PACE 1: Computer aided building appraisal

PACE 1 is a computer aided appraisal facility for use at the strategic stages in architectural design. Unlike many design programs the emphasis is not on optimisation of a single parameter but on production of a comprehensive and integrated set of appraisal measures. It can be used to design a specific building, or for developing an understanding of interactions between design variables; it can set up and automatically update a data bank of building design costs and performance characteristics. The on-line version is easily used by designers with no specialist knowledge and is inexpensive to run. The package is the outcome of a year's work financed by a grant and was produced by the Architecture and Building Aids Computer Unit, Strathclyde (ABANUS) at the University of Strathclyde's Department of Architecture and Building Science. From 1967 to 1970 the Building Performance Research Unit, under the direction of Professor T. A. Markus, was developing appraisal measures to be used in the course of design (see also 7.1.7, p 9.56), and a computer program package was a logical extension of this work.

Form and use of PACE 1

PACE 1 (Package for Architectural Computer Evaluation) is designed to be used at the outline proposals stage of design. The version of the package described in this paper is written in Fortran IV and runs on the time-sharing system operated by Systemshare Ltd. Input is by means of a teletypewriter terminal and connection to the central processor is by 4K telephone lines.

As the input and output formats show (Tables I and II), the mode of interaction between the designer and the computer is 'conversational', with the machine taking the initiative. Responses from the designer may be typed directly on to the keyboard as the program runs or prepared beforehand on paper tape which automatically feeds in data as required by the program.

To illustrate the form and use of the package, a simple example is discussed below. Consider a school building made up of six primary functional units (called components in the terminology of the program). The relationships between components can be determined on a 0–10 scale on whatever basis the designer considers appropriate. 1. The designer's initial concept of the scheme in relation to the site, with volumes labelled in accordance with 1, is shown in 2. Components 1 to 5 are all rectilinear and can therefore be considered to be made up of only one element; component 6 is 'L-shaped' and is made up of two rectilinear elements: 6, 1 and 6, 2. To carry out an appraisal of this design concept, the designer 'describes' his scheme to the machine as outlined below.

1. Relationships between components can be determined on any basis designer thinks appropriate if they can be expressed on a 0–10 scale, eg data on numbers of journeys in similar buildings could be reduced to such a scale, or designer could assess relationships on subjective basis.

2. Designer's initial conception of scheme.
Input format
When the program is called up (see table 1) the computer prints the program name, the date and the time. It then asks the question, 'Are your units in metric? 0/1?', and waits for a reply to be typed on the keyboard by the designer. In this case the units are imperial so and the designer types 0 to indicate 'No'. (Throughout table 1 designer's responses have been underlined for easy interpretation.) The current version of FASCE 1 operates in imperial units and produces the output in imperial units, but it will accept metric input; a fully converted program is being written. The input, as can be seen from table 1, is in five sections—general information, geometrical information, site information, constructional information and activity information.

General information
In this section the designer specifies the building type, the number of occupants, the location of the site and the height of the site above sea level. The computer can then access stored data on pattern of occupancy, recommended environmental standards and climate.

Geometrical information
The geometrical configuration of the scheme is input by typing in the co-ordinates of the two opposing vertices of each spatial unit. The response 1, 1 labels the element and the response 1, 1, 0, 350, 360, 10 gives the x, y and z co-ordinates of the vertex nearest to and furthest from the origin. 2 This simple input statement uniquely defines the size, shape and location of component 1. The elements are entered in any order and the response 0, 0 typed to indicate that this part of the input is complete. The computer also requests information on the floor-to-floor height and the ground floor level (in relation to z = 0). The orientation of the scheme is input by giving the angle between the y-axis and the north point. No modular constraint is imposed by this form of input, unless specifically applied.

Site information
To describe the site to the computer, a rectilinear grid is placed over the site with a numerical value for each cell in the grid 3 (for a discussion of site values see Willoughby). After the input of the site's overall dimensions, the designer can specify how coarse or fine this grid is; for a uniform site the designer may specify, say, two rows and two columns; for a varied site he may specify, say, a 20 x 30 grid. The actual values attached to the cells may be on any scale (in this case 0, 100) and are input as a row at a time, starting with the row adjacent and parallel to the x-axis. The size of the site cells does not have to relate to the size of the spatial blocks given to the computer as geometrical information.

