Chapter 4

Building Appraisal

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4.1. The Concept of Appraisal

To identify the nature and role of appraisal in building design it is appropriate to refer to two well-established descriptive models representing the operation and the objectives of the design activity.

Figure 4.1 is the model of the operation of the architectural design activity proposed by the Building Performance Research Unit [1]. In common with models of the design activity relevant to fields other than architecture, the processes of analysis, synthesis and appraisal occur at each stage in the development of a design solution. The stages—outline proposals, scheme design and detail design—are taken from the RIBA Plan-of-Work [2] and are considered to represent the desired sequence within the design activity. The processes of analysis, synthesis and appraisal can be defined as follows.

Analysis. The collection, collation and correlation of all the information which is implicit or explicit in the brief. Analysis of this information involves the process of ordering it in such a way as to provide insights into the nature of the design problem and, possibly, to suggest solutions.

Synthesis. The creation or generation of formal design solutions. The process of synthesis is thus one of hypothesizing the form that the solution, or some part of the solution, might take.

Appraisal. The testing of alternative formal design solutions.
Appraisal will thus involve the representation, measurement and evaluation of the three alternatives:

1. Representation—the means chosen to model the hypothesized solution
2. Measurement—the calculation of cost and performance attributes of the hypothesized solution
3. Evaluation—the comparison of the cost and performance measures with criteria, e.g. norms, optima or constraints

As implied in Fig. 4.1, the designer may iterate between the processes of synthesis and appraisal while developing a scheme. The outcome of the appraisal process should be organized to afford the designer as much guidance as possible in his search for that alternative which best satisfies the criteria of the brief.

The objectives of the design activity, as opposed to its operation, are somewhat more difficult to define. The model in Fig. 4.2, again proposed by the Building Performance Research Unit [1], is a useful starting point.
Four subsystems are identified. On the extreme right of Fig. 4.2 is the subsystem representing the objectives of the client/user organization; in order to meet these objectives the client/user organization engages in a set of activities—the subsystem which is second from the right in the diagram. On the extreme left-hand is the subsystem representing the building hardware; the hardware exists solely to provide and maintain an environment—the subsystem second from the left.

Thus the client/user objectives give rise to client/user activities; the building hardware gives rise to an environment. The designer's task is to design the building hardware to provide an environment which will promote rather than inhibit the client/user objectives.

The capital costs of the building hardware and the recurring costs (such as repairs and energy supply) to maintain the environment, together make up the costs-in-use of the building—as such they represent the investment to be made by the client/user organization. The degree to which the activities and hence the client/user objectives are promoted, represents the performance of the building; the level of performance can thus be taken as the return on the building to the client/user organization.

Using this terminology, a definition can be formulated: the design objective is to maximize the return on the client/user investment.

The concepts contained in the two models discussed can now be combined to provide an insight into the nature and role of appraisal in design. Figure 4.3 suggests an iterative process used by the designer as he attempts to converge on an appropriate solution to the design problem. The number of variables in any design hypothesis (such as shape, construction, orientation and fenestration) is extremely large; consequently the area of search for the most appropriate solution is also extremely large. Not surprisingly, then, considerable thought has been invested in the development of computer systems for the rapid appraisal of design alternatives.

A typical computer-aided appraisal system is illustrated in Fig. 4.4. The designer represents his design hypothesis by drawing plans on to the screen of a graphics terminal (typically a Tektronix Direct View Storage Tube Terminal). The plan, suitably encoded, is passed as data from the terminal to the computer (by telephone line if the computer is remotely sited). The appraisal program within the computer interprets the data and engages in the measurement of the cost and performance attributes of the design and, when ready, outputs to the terminal the measures organized in some readily interpretable format. The designer evaluates this output and, if appropriate, modifies the form of the building accordingly.

Fig. 4.3. Iterative appraisal process used by the designer as he attempts to converge on a design solution.

Fig. 4.4. Operation of a typical system for appraisal by computer.
4.2. Appraisal of Building Form—'Steady-State' Conditions

The application of a typical program suite to the appraisal of the overall form of a building can be usefully exemplified by reference to PHASE—Package for Hospital Appraisal, Simulation and Evaluation [3]. This package, developed by the Architecture and Building Aids Computer Unit, Strathclyde (ABACUS), with financial support from the Scottish Home and Health Department and the Scottish Development Department, has already been used to aid in the outline proposals stage of the two new district general hospitals.

4.2.1. The Structure and Form of PHASE

The execution of the program is carried out in two stages. The first stage involves the inspection and upgrading of data files; the second is concerned with the appraisal routines. During this operation of the program, a dialogue is maintained with the designer. This controls the sequence of operations and allows the designer to loop-back within the program to a previous operation. A flow chart showing the structure of the program is shown in Fig. 4.5.

The building program consists of a set of data files, an input sequence, input check and an output sequence, each of which is described in turn.

For the appraisal of hospital design, a considerable amount of varied information has to be stored in a data bank. For convenience of use this information is structured into four basic data files—a standard data file, solution file, project file and scheme file.

The standard data file This file contains information on environmental conditions, cost and interdepartmental traffic associations. Where relevant, they are stored for each of 40 individual hospital departments. Environmental data include air change rates, occupancy numbers, hours of occupancy, percentage wall glazing, percentage roof glazing, day and night external temperatures, solar heat gains, thermal transmittance values and desired lighting levels. Cost data include elemental capital costs, service running costs and fuel tariffs. Association data are in the form of a matrix reflecting the traffic between each pair of the 40 hospital departments. These data are taken from such authoritative sources as the Department of
Health and Social Security's hospital guidance publications, the Scottish Home and Health Department's Hospital Planning Notes and the HIVE Guide.

The solution file. The function of the solution file is to store the cost and performance characteristics of previous projects and of earlier schemes relating to the current project. These data are accumulated automatically and are used to provide the basis for a comparative evaluation of the characteristics of one scheme against other similar schemes.

The project file. This file contains information which is likely to remain constant throughout the design project. It includes information relating to the contours and orientation of the site, the building life and interest rates. Site information is formatted by imagining a grid placed over the site. A spot height is entered on each cell of the grid. The spot heights are fed into the project file together with the angle of orientation of the grid.

The scheme file. The scheme file may be created online or, more conventionally, offline by producing a paper tape and subsequently reading the tape data into file. This file contains the three-dimensional description of the proposed scheme.

The block form is subdivided into components, which correspond to hospital departments and may number up to 40, and elements, which are used to describe a complex component by the use of rectangular blocks and may number up to six for each component.

A function number is attached to each element, identifying it with the appropriate list of standard data held on file. An index 0/1 establishes whether the element being described is on the ground or not.

The size and shape of each element is described by stating the x, y and z co-ordinates of a reference point, together with the length, breadth and height of the element and its angle of deviation from the x-axis of the site grid. From this angle the program calculates the angle to true north by accessing the project file to obtain the orientation of the site grid. This specification is compiled for all hospital departments, and when completed forms the scheme file for the run being undertaken.

Because of variations in performance specifications, operational policies, market conditions and so on, a facility for the inspection and alteration of all data prior to the execution of a program run is therefore provided. The designer is able to obtain a printout of the listing of any file, or in a specific case an edited version containing those lines specified for inspection.

A simple question and answer sequence allows the program and the appropriate set of data files to be created or selected from file. The program can thus be used by a designer who is not familiar with computer usage.

The input check involves the display, on the screen of the graphics terminal, of either the building plan, floor by floor (Fig. 4.6) or of an axonometric view of the whole building. Input errors can thus be detected and altered accordingly and last-minute changes in design intention can be incorporated. The method of effecting these modifications is described later.

Fig. 4.6. Input check of the overall floor plan on site, as displayed on the screen of the graphics terminal.
The program output is at two levels—synoptic and detailed. The synoptic output is produced automatically for each run of the program. Once the synoptic output has been obtained, the user is given the option of receiving:

1. All the detailed output.
2. Part of the detailed output
3. No detailed output, whereupon the program enters the terminating sequence.

The synoptic output, shown in Fig. 4.7, initially contains a check output of floor areas, wall areas and roof areas. The remaining measurements are produced in tabular form, in which each measure can be compared to a sample of results from existing hospitals with similar characteristics. When a solution has been fully worked out, it can be entered in the table as the most recently attempted project result. If four results are already entered, the first result that had been entered is displaced as the columns are updated with the new result.

The wall/floor ratio and plot ratio are accepted standards, either desirable or mandatory. Site utilization is a measure of the area of site covered by the building and reflects relative density. Plan compactness compares the plan perimeter to the circumference of a circle of equal area. Mass compactness compares the surface area of the solution to that of a hemisphere of equal volume.

Department location is a total travel factor—a figure produced from the sum of all the products of the associations and their respective distances, which reflects the performance of the proposed layout in relation to the conditions imposed by the departmental association. The lift dependency factor is produced from the number of vertical journeys used in the calculation of the department location factor. From these measures, and by relating the performance to the size of the hospital, an index per bed can be produced. This allows meaningful comparisons of layout to be made between hospitals of differing size.

The boilerhouse location index is produced from the sum of all the products of the heating loads and their respective distances from the boilerhouse, in a similar manner to department location.

The indicative capital and energy costs are totals produced from the relative cost tables which are presented in the detailed output. The full detailed output consists of:

1. Department location
2. Matrix of divergence
3. Boilerhouse location matrix
4. Detailed capital costs
5. Detailed energy costs
6. Heat gain/loss diagnostics for any specified number of components

**Department location.** The first section of detailed output consists of a printout of all the departmental activity relationships which have not been satisfactorily met. A list of those relationships which could possibly be sacrificed is also given in order to effect an overall improvement in activity performance.

**Matrix of divergence.** In a similar manner to the procedure adopted for department location, a matrix of divergence is produced.
to illustrate which departments have been located too far from the boilerhouse in relation to the heating load required in the department. A sample output is shown in Fig. 4.8.

Boilerhouse location. From a knowledge of the department heating loads, the maximum hourly hospital load is calculated. This occurs at a particular time—e.g., during a morning in January, and for this period the product of the loads for each department and the distance from the boilerhouse to each department are summed to produce a boiler location factor.

Detailed capital costs. A table is produced of the capital costs for a range of elements. The elements selected are those elements whose quantity significantly varies with changes in building form (Fig. 4.9).

The quantity of each element, which is measured from the design proposal being appraised, is multiplied by the appropriate cost taken from the standard data file to produce a present worth for each element. The present worth is then measured over the expected life of
the building to produce an annual equivalent cost for a given interest/life factor.

The costs measured include normal building elements such as walls, floors, roofs and windows, and in addition certain items of engineering services, including the capital cost of boilers, ventilation and air-conditioning plant.

Detailed energy costs. In a similar manner to capital costs, a table of basic energy costs is compiled. These costs are produced for heating, lighting, ventilation and air conditioning as a present worth. In addition an annual equivalent cost is produced over the expected life of the building for a given interest/life factor (Fig. 4.10).

![Table: Energy Costs](image)

**Fig. 4.10** An elemental breakdown of energy costs.

Heat gain/loss diagnostics. For any specified number of departments, a printout can be obtained of the heating loads (losses) or overloads (gains) for each department, in each month of the year, at four points during the day (Figs. 4.11 and 4.12). This is performed to study the load pattern of a hospital over a typical day.

The loads take into account heat loss through the building fabric and from ventilation, and the heat gain from occupants, lighting and solar radiation. The standard data file is accessed for the required environmental data for each department, which together with a measurement for all the surfaces of the proposed design are used to automatically produce loads for each department. These loads are based on particular departmental characteristics such as temperatures, number of air changes, hours of occupancy, times of occupancy, numbers of occupants and lighting levels, in addition to

![Diagram: Heat Gain/Loss](image)

**Fig. 4.11** Heat gain/loss diagnostics providing average heat gains and losses at four times in the day for each month, for any chosen department.

![Diagram: Heat Gain/Loss](image)

**Fig. 4.12** Degree to which heat gains raise temperatures above the desired level at four times in the day for each month, in any chosen department.
thermal transmittance and percentage glazing values appropriate to each surface of each hospital department.

Following the detailed output, or following the synoptic output if no detailed output is required, a number of questions are presented.

The first question allows the user to modify the form of his scheme by allowing changes in the geometry. The opportunity therefore exists to iteratively converge on a solution which, on the basis of the output appraisal and other non-quantifiable design criteria, appears to be the most advantageous.

The second question simply allows the user to hold the scheme in its current state of development until some future occasion. The third question provides the user with the opportunity to add this current scheme into the solution file, which is reproduced in the synoptic output each time the program is run, so that this file can be constantly updated.

If it is decided to change the geometry of the scheme, the program returns the user to the floor plans and provides a menu of commands which, along with the cursor, allows easy manipulation of the geometry (Fig. 4.13).

The cross-wire cursor is controlled in the case of the Tektronix DVST terminal by two thumb-wheels. By pointing the cursor at the command menu and at appropriate reference points, the designer can move, reshape, add to, delete from, or change the scale and planning grid of the proposal.

If a perspective view of the scheme is desired, the current geometry can be stored in file and subsequently accessed by another program which will automatically generate perspective views from any chosen viewpoint (Figs. 4.14 and 4.15).
4.2.2. The Use of PHASE in Practice

One of the main uses to which the PHASE package has been put is for the exploration of alternative generic forms for hospital buildings. Figures 4.16-4.19 illustrate four alternative formal strategies which were appraised by PHASE. Each, in turn, was modified in response to the output, and the cost/performance profiles based on the synoptic output were recorded and compared in Fig. 4.20.
The baseline in each cost/performance profile is the numerical average for each attribute taken over the entire set of alternative schemes. The cost/performance measures for any individual scheme thus represent the percentage deviation, on each attribute, from the norm; conventionally 'good' has been plotted above the baseline, 'bad' below the baseline.

Fig. 4.18. Strategy C for the form of a hospital building: communications—double linear wards—linear.

Fig. 4.19. Strategy D for the form of a hospital building: communications—double star with spurs wards—semi-deep.

4.3. Appraisal of Building Operation—'Dynamic' Conditions

As described in Section 4.2, the package PHASE appraises the built form under 'steady-state' conditions. The suite of programs known as PHASE is considerably more extensive than implied in Section 4.2 and is capable of dealing with the more dynamic operational characteristics of the built form and includes staff movements, services and energy distribution and cyclic heat flow.
The appraisal, i.e. the representation, measurement, and evaluation of the more dynamic aspects of building performance requires computer models which are somewhat different from those utilised in static-state conditions although both may be successfully combined in one suit of programs. To illustrate the main characteristics of dynamic appraisal, the program known as AIR-Q developed by ABACUS, with funding from the Science Research Council, will be described. The logic embodied in the AIR-Q program aims to aid the designer in the problem of appraising the adequacy of any proposed passenger-handling system with an air terminal complex, which is subject to various loads arising at certain times of the year, month, or day. The main elements of the passenger-handling system are shown diagrammatically in Fig. 4.21. In reality, the network of passenger flow is far more complex than that shown.

Fig. 4.21. Main elements of an air terminal passenger-handling system.
movements and processes is exceedingly complex; the pattern of flow in Fig. 4.22 is typical of a major air terminal. Such a network, in which the nodes represent an activity (performed on or by a passenger) and the links between nodes represent possible directions of movement, whether of the whole airport system or part of it, provides a convenient model through which it is possible to simulate passenger movement.

The input to the program AIR-Q consists of the network itself, the service parameters and the system throughput.

Network. Figure 4.23 shows the network representing part of the passenger-handling system as it is assembled by the designer on the graphics screen using the cursor and menu. Octagonal nodes represent entries to the system at which arrivals are randomly distributed over specified times of the day. Diagonal nodes represent 'trigger inputs' at which arriving passengers are fed into the system according to bus or aircraft schedules. Square nodes are normal process stations (such as check-in and baggage reclaim) and double square nodes represent process stations which are operational only during 'opening times' (such as bank and bar). Links, to which the percentage split of passengers is associated, can be 'normal' (shown full) or 'trigger' (shown dashed).

Service parameters. For each process node the designer inputs a number of servers and a serving time. Serving time would normally be input as the mean and standard deviation of a negative exponential distribution from which the program selects specific values for each passenger. The program can automatically increase or decrease the number of servers in response to the queue size.

Throughput. The throughput, related to bus and aircraft schedules, can be the normal expected loading on the system or any hypothesized loading associated with anticipated schedule delay and growth in passenger numbers. The program operates by tracing, over the simulation period, the history of passenger movement through the system. For each time interval within the simulation period, records are stored which can be interrogated and output by the program user. Two types of output can be obtained:

1. The level of overcrowding, which is related not only to excess population in any part of the system but also to the length of time the excess occupies the available space
2. The time spent by a passenger, either queuing or waiting

Overcrowding information is output on the screen in the form of histograms of queue size and queueing time over any chosen period (Fig. 4.24); each distribution is summarized by a mean and standard deviation. Average passenger process time for any period over any route can also be output and compared with target figures.

The program AIR-Q, with the help of the British Airports Authority, has been successfully used and validated in the context of two Scottish airports.
4.4. IMPLICATIONS FOR THE PROFESSION

Although the PHASE and AIR-Q programs may appear, superficially, to be somewhat different, both fall within the definition of \textit{appraisal}, as characterized by Figs. 4.3 and 4.4. In PHASE, the designer hypothesizes alternative geometries and constructions for the building and the program responds with measures of cost and performance; in AIR-Q, the designer hypothesizes networks, service provisions and throughputs and the program responds with measures of performance.

Both programs allow the designer to decide, iteratively and explicitly, on an appropriate design solution.

The principle of appraisal by computer can be, and indeed has been, extended over a wide range of building types (including schools [5] and housing [6]) and over a wide range of building subsystems (including lifts [7] and engineering services [8]). As acceptance of the value of explicit appraisal grows, the implications for professional working will become obvious.

One major pay-off may be in the degree to which effective collaboration between members of the design team will be promoted. A common model of the design concept could be accessed by each member of the design team—architect, structural engineer, services engineer, quantity surveyor—from a terminal in his/her own office. Proposals initiated by any one member of the team could be immediately appraised by all the other members, thus reducing the costly delays and misunderstandings inherent in the tradition mode of working.

Indeed the fact that the model is largely explicit may mean that the design team could usefully be extended to include representatives of the client/user organization. The fact that cost/performance

\begin{figure}
\centering
\includegraphics[width=0.8\textwidth]{image}
\caption{Fig. 4.24. Histograms output by the computer, showing the populations at any node or group of nodes during any chosen time interval.}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=0.8\textwidth]{image}
\caption{Fig. 4.25. Use of appraisal software in two distinct situations: as a design aid in a specific problem (lower loop) and as a means of establishing generalized causal relationships between design and cost/performance variables (upper loop).}
\end{figure}
implications are made explicit may re-focus the attention of the design team on the value judgements which have to be applied in order to choose between alternative cost/performance profiles: value judgements are properly the province of the client/user representatives.

So far, use of appraisal programs has been discussed in the context of individual building design projects. Ultimately, a more fundamental and important use may emerge in the exploration of the causal relationships existing between design variables and cost/performance variables. To explore the causal relationship between, say, shape and, say, energy costs, the designer can make several passes of the program; in the series of runs he keeps all design variables constant, except shape which he varies on each run in a systematic way. From the output he can trace the effect of change of shape on energy costs, or indeed on any other of the cost/performance measures. This use of appraisal software is represented by the upper loop in Fig. 4.25. Quite clearly the generalized relationships thus established can guide the designer in the course of using the program in a real and specific design problem.

![Diagram](image)

Fig. 4.26. Experiential appraisal: visual.

4.5. ACKNOWLEDGEMENTS

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REFERENCES