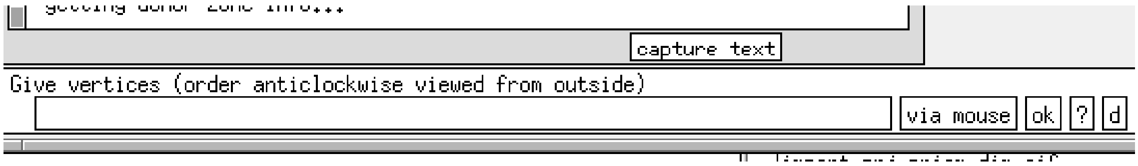


Figure 29: Option to edit vertices or use mouse clicks.

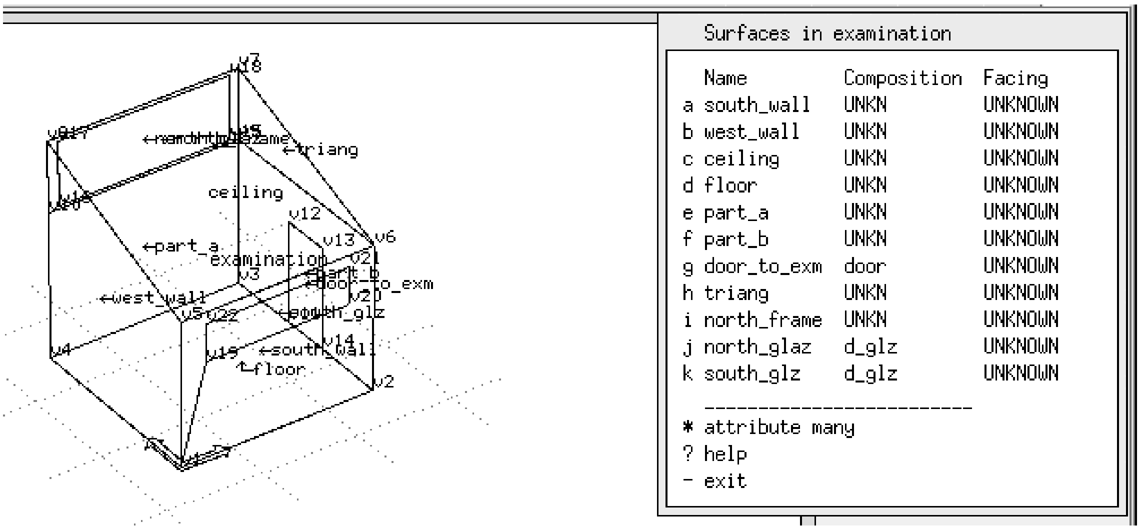


Figure 30: Examination room (mostly complete).

Do the same for the wall on the upper North face. In the wireframe we see the inside face so the vertices are 9 10 8 7. Actually this will become the frame around the clearstory window.

Our final task is to insert the clearstory glazing. Select the `inserted into another surface->as percentage` option and give 80%. This will centre the glazing in the surface and is a quick approach when the exact position of the glazing is not an issue. You should now have something like Figure 30 after you have named the surfaces. Follow a similar procedure to complete the attribution of the composition of the surfaces

Model topology

Having completed the form of the zones there remains the task of defining the boundary conditions which apply to each surface in the model. You were told not to bother with this as you were defining the surfaces because there was an automated process for this and our next task is to use this. Sometimes delaying attribution is a really good tactic! Go to `zones definition->connections & anchors->topology tool` (see Figure 31).

The topology tool (see upper part of Figure 32) is a module of ESP-r which scans the polygons of a model looking for surfaces in various zones which are close matches in terms of shape and position and makes inferences from this to complete the boundary condition attribute of each surface. You control the tolerance and the extent of the search parameters and if the tool is unsure of what to do it will pause and ask for confirmation (lower part of Figure 32).

One by-product of using the topology tool is that it checks every surface in your model in sequence so it makes a great way to *review* your model. Imagine that the client on this project asked you to extend the model...if you periodically invoked the topology tool (say after adding two zones) you will have a chance to review the model at the same time it is searching for matches to the new surfaces you have added.

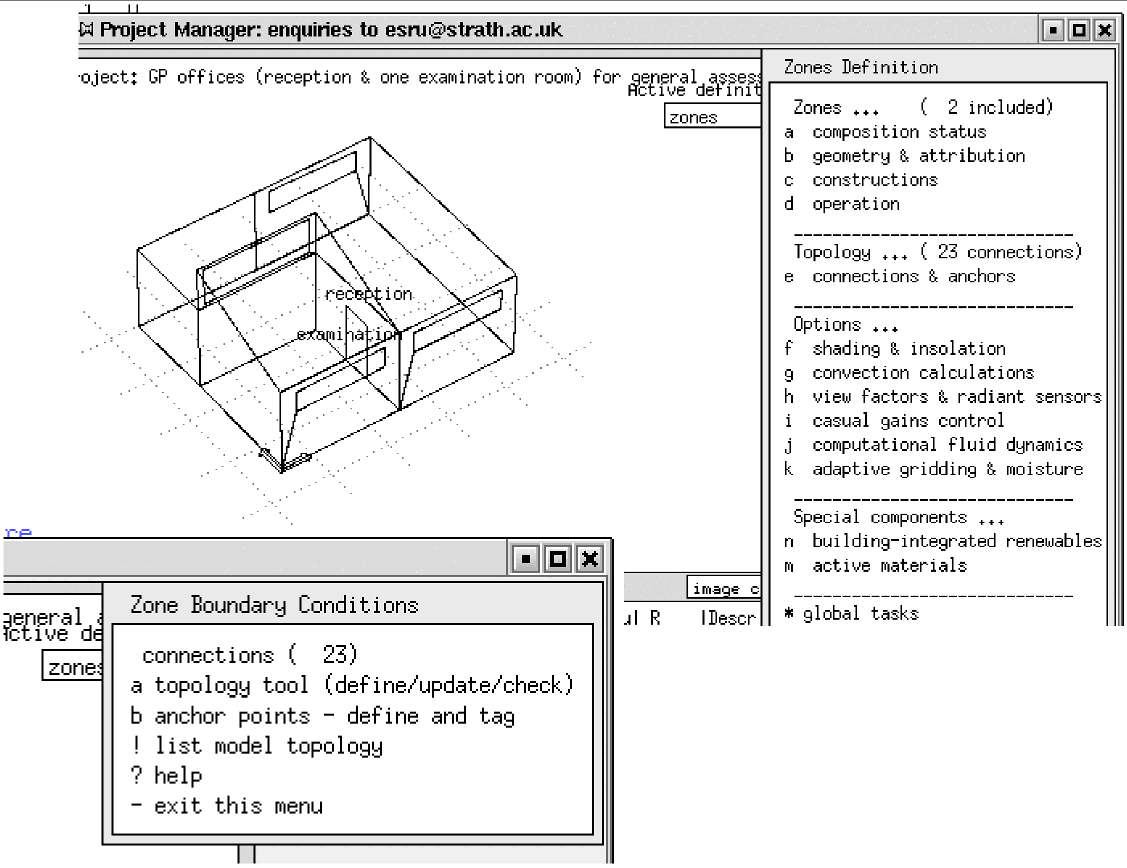


Figure 31: Topology options in the project manager

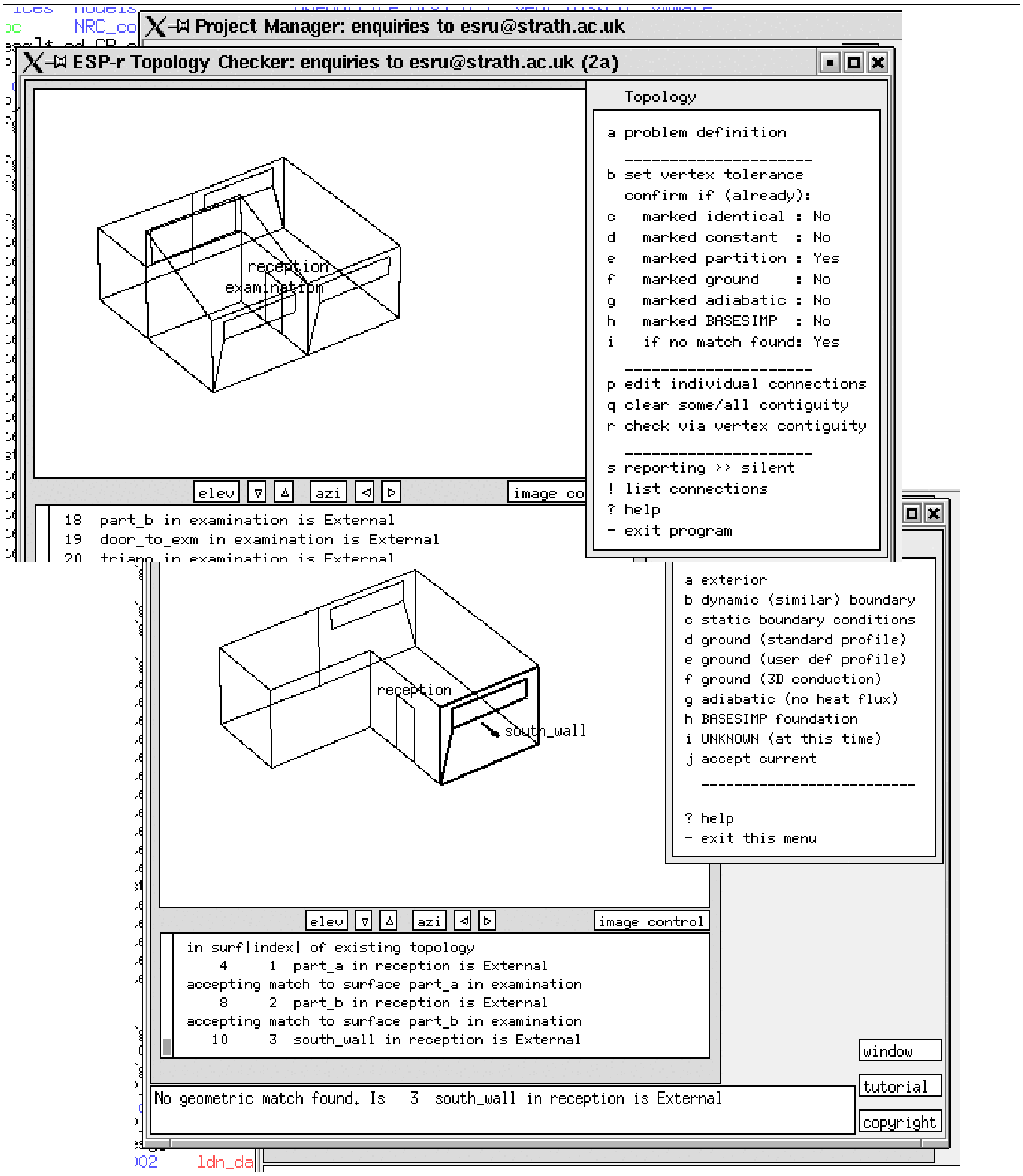


Figure 32: Topology checking main interface and confirmation options.

Geometry revisited

ESP-r offers several options for geometric input: creating rectangular bodies, extruding floor plans, working with polygons, clicking on points on a grid, clicking on points on a bitmap image (e.g. site plan, building plan or elevation) or importing CAD drawings. The previous section dealt with rectangular bodies, extruded floor plans and polygon enclosures. This section focuses on clicking on points on a grid with the goal of creating the same model as the first exercise.

The planning stage is essentially the same:

- review the available information (see Figure 1 and Figure 10)
- establish the level of detail required
- sketch the model (use your previous sketch)
- identify critical dimensions and/or points on the sketch
- decide on the sequence of zone and surface creation, ensuring maximum re-use of information as well as limiting the risk of mis-aligned points

Use the Project Manager to review the model from the first exercise and find your notes from the previous exercise. The overall dimensions of the model are 8m (east-west) and 7m (north-south) in Figure 10 and corners fall on a 1m grid. The exemption is the windows and doors – but as these will be added later. For this exercise use a 0.5m grid for generating the zones.

The identification of critical dimensions, perhaps by marking on an overlay of your initial sketch is a key step. You will be working on an open grid and shifting your attention between the grid on the screen and your sketch. A useful technique is to mark your progress on the sketch.

In this exercise you will extrude both zones in sequence and then use the normal geometric manipulation facilities to make the examination roof sloped and add the windows and doors into each zone. If you work to 'your' plan you can create a sequence of zones (or even a whole model) in one session. A skilled user might expect an average rate of one surface every five seconds. This exercise is intended to help you acquire the skills needed to use the click-on-grid facility and to limit your risk of 'loosing the plot'.

To the keyboard then...

As with the earlier exercise, begin a new project by exiting any open versions of `esp-r`. Returning to your home folder or to the folder where you keep your models. The steps are illustrated in the following Figures. In a command window type in `esp-r`

To create a new model following the same process as you initially used:

- select `Project Manager -> new with gp_grid` as the root name.
- Accept the folders for this new model
- fill in the high level description of the project (the seconds you take with documentation always saves time and confusion later)

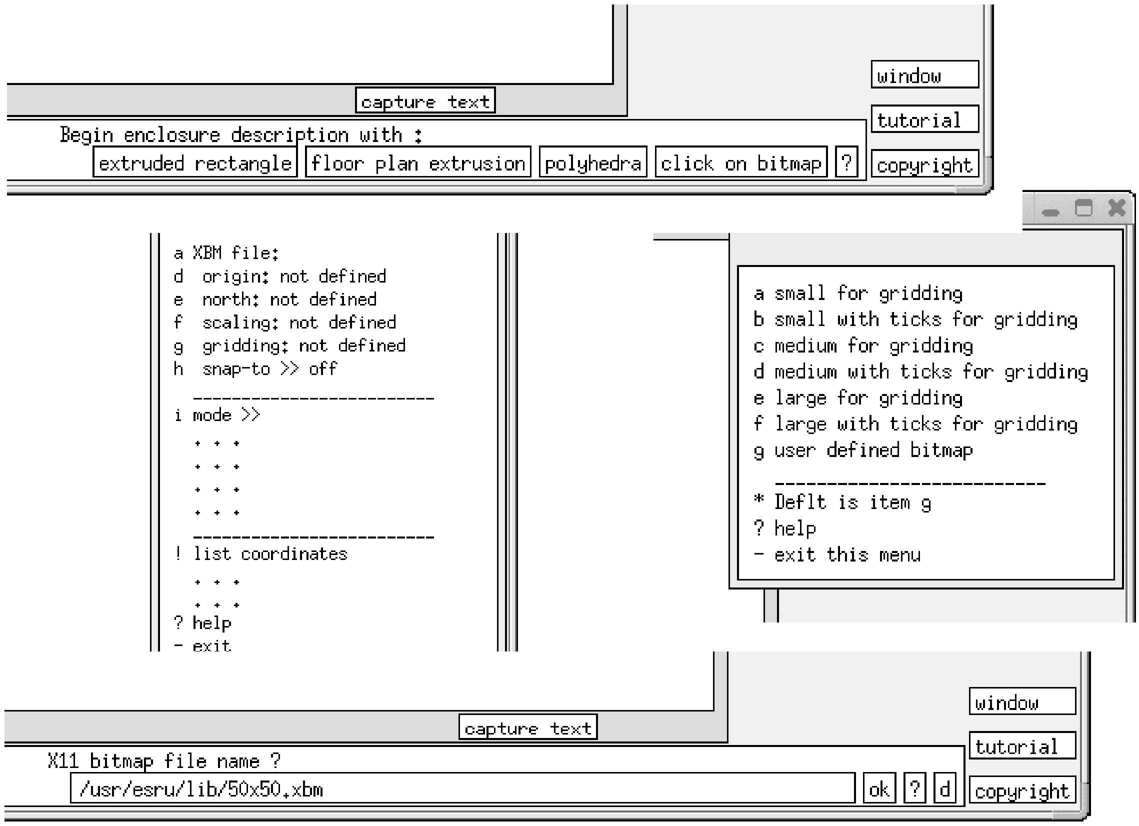
fill in the site data (Birmingham is 52.5 N and 1.7W).