Constructional information
This section of input allows information to be given about the proportion of glazing and the insulation properties of each face of each spatial element. If the designer wishes to waive this option, the machine will assume values on his behalf, eg if he answers 0 to the initial question in this section, the machine will inform him that it will assume 25 per cent area of glazing on all vertical surfaces, no glazing on horizontal surfaces, and medium standard insulation throughout. If he elects to input his own data, the machine will ask for the glazing data and the insulation data for each element. A glazing data response of 2, 3, 4, 5, 6 indicates 20 per cent area of glazing on the vertical surface nearest the x-axis, 30 per cent on the vertical surface nearest the y-axis, 40 per cent on the vertical surface furthest from the x-axis, 50 per cent on the vertical surface furthest from the y-axis and zero glazing on the upper horizontal surface. An insulation data response of 2, 2, 2, 1, 1, 3 indicates medium standard insulation on all four vertical surfaces (dealt with in the above order), low standard insulation on the upper horizontal surface and high standard insulation on the lower horizontal surface. The computer will take full account of horizontal and vertical interfaces between spatial elements and components; thus if component 3 abuts component 1, the proportion of glazing on the relevant surface of component 1 will relate only to the unadjacent surface.

Activity information
The final section of input is the relationship matrix shown in 1. The numerical values are typed in for each component in turn (1 and table 1).

Output format
Table 1 gives the output format as it is typed by the computer. The output is in four sections: costs, spatial performance, environmental performance, and activity performance. Before dealing with these, it is necessary to explain the three columns of numerical values. The first column headed 'VALUE' is the absolute value measured by the computer in the appropriate units; the second column headed 'UNIT VALUE' is a standardised measure intended to be independent of the scheme's size; the third column headed 'MEAN' is the mean unit value of all previously computed schemes of similar building type.

Costs
This first section of output deals with capital and running costs; the first column is in pounds, the second and third columns in pounds per occupant. Capital and maintenance costs are computed by taking off quantities of floor and surface area and multiplying by unit cost data held in file under each building type. Lighting and heating costs are obtained by multiplying the lighting and heating loads (computed as described below) by current unit energy costs which are held in file. When the designer chooses his fuel type, hot water costs and total costs can be computed.

Spatial performance
Spatial performance is measured by a set of ratio values, so entries do not appear in the first column. Site utilisation is computed according to the traditional definition, ie total floor area of the scheme divided by site area, as is plot ratio, ie total floor area of the scheme divided by gross floor area. Plan and mass compactness are computed on definitions developed by the Building Performance Research Unit; plan compactness is the inverse ratio of the plan perimeter to the circumference of a circle of equal area (POP AJ 7.170 p26); mass compactness is the inverse ratio of surface area of the mass to surface area of a hemisphere of equal volume (VOLM AJ 7.170 p26). The remaining measures—site value—involves the numerical quantities attached to the cells in the site grid and is defined as the ratio of the average value of the cells covered by the scheme to the average value of all the cells on the site.

Environmental performance
As opposed to actually measuring the environmental characteristics of the scheme, this section of the output essentially gives plant sizes which will give adequate environmental conditions. The storm water piping is sized by taking account of roof area and stored information on maximum storm water precipitation. The area requiring permanent artificial lighting and the
<table>
<thead>
<tr>
<th>Table 1: Input format</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAGE 1</td>
</tr>
</tbody>
</table>

WHAT IS YOUR JOB NAME

TAPEXLE

ARE YOUR LENGTHS IN METRIC UNITS Y/N

Y

******

INPUT EXAMPLE

******

GENERAL INFORMATION

***************

WHAT IS YOUR NATION NITYPP

INCHES

F"H

BED HOSPITAL

DORMER

SAPPORT

SAPPURLY

WHAT IS THE TOTAL OCCUPANCY OF ROOM

TAPEXLE

WHAT IS LOCATION OF SITE

1. DOT

2. DOT

3. DOT

WHAT IS THE Altitude IN THE Nearest 50 FEET

TAPEXLE

PROPERTY INFORMATION

***************

TYPE COMPONENT NO. AND ELEMENT NO. ON ONE LINE
THEN TYPE IN PROPORTION GLAZING ON EACH OF THE 4 FACES
AND NEXT TYPE SIMILARLY FOR INSULATION + FLOOR

