Note on the computer as an aid to the architect

By G. R. Fair, A. D. J. Flowerdew, W. G. Munro and D. Rowley*

This paper is a description of a computer program written to evaluate the design of houses built from a pre-specified set of industrialized building components. This program was used as part of the display at the IBIS stand in the 1964 Industrialized Building Systems and Components Exhibition.

There is at present much interest in "building systems"—methods of building in which components varying in size from foot-wide wall panels to complete floors are made in a factory and assembled on site.

One such system† consists of a set of components—wall panels, door and window panels, heating and plumbing units, staircases, structural columns and so forth. These comprise a complete "kit of parts", which are designed to a common 4 in. module and can be fitted together in almost any arrangement, so long as the components are set in position on the "tartan grid" illustrated in **Fig. 1.** Wall units, doors and windows lie along the grid lines between the intersections; columns at the intersections. A full description of this system will be found in *The IBIS System*—a descriptive booklet issued at the Richard Thomas and Baldwins—Pressed Steel Company stand at the 1964 IBSAC Exhibition. See also Gordon (1965) and Williams (1965).

The variety possible with this system, and its modular basis, suggested that a computer could usefully carry out many of the routine checks and calculations which an architect must undertake. Freed from this work he would then be able to explore more fully the design possibilities open to him.

Such a computer system is described here. It was produced in great haste for demonstration at the 1964 IBSAC Exhibition and as such incorporates only a sample of the various checks and calculations possible.

The computer system as demonstrated

Visitors to the exhibition were invited to design houses by laying out symbolic components on planning boards marked with the tartan grid, as shown in **Fig. 2.** The type, position and orientation of each component were punched onto paper tape and fed to the computer, which then drew a plan of the design in about four minutes, using a digital plotter. This exposed any errors in data preparation, which were then corrected.

For each room, the computer calculated and listed dimensions, area, heat losses, the light level provided by the windows, and the level of artificial lighting required.

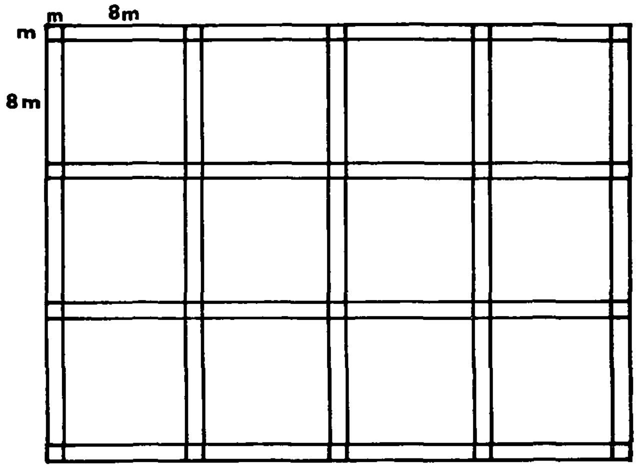

Fig. 1.—The tartan grid

Some aspects of the design—the provision of bathrooms and lavatories, and of storage space, and the ratio of "circulation" space (halls and landings) to the whole, were checked against current standards of "good design".‡ The design was also checked to ensure that it was structurally sound, and that the proposed arrangement of components satisfied the disciplines of the building system with regard to plumbing, ducting, etc. Finally the components used were listed. A typical plan and listing are shown in **Figs. 3a** and **3b.** (Fig. 3b is the analysis of a design of which Fig. 3a is the ground floor.)

If the computer exposed some deficiency in the design, the visitor could amend the planning board, whereupon the corrections were fed to the computer and the checks repeated. This process could be continued until both architect and computer were satisfied.

At the exhibition a number of architects and builders went through this procedure. Their general reaction was very favourable, once they had realized that the computer was not usurping their creative function.

Most of the designs were for fairly conventional local-authority housing, but there were some interesting

† The IBIS system, designed by Alex Gordon and Partners. The idea of using a computer was first developed by Ken Claxton of A.G.P.