After the site details have been entered select `browse/edit/simulate -> composition-> geometry & attribution`.

Select `dimensional input`. Whether you are using the grid facility for one or twenty zones, you will be asked for the name of the first zone to be created as well as a brief description.

Name the zone **reception** and then provide a phrase of documentation (just because you are using a different coordinate input method this is no excuse to scrimp on model documentation!

Before using your keyboard and mouse have a read of the next pages and figures. There are several steps involved and it takes a few iterations before this facility can be reliably used.



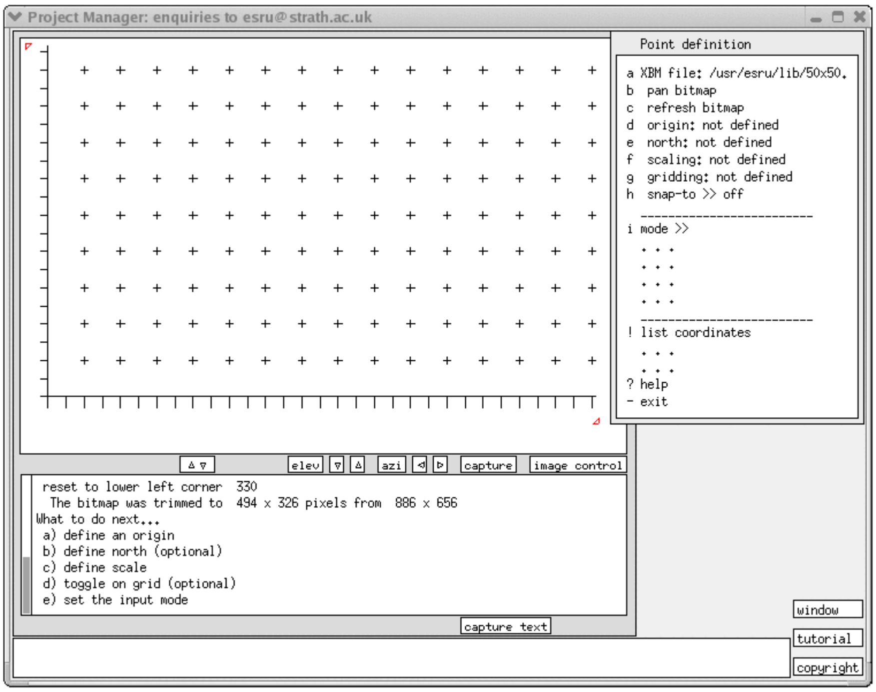


Figure 33: Opening the click-on menu and specifying the XBM file (from list).

Lets start clicking...

To use the click on grid approach to geometry definition choose the `click on bitmap` option. This opens up an initial (blank) command window as shown in Figure 33 which allows you to select one of several pre-defined grids or to supply your own bitmap (scanned from a document or created from a CAD tool).

Before selecting the grid file, adjust the size of the graphic feedback area (use the up and down arrows on the horizontal bar between the graphic feedback and text feedback areas. You might also use the window manager to resize the Project Manager so that you have plenty of room to work. This will prevent you having to 'pan-around' the grid as you work.

For this exercise select the `medium with tick for gridding` option and accept the suggested file name in the dialog box.

The initial grid requires further information in order for you to use it as a basis for creating new zones:

- identify the origin (X=0.0, Y=0.0) typically slightly in from the lower left corner
- define the scale of the grid by drawing a line of a know length (see Figure 37).

If you plan to define zones which extend into the negative X or Y dimension you would adjust the position of the origin to reflect this. Note that you can pan to the right and/or upwards as necessary but you cannot pan any farther left or down after you setup the initial origin. For this exercise, place the origin as in Figure 4 (i.e. Directly over one of the tick marks).

A tick mark could represent 500mm or 2m depending on how extensive the model needs to be. For the current exercise draw a line that is 10 tick marks long and give the length as 10.0. Now that the scale is defined the 'real' grid can be overlaid by selecting the `gridding` option (choose 0.5m) and then the `snap-to` option (Figure 36).

The `mode >>` menu option (Figure 34) lists a number of choices for entering data points. The first two options are useful for topographic/site

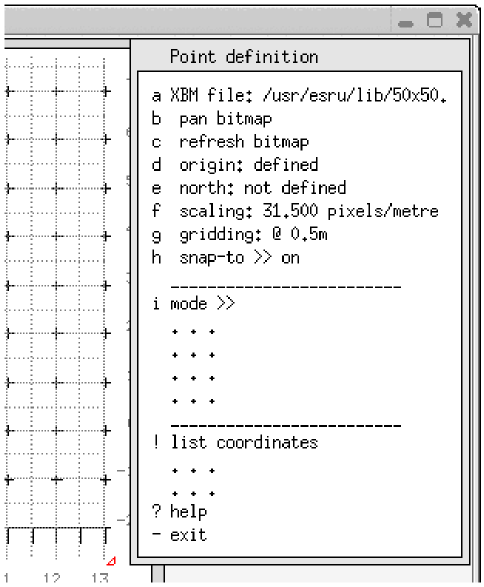


Figure 36: Set gridding and snap-to options.

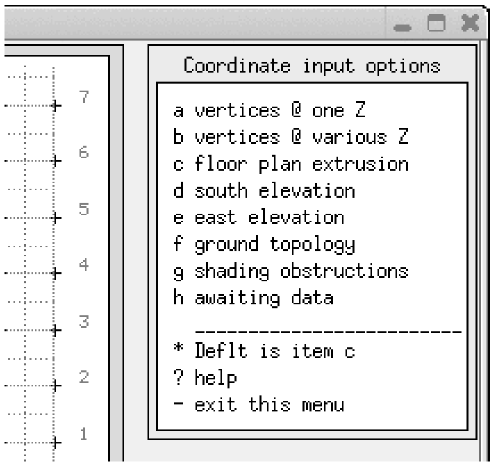


Figure 34: Input modes (options).

Figure 35: Control options during point selection.

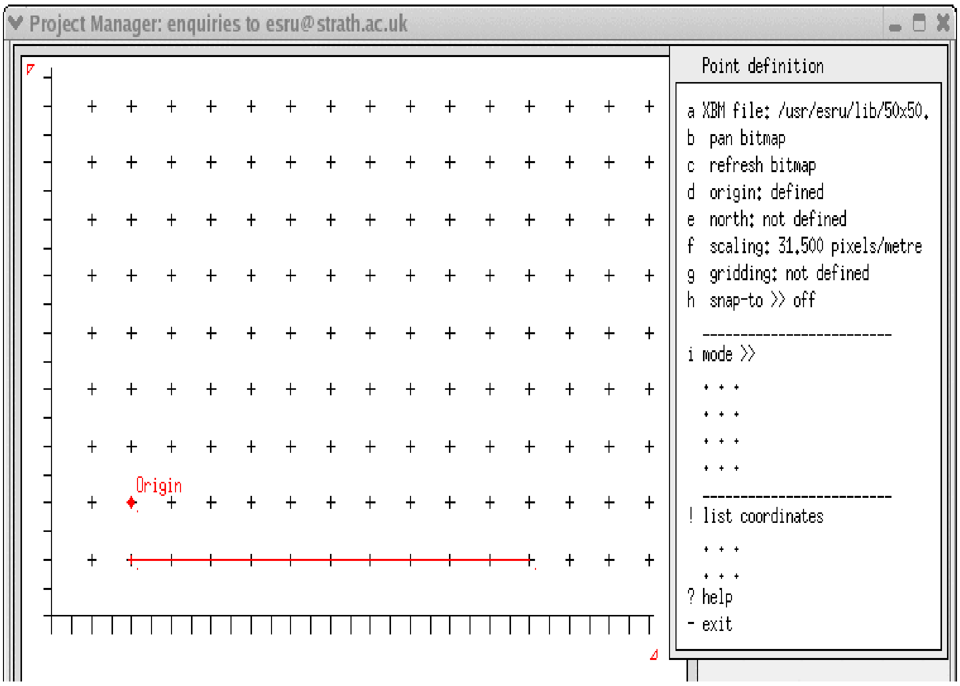


Figure 37: Initial tick marks and scaling options.

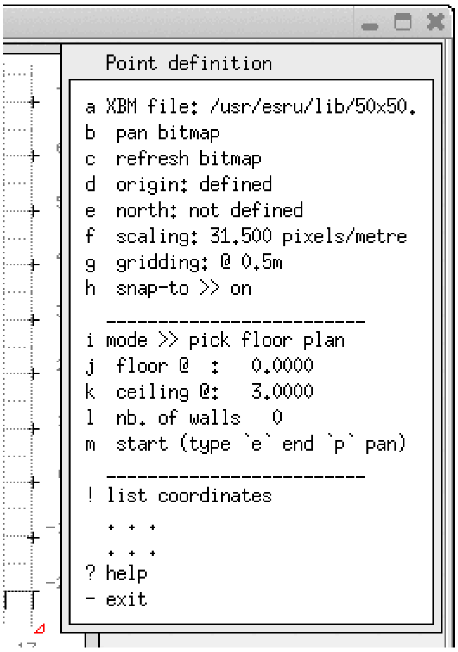


Figure 38: Options within floor plan mode.

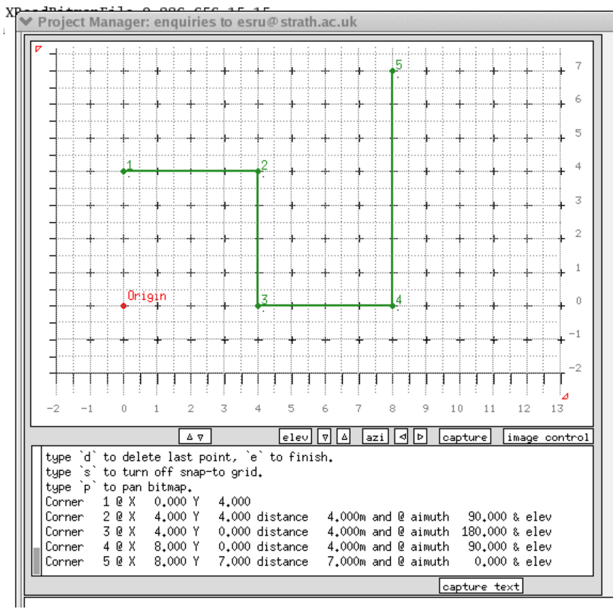


Figure 39: Partially defined initial zone.

data. The floor `plan extrusion` option is equivalent to the floor plan extrusion used in the initial exercise to create the reception zone. However, this time rather than typing in coordinates,

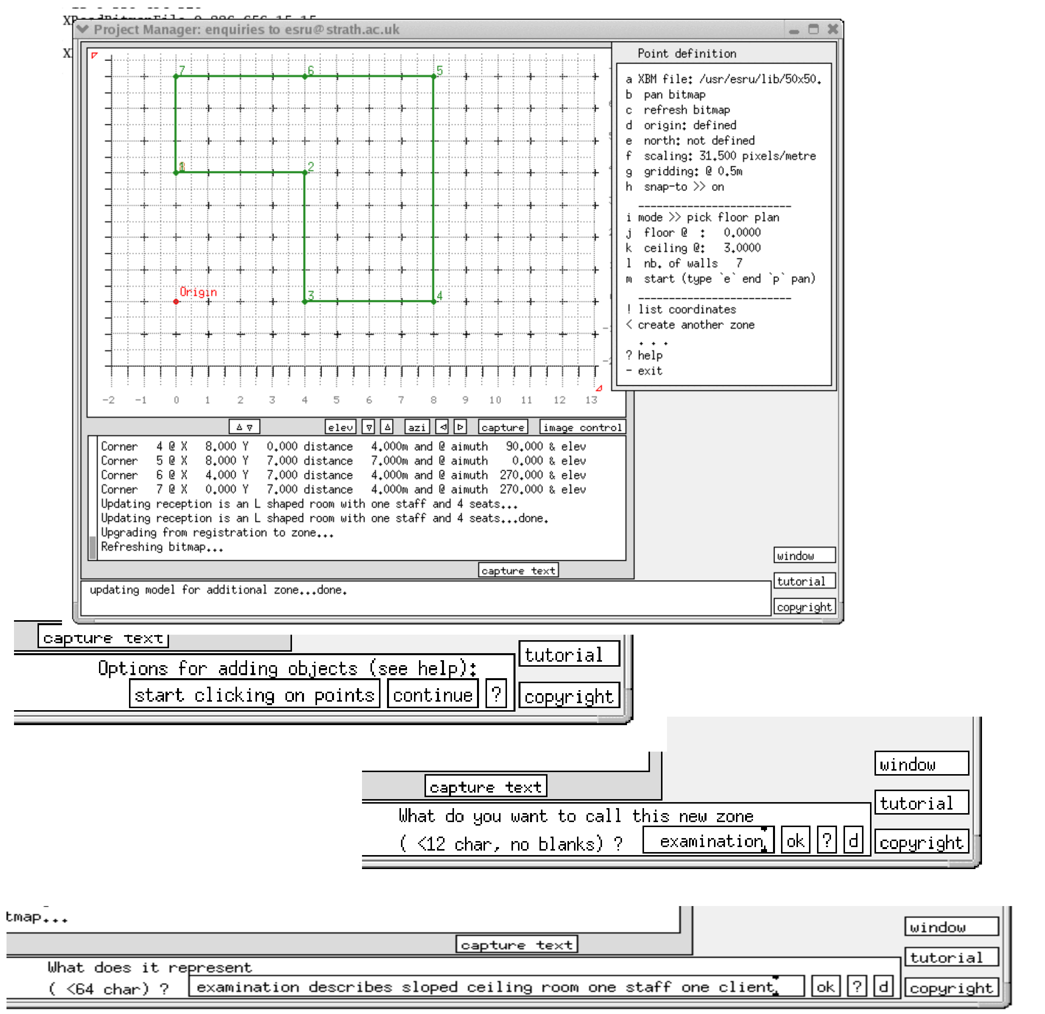


Figure 40: Preparation for addition of examination room.

you will be clicking on points on the grid you created.