+ FLOOR STANDARD INSULATION

+ HIGH STANDARD INSULATION

FINISH WITH 2ND E VERS

TAPEXLE

GLAZING DATA

TAPEXLE

INSULATION DATA

TAPEXLE

******

ACTIVITY DATA

***************

TYPE ASSOCIATION OF COMPONENT ON FACE

OF ROOM NO.

COMPONENT NO.

TAPEXLE

COMPONENT NAME

TAPEXLE

COMPONENT NO.

TAPEXLE

COMPONENT NAME

TAPEXLE

WHAT IS THE Average Internal Floor To Floor Height

TAPEXLE

WHAT IS YOUR GROUND FLOOR LEVEL

TAPEXLE

WHAT IS THE Angle BETWEEN THE Y AXIS AND TRUE NORTH

TAPEXLE

******

SITE INFORMATION

***************

WHAT ARE YOUR X AND Y SITE LIMITS

TAPEXLE

HOW MANY ROWS AND COLUMNS HAVE YOU IN YOUR SITE MATRIX

TAPEXLE

TYPE IN SITE VALUES FOR EACH ROW

ROW 1

TAPEXLE

ROW 2

TAPEXLE

******

CONSTRUCTIONAL INFORMATION

***************

55 PERCENT GLAZING ON W WALLS, ON GLAZING ON ROOF AND
MEDIUM STANDARD INSULATION HAS BEEN ASSUMED

DO YOU WISH TO INPUT PARTICULAR GLAZING AND INSULATION
VALUES FOR ANY OF THE ELEMENTS Y/N

TAPEXLE

******


d Site and orientation information
volume requiring mechanical ventilation are obtained by computing the floor area and volume of the central core (a predefined distance from the outside glazed surfaces of the scheme). Sizing of the total water storage and heating water calorifier is achieved by application of design recommendations from the TReX guide, using stored constants, and data on the number of occupants.

Heat loss and gain are computed each hour for individual spatial components and are based on:
1. Stored information on hours of occupancy (dependent on building type).
2. Stored information on air changes rates (dependent on building type).
3. Stored information on transmittance coefficients (dependent on standard of insulation and proportion of glazing).
4. Stored information on indoor/outdoor monthly temperature differences (dependent on site location and altitude).
5. Stored information on solar gain factors (dependent on orientation of the four vertical surfaces, and area of glazing on each).
6. Heat gains from the occupants (dependent on number of occupants).
7. Lighting gains (dependent on volume and glazed periphery).

The table is sized on the basis of the maximum computed hourly heat loss. Apart from giving the resultant heat loss/unit area, the program gives the designer the option of obtaining monthly heat losses and gains for any number of individual spatial components; in the example, the losses and gains (gains identified by a negative sign) January to December, have been given for components 1 and 6. Throughout this section, with the exception of heat loss/unit area, the unit value, the values in the second column, are divided by absolute values in the first column by the number of occupants in the scheme (Table 11).

Activity performance

The final section of output provides measures of the degree to which the relationships input under activity information are satisfied by the proposed scheme. If the relationship measure in between components i and j is αij, the value between these components in the proposed scheme is αijp. Then αij should be inversely proportional to αij if the greater the relationship between two components, the closer together they should be. Ideally, \( \alpha_{ij}p = k \) a constant. Since the magnitude of this constant varies from scheme to scheme depending on the size of the scheme and the scale of relationships values, a standard is produced by computing the set of values:

\[
\alpha_{ij}p = \frac{\text{mean } \alpha_{ij}}{\text{mean } \alpha_{ij}}
\]

These are printed out in the matrix shown in the final section of Table 11. The ideal situation is represented by zero values in the matrix, i.e., \( \alpha_{ij}p = 1 \). In every case to show that the optimum solution has been achieved. It follows that a high positive value, as between components 1 and 5, indicates that these two components have been located too far apart; a high negative value, as between components 2 and 3, indicates that these two components have been located too close together.