‡ Mainly derived from the Parker Morris report: *Homes for Today and Tomorrow.*

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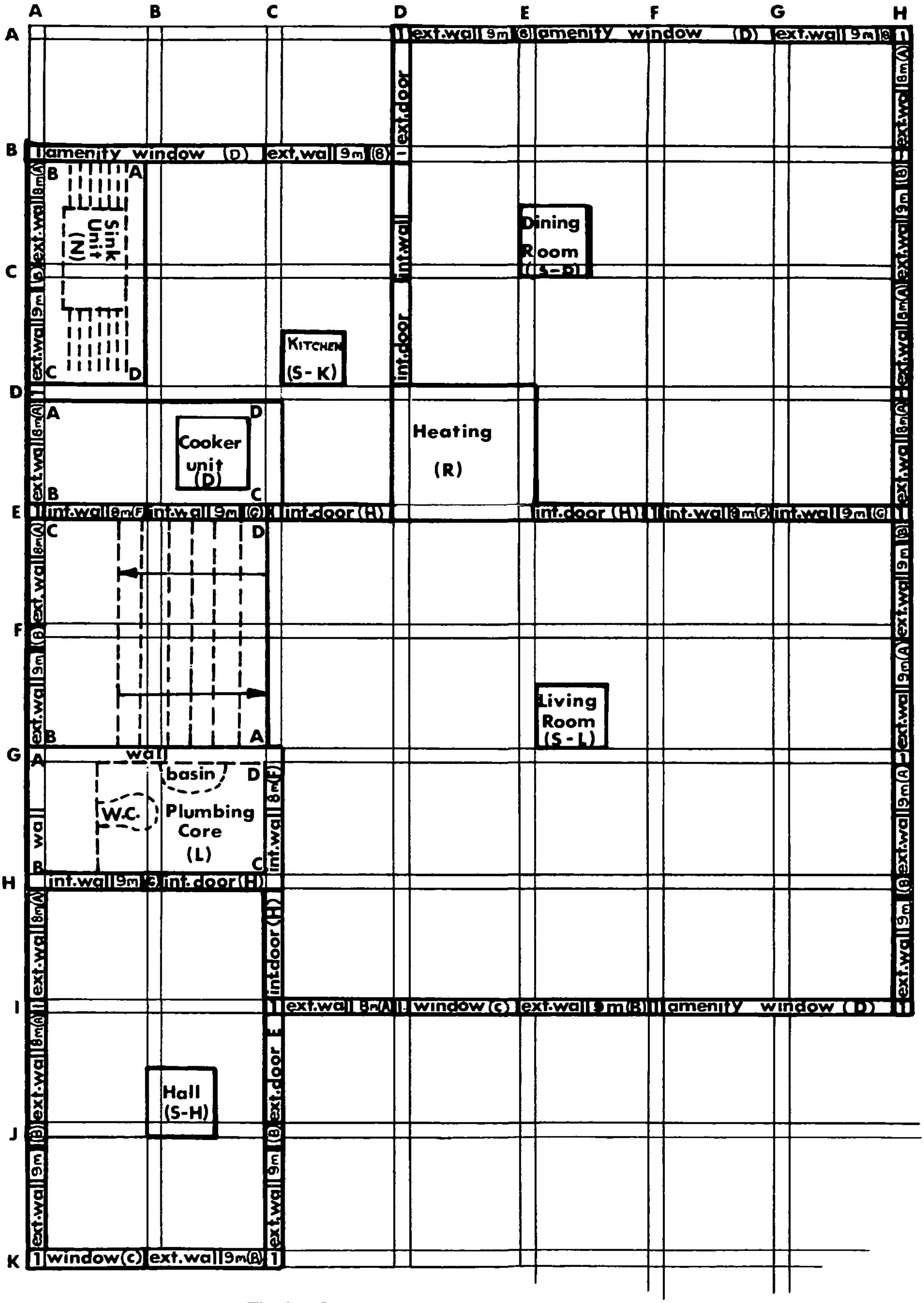

