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A computer-aided architectural design system for the analysis, synthesis and appraisal of domestic activity spaces and house plans.

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1981

A COMPUTER–AIDED ARCHITECTURAL DESIGN SYSTEM FOR THE ANALYSIS, SYNTHESIS AND APPRAISAL OF DOMESTIC ACTIVITY SPACES AND HOUSE PLANS.

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SUPERVISION ARRANGEMENTS.

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DECLARATIONS.

1. Content of Work.

1.1. The candidate has not, while registered for this CNAA Ph.D. submission, been a registered candidate for another award of the CNAA or of a University during the research programme.

1.2. None of the original material contained in this thesis has been used in any other submission for an academic award. Acknowledgements for assistance received are given under the heading of Acknowledgements, and any excerpt from other work has been acknowledged by its source and author.

2. Advanced Studies.

These included attendance at a Fortran computing and programming course of the Mathematics Department of the Robert Gordon's Institute of Technology in the Autumn term of session 1977/78, as well as an advanced course of reading directed by the project supervisors, which sources are indicated in the Bibliography.

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1. References.

1.1. Bibliographical references are placed within round brackets at appropriate positions in the text, e.g. (1.1), (6.3) etc., where the first numeral refers to the section number and the second numeral to the reference number. These sectionalised references can be found under the section headed References.

1.2. Author's comments or references to other parts of the thesis or to figures or tables are also placed within round brackets, e.g. (this could be disputed), (See Section 5), (See Fig. 2.3), (See Table A3.2).

1.3. Where a table or figure from another source has been used in its original form the word <u>from</u> appears following the table head or figure caption, followed by the reference entry, e.g. From Jones, E.(14.5), or if the original table or figure has been altered in some way the word <u>after</u> is used instead, e.g. After Jones, E.(14.5).

2. Abbreviations.

A number of frequently used or long names of organisations etc., have been abbreviated in the text, references or in the bibliography, and these are fully described in Sub-section R1, headed Abbreviations. Other abbreviations are those in common usage.

3. Terminology.

Novel nomenclature is defined within the text where the new concepts occur.

KJARTAN LANGSKOG: CNAA Ph.D. THESIS ABSTRACT. JUNE 1981.

A COMPUTER–AIDED ARCHITECTURAL DESIGN SYSTEM FOR THE ANALYSIS, SYNTHESIS AND APPRAISAL OF DOMESTIC ACTIVITY SPACES AND HOUSE PLANS.

Investigations on functional aspects of domestic activity spaces and of other related design theories has led to the formulation of novel design models for the analysis, synthesis and evaluation processes of house design. A theoretical model of the 2–D plan layout of activity spaces was first developed so as to allow appraisal of the space utilisation efficiency of such layouts, taking into account the distribution of elements (predominantly furniture and fittings) and the user space required for using these elements, and also to allow for the development of a model to "assemble" and combine these elements to form activity spaces.

For the synthesis design process a model was developed, according to which layouts would be assembled on 5 design levels, each level being defined by its layout size and type, using modular elements from the lowest of these design levels, which contained a library of domestic planning elements, and taking into account layout design on dimensionally co-ordinated grids. Any intermediate plan level would be worked on, as desired, to arrive at level 5, the complete floor plan. Subsequently, a computer graphics program was obtained, amended and complemented, which allowed implementation of the synthesis design model, thus providing the interactivity and flexibility required for the "manipulation" of planning elements.

For the appraisal design process, a mathematical method of evaluating proportional floor area usage of activity spaces was developed, based on a penalty system containing three main penalty factors: one, a penalty factor based on the cumulative effects and degree of admissibility of overlaps of various elemental sub-areas, each area relating to the nature of the associated activity performed; two, a penalty factor based on the economy of the perimeter length of the activity space; and three, a penalty factor based on the economy of proportional floor area consumption within the activity space. The appraisal process becomes iterative with various layout alternatives being investigated as the designer attempts to improve solutions towards some optimum layout. A numerical computer program was obtained and substantially rewritten and complemented to enable both numerical and graphical output by separate programs which operated in conjunction with the synthesis graphics program to allow evaluation of layouts according to the proposed evaluation model.