End of process

The computer gives three possibilities at the conclusion of the output. The first invites the designer to change the geometrical or constructional input information, or modify his design concept; Table 11 shows how this is achieved. The second possibility is applicable when the designer is satisfied that the scheme is a good one; by answering yes, all the unit...
**Table I: Modifying input information**

<table>
<thead>
<tr>
<th>DO YOU WANT TO CHANGE INPUT INFORMATION</th>
<th>S/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE COMPONENT NO. AND ELEMENT NO. ON ONE LINE AND ON NEXT LINE A CO-ORDINATE</td>
<td>YES</td>
</tr>
<tr>
<td>DO THIS FOR ALL ELEMENTS - FINISH WITH TWO ENDS</td>
<td></td>
</tr>
</tbody>
</table>

**Table II: Alter geometrical information**

<table>
<thead>
<tr>
<th>DO YOU WANT TO ALTER CONSTRUCTIONAL INFORMATION</th>
<th>S/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE COMPONENT NO. AND ELEMENT NO. ON ONE LINE THEN TYPE IN PROPORTION LINING ON EACH OF THE 4 FACES AND ROOF THEN SIMILARLY FOR INSULATION - FLOOR</td>
<td></td>
</tr>
<tr>
<td>TYPICAL STANDARD INSULATION</td>
<td></td>
</tr>
<tr>
<td>3D HIGH STANDARD INSULATION</td>
<td></td>
</tr>
<tr>
<td>FINISH WITH TWO ENDS</td>
<td></td>
</tr>
</tbody>
</table>

**Table III: Glazing data**

<table>
<thead>
<tr>
<th>GLAZING DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/S</td>
</tr>
</tbody>
</table>

**Table IV: Insulation data**

<table>
<thead>
<tr>
<th>INSULATION DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/S</td>
</tr>
</tbody>
</table>

---

**4 Specimen computer-drawn perspective of scheme can be used as basis for worked-up perspectives**

Values relevant to his scheme are used to modify, in upgrade, the mean values stored from all previous schemes of similar building type. On subsequent use of the program, therefore, the mean values in the third column of output will be the most up-to-date available. The third possibility gives the option of obtaining perspective views of the scheme; if the designer answers 'I', the computer produces paper tape which, when fed into a graph plotter, will cause eight perspective views to be drawn. Some indication of the quality of the draughtsmanship is given in 4.

**Use**

Several forms of the program exist and there are several purposes to which the program can be put. The form just discussed is 'conversational' with the designer responding 'on-line' by typing on the keyboard of the teletypewriter terminal. If desired, a paper tape of responses can be prepared 'off-line' and threaded into the terminal; in this case the computer types out the questions as before but proceeds to feed itself automatically with responses from the paper tape, as required, without intervention of the designer. Another version is for batch-processing; for this a set of cards is punched with responses or data. Cards are handed into the computing department or bureau and results sent back later, at an interval depending on the turn-round time of the batch processing system.

Of course the version used could depend on the purpose to which the program is put. If the program is used on a specific building design then, as suggested in the appendix, the designer will wish to hypothesize a scheme, appraise it, modify the hypothesis, re-appraise, modify, re-appraise and so on until he is satisfied that convergence on an 'optimum' solution has been reached. Therefore, he will wish to make repeated changes to the scheme by answering 'I' to the question 'Do you wish to change the input information?': the keyboard version is appropriate in this case.

Alternatively, a number of simultaneously developed schemes can be compared using the package; five alternative design strategies for a district general hospital are shown in 5 to 9, and table IV is a summary of some of the output information produced by FACING PAGE 1. In this case input by pre-punched paper tape would be most appropriate.

A different use to which the program can be put is that of a research and development tool. Designers have very little information on the causal relationships between design variables. If it is desired to investigate the relationship between compactness and heat loss, for instance, the technique would be one of systematically varying the layout while keeping all other input variables constant. Both the conversational paper tape and batch process versions of the program are ideal for this purpose.