Fig. 2.—Ground floor plan laid out on planning board

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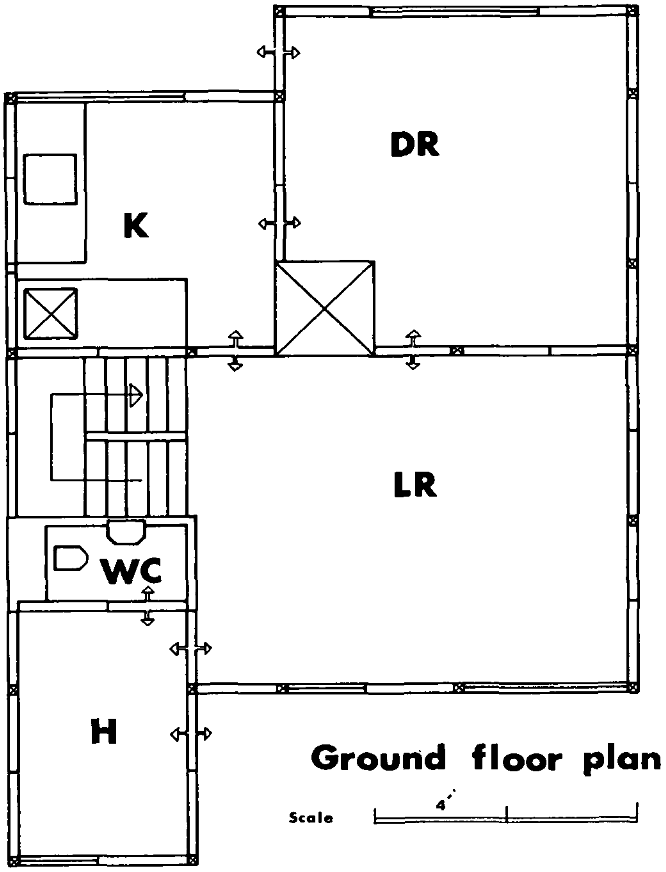

Fig. 3a.—IBIS check plan produced by digital plotter

ROOM SIZES AND HEATING REQUIREMENTS

GROUND FLOOR	FLOOR AREA (SQ. FT.)	MAXIMUM DIMENSIONS	HEATING REQUIRED (BTU/HR)
HALL	49	8′8″X 5′8″	1800
LIVING-ROOM	173	11′8″X 20′8″	7500
W.C.	15	2′8″X 5′8″	600
KITCHEN	75	8′8″X 8′8″	2800
DINING-ROOM	127	11′8″X 11′8″	4700
FIRST FLOOR			
BATHROOM	32	5′8″X 5′8″	1200
BEDROOM 1	136	11′8″X 11′8″	5000
LANDING	33	11′8″X 8′8″	2500
BEDROOM 3	68	8′8″X 8′8″	2500
BEDROOM 2	136	11′8″X 11′8″	5000
STORAGE	7		

ROOM LIGHTING

GROUND FLOOR	LIGHT LEVEL REQUIRED (LUMENS/ SQ. FT.)	DAYLIGHTING PROVIDED (LUMENS/ SQ. FT.)	ARTIFICIAL LIGHTING NEEDED (WATTS)	WINDOW AREA (SQ. FT.)
HALL	7	10	70	10
LIVING-ROOM	7	15	240	48
W.C.	7	0	20	0
KITCHEN	15	20	220	38
DINING-ROOM	7	16	190	38
FIRST FLOOR				
BATHROOM	7	11	40	10
BEDROOM 1	7	17	190	48
LANDING	7	0	40	0
BEDROOM 3	7	19	90	38
BEDROOM 2	7	14	190	38

BOILER SIZE REQUIRED IS 36000 BTU/HR.

TOTAL AREA IS 913 SQ. FT.

CIRCULATION AREA IS 15% OF TOTAL.

STORAGE AREA IS 1% OF TOTAL.

STORAGE AREA IS ADEQUATE FOR 0 PERSONS.

LAVATORY PROVISION IS ADEQUATE FOR 5 PERSONS.

STRUCTURAL CHECK

	A	B	C	D	E	F	G	H	I	J	K	L	M
A													
B				1	•	•	•						
C	•	•	•	•	•	•	•						
D	•	•	3	2	2	2	2						
E	•	•	•	2	2	2	2						
F	•	•	•	2	2	2	2						
G	•	•	•	•	•	•	•						
H	•	•	•	•	•	•	•						
I	•	•	•	•	•	•	•						
J	•	•											
K	•	•											

• STRUCTURALLY OK.

1 UNSUPPORTED COLUMNS.

2 NO STRUCTURAL BAYS.

3 STAIRCASE COLUMNS OMITTED.

HEATER TO FLUE OK

PLUMBING CORE TO PLUMBING CORE OK.