Together with specifications for a computer program which, when implemented, will provide the designer with a design information retrieval system for use at the analysis design process, the developed programs constitute a novel CAAD system,of particular relevance at Stages C (Outline Proposals) and D (Scheme Design) of the R.I.B.A. Plan of Work. The system provides the architect with a flexible design and appraisal technique, which increases the speed and more importantly, the quality of his work in designing adaptable, marginal layouts, and lends itself to a number of other space utilisation applications as well as forming an excellent basis for design participation.

SECTION 1: INTRODUCTION

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INTRODUCTION.

The work contained in this thesis is concerned with the advancement of novel models of the design, nature and evaluation of domestic layouts, and the consequential implementation of these models by a package of computer graphics programs. In this first section the research project is described in outline, and in addition a brief guide to the thesis is presented for the benefit of prospective readers.

1.1. Project Introduction.

The background to the project, its nature and outcome is as follows:

1.1.1. Background of the Research Project.

The work was conceived from the author's interest in the nature of the design process, and a keen interest in house design. It was observed that several problems existed in the design of domestic layouts, and that these often were the cause of shortcomings in the quality of such layouts. The need for cost effective designs often leads to severe reductions in floor area, and if careful attention is not paid to possible furniture arrangements within rooms, the inevitable results are non-ergonomic spaces, or spaces which invite a low spatial standard and are not adaptable for several uses. The time allocated to designing such marginal spaces is usually short as the cost yeardstick, both in the private and public housing sector, does not allow for time-consuming exercises and economy is the overriding factor.

The results of these cut-cost policies are well known: user dissatisfaction, lack of storage areas, non-adaptable spaces, cramped furniture layouts, no possibility of extension and many others. In todays economic climate the answer to these problems is not going to be an increase in floor areas and more time allowed for the design stage. If anything, further cutbacks of these factors will follow. To ensure decent spatial standards or comfort another remedy had to be found soon, because errors in housing designs are multiplied extremely quickly.

Set against this background, there is a strong social reason for minimising the design errors at the drawing board stage and, bearing the nature of the design process in mind, it was considered that this could best be done by improving design techniques and finding methods of quickly evaluating layouts.

1.1.2. Nature of the Research Project.

Thorough investigation of the generally accepted model of the design activity (See Fig. 2.1), which consists of the analysis, synthesis and appraisal activity stages, and the isolation of shortcomings in modern built houses, clarified the necessary purpose of the work to be as follows:

1. To improve the flexibility and speed of design techniques at the synthesis design activity, probably by the use of computer graphics.

2. To develop a method of evaluating domestic layouts at the appraisal activity, which probably could only be done with satisfactory speed by means of the computer, giving the architect an objective assessment of a layout in addition to his own subjective assessment.

3. If the computer was to be used then it would be sensible to allow for a design information bank system which could be utilised at the analysis design activity, and which would further save time.

Considering the time and resources available for the project, it was decided to limit the scope of the work to include only the development of analysis, synthesis and evaluation techniques relating to 2-dimensional layouts of domestic activity spaces or room layouts. In architectural terms, use of such design models and techniques would be of particular relevance at Stages C and D of the RIBA Plan of Work. Because of the time scale involved it was also decided to make use of existing relevant computer programs, if available, and to acquire programming assistance where necessary.

The method and sequence of the work has been as follows:

1. A thorough investigation was made of functional or planning aspects of the plan layout of activity spaces, and a comprehensive study was made of related design theories and systems.

2. Based on the preliminary functional investigation a theoretical model of the plan layouts of activity spaces was developed in such a way as to allow appraisal of the efficiency of such layouts. This entailed mainly a classification of layout space areas.

3. A detailed model of the synthesis design process was developed which allowed the 'assembly' of domestic layouts on a number of design levels, each defined by its layout size and category. At the lower end of this scale was a library of house planning elements, such as furniture, wall elements, stairs, windows, doors and so forth, and at the top level would be complete floor plans. It was recognised that means of quick assembly and manipulation of planning elements into layouts could only be achieved through use of computer graphics.