A third purpose to which the program can be put is building up a composite and integrated data bank of cost and performance characteristics of different building types. By putting in a large number of disparate schemes to the batch processing version a progressively comprehensive set of mean values can be accumulated in file. Such an activity is the first step in the establishment of building design performance specifications.

Use has been made of the program for all three purposes by academics, practitioners and public authorities. It is intended to produce a case study of the use of the package in a specific design context in the near future.

**Availability and economics**

The on-line version of FACING PAGE 1, accepting keyboard, paper tape input or a combination of both, is operable on most commercial time-sharing systems using Fortran.

Time-sharing bureaux have large computers sited in one or more centres of population in the U.K. Subscribers to the system can hire or purchase a teletypewriter terminal which has a keyboard similar to that of an electric typewriter, but with additional facilities to read and produce paper tape and print on a continuous roll of paper. Each subscriber's terminal is connected through a special device to the normal ABC telephone system. When the subscriber wishes to use the central computing facilities he simply dials the computer's telephone number and communicates by using the terminal. The subscriber pays for the terminal and auxiliaries (approximately £42/month rental or £300 to purchase), the core line (approximately £4/quarter), the core calls (at normal rates) and computer time used.

The charges for computing time vary between bureaux (see comparison of commercial time-sharing systems) and depend on the speed of the central processor being operated but typically are about £10/hr. One bureau, Systemshare Ltd., makes FACING PAGE 1 available to subscribers at no extra cost; the computing charges for a run like that shown in table I and II would be about £5.

The batch processing version is operable, with minor modification, on any batch processor using Fortran IV. As no time is taken up in man/machine dialogue, running costs in the batch mode are even lower, but, of course, immediacy of output has to be sacrificed.

Use of both versions of the program package, on University of Strathclyde hardware or the client's own system, is negotiable through Brain Services, the consultancy limb of the Architecture and Building Aids Computer Unit, Strathclyde.
Future developments

Developments and modifications currently in hand include:
1. Amortisation of capital costs (based on an input of anticipated life) to give costs-in-use.
2. A version working entirely in sz units.
3. Output of cut and fill based on an input of site ordinance levels.
4. Output of sun incidence on each face of each component, taking account of obscuring masses.
5. A fourth column in the output giving the standard deviation of cost and performance data from previous schemes.

A major advantage of the program structure is the facility with which additional appraisal measures can be 'botted in' to the program as they are devised. While it is envisaged that the package will continually be improved and expanded in minor ways, proposals exist for longer term developments as discussed below.

PAGE 2 and PAGE 3

ABACUS intend to proceed with a similarly structured package for the scheme design stage of design (PAGE 2) and the detailed design stage (PAGE 3). As shown in the appendix the structure of the geometrical data will be quite different in the case of PAGE 2 and PAGE 3.

Packages for specific building types

As there is obviously a limit to how specific PAGE 1 can be in relation to different building types, it is proposed to develop a set of packages, one for comprehensive schools, one for district general hospitals and one for housing. Each of these will embody a similar structure to the generalised PAGE 1 but will be able to deal at much greater depth with particular costing structures, use patterns and so on.

Auto-modifying package

As PAGE 1 stands, it plays a part in repetitive man/machine interaction leading to convergence on an 'optimum' design solution. By far the most exciting development prospect is that of identifying the rules the designer uses to decide how to modify his scheme on each iterative cycle. If the rules can be identified, they can be programmed and the way is open for a computer mechanism which, given an initial hypothesised scheme, will progress with and automatically upgrade it to a pre-specified level of performance. A start has been made on the development of the basic software necessary for such a package.

Graphic input output

Use of the package will be facilitated by a graphical interface with the computer. Work has started on the development of the necessary software and a pilot version to check feasibility, operates on a Marconi Elliott 905/928.

Appendix

Concept of appraisal

Observation of architectural design has suggested a model, such as that represented in 10 in which the sequential stages in the activity—outline proposals, scheme design and detailed design—contain three processes: analysis, synthesis and appraisal. Consideration of the role the computer could play in design leads to the conclusion that the best pay-off will come from its application to the process of appraisal. Working in the traditional mode, the designer (or the design team) carries out the process of analysis and, on this basis conceives a design synthesis; at this point, rudimentary appraisal may take place. The process of appraisal is
Table iv Summary output of five hospital designs

<table>
<thead>
<tr>
<th>Linear</th>
<th>Two-way linear</th>
<th>Lattice</th>
<th>Exo-centric</th>
<th>Harness</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost (£)</td>
<td>16 699 331</td>
<td>3 638 595</td>
<td>3 482 396</td>
<td>3 626 477</td>
<td>3 610 531</td>
</tr>
<tr>
<td>Maintenance cost (£)</td>
<td>10 277</td>
<td>15 966</td>
<td>15 327</td>
<td>16 836</td>
<td>15 886</td>
</tr>
<tr>
<td>Heating cost (£)</td>
<td>7 937</td>
<td>9 256</td>
<td>7 944</td>
<td>11 944</td>
<td>7 998</td>
</tr>
<tr>
<td>Lighting (£)</td>
<td>107 243</td>
<td>106 940</td>
<td>102 152</td>
<td>118 034</td>
<td>120 659</td>
</tr>
<tr>
<td>Dist. heat</td>
<td>51 128</td>
<td>51 937</td>
<td>48 700</td>
<td>56 301</td>
<td>57 824</td>
</tr>
<tr>
<td>Water heating (£)</td>
<td>67 315</td>
<td>68 755</td>
<td>64 402</td>
<td>76 119</td>
<td>72 226</td>
</tr>
</tbody>
</table>

| Site utilisation | 0.1048 | 0.1123 | 0.1035 | 0.1235 | 0.1234 | 0.1167 |
| Site value       | 48 8077 | 49 5865 | 49 5655 | 49 8077 | 49 5855 | 49 7474 |
| Plot ratio       | 0.2720 | 0.7619 | 2.1763 | 1.9847 | 1.8515 | 2.0033 |
| Plan compactness | 0.5064 | 0.8650 | 0.6029 | 0.6078 | 0.3880 | 0.8720 |
| Mass compactness | 0.3610 | 0.3013 | 0.3384 | 0.3497 | 0.2825 | 0.3242 |
| Rain water pipe (sq ft) | 2 228 | 3 479 | 2 353 | 2 874 | 3 366 | 2 296 |
| Peri. artificial light (su sq ft) | 150 042 | 140 392 | 126 431 | 210 106 | 150 247 | 180 502 |
| Mech. ventilation (cu ft) | 12 578 | 4 723 789 | 4 618 820 | 7 090 014 | 3 955 647 | 5 460 672 |
| Heat loss per unit area (Btu/sq ft) | 152 124 | 169 699 | 152 859 | 206 055 | 176 785 | 185 444 |
| Total water storage (gal) | 60 000 | 60 000 | 60 000 | 60 000 | 60 000 | 60 000 |
| Hot water calorifier (gal) | 12 000 | 12 000 | 12 000 | 12 000 | 12 000 | 12 000 |
| Boiler (Btu/h) | 43 313 984 | 43 734 356 | 41 885 386 | 46 478 120 | 46 948 246 | 44 742 811 |

Activity st. deviation: 0.63 0.64 0.56 0.55 0.58 0.61

Specification of an appraisal package

To be effective in practice, an appraisal package should embody the following characteristics:

1. Simplicity in use. It must be possible for designers inexperienced in use of computer hardware and languages to put in their scheme, modify it and interpret the results with minimum wastage of time and possibility of error.

2. Relevance of output. The output of any package must be appropriate to the current stage of design and sufficiently detailed to suggest modifications to the scheme which will lead to convergence on an optimum solution.

3. Efficiency. The ratio of the 'meaningfulness' of the output to the 'laboriousness' of the input must be sufficiently high to convince designers that a pay-off from use is likely.

All appraisal packages feature the sequential processes of representation, measurement and evaluation (and see Marcus). First, the scheme to be appraised is represented to the computer; second, the computer measures the cost and performance of the scheme; and third, the measures of this particular scheme are presented in conjunction with design criteria so that evaluation can take place.

Representation

The main problem in representing an architectural scheme to a computer is describing the geometry. The method used must be readily handled by the machine, be related easily to other variables such as site conditions, construction and structure, and be meaningful to the designer.

At outline stage in design it is appropriate to deal with 'blocks' of space which are functionally and/or environmentally disparate; at scheme design and detailed design stages the arguments are in favour of geometrical specification of the surfaces which bound the spatial elements.
Spatial 'blocks' may be represented to a digital computer in a number of ways. In the case of right parallelepipeds (as a regular shape, the opposite ends of which form three pairs of equal rectangles) some of the choices are:
1 Cartesian co-ordinates of two opposing vertices.
2 Cartesian co-ordinates of one vertex with length, breadth and height of the 'block'.
3 Polar co-ordinates of two opposing vertices.
4 Polar co-ordinates of one vertex with length, breadth and height of one 'block'.

If the sides of the right parallelepipeds are pre-coded, specification can be made by means of the co-ordinates of one vertex, or the centroid, together with the appropriate code. Additional coding can relate to the function, environmental and structural characteristics of the 'block'.

In the case of the surfaces which bound spatial elements, the geometric description of rectangular surfaces is analogous to that of right parallelepipeds but requires one less bit of information. Additional coding can relate to physical characteristics of the surface.

Representation of site conditions at outline proposals stage can be achieved by considering the site covered by a grid, to each cell of which may be allocated a numerical value relating to site conditions and ordinance height.

To facilitate subsequent evaluation it may be appropriate to input a representation of user activities as well as the representation of the configuration of the proposed scheme. The traditional relationship matrix is an appropriate form for this 1.

**Measurement**

Measurement of the scheme under appraisal is possible in two types of variables: cost and performance. For each item, as capital cost and maintenance cost, the process is one of 'taking-off' quantities and applying unit cost indexes which are kept in file. For running costs associated with services, an analysis of loadings is required.

Performance variables cover a wide field but may be categorised as follows:
1. Spatial performance. Variables associated with the relation of the scheme to the site, e.g. site utilisation, compactness, volume of cut and fill.
2. Environmental performance. Sizing of plant to maintain an acceptable environment, with costs if required.
3. Activity performance. Measures relating to the degree to which user's requirements are met.

**Evaluation**

Criteria against which cost and performance measures may be compared are of three types:
1. Constraints. Set by the client organisation, e.g. a minimum percentage daylight factor.
2. Norms. Based on a sample of cost and performance measures from previous schemes of similar size and type, e.g. mean journey time in 400-600 bed hospitals.
3. Optima. Computed maxima or minima for each variable individually, e.g. a compactness index of 100 per cent.

Constraints and optima present no real problem; constraints are either obvious or relatively meaningless. The most effective comparison criteria are norms from previous schemes of similar type and the problems are to create and maintain a data file from which these norms can be drawn. One method of achieving an effective data file is illustrated in 10. The 'working' file contains the measures of the scheme which is currently being appraised, the 'temporary' file contains the measures of a single, and most recently completed scheme of a similar type; the 'permanent' file contains the mean value of each measure computed from all previous schemes of similar type. While working on the current scheme, the designer can access the data in the temporary file and the data in the permanent file for comparison purposes. When he is satisfied that an 'optimum' solution has been reached, he can transfer the measures from this current 'optimum' scheme into the temporary file, pushing what was in the temporary file into the permanent file. In this way, the data files are generated and continuously updated.

The virtue of the temporary file is that it gives a comparative example of the relationships within two sets of appraisal measures - relationships which are obscured when mean values of each variable are computed in the permanent file.

**Acknowledgments**

The authors wish to thank the RIBA for sponsoring this work and Systemshare Ltd (Edinburgh) for their generous dispensation in the matter of pay-out for computer time used. Our colleagues in ARACUS and the Building Performance Research Unit have contributed substantially to the concept and implementation of PAGE 1.

**References**

1 WILLOUGHBY, T. M. Computer aided design of a university campus. *Architects' Journal*, 25.3.70 p733-758 [721 (A3go)]