BATH TO PLUMBING CORE OK.

Fig. 3b.—Computer print-out

exceptions. One visitor produced a design for the Parthenon (for which the heating was inadequate), and another, less ambitious, for an Irishman's bothy for 10 persons and a pig (in which the heating was more than adequate, probably because there were no windows).

Programming methods used

The programs were written in a hurry and are neither elegant nor "efficient". They were, however, general enough to handle some very odd designs, and an account of them may be of interest.

The main problem was to find a general method of deciding what rooms were defined by a given list of components and their positions. It was essentially an exercise in pattern recognition. It was necessary to allow not only for rectangular but also for L-shaped, U-shaped and even O-shaped rooms.

Referring to **Fig. 4**, the space between adjacent sets of grid lines running across the page is called a "row". Components running up and down the page divide rows into "sectors". The components are sorted so that the program examines each sector in turn, starting with the bottom left-hand corner and following along that row, then back to the left-hand end of the next row, and so on. In the rather cramped (in terms of living space) example shown, the component arrangement defines 17 sectors A–Q. The odd shape was chosen to demonstrate the program logic. The program processes them thus:

Sector A—part of the outside world
Sector B—begins a room, room 1
Sector C—begins another room, room 2
Sector D—part of the outside world
Sector E—part of the outside world

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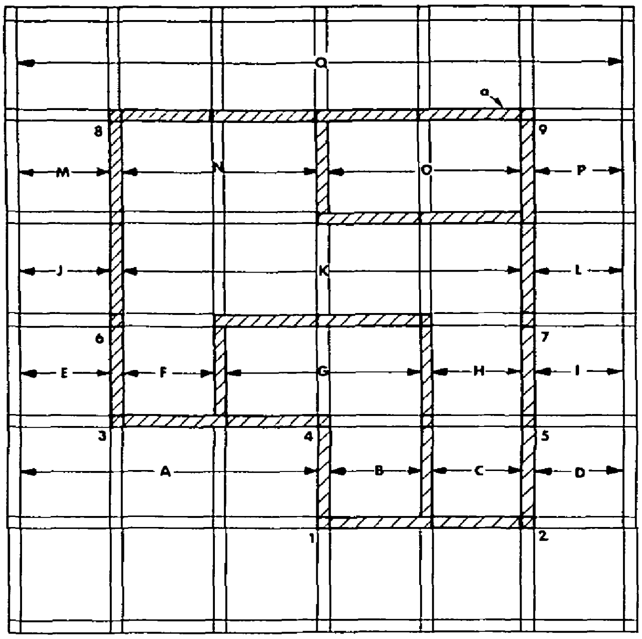

Fig. 4.—A possible component layout, and the "sectors" into which the program breaks it up

Sector F—begins another room, room 3
Sector G—connected to room 1
Sector H—connected to room 2
Sector I—part of the outside world
Sector J—part of the outside world
Sector K—connected to rooms 2 and 3, so they are in fact a single room, room 2
Sector L—part of the outside world. Room 1 has received no "contribution" from this row and is therefore complete
Sector M—part of the outside world
Sector N—connected to room 2
Sector O—begins another room, room 3
Sector P—part of the outside world
Sector Q—part of the outside world. Neither room 2 nor room 3 has received a contribution from this row and both are therefore complete. End.

Solution—Room 1—sectors B and G
Room 2—sectors C, F, H, K and N
Room 3—sector O.

If the component "a" were not present, then in processing sector Q, the program would recognize that Q was connected to O, and so that O was in fact part of the outside world, and not room 3 as it originally appeared. It is necessary to process the "outside world" sectors in case this sort of connection occurs. In Fig. 4 only wall-type components are shown. There can also of course be staircases, bath units and so forth, but these do not themselves define rooms.

Rooms are given names, by which they were referred to on the print-out, by placing "label" components within their boundaries. As the program processes the sectors in turn, so it accumulates information about the rooms, their area, dimensions, and the number of doors, windows, and external wall components they contain.

This information is used in the heating and lighting calculations. In calculating heat loss account is taken of losses through walls, windows, foundations and roof, as well as those due to air changes. This calculation is more rigorous than those on which many domestic central-heating estimates are based, but is still capable of considerable refinement. Lighting is a much more complex subject. Accurate calculations cannot be made without knowledge of the surrounding sky-line and of the orientation of the house. The formula used is an approximate one based on window and floor area and dimensions, and could be improved.