4. A theoretical method of evaluating the efficiency of activity spaces was developed which took into account the distribution of planning elements and the user spaces required for using these elements. A number of area and perimeter parameters pertaining to activity space layouts were defined, including overlapping areas of elements and user spaces, and interrelationships of such parameters produced a formula for the efficiency of activity spaces. This efficiency measure contains three penalty factors, as follows:

   4.1. A penalty factor based on overlapping areas of element space categories and associated penalty weighting factors.

   4.2. A penalty factor based on the economy of the perimeter enclosure of the activity space.

   4.3. A penalty factor based on the economy of proportional floor area usage within the activity space.

5. A sample of activity space layouts were chosen and these were evaluated manually according to the proposed evaluation method.

6. Test subjects were asked to assess a selection of the activity spaces used in the manual evaluation test, and the questions of the associated questionnaire were coaxed in such a way as to allow a comparison between the objective and subjective activity space evaluation results.

7. Statistical tests showed that there had been no sample agreement among subjects in the subjective test, and that no positive correlation could be shown between the objective and subjective tests. This would seem to indicate that layout evaluations of the kind proposed by the developed method can not be carried out subjectively.

8. Consequently, existing computer programs were obtained, which satisfied part of the requirements for the synthesis and evaluation methods proposed. These programs were subsequently amended and complemented so as to make implementations of the proposed design methods possible, and a model for a complete CAAD system was formulated, which included specifications for an analysis design information program.

9. Finally the programs were validated as follows:

   9.1. The numerical evaluation program was used to obtain results for the sample of activity spaces previously used for the manual evaluation runs, and the two sets of results were found to be identical, thereby proving the accuracy of the program.

   9.2. The specified and implemented programs were reconsidered in respect of their user ergonomics, and found, subject to hardware changes, to be satisfactory.

1.1.3. Results and Impact of the Research Project.

The outcome of the work was the previously mentioned specified and implemented analysis, synthesis, layout and evaluation models and their associated computer graphics and numerical appraisal programs. These programs have so far only been used within this research project and have therefore as yet had no practical impact on the design of domestic layouts. The program validations have shown that the main objectives for improvement of the synthesis and evaluation design processes have been met by the programs, and that they are now ready, subject to refinements discussed in Section 12, to be used in practice as novel design aids.

1.2. Guide to the Thesis.

The thesis should be of interest to two types of readers: one being architects who wish to use the developed programs to design and evaluate domestic layouts, and one being research architects interested in (house) design and development of the proposed and other design techniques. The reader wishing simply to use the programs need only read Sections 1, 4, 5, 8, 9 and 10, whereas the reader wishing to carry out further research will also need to read Sections 2, 3, 7, 11 and 12.

Section 2 of the thesis is devoted to an investigation of functional aspects of domestic layouts. Initially a list of domestic spatial activities is drawn up, and an associated library of design elements is detailed. Rules for the combination of elements are developed and element and layout areas are classified into space categories, resulting in a theoretical model of an activity space, as well as proposals for improvements in the analysis, synthesis and evaluation design techniques and methods.

Section 3 contains an investigation of the principal existing domestic design systems and theories found. The investigation concentrates on how the various theories relate to the design techniques needed in order to improve the design of domestic layouts, and advantages and shortcomings are discussed.

Based on the investigations made in Sections 2 and 3, novel models for the analysis, synthesis and appraisal design processes are advanced in Section 4. The synthesis design model is based on how layouts can be assembled at various design levels defined by their layout size, from a library of house planning elements, which constitutes the lowest library called design level 1. The evaluation model is based on the concentrated floor areas contained within an activity space, including elemental overlap areas, and perimeter length, and on how these various parameter values interact. A formula is developed for the efficiency of floor area usage of layouts, in which penalties are incurred for elemental area overlaps, excessive perimeter length and excessive overall area within an activity space.

Section 5 describes an experiment in which an actual sample of activity spaces are manually evaluated using the developed evaluation method, and shows how the method is practicable and the value of the evaluation results.