Once you have selected the floor plan extrusion input mode (see Figure 38) set the floor elevation to 0.0 and the ceiling elevation to 3.0 (to match Figure 1)

Just before starting to define points it is worth noting that you are able to interrupt the input process and move around a bitmap. The options available will be listed in the text feedback area (see Figure 35).

Us the `start` option to begin defining points starting at the grid nearest 0.0, 4.0 and then 4.0, 4.0 etc. until you reach 0.0, 7.0 (see Figure 39) after which you will type the character `e` to end the input (Figure 5). With the snap-to option you only need to click near the point and it will snap to the nearest grid. If the snap-to option is off the Project Manager will accept the actual point where you click.

If you make a mistake or the point snaps to an incorrect grid point then immediately type the character `d` to delete the last entry (multiple deletes are possible.

After you have signaled the end of points for the initial zone (by typing the character e) you can save the zone data (if you did it correctly) or try again if you are not satisfied. While saving the zone data, an additional file is created to hold the 'topology' of the model and you can safely accept the file name offered for confirmation.

A new option `create another zone` will be displayed in the menu once the initial zone is saved. This can be used as many times as required to extrude zones (using the current floor and ceiling height attributes). In the current exercise the examination room needs to be added. It has the same initial floor and ceiling height as the reception zone so those attributes need not be altered. When you are ready, select the `create another zone` option and supply a name and description for the examination room (Figure 40).

Note that three of the corners of the examination room are at the same grid points as used by the reception and unless you specify otherwise, those coordinates will be used. Note also that the edges of the reception are still visible so that it is easy to create new zones adjacent to (including above or below) prior zones. Since you are extruding a floor plan you will proceed anti-clockwise from the origin typing the character `e` when you have done all four corners.

When you started clicking on each subsequent zone, a message is included in the text feedback to remind you of the control options currently active (Figure 35). When you signal that you have finished selecting points for the examination room (by typing the character e) you will be presented with options to save or repeat the zone definition.

As the examination room is the last zone, exit from the click-on facility and you will be presented with a wireframe view of the zones you have created (Figure 41). These zones still require surface attribution as well as the addition of doors and windows.

Such tasks can be accomplished by using the `geometry & attribution` facilities introduced in the initial exercise. Follow the steps for adding windows and doors and attributing the surfaces in reception. You will also need to adapt the flat ceiling of the initial shape to create a sloped roof and then add in the necessary surfaces to fully enclose the room.

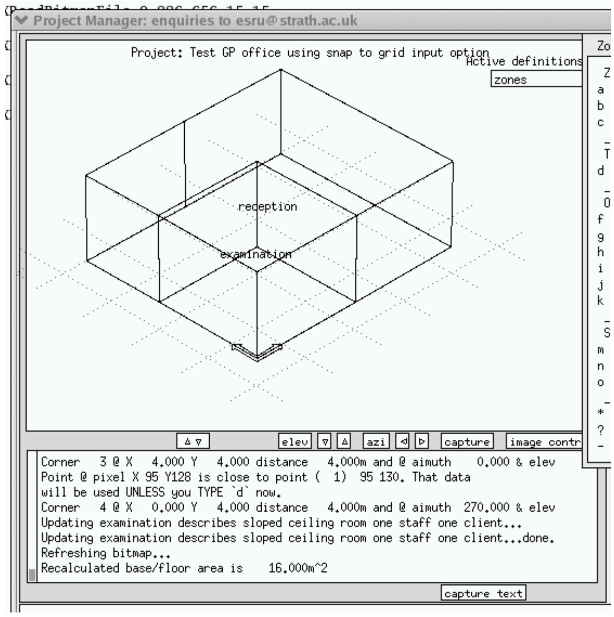


Figure 41: Two rooms after click-on session.

Clicking on a bitmap

A variant of the click-on-grid approach is to supply your own bitmap (plan/section/elevation/site-plan) and click on points found in that image to create one or more thermal zones.

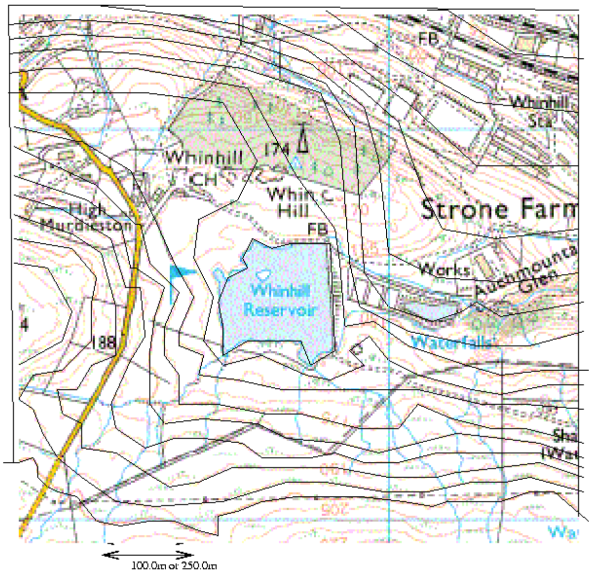


Figure 42: Ordinance Survey map with sketched lines for lumped contours.

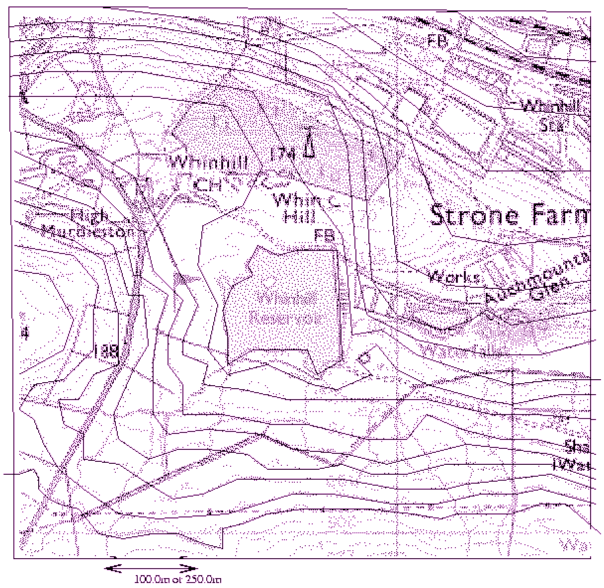


Figure 43: X11 bitmap image of site contours with points selected.

In Figure 42 and Figure 44 an UK Ordnance Survey map has been converted into an X11 bitmap file and used with the click-on-bitmap facility to create ground topography surfaces to associate with a model. Note that the solid lines (representing the contours selected) is an approximation of the contours on the map because ground representations supports several hundred surfaces rather than several thousand surfaces. The options used to within the bitmap facility were *points with different Z*. As a second step the ground topography facility was used to triangulate the ground form (see Figure 44).

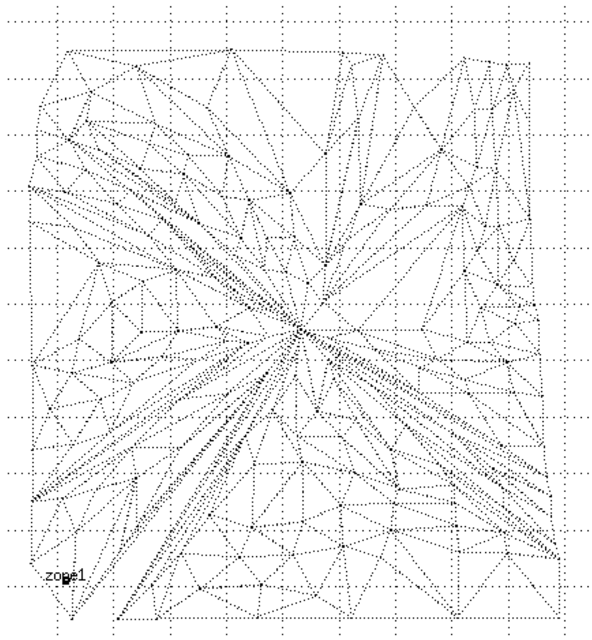


Figure 44: Model ground topology after triangulation.

A tactical warning – try a small portion of a map until you are comfortable with the facility. It expects you to define the bounding points first!

Another example of using a scanned image to import information that is only available in hard-copy form (no CAD data). The theatre shown in was initially constructed in the mid seventeen hundreds and the last set of drawings available were from the mid nineteen seventies. It is also notable in that almost nothing is rectilinear.

A tactical warning – using a click on bitmap approach is no excuse for skimping on the planning of your model! It is far to easy (bitter experience) to get carried away with the clicking and

- include more complexity than necessary
- get lost while doing the clicking
- collect points in such a way that the time taken to post-process the surfaces is greater than that associated with the clicking.

So ALWAYS...

- mark-up your image with indications of the critical points you want to capture and the bounds of the zones you will be creating,
- if you have bitmaps for more than one level make sure you can keep the points in-register and that the scale can be setup to be equivalent,
- sketch your model in three dimensions so that you can plan how partitions between zones work,

If you have ceilings and/or floors that are not level there are several possible approaches, some of which will save you time and some will not. Do a series of experiments with constrained models to see what approach to the click-on-bitmap works best for you. Keep a note of what works so that you can follow this tactic when confronted with a similar project in the future.

•

Which approach to take

ESP-r presents choices of geometric input modes, but it is up to you to select the approach or mix of approaches which are appropriate for your skills and for the model you wish to create. In planing your simulation tasks consider the regularity of the plan, the quality of the bitmap image and the level of clutter in the CAD file. A plan with a 1.3m x 1.7m repeating pattern will not easily fit within ESP-r's gridding options. A bitmap with only a few pixels per metre will be difficult to accurately select points on and a CAD model that includes thousands of extra surfaces for furniture might be a good candidate for converting into a bitmap. Also consider whether you might use the click-on-bitmap facility to acquire critical points on curved elevations and in non-rectilinear plans into a dummy zone which you then borrow from to create the model.

The mode in Figure 46 was initially composed by clicking on a set of points from Figure 45 which were placed in dummy zones. Surfaces and points from those dummy zones were then used to build up the model zones. And there was a detailed plan of the zoning worked out prior to the use of the click-on-bitmap facility. Even with this, considerable care was required and post-processing and reconciliation of the partition surfaces was required. This is an example of what can be accomplished by an experienced user and is just the sort of project which would be cruel and unusual punishment for a novice.

The model in Figure 47 was largely composed by a clicking on a mix of Ordnance survey maps, old planning documents and drawings. The model, including zone geometry, shading obstructions and ground topography was created and initial simulations commissioned within 12 hours of the completion of the simulation planning phase. It would have been faster, but one drawing was off-scale and several zones had to be adjusted to bring them into alignment.

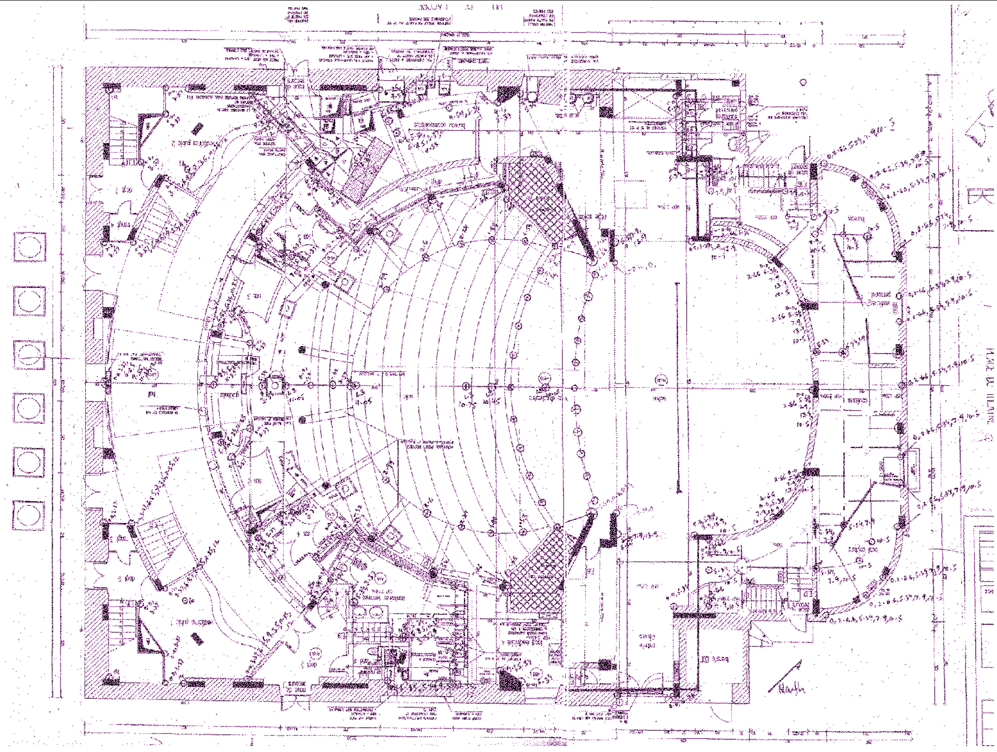


Figure 45: X11 bitmap of a 1750 theatre.

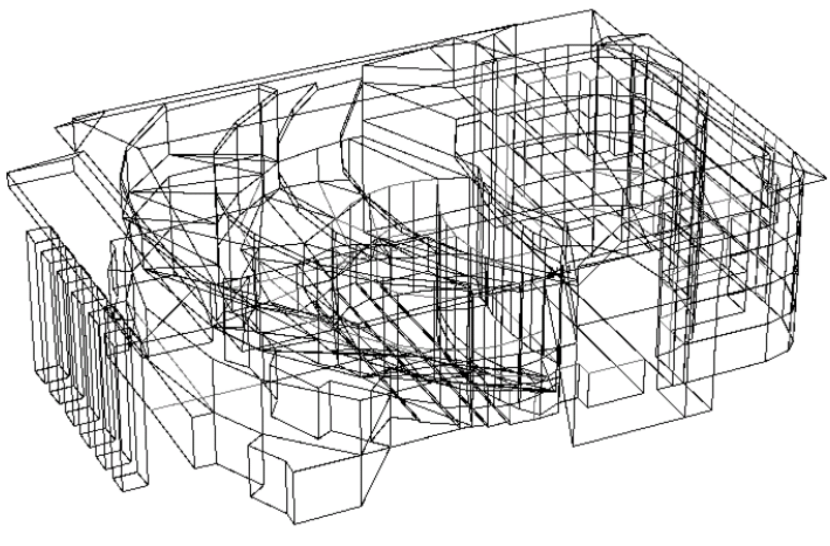


Figure 46: ESP-r model of the theatre.

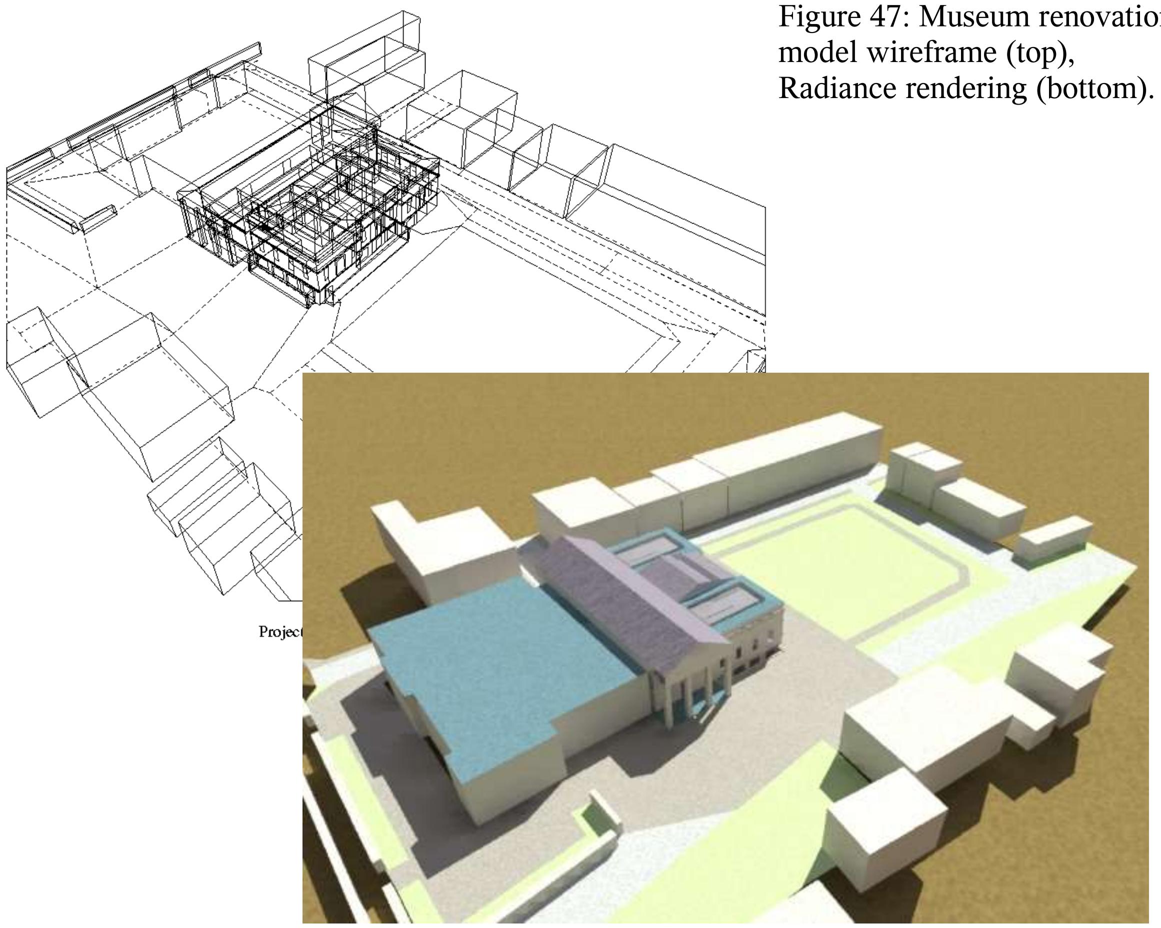


Figure 47: Museum renovation model wireframe (top), Radiance rendering (bottom).

Schedules

The form and composition of a model is one part of the simulation process. Many users think they have almost completed their work when the geometry is done. Far from it, buildings are almost always places where people are coming and going and lights are being turned on and off and all manner of electrical devices are found.

Usually we lack both the detailed information and the resources to undertake an exhaustive definition. It is, however, in our interest to define the essential characteristics of what goes on in a building and learn from the performance patterns that emerge sufficient clues to imagine the circumstances where the building would perform poorly.

For the current building a brief description was given in the 'How the building is used' section, specifically Figure 3 and 4. Re-read that section. Also look at Figure 53 for reception data. Before we define the operational characteristics of the reception and examination room within the *Project Manager* a bit of planning will (you guessed it) save time and reduce the chance of errors later on.

ESP-r supports zone operational characteristics in terms of weekdays and two separate weekend days (typically labeled as Saturday and Sunday). It is possible to define unique values for each timestep of a simulation, but lets not go there yet. Casual gains (e.g. people, light, small power) are one operational characteristic of a zone and schedules of infiltration (air from the outside via intentional sources such as fans or unintentional sources such as cracks in the facade) and ventilation (air from another thermal zone) and there are a limited number of controls you can impose on infiltration and ventilation schedules.

In the reception there is 'one staff and up to 3 visitors with 10W/m2 lighting and 1 50W' From the figure it is clear the occupancy changes throughout the day (ramping up from 7h00 and with a dip for lunch and almost nothing happening after 17h00) but the lights are on during office hours plus some time for cleaning staff (8h00-19h00). In the examination room there is one staff and one visitor with 10W/m2 lighting and 1 100W computer '. From the figure it is clear that occupancy varies during the day and that both lights and small power (labeled as equipment) are on from 8h00-19h00 and nothing happens on the weekend.

Why bother with varying the occupancy during the day? Several reasons – full time peak loads usually do not happen in reality so a bit of diversity is more realistic, reducing the load during a lunch hour allows us to check whether the building is sensitive to brief changes in gains and the ramp-up just before office hours and the ramp-down after office hours approximates transient occupancy. The peak demands are long enough to indicate whether heat will tend to build up in the rooms. Such patterns will also exercise the environmental system and perhaps provide an early clue as to the relationship between building use and system demands. Quite a lot of value for a few minutes thought at the planning stage.

What are *casual gains* in ESP-r? The lower portion of 3 and Figure 4 shows the attributes of the casual gains – each has a day type (Wkd/Sat/Sun) a casual gain type label (Occupt/Lights/Equipt) a period (start hour and end hour) a sensible and latent magnitude, and for the sensible portion the fraction of the gain which is radiant and the fraction which is convective. The convective and radiant fractions shown are defaults which might later be adjusted to reflect the properties of specific light fittings and occupants.

In the reception the peak occupant sensible gain is 400W and in the examination room the peak is 200W equating to 100W per person. The latent magnitude is roughly half the sensible value. Such assumptions if documented (a block of text 248 characters) really do help clarify the numbers held in the file and can speed up later QA tasks.

One of the first questions you will be asked when you begin to define the operational characteristics of zones is the number of periods for each day type and the start time of each period. For weekdays the reception has 8 occupant periods and 3 periods for lighting and 3 periods for small power. On Saturday and Sunday there are zero periods.

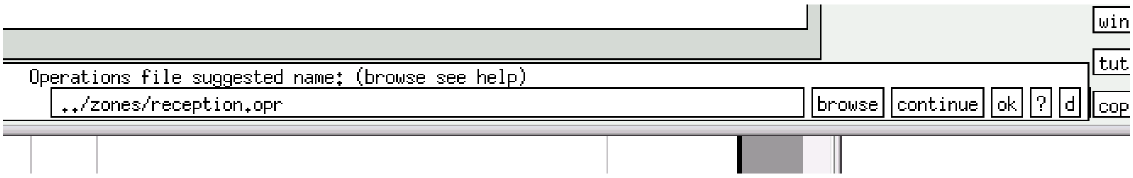


Figure 48 Operation file choice.

With this information we can now proceed to define the operations for the reception. In the *Project Manager* go to `Model definition -> composition -> operation`. Select the zone reception and you will be presented with an initial file choice (see Figure 48). The file name is suggested based on the name of the zone. You can confirm this or browse for another existing file (in case you want to use one you had created earlier) or continue if you decide not to define the operations for reception. Accept the suggested name by clicking on the `ok` button and read the notice shown in Figure 49.

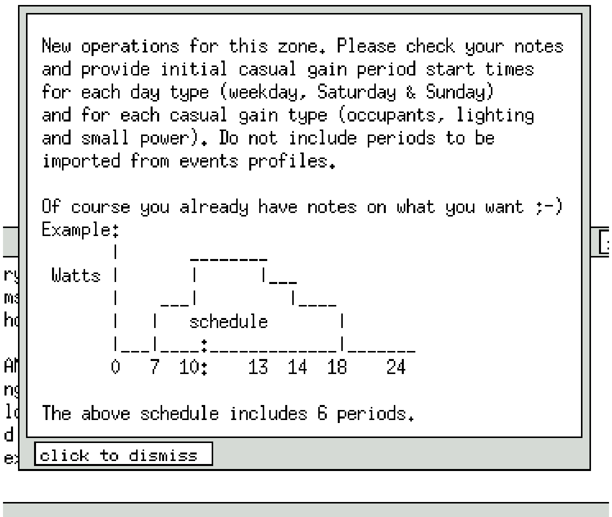


Figure 49 Initial hint for defining periods.

And the next dialog will as for the number of weekday periods for occupants, lights and small power which you can fill in as in Figure 50 as well as the start time for each period (see Figure 51).

Figure 50 Weekday periods.

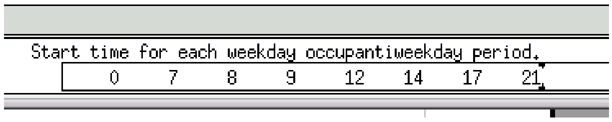


Figure 51 Start time for each period.

Do the same for lighting gains and small power gains on weekdays and the repeat the process for Saturdays and Sundays. You are now presented with the menu in .

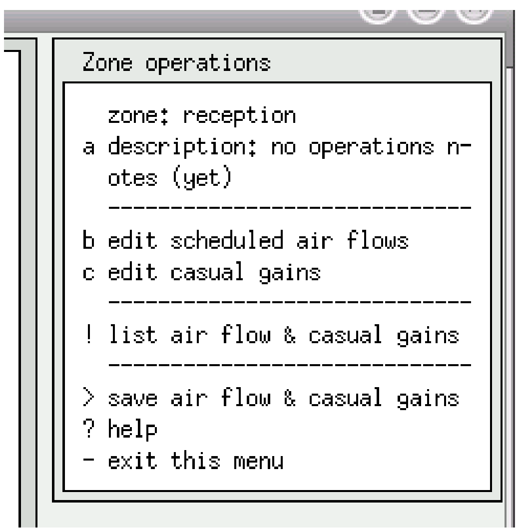


Figure 52 Initial zone operations menu.

Fill in the description of the zone operations using words and phrases which will clarify what is happening (note the editing box has < > arrows so you can scroll to a more text). Next select option c to fill in the rest of the casual gain period details. You will be presented with a menu with period data which you need to fill in based on your notes. After you have defined the magnitude of the sensible and latent gains and accepted the default radiant and convective split you should see something like .

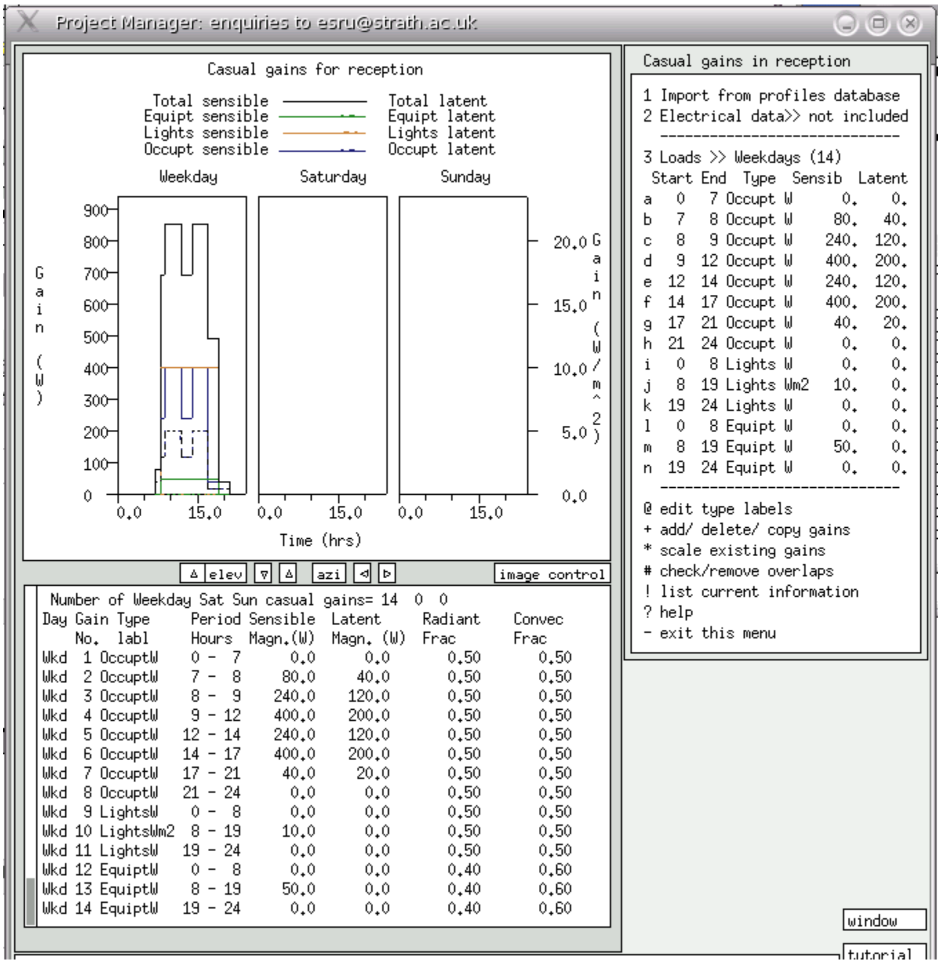


Figure 53 Reception casual gains.

As you were filling in the period data you will note that you have a choice of units (see Figure 54)

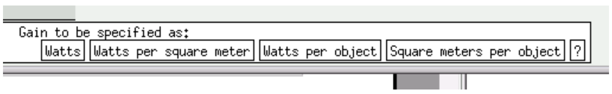


Figure 54 Casual gain unit choices.

In this case occupants were put in as Watts, lighting was put in as W/m2 (note the label changes to reflect this) and small power as Watts.

Scheduled air flows

Early in the design process building details may not support a detailed description of how air moves within buildings or how tight the facade might be so engineering approximations are often used. The brief didn't actually mention anything so an initial assumption needs to be made. In an actual project discussions would be made within the design team to quantify this figure. For purposes of this exercise lets have a rather leaky facade and assume that the doors are closed between the reception and examination room.

We can represent this with one period each day covering the 24 hours with a value of 1 ac/h infiltration and no ventilation (see Figure 55). Later we might decide to lower the infiltration rate to see if the building is sensitive to an upgrade in the quality of the facade.

Other sections of the cookbook outlines other options for treating air movement via mass flow networks which can assess pressure and buoyancy driven flows between thermal zones or via Computational Fluid Dynamic Domains.

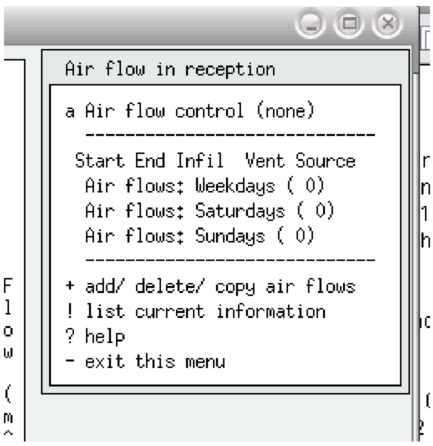


Figure 55 Initial air flow periods.

Importing operation schedules

Section to be written...

Climate data

Simulation tasks will demand considerable computing and staff resources as well as extra time for assuring the quality of models unless we find ways to focus and constrain models and the assessments we carry out. In this section the focus in on how to deliver useful information faster (and without exhausting ourselves) by resisting our impulse to create overly complex models and run overly long assessments.

ESP-r has a number of facilities which allow us to **scale** our models and assessments so we get, for example, annual heating and cooling requirements on a whole building without simulating every day of the year or every floor of an office building.

For many building types there is a strong correlation between predictions over one or two weeks in each season and seasonal demands. If we can establish that this is the case, scaling of performance predictions becomes an option.

The ESP-r distribution comes with a number of climate data sets and is installed so that additional data on seasons (early-year winter, spring, summer, autumn, late-year winter in the Northern Hemisphere, early-year summer, autumn, winter, spring later-year summer in the Southern Hemisphere) and typical assessment periods can be easily accessed by the climate module **clm** and the **Project Manager**.

To better understand how this works our first task is to install a new climate files and specify the days in each season and use **clm** facilities to recommend typical assessment periods in each season. After this we will derive initial scaling factors for heating, cooling, lighting, small power etc. demands.

We will begin by downloading a new climate data set from a United States DoE web site <http://www.eere.energy.gov/buildings/energyplus/weatherdata.html>. The site offers US locations, Canadian Locations and International Location. Lets choose an international location – Geneva Switzerland. The file for this site is CHE_Geneva_IWEC.zip. Download it and save to a convenient location. On a Linux or MacOSX or Unix box use the command `unzip CHE_Geneva_IWEC.zip` to unpack this file. One of the files will be CHE_Geneva_IWEC.epw. Take this file into a text editor (nedit is used in Figure 56). There are several changes we might need to make in the file. If the first line is:

```
LOCATION,GENEVA,,CHE,IEWC
Data,067000,46.25,6.13,1.0,416.0
```

this needs to be edited to

```
LOCATION,GENEVA,-,CHE,IEWC
Data,067000,46.25,6.13,1.0,416.0
```

ESP-r expects at least one character between two commas. The next change is that line 6 include a # character before the WMD number and this should be replaced by a blank character. Line 6 is also 702 characters long and ESP-r can only read text lines that are less than 248 characters. After reading the ASHRAE notice, edit the notice text shorten it. The last change is that some EPW files have a blank line at the end of the file (line 8769). Remove this line and save the file. The revised file is shown in Figure 57. Further, and possibly updated instructions for how to edit EPW files will be found in the ESP-r source distribution *climate* folder.

Importing climate data

Next we need to import this file and convert it into a form which ESP-r can deal with. In a command window go to the location of the edited file and issue the command (as one line):

```
clm -mode text -file CHE_Geneva_IWEC -act epw2bin silent CHE_Geneva_IWEC.epw.
```

This creates a new ESP-r climate file CHE_Geneva_IWEC. The message “error reading line 1” is sometimes seen when doing the conversion, but does not usually affect the conversion. The command given to the clm module includes the name of the new binary climate file to be created after the key word *-file*. The words *-act epw2bin silent* tells it to undertake the conversion without further interactions.

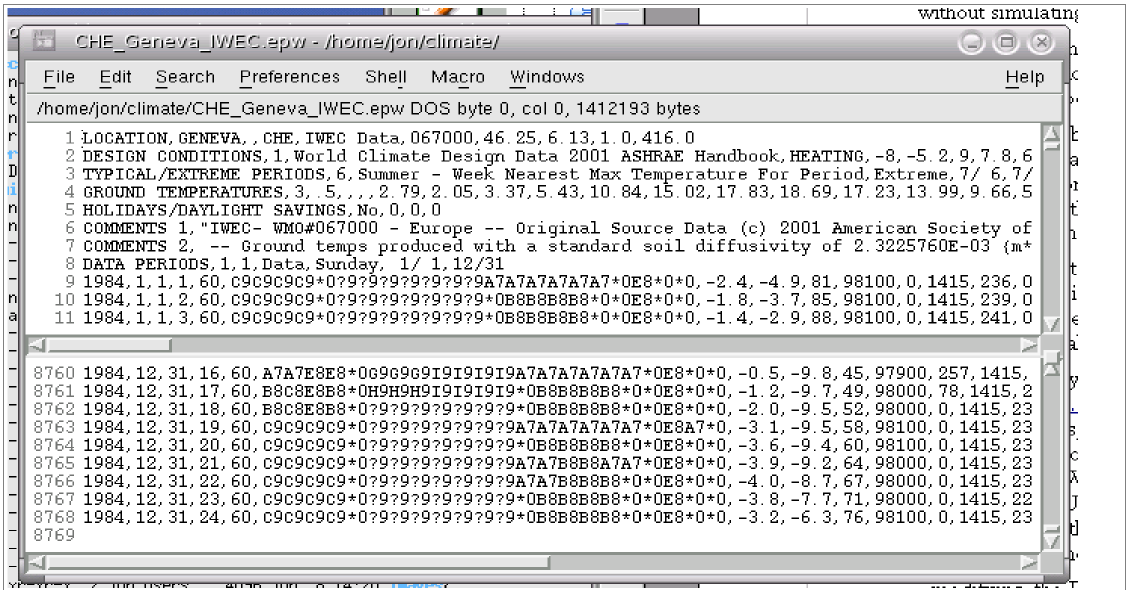


Figure 56: EPW file header before editing.

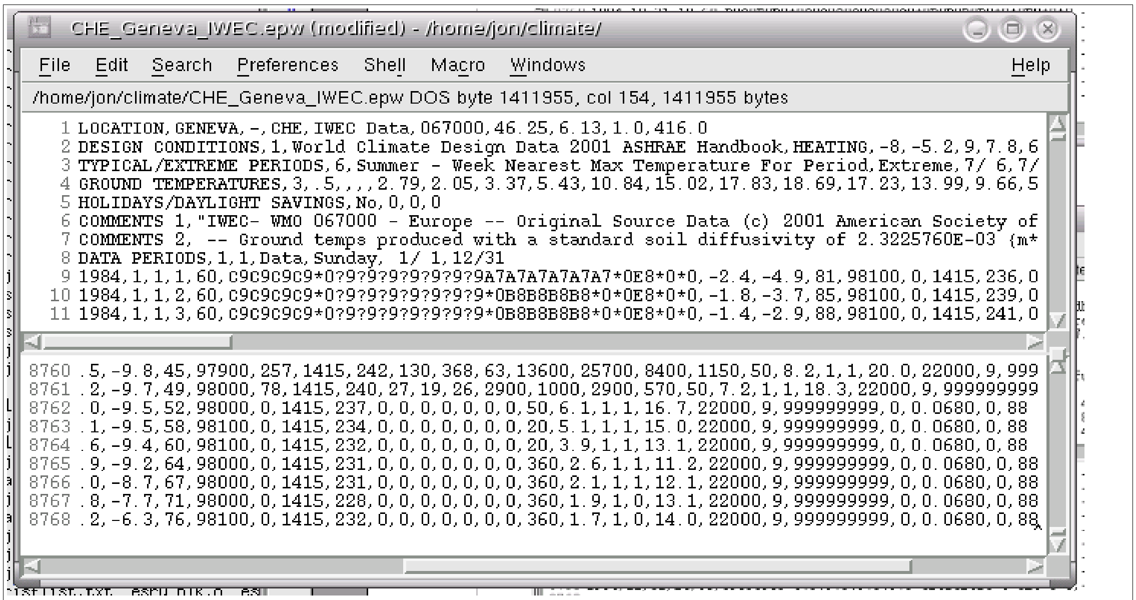


Figure 57: EPW file after editing.

To check that the conversion worked, invoke the **clm** module with the new file:

```
clm -file CHE_Geneva_IWEC
```

If the conversion was correct you should see the lines

```
Climate data: GENEVA – CHE
46.2N  8.9W: 1984  DN
```

in the text feedback area of the interface.

Defining seasons and typical periods

Our next task is to define the days associated with each season. There are any number of approaches one might take and we will use a combination of looking at the patterns of temperatures over the year and the solar radiation. In the climate module choose `graphical analysis` from the menu options. Then pick `dry bulb temperature` and `draw graph` to get a display similar to that in Figure 58.

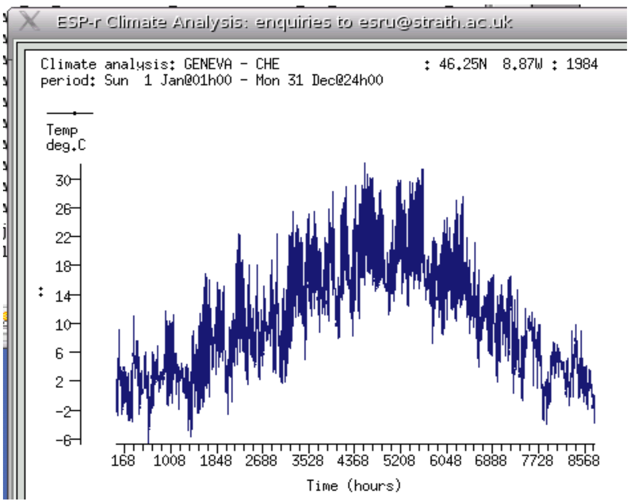


Figure 58 Outside ambient (dry bulb) temperature over the year.

The axis at the bottom of the graph is hours, each tick mark being 168 hours or one week. There are extreme low temperatures in weeks 4, 9, 46 and 52. In week 14 it reaches 22ºC. The warmest period is between week 26 and week 32. Another way to look at climate information is to look at weekly heating and cooling degree days. To to this select `synoptic analysis` and then choose `dry bulb temperature` and then `degree days` and then `weekly`. Take the default base heating and cooling temperatures This will produce a table as Figure 59.

Climate data: GENEVA - CHE
46.2N 8.9W: 1984 DN
Degree day analysis: heating base at 17.0 & cooling 21.0 Deg C

Week	(starting)	Heat dd avg/day	Heat dd total	Cool dd avg/day	Cool dd total
Week: 1	(Sun 1 Jan)	15.43	108.02	0.00	0.00
Week: 2	(Sun 8 Jan)	15.85	110.93	0.00	0.00
Week: 3	(Sun 15 Jan)	14.01	98.08	0.00	0.00
Week: 4	(Sun 22 Jan)	15.80	110.60	0.00	0.00
Week: 5	(Sun 29 Jan)	14.29	100.02	0.00	0.00
Week: 6	(Sun 5 Feb)	13.02	91.16	0.00	0.00
Week: 7	(Sun 12 Feb)	13.93	97.52	0.00	0.00
Week: 8	(Sun 19 Feb)	15.83	110.83	0.00	0.00
Week: 9	(Sun 26 Feb)	15.90	95.42	0.00	0.00
Week:10	(Sun 4 Mar)	12.75	89.26	0.00	0.00
Week:11	(Sun 11 Mar)	9.83	68.81	0.00	0.00
Week:12	(Sun 18 Mar)	8.05	56.34	0.00	0.00
Week:13	(Sun 25 Mar)	12.30	86.08	0.00	0.00
Week:14	(Sun 1 Apr)	5.25	36.78	0.03	0.18
Week:15	(Sun 8 Apr)	7.94	55.60	0.00	0.00
Week:16	(Sun 15 Apr)	8.18	57.28	0.00	0.00
Week:17	(Sun 22 Apr)	7.21	50.46	0.00	0.00
Week:18	(Sun 29 Apr)	6.53	45.73	0.01	0.08
Week	(starting)	Heat dd avg/day	Heat dd total	Cool dd avg/day	Cool dd total
Week:19	(Sun 6 May)	8.25	57.75	0.02	0.13
Week:20	(Sun 13 May)	2.53	17.73	0.31	2.15
Week:21	(Sun 20 May)	3.30	23.07	0.12	0.84
Week:22	(Sun 27 May)	1.16	8.15	0.31	2.18
Week:23	(Sun 3 Jun)	2.70	18.89	0.01	0.08
Week:24	(Sun 10 Jun)	0.95	6.66	0.69	4.81
Week:25	(Sun 17 Jun)	3.25	22.75	0.63	4.38
Week:26	(Sun 24 Jun)	1.55	10.87	0.82	5.76
Week:27	(Sun 1 Jul)	0.63	4.39	1.45	10.16
Week:28	(Sun 8 Jul)	0.03	0.24	3.33	23.33
Week:29	(Sun 15 Jul)	0.16	1.14	1.70	11.90
Week:30	(Sun 22 Jul)	1.08	7.55	0.32	2.27
Week:31	(Sun 29 Jul)	0.82	5.71	1.60	11.17
Week:32	(Sun 5 Aug)	0.39	2.75	1.58	11.05
Week:33	(Sun 12 Aug)	0.29	2.04	2.56	17.94
Week:34	(Sun 19 Aug)	0.59	4.10	1.86	13.00
Week:35	(Sun 26 Aug)	2.35	16.42	0.02	0.12
Week:36	(Sun 2 Sep)	2.73	19.13	0.08	0.58

Figure 59: Heating and cooling degree days per week from January to August.

The average heating degree days is roughly 15.0 for the first nine weeks and then drops to roughly 8.0 (except for week 13). Weeks 27 to 34 have cooling degree days between 10 and 23. This follows the same pattern as seen in the graph. If we set a winter heating degree day cutoff point of 12 and a summer cooling degree day cutoff of about 10 then the definition of seasons is straightforward.

Before we actually set the dates, note that 1 January is on a Sunday and the start of each subsequent week is also a Sunday. Later, when we search for typical weeks they will begin on a Sunday. Some practitioners prefer to run assessments that begin on Mondays and end on Sundays. If we wanted to enforce that preference what we need to do is to change the year of the climate set so that j January happens on a Monday (e.g. 2001). This change can be found in the `edit site data` menu option of the main clm menu. Once this is changed, return to `synoptic analysis` and ask for the weekly degree day table again.

Using these cutoffs the seasons are as:

- early-year winter 1 January – 11 March
- spring 12 March – 24 June
- summer 25 June – 26 August
- autumn 27 August – 18 November

- late-year winter 19 November – 31 December.

To supply this information go to the `manage climatelist` option on the main menu. You will be presented with the options shown in Figure 60.

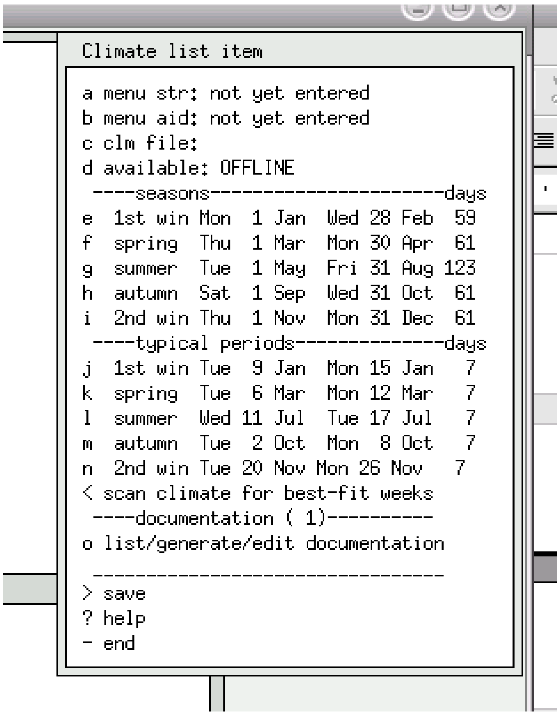


Figure 60: Climate list initial data fields.

What is shown are initial default dates for seasons and typical periods which you will need to update. Start by selection options a and b to define the menu selection and documentation phrases describing this climate data. For example the menu aide memoire could be *Geneva – CHE was source from US DoE*. Menu option c is the full path and name of the climate file that ESP-r will access. For the file we have been working with this is */usr/esru/esp-r/climate/CHE_Geneva_IWEC*. Menu option d is a toggle which tells ESP-r whether the file is ONLINE or OFFLINE. Set this to ONLINE.

The section of the menu under seasons allows us to edit the beginning and ending date of each season.

After defining each season we can use the scan climate for best-fit weeks to search for weeks that are closest to the seasonal average conditions. The criteria for heating and cooling are based on a combination of heating and cooling degree days and solar radiation. The **clm** module will determine the seasonal average weekly heating degree days and cooling degree days (102 and 0 for early year winter) as well as the solar radiation (11.05). It will then look for the week with the least deviation after confirming the weighting we want to give to heating DD, cooling DD and radiation. These are initial set to 1.0 to give an equal weighting. It finds the smallest deviation (0.14) for the week eight which starts on Monday 19 February. After confirming each of the suggestions the interface should look like Figure 61.

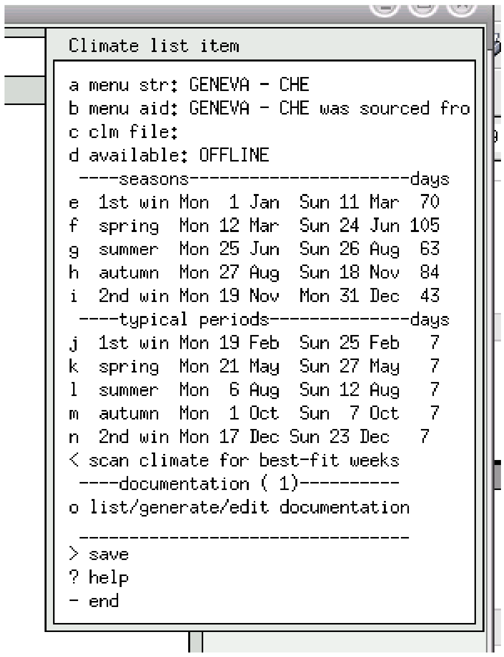


Figure 61: Climate list data fields after editing.

Climatelist entries

The final tasks are to record this information via the `list/generate/edit documentation` option `initialise` option and then use the `save` option. The initial file name is */tmp/climateitem*. A better name is */tmp/climateitem_geneva*. A listing of the contents of this file are shown below:

```
*item
*name        GENEVA - CHE
```

```
*aide        GENEVA - CHE was sourced from US DoE
*dbfl
*avail       OFFLINE
*winter_s  1  1 11  3 19 11 31 12
*spring_s 12  3 24  6 27  8 18 11
*summer_s 25  6 26  8
*winter_t 19  2 25  2 17 12 23 12
*spring_t 21  5 27  5  1 10  7 10
*summer_t  6  8 12  8
*help_start
Climate is GENEVA - CHE
 Location: 46.25N  8.87W : 2001
 Month  Minimum  Time      Maximum  Time
Mean
 Jan   -6.8 @ 4h00 Fri 26  11.1 @16h00 Sun 14  1.1
 Feb   -5.8 @ 7h00 Tue 27  11.7 @16h00 Wed  7  2.4
 Mar   -2.7 @ 7h00 Tue 27  16.8 @16h00 Sat 10  5.9
 Apr    1.4 @ 7h00 Wed 11  22.4 @16h00 Wed  4 10.1
 May    1.6 @ 4h00 Tue  8  25.5 @16h00 Tue 15 13.4
 Jun    7.7 @ 1h00 Tue 19  29.0 @16h00 Mon 25 16.7
 Jul   10.5 @ 4h00 Thu  5  32.1 @16h00 Mon  9 20.3
 Aug    7.1 @ 4h00 Thu 30  31.4 @13h00 Wed 22 19.9
 Sep    8.3 @ 7h00 Fri  7  27.6 @16h00 Sat 22 15.7
 Oct    0.1 @ 7h00 Wed 31  21.1 @13h00 Mon  1 10.6
 Nov   -4.1 @ 7h00 Sun 25  14.7 @16h00 Fri  2  4.7
 Dec  -4.0 @22h00 Mon 31    9.8 @13h00 Mon 17  2.8
 Annual -6.8 @ 4h00 26 Jan 32.1 @16h00  9 Jul 10.4
 ---Seasons & typical periods---
Winter season is Mon  1 Jan - Sun 11 Mar
Typical winter week begins Mon 19 Feb
Spring season is Mon 12 Mar - Sun 24 Jun
Typical spring week begins Mon 21 May
Summer season is Mon 25 Jun - Sun 26 Aug
Typical summer week begins Mon  6 Aug
Autumn season is Mon 27 Aug - Sun 18 Nov
Typical autumn week begins Mon  1 Oct
Winter season is Mon 19 Nov - Mon 31 Dec
Typical winter week begins Mon 17 Dec
*help_end
```

The contents of the file will become one item when copied into the ESP-r /usr/esru/esp-r/climate/climatelist file. You need to insert the text between an existing **help_end* and **item* line. Note that on some computers you will not have permission to edit the /usr/esru/esp-r/climate/climatelist file.

Before closing the clm module, it is useful to save the ESP-r climate data into an ASCII format file. Do this via the `export to text file` option of the main menu. Accept the default file name *CHE_Geneva_IWEC.a* and the period. The climate file CHE_Geneva_IWEC should be placed in the folder /usr/esru/esp-r/climate and the ASCII version CHE_Geneva_IWEC.a should be kept as a backup in case the binary climate file becomes corrupted. Again, on some systems, you may have to ask administrative staff to copy to file to /usr/esru/esp-r/climate (or wherever the file climatelist is located on your machine).

Plant

In ESP-r environmental control systems can be represented as either so-called idealised zone/flow controls or as a network of system components which is often called a plant system. The choice of which approach to take is partly based on how much you want to know about the detailed performance of the environmental control system and partly on how much descriptive information you can acquire about the composition of the environmental control.

Those interested in the psychrometric state within components of the environmental controls will tend towards a network of components. Similarly, if interactions between components and/or controls must be tracked at sub-minutely intervals a network of components is required. And zone controls simply do not include components such as heat exchangers or spray humidifiers.

Tactical users of simulation do not rush to create networks of components until they have learned all they can from ideal controls. And they do this because creating networks of components tends to take longer (more descriptive information and more linkages between components). Such networks need tuning like real systems who's interactions are in the frequency of seconds or fractions of a second.

Traditionally, networks of system components necessitated a steep learning curve. Recent versions of ESP-r provide additional feedback on the composition of such networks as well as a full complement of performance reporting facilities. These will feature in the discussion to follow, but even with this a tactical approach yields significant results.

So **rule one** is to start with zone and/or flow controls and only move to networks of components if you need information at higher resolution.

- **Rule two**: planning and sketches are essential.
- **Rule three**: walk before you run.
- **Rule four**: document what you do.

First exercise – using a component network to represent mechanical ventilation

Mechanical ventilation is one aspect of building design which simulation can play a role. We will create several models of a mechanical ventilation design to explore such systems respond to changing demands and boundary conditions.

The first approach is to represent all aspects of a mechanical ventilation design within the component network (there is a component which provides a simplified representation of a thermal zone. Although this will not provide a full accounting of the interactions between supply and demand sides it is an approach suited to early design stage questions where little might be known of the zones.

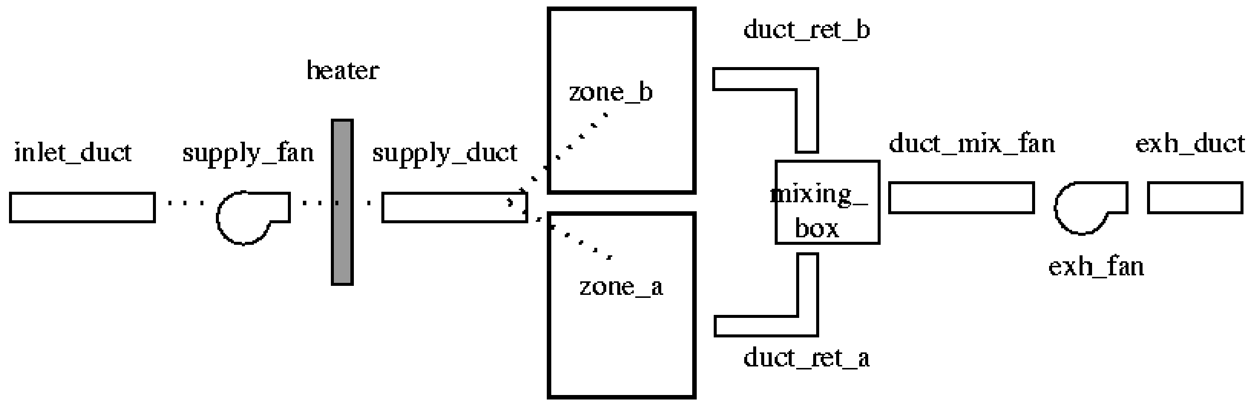


Figure 62: Basic mechanical ventilation system

Figure 62 shows a standard mechanical ventilation system which has a supply and an exhaust fan and a heater coil just up-stream from the supply fan. Two zones are supplied and the extracts from each zone are combined in a mixing box just before the exhaust fan.

Planning is essential, even for a simple model like this. Sketch out your network first and decide on names for the components. Most of your work within the **project manager** will involve names of components and numbers representing component attributes and your sketch is essential for keeping track of your work, supporting QA tasks and communicating with clients.

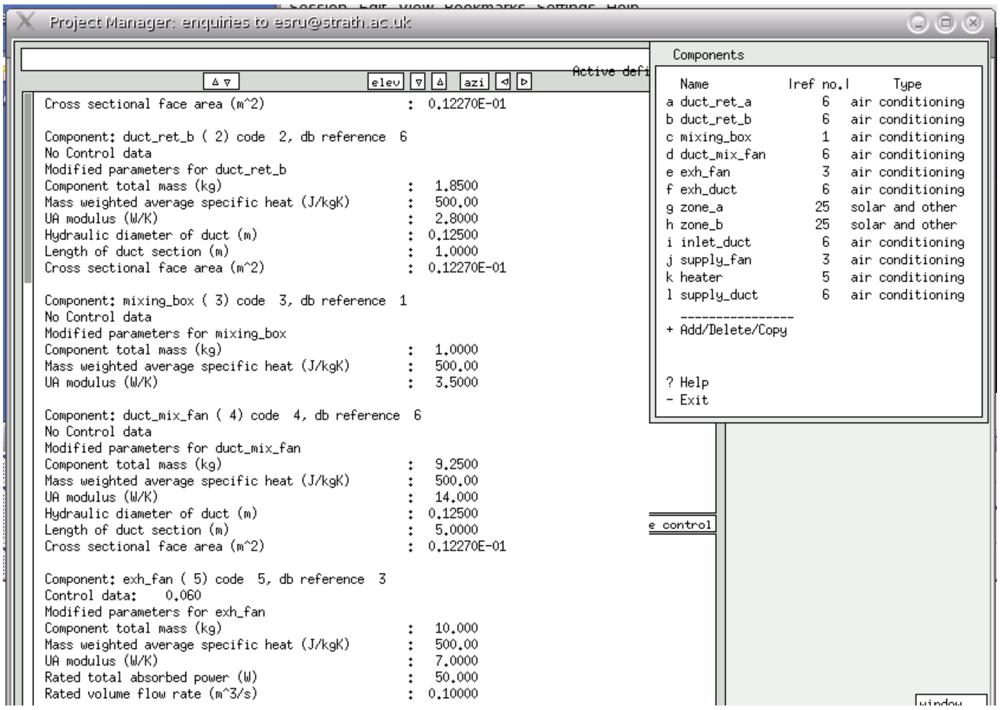


Figure 64: Components (with text feedback expanded to show attributes)

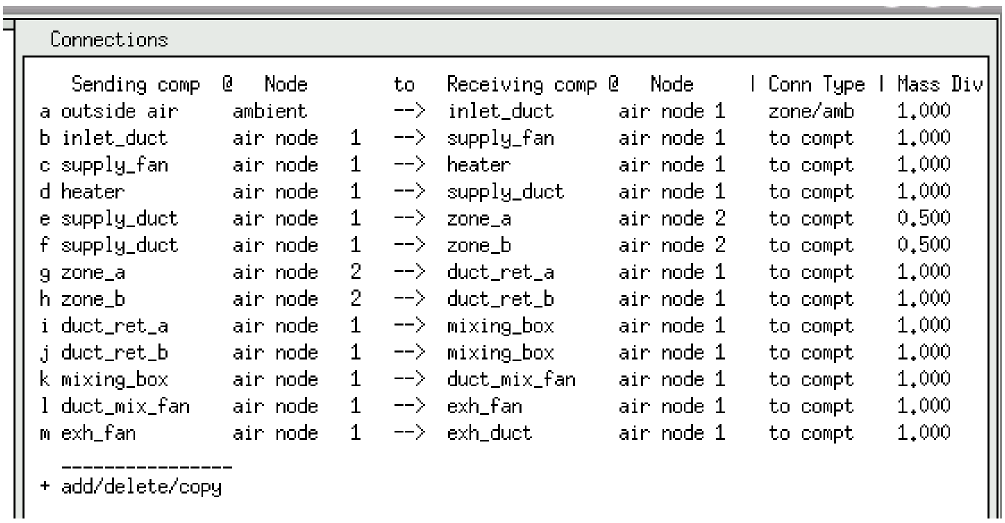


Figure 63: Connections between components

After sketching the network gather the component information. The list on the next page contains component information for the 12 components and you should refer to this as you create your network. Components *have a sequence* – the initial group go from the returns from the zones to the exhaust and then come the idealized zones and then the inlet_duct to supply_duct. Adopting a sequence which proceeds from the return to the supply can make subsequent tasks easier. After the name of the component is a number in ( ) which is the component index within the plant network. Include this number on your sketch in addition to the component name, there are a few places in the interface where you have to type in this index rather than selecting from a list of component names.

Most components include an attribute for the total mass of the component. For these exercises this need not be exact. There is also a mass weighted average specific heat which tends to be either 500.00 or 1000.00. Each component also has a UA modulus. These parameters support calculations of how the casing of the component interacts with its surroundings.

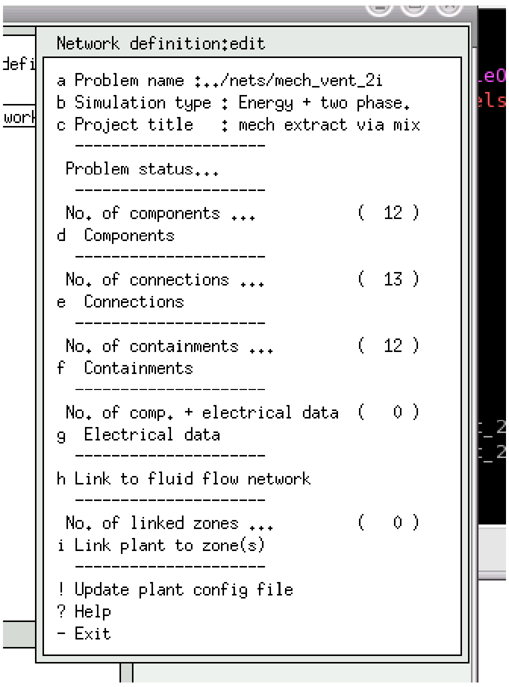


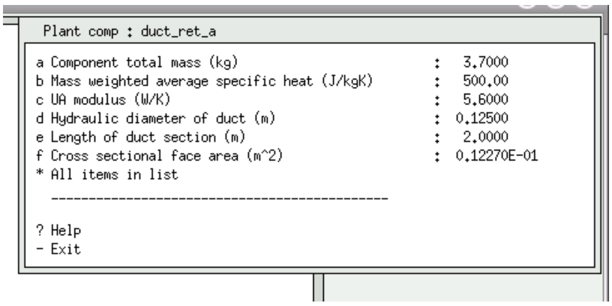
Figure 65: Finished network

Ducts have additional parameters, including the length of the duct, cross-sectional area and hydraulic diameter. If you pre-calculate these it will speed up your descriptive tasks as well as reducing mistakes (see Rule two).

```
Component: duct_ret_a ( 1) db reference  6
Modified parameters for duct_ret_a
Component total mass (kg)                    :  3.7000
Mass weighted average specific heat (J/kgK): 500.00
UA modulus (W/K)                             :  5.6000
Hydraulic diameter of duct (m)               :  0.12500
Length of duct section (m)                   :  2.0000
Cross sectional face area (m^2)           : 0.12270E-01

Component: duct_ret_b ( 2) db reference  6
Modified parameters for duct_ret_b
Component total mass (kg)                    :  1.8500
Mass weighted average specific heat (J/kgK): 500.00
UA modulus (W/K)                             :  2.8000
Hydraulic diameter of duct (m)               :  0.12500
Length of duct section (m)                   :  1.0000
Cross sectional face area (m^2)           : 0.12270E-01

Component: mixing_box ( 3) db reference  1
Modified parameters for mixing_box
Component total mass (kg)                    :  1.0000
Mass weighted average specific heat (J/kgK):  500.00
UA modulus (W/K)                             :  3.5000

Component: duct_mix_fan ( 4) db reference  6
Modified parameters for duct_mix_fan
Component total mass (kg)                    :  9.2500
Mass weighted average specific heat (J/kgK):  500.00
UA modulus (W/K)                             :  14.000
Hydraulic diameter of duct (m)               : 0.12500
Length of duct section (m)                   :  5.0000
Cross sectional face area (m^2)           : 0.12270E-01

Component: exh_fan ( 5) db reference  3
Control data:   0.060
Modified parameters for exh_fan
Component total mass (kg)                    :  10.000
Mass weighted average specific heat (J/kgK):  500.00
UA modulus (W/K)                             :  7.0000
Rated total absorbed power (W)               :  50.000
Rated volume flow rate (m^3/s)               : 0.10000
Overall efficiency (-)                       : 0.70000

Component: exh_duct ( 6) db reference  6
Modified parameters for exh_duct
Component total mass (kg)                    :  5.5000
Mass weighted average specific heat (J/kgK):   500
UA modulus (W/K)                             :  8.4000
Hydraulic diameter of duct (m)               :  0.12500
Length of duct section (m)                   :  3.0000
Cross sectional face area (m^2)           : 0.12270E-01

Component: zone_a ( 7) db reference 25
Control data: -500.000
Modified parameters for zone_a
Component total mass (kg)                    :  10920.
Mass weighted average specific heat (J/kgK):  1000.0
Wall U value (W/m^2K)                        :  0.40000
Total surface area of walls (m^2)            :  78.000
Zone space volume (m^3)                      :  45.000
Inside heat transfer coefficient (W/m^2K)   :  5.0000
Outside heat transfer coefficient (W/m^2K)  :  18.000
Outside air infiltration (ACH)               :  0.0000

Component: zone_b ( 8) db reference 25
Control data:-1000.000
Modified parameters for zone_b
```

```
Component total mass (kg)                        :  7560.0
Mass weighted average specific heat (J/kgK):  1000.0
Wall U value (W/m^2K)                           : 0.40000
Total surface area of walls (m^2)               :  54.000
Zone space volume (m^3)                         :  27.000
Inside heat transfer coefficient (W/m^2K)  :  5.0000
Outside heat transfer coefficient (W/m^2K) :  18.000
Outside air infiltration (ACH)                 :  0.0000

Component: inlet_duct ( 9) db reference  6
Modified parameters for inlet_duct
Component total mass (kg)                        :  9.2500
Mass weighted average specific heat (J/kgK):  500.00
UA modulus (W/K)                                 :   14.000
Hydraulic diameter of duct (m)                   :  0.12500
Length of duct section (m)                       :  5.0000
Cross sectional face area (m^2)          :  0.12270E-01


Component: supply_fan (10) db reference  3
Control data:    0.060
Modified parameters for supply_fan
Component total mass (kg)                        :   10.000
Mass weighted average specific heat (J/kgK):   500.00
UA modulus (W/K)                                 :   7.0000
Rated total absorbed power (W)                   :   50.000
Rated volume flow rate (m^3/s)                   :  0.10000
Overall efficiency (-)                           :  0.70000

Component: heater (11) db reference  5
Control data: 3000.000
Modified parameters for heater
Component total mass (kg)                        :   15.00
Mass weighted average specific heat (J/kgK):   1000.0
UA modulus (W/K)                                 :   3.5000

Component: supply_duct (12) db reference  6
Modified parameters for supply_duct
Component total mass (kg)                        :   1.8500
Mass weighted average specific heat (J/kgK):   500.00
UA modulus (W/K)                                 :   2.8000
Hydraulic diameter of duct (m)                   :  0.12500
Length of duct section (m)                       :   1.0000
Cross sectional face area (m^2)            : 0.12270E-01
```

The pattern for creating components is similar (see Figure 66). When you have finished defining the components you should see something like Figure 64. Save your network and ake a moment to review the components listed in the interface menu with your sketch to ensure they are consistent.



```
Plant comp : duct_ret_a
a Component total mass (kg)                        :   3.7000
b Mass weighted average specific heat (J/kgK)      :   500.00
c UA modulus (W/K)                                 :   5.6000
d Hydraulic diameter of duct (m)                   :  0.12500
e Length of duct section (m)                       :   2.0000
f Cross sectional face area (m^2)                  :  0.12270E-01
* All items in list
  ---------------------------------------------
? Help
- Exit
```

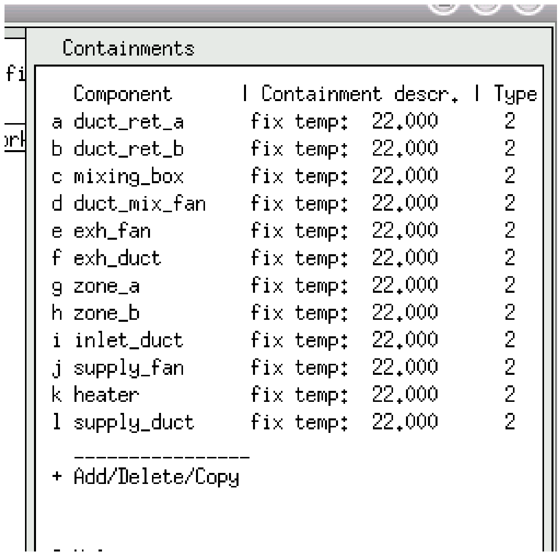
Figure 66: Typical component menu.

The next task is to link the components together. Linking plant components together is different from linking flow network components together. Clear your mind – the pattern is to begin your focus at a component that **receives** flow and figure out which component is **sending** the flow. Referring back to Figure 62 – the *heater* is supplied by the *supply_fan* so when you set up a link the first component in the link is the *heater* and the second component in the link is the *supply_fan*

Look again at the list in Figure 63, (this is what you will end up with after you had completed all of the links) and draw this (a coloured line works well) on your sketch of the network. When this makes sense, start the process of adding connections (hint – mark completed connections on sketch as you do them). The mass diversion for supply_duct ->zone_a and supply duct ->zone_b are 0.5 because each takes half of the output of the component supply_duct. Except for the receiving component inlet_duct, which takes its supply from ambient air, each of the other connection is *with another component*. When the connections are complete save the network.

Defining containments

Components can be located in several different contexts, such as surrounded by a fixed temperature, or ambient temperatures. The definition of containments allows you to specify what you want for each component. For purposes of this exercise we want to attribute each component with a



```
Containments
  Component        | Containment descr. | Type
a duct_ret_a        fix temp:  22.000     2
b duct_ret_b        fix temp:  22.000     2
c mixing_box        fix temp:  22.000     2
d duct_mix_fan      fix temp:  22.000     2
e exh_fan           fix temp:  22.000     2
f exh_duct          fix temp:  22.000     2
g zone_a            fix temp:  22.000     2
h zone_b            fix temp:  22.000     2
i inlet_duct        fix temp:  22.000     2
j supply_fan        fix temp:  22.000     2
k heater            fix temp:  22.000     2
l supply_duct       fix temp:  22.000     2
  ----------------
+ Add/Delete/Copy
```

Figure 67: Containments for each component

fixed temperature of 22C. The figure below shows what you should expect to see.

Finishing off the model and testing

At this point your interface should look like Figure 65. Notice that there is a place for you to include some notes – (**Rule 4)** before you forget what this network is about!

And now it is time to test out the model to see if it is complete and syntactically correct. First setup simulation parameters – the name of the results file, the period of the simulation and what sort of timestep to use. You can then re-run this assessment without having to look around for scraps of paper telling you how many timesteps per hour.

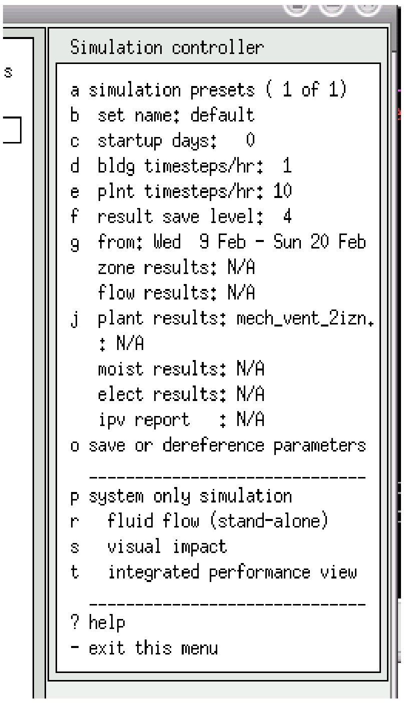


Figure 68: Simulation parameters.

Exit from the plant menu and look for the **Actions -> simulate** menu. We want to setup a default set of parameters as in Figure 68 and then commission an interactive simulation.

The simulator will notice that the model includes only a network of components and will solve only a *system only simulation*. It will request confirmation for using zero startup days (accept this), the default climate and the name of the results file to be created (write this name down, you will need it in a few minutes). The simulation should take a few seconds. Exit from the simulator and invoke the results analysis module. Note the initial file name in the results analysis module is incorrect. What is shown is the configuration file name and what is required is the results file name (e.g. change mech_vent.cfg.to mech_vent.plr) it will then ask for the configuration file name (so type it in again). Once this minor irritant is out of the way you can find out how the ventilation design works.

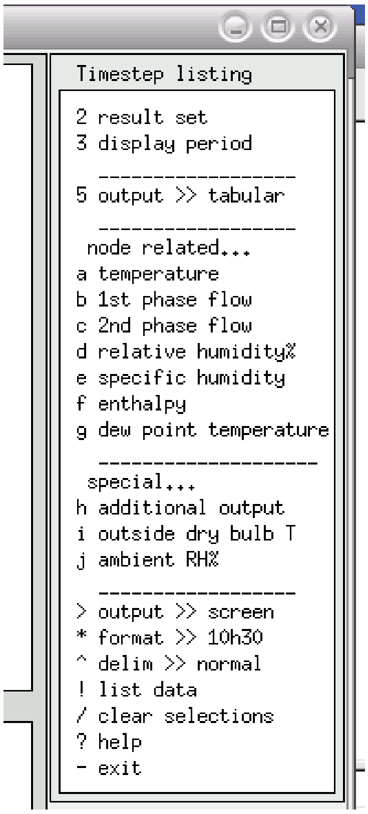


Figure 69: Results analysis menu

The results analysis facilities (see Figure 69) for network components are in one menu which allows you to toggle between tabular, psychrometric chart, summary statistics, histograms and graphic plots. Items selected will be re-displayed as you toggle between views. Figure 70 shows the temperatures at return ducts a & b and Figure 71 statistics of temperature and enthalpy at return_duct_b.

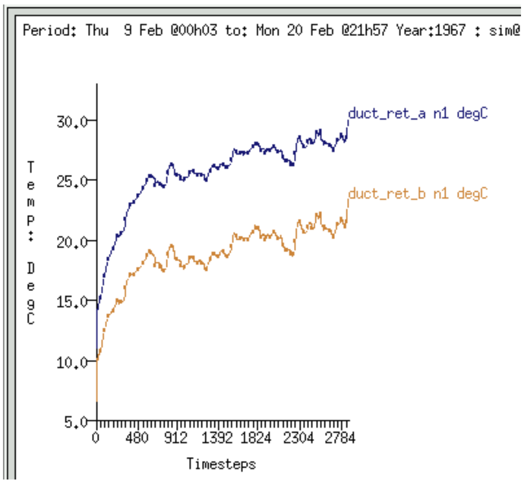


Figure 70: Graph of return ducts a & b

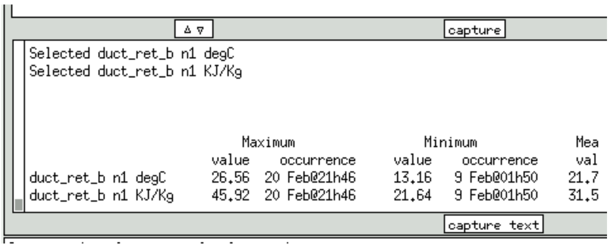


Figure 71: Statistics at return duct b

Spend a few moments browsing the reports and graphs in search of patterns that indicate how the ventilation system is working.

One pattern you might note is the diversion ratio of 0.5 from the supply duct to zone_a and zone_b results in the return from zone_b being cooler than from zone_a.. If the diversion ratios were altered (in the connections menu Figure 63 for supply_duct -> zone_a and supply_duct -> zone_b) the differences in temperature might be reduced.

Changing the diversion ratios requires editing the connection and re-entering some of the existing details. To save time, jot down the information for the two connections you are about to edit before you start the editing process (the interface says what the current value is, but until you get used to this such notes can help. One technique is to save the component network file to a slightly different name when you make such changes so that you recover the original file. After saving the changes and commissioning another simulation check and see the change in performance (Figure 72).

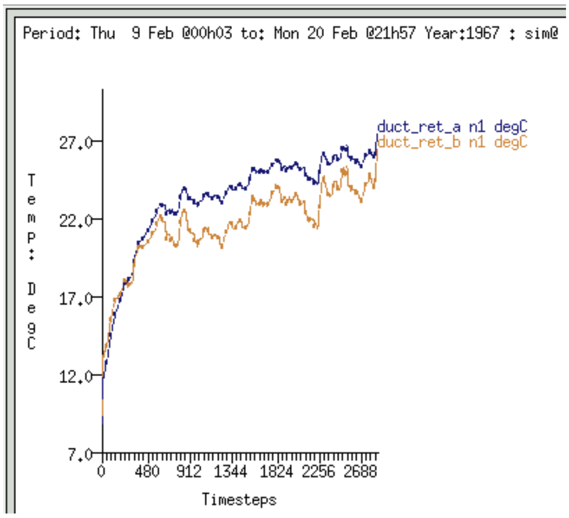


Figure 72: Temperatures in return ducts after adjustment

Moving from ideal demands to thermal zone demands

In the initial model demands that the mechanical ventilation had to respond to were via component representations of zones. You can also associate a network of environmental system components with thermal zones. In this case we need to add two zones to the model which will have the same volume and surface area and overall thermophysical properties as the component representations.

The component zone_a has a volume of 45m^3 and a zone which is 4m wide x 4m deep x 2.81m high will be equivalent in volume and surface area. The component zone_b has a volume of 27m^3 and a zone which is 4m wide x 2.4m deep x 2.81m high will be equivalent. If all surfaces in the rooms are attributed with the construction external_wall and face the outside then the overall UA will be similar to that of the component representation. These zones are rectangular and have no windows or doors, so the process of creating the geometry and applying attribution is straightforward.

One option is to begin a new model and to build up both the zone and component network to match the requirements of the exercise. A second option would be to upgrade the existing model to include the zones and to adapt the existing network of components. Both options have benefits and drawbacks and it is well worth exploring both.

For this exercise lets modify the existing model and the first task is to make a backup copy of the model. If the original model folder is named mech_vent then give the following command:

```
cp -r mech_vent mech_vent_2z
```

Then go into the configuration folder of mech_vent_2z and restart the project manager with the configuration file we want to modify. As soon as the model loads change the root name to mech_vent_2z and alter the model description phrase (as a reminder that this is a different model).

The model has no zones, so go to the zone composition and create zone_a and then zone_b based on the information given above. At the end

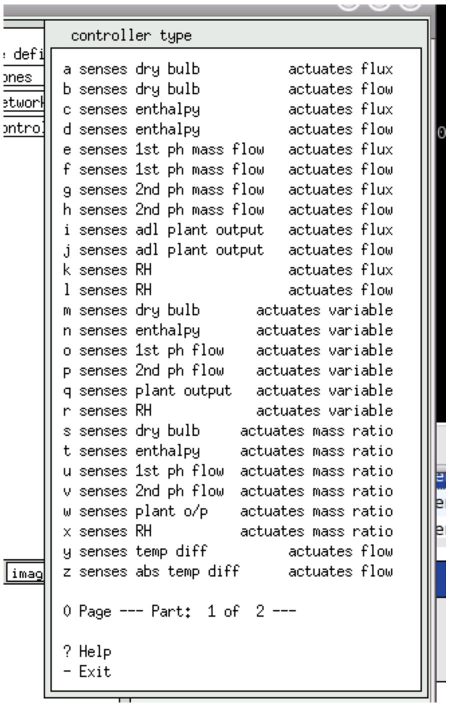


Figure 73: network component control types

of this process you would see something like Figure 74 for zone_a and something like Figure 75 for zone_b.

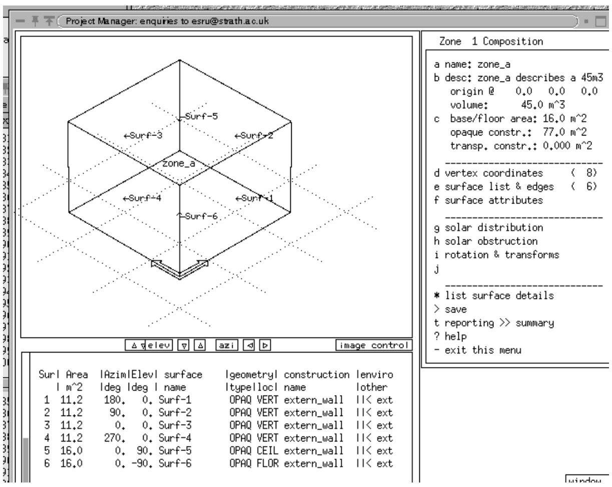


Figure 74: Zone a details

Schedules...

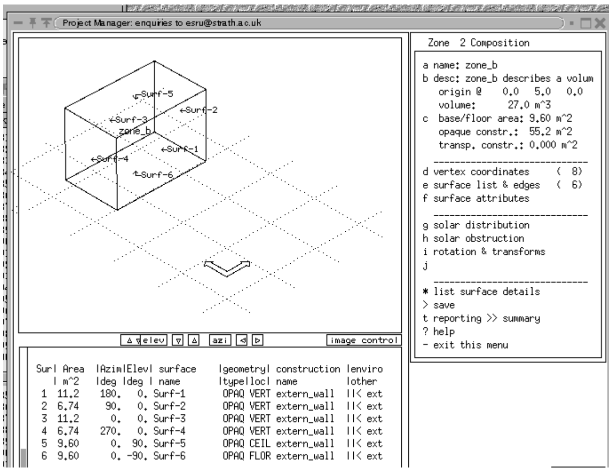
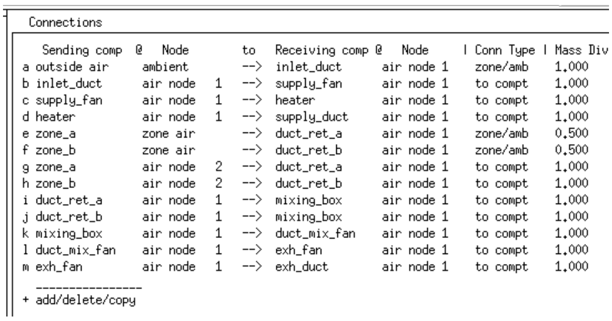


Figure 75: Zone b details

Modifying existing network of components takes several steps: first make a backup copy of the existing network, second change the connection to supply_duct -> zone_a (a connection between components) to supply_duct -> duct_ret_a (a connection between a component and thermal zone_a). In this case the receiving component becomes duct_ret_a, the connection type is 'from a building zone' and then zone_a is selected from the list of available zones. The next question is about the supply for the zone and this remains component supply_duct with a diversion ratio of 0.5.

The same needs to be done with the connection supply_duct -> zone_b to become supply_duct -> duct_ret_b (a connection between a component and thermal zone_b). After these changes have been made the interface will look like Figure 76 .


Connections

	Sending comp	@ Node		to	Receiving comp @	Node	Conn Type	Mass Div
a	outside air	ambient		-->	inlet_duct	air node 1	zone/amb	1.000
b	inlet_duct	air node	1	-->	supply_fan	air node 1	to compt	1.000
c	supply_fan	air node	1	-->	heater	air node 1	to compt	1.000
d	heater	air node	1	-->	supply_duct	air node 1	to compt	1.000
e	zone_a	zone air		-->	duct_ret_a	air node 1	zone/amb	0.500
f	zone_b	zone air		-->	duct_ret_b	air node 1	zone/amb	0.500
g	zone_a	air node	2	-->	duct_ret_a	air node 1	to compt	1.000
h	zone_b	air node	2	-->	duct_ret_b	air node 1	to compt	1.000
i	duct_ret_a	air node	1	-->	mixing_box	air node 1	to compt	1.000
j	duct_ret_b	air node	1	-->	mixing_box	air node 1	to compt	1.000
k	mixing_box	air node	1	-->	duct_mix_fan	air node 1	to compt	1.000
l	duct_mix_fan	air node	1	-->	exh_fan	air node 1	to compt	1.000
m	exh_fan	air node	1	-->	exh_duct	air node 1	to compt	1.000

+ add/delete/copy

Figure 76: connections after editing

The next step is to remove the now redundant connections g and h in the above figure and to finally go into the list of components and remove the ideal components zone_a and zone_b. The result will be a network of 10 components, 11 connections and 10 containments.

Links to zones and controls

At the bottom of the network definition menu there is an option *link plant to zone.* Before we can use this facility we need to define two zone controls and that requires saving the network of components and changing to the zone controls menu to initialise the controls and then return to the network component interface to complete the process. Perhaps a future version of ESP-r will include a wizard to sort this out...

The first zone control senses the temperature in zone_a and actuates at the air node of zone_a and has one day type and one period in that day and the control type to *flux connection between zone and plant* but skip filling in the details.

The second zone control should sense the air temperature in zone_b and actuate at the air node of zone_b and have one day type and one period with the flux connection control law (see Figure 77). While you are in the control facility there is an option to set (another type of) linkage between the control law loops you just created and the relevant thermal zone. When you have done this save the zone controls.

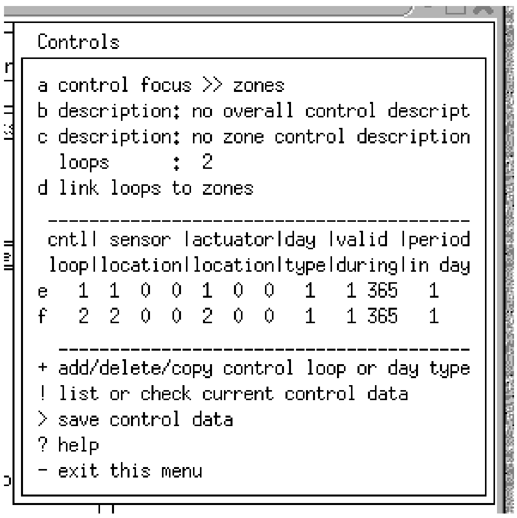


Figure 77: Initial zone control settings

Now return to the network of components and select the item *link plant to zone.* The control file will have been scanned and there should be two entries, the first for connected zone zone_a and the second for connected zone_b, both with a convection type connection. The remaining fields define the nature of the supply and whether there is an extract.

The link for zone_a uses the component supply_duct as the supply and the duct_ret_a component is the extract. The link for zone_b uses the component supply_duct as its supply and the duct_ret_b as the extract.

The interface will look like Figure 78 when this is completed. This is a good time to save the network of components. You will be asked whether the zone controls should be updated to reflect the recent changes in the network of components (say yes).

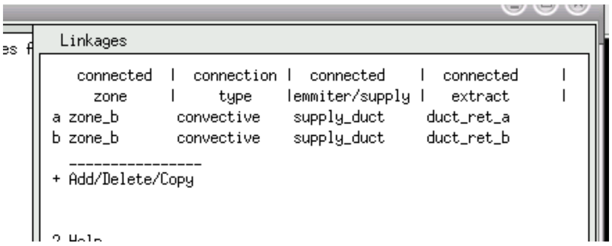


Figure 78: Completed linkages between zones and components

Almost finished. The zone controls need to be adjusted. The linkage function guessed at the capacity of the heater component and will have set the heating and cooling capacity of the zone control to a value which is incorrect (the actual value of the heater 3000W and 0W cooling).

Up to this point we have used zone controls to establish the link between the thermal zone and network component domains and some of the parameters in the zone controls (e.g. the capacity) are based on information used during the definition of the network of components.

We now have to define the logic which will drive the heater component and for this we must define a so-called *plant control*. There will be one control loop, it will sense node one within the duct_ret_a component and it will actuate node one within the heater component. The controller type is *senses dry bulb actuates flux* (from within the list shown in Figure 73). There is one day type and three periods during the day. From 0h00 to 7h00 the control will use a *period switch off control*, from 7h00 there will be an *on-off control* with a heating capacity of 3000W and a cooling capacity of 0W and from 18h00 a *switch off control*.

The selection of control laws (see Figure 79) is somewhat terse, but the help message clarifies the relationship between the control law and the control type. These relationships are required because some components work on flux and some on flow and the actuation needs to reflect this.

A word about the data for the on-off control period. There are seven parameters:

- mode of operation (1.00)
- off setpoint (23C)
- on setpoint (19C)
- output at high (3000W)
- output at low (0W)
- sensor lag (zero) actuator lag (zero)

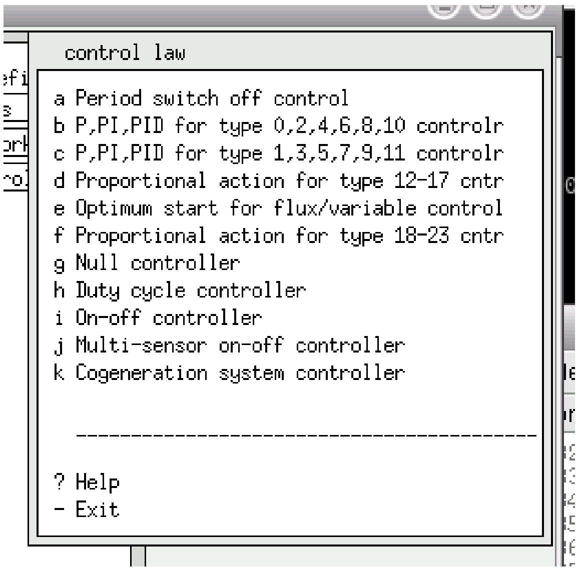


Figure 79: network component control laws

When the plant control is complete and saved it is a good idea to generate a fresh QA report for the model. This will provide additional feedback for checking that your model is consistent.

After you have reviewed the QA report adapt the simulation parameter sets. Use a 15 minute timestep for the zone solution with the plant simulation at 10 timesteps per building timestep and ensure that there are names for the zone and plant results files filled in.

Commission an interactive simulation. If all went well the simulation will take a few minutes to run (the plant is solving every minute). When you go to look at the performance prediction look for performance graphs such as in Figure 80. The upper olive-gree lines are the heater temperature and flux output (labeled as other). The lines below are the temperatures at various points in the ducts. It is also worth looking at the performance characteristics reports for the zones. One of the reasons one might need to use a network of components is to inquire into the internal state of the components so this is a good time to review what is on offer and, importantly, what information about the components are required to recover performance data.

Figure 80: performance predictions within model with thermal zones

One way of discovering the performance sensitivity of networks of components to changes in control parameters is to run a series of simulations typically changing one aspect of a control or a component parameter at a time. This process works even better if a friendly control engineer takes part in the exploration. Certainly an on-off control will result in different performance characteristics to a PID controller, but remember to walk before you run when it comes to PID controllers!.

Looking back at the initial purpose of setting up a network of components. Judging the additional resources needed in comparison with ideal zone controls is best done once you have defined a couple of component networks and developed some proficiency at the tasks involved. The goal is to employ the most appropriate approach to a given simulation project and only using complex facilities where a less complex approach does not support the requirements of the project.

Index

P

still to be done..1

Y

still to be done..1