In this building system, structural support is given by "bays", rectangular arrangements of four columns with beams joining the tops of the columns. Because of limitations on beam lengths only certain bay sizes are allowed. Every part of the building must be covered by a bay, but in addition, staircases have to be surrounded by bays of particular sizes, and may not be crossed by other bays. In multi-storey buildings, columns on upper floors have to be supported by columns on lower floors.

The program analyses the bays that can be formed by the columns used. This defines the area which is correctly supported and which is then compared with the area enclosed by the building. The results of this comparison are printed as shown in Fig 3b, with a symbol for every grid square within the building. Each square is either adequately supported (*), not covered by a structural bay (2), in an unsupported staircase well (3), or near an unsupported column (1). This semi-pictorial presentation proved very useful in locating errors on the planning board.

Baths and sink units had to bear one of a specific set of spatial relationships with the service duct in the plumbing core, as did flue units with heaters. The program checked actual arrangements against these relationships and noted errors.

Possible extensions

At the exhibition it took about 30 minutes to punch, draw, repunch, analyse and list for each design. Automatic input planning boards and components and visual display output devices could be used to cut this time to less than a minute, although this might be expensive.† Several such input/output stations could use one computer on a time-sharing basis, so that each architect could "doodle" on his planning board and have his designs analysed continuously.

Details of past designs could be stored on discs or tapes, and those of any particular type displayed, for modification to meet a particular requirement. Cost information could be included, as could consideration

† A method using a light pen on a cathode-ray tube is now being developed by Mr. W. M. Newman of Imperial College. (*See Mr. Newman's paper on* p. 21 *of this issue.—Ed.*)

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of further ergonomic and planning factors. It may also be possible to undertake some actual "design-by-computer"; for example, the placing of columns and beams to achieve an adequate or even an optimal structure.

Conclusion

Computer systems can be constructed which offer a very useful service to an architect designing in a modular, component-based building system. Experience with the demonstration system showed that architects would welcome this assistance.

Acknowledgements

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The IBIS System, obtainable from the IBIS Office, Richard Thomas and Baldwins Limited, R.T.B. House, 151 Gower Street, London, W.C.1.

Book Review

Computer Augmentation of Human Reasoning, edited by Margo A. Sass and William D. Wilkinson, 1965; 235 pages. (London: *Macmillan*, 40s.).

Inevitably this volume will tend to be regarded as a sequel to *Computers and Thought* (reviewed here in October 1964). Neither book suffers by the comparison, the obvious differences stem from the welcome advance in the subject and consequent shifts of viewpoint and emphasis amongst those contributing to that advance.

The book includes eight prepared papers, a "keynote speech" and a verbatim record of a final panel discussion on Potential Implementation. Both the speech and the discussion could well have been subjected to some editing before publication, the former in particular is printed as a string of ill-matched jocularities whose sheer ineptitude is offensive in the company of the excellent, prepared papers. The panel discussion could do with the excision of the noise inevitable in extempore delivery.

The eight papers range from theoretical consideration of heuristic problem solving to implementation systems and hardware. The occasion for their presentation was a symposium held in June 1964 and sponsored by the *US Office of Naval Research* and the *Bunker–Ramo Corporation.* Two of the contributors came from industry, the others from academic bodies, despite which the emphasis throughout is on currently practical implementation.

The panel discussion is noteworthy for the contributions of Jordan J. Baruch, a consultant, who throughout draws on his experience in the implementation of a hospital medical information system for illustrations of both systems procedures and user reaction. The other panellists concentrated more on the financing and management of research in this area than on actual implementation experience, an emphasis that illuminates economic desiderata and considerations, as well as user requirements, to some effect.

The book is concluded with a bibliography of some 400 items relevant to the theme of the symposium.

The general impression left by the work presented is that the development of central processors and mass storage is sufficiently far advanced to enable us to plan effective aids to human reasoning. What is not clear is that we have sufficient grasp of the nature of our own requirements and activities to implement these computer aids, and in a European context that we have good and cheap enough communications facilities to enable potential users to have adequate access to the information systems.

H. D. BAECKER

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