Section 6 describes an experiment in which test subjects are asked to evaluate a selection of activity spaces used for the manual evaluation experiment. Subsequently, statistical tests are made to investigate the sample agreement between subjects and the ranking correlation between efficiency ratings of the objective and subjective tests. Lastly, the need for computer implementation of the design system is shown to have been established.

Section 7 contains a survey of relevant existing and available computer programs which would be suitable for implementing the proposed design models, and a choice and description of these programs are made.

Section 8 contains a description of the complete CAAD systems model and its optimum as well as available hardware and software.

Section 9 is devoted to specifications of amendments and changes to the computer programs which were obtained, as well as specifications for additional programs, particularly for the numerical evaluation method. The programs are grouped as analysis, synthesis and evaluation programs into a package called CHAISE.

Section 10 is a temporary program manual for the currently implemented programs, and Section 11 contains a program performance validation. The sample of activity spaces used for the manual evaluation run are input to the synthesis graphics program and the stored layout data structures are used as input to the CRUNCH numerical evaluation program to obtain evaluation results, which are compared to the manual evaluation figures. User ergonomics of the various programs are also discussed.

Finally, Section 12 deals with discussions of the appropriateness of the proposed design models and whether their requirements are met by the resultant CAAD programs. Ending the chapter is a sub-section which contains suggestions for how the CAAD system can be extended and used in future work.

SECTION 2: AN INVESTIGATION OF FUNCTIONAL ASPECTS OF DOMESTIC LAYOUTS

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AN INVESTIGATION OF FUNCTIONAL ASPECTS OF DOMESTIC LAYOUTS .

2.1. Introduction.

This section describes the investigations of functional aspects of domestic functional space layouts that were necessary to study in order to form a basis for and, to advance the intended design system. Section 3 deals with existing design systems that were studied which could be seen to be related to the proposed design system of this work. Another basis for advancing the design system is practical architectural design experience and observations.

The above mentioned investigations along with an examination of the architectural (or any) design process itself led to an identification of particular areas within the process where it was thought that techniques and methods should be improved. Several sources were studies on the subject of the design process and design methods (2.1 – 2.13). The model proposed by Markus and others (Fig. 2.1), is iterative between the synthesis and appraisal activities on each design stage. This iterative phenomenon is a crucial basis in searching for appropriate design techniques, although it would appear that decisions are not taken once and for all at each design stage, but rather that problems are solved to varying degrees of completion at each of these stages. That is to say, decisions are not only taken iteratively between design activities of any one design stage, but they would seem to be taken iteratively between design stages as well. This latter concept implies that design is a multi-dimensional and lateral activity, rather than a linear design activity.

Looking specifically at the Outline Proposal and Scheme Design Stages of the RIBA Plan of Work (2.15), it was found that the shortcomings of existing design systems and techniques (See section 3) are as follows:

1. Their lack of providing the architectural designer with a flexible and instant means with which he can generate or synthesize solutions to layout problems, and in particular layout problems concerning domestic activity – spaces.

2. Their absence of techniques and models capable of objectively assessing the "efficiency" of layouts in terms of floor area usage of domestic (or any) activity – spaces, at the appraisal design process or activity (See Fig. 2.1 for use of words; process, stage etc.).

This growing realisation of shortcomings of conventional design systems (usually pencil and tracing paper at the synthesis process, and the designer's subjective assessment only at the appraisal process), prompted and was the reason for the functional investigation.

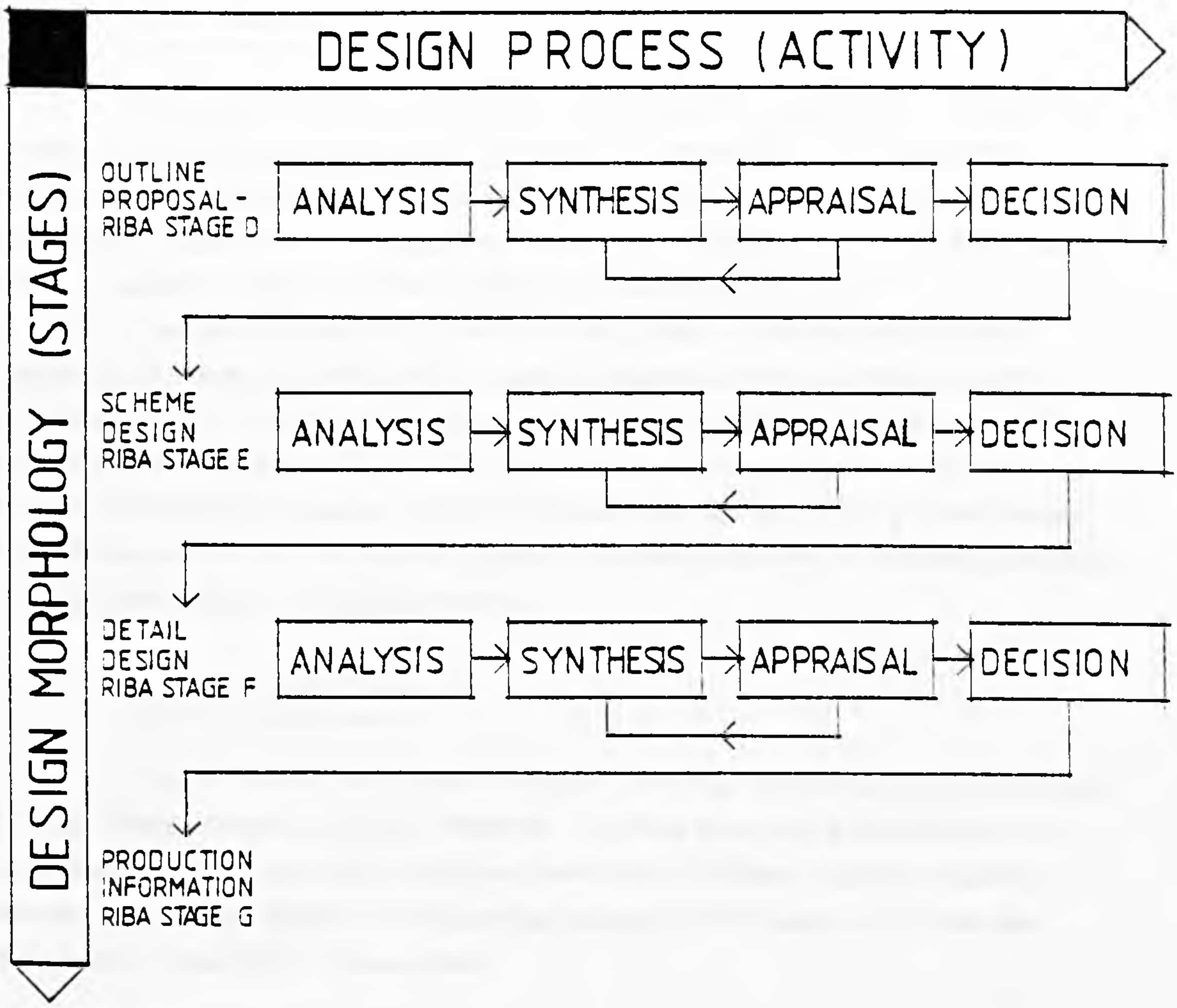


Fig. 2.1. Model of the Design Activity. After Markus et al. In Maver, T.W. (2.14).

In order to clarify the overall objectives of such a functional investigation and to propose a tentative model for an improved design system, the following sub-objectives for design techniques and methods were identified as being of importance (further reference to the complete design system is made to Sections 4 and 8) :

1. At the Analysis Process:

The system of thinking in terms of "tailor-made" rooms must be replaced by thinking in terms of adaptable activity – spaces, i.e. spaces that may change their uses according to fluctuating requirements of the occupants. Adaptable also implies that the activity – spaces should be capable of accommodating several activities at the same time, i.e. spaces are often specified as requiring to be multi-functional.

A peripheral objective (in terms of this project) at the analysis process is that design performance specifications, such as planning criteria, user requirements (including spatio – functional aspects), cost, technical problems and environmental factors such as daylight, sunlight, aspect, prospect, view, temperature, silence/noise, privacy, cleanliness, ventilation, humidity and artificial lighting, and any other relevant information suitable for the architect, should be readily available for reference, preferably accessible through one information source.

2. At the Synthesis Process:

A more flexible and quicker method of creating, manipulating, assembling and storing "house design (planning) elements", such as furniture, wall elements, etc., than those currently in practice, must be developed to facilitate a quicker response between generating a design idea and producing the finished design, i.e. in this case the activity – space plan or house plan.

3. At the Appraisal Process:

A flexible design method requires credible, and fast means for evaluating architectural arrangements such as activity – spaces and house plans, than those methods currently available.

The tentative objectives of the functional investigations led to the identification of the following items to be specified at the various design activities:

1. <u>At the Analysis Activity:</u>

    1.1. Design information as mentioned. This task would not form part of the present work.

    1.2. A list of domestic spatial activities, their sub-activities and associated activity – spaces.

    1.3. Environmental and other requirements for each domestic spatial activity. This task would not form part of the present work.

2. <u>At the Synthesis Activity:</u>

    2.1. A library of "house planning elements" associated with each of the domestic spatial activities or activity – spaces, and the sub-activities.

    2.2. Rules for the combination, "assembly" or manipulation of house planning elements in forming or changing 2 – dimensional activity–spaces or architectural arrangements.

    2.3. Rules for the dimensioning of architectural arrangements.

3. <u>At the Appraisal Activity:</u>

    A number of spatio – functional appraisal measures and a model for evaluating the efficiency of a domestic floor plan. Reference is made to Sub-section 4.4 for a detailed treatment of the Appraisal Model.

2.2. Domestic Spatial Activities and Functions.

A scrutiny of several collated key references (2.16 – 2.31) resulted in the following list of domestic spatial activities and functions (Table 2.1).

The domestic (internal and external) activities and functions evolved were those that are fairly common to the North-West European/North – American cultures, and only those that were thought to require or influence floor–space were included. Some activities, like for instance living or studying are often, of course, not restricted to a particular activity – space but they may take place in zones primarily designated for other activities.

For the purpose of this research project it was decided to limit the investigation to indoor activities and well defined functions. In order to determine the desired items of space (house) planning elements, such as for example furniture, it was necessary to split main activities into sub-activities, each sub-activity requiring floor–space, empty or occupied by a house planning element (2.32, 2.33).

Table 2.1. Domestic Spatial Activities and Functions.

DOMESTIC ACTIVITY/ FUNCTION	CORRESPONDING ACTIVITY – SPACE OR ROOM OR ELEMENT
A. INDOOR ACTIVITIES	
1. SLEEPING	Bedrooms of varying sizes.
2. EATING	Dining-room or area.
3. MAKING FOOD	Kitchen Utility Kitchen.
4. HYGIENIC ACTIVITIES	Bathroom W.C. Shower-room Sauna.
5. LIVING	Livingroom, different versions: Living and dining room, 2nd. Livingroom, Sitting-room, T.V. Room etc., Floor-space.
6. CLOTHING MAINTENANCE (WASHING CLOTHES)	Utility-room (space) Wash-room (space).
7. WORKING: 7.1. PHYSICAL WORK 7.2. MENTAL WORK	 Hobby-room, Workshop etc., Cleaning Study etc.
8. PLAYING	Playroom or play-space in other area.
9. STORING: 9.1. FOOD 9.2. CLOTHES (incl. linen) 9.3. FUEL 9.4. SPORTS – EQUIPMENT 9.5. OTHER STORAGE	 Foodstore, cupboards, fridge, freezer. Clothing-store, cupboards, linen-store, wardrobes. Fuel-store, cupboards etc. Sports equipment store, cupboards etc. Cupboards, shelves etc., Cleaning Cupboard.
10. CIRCULATING	Corridors, floor-space, stairs, lifts, ladders, doors.
11. ENTERING/LEAVING	Vestibule, Lobby, Hall, stairs.

Table 2.1. (Continued).

DOMESTIC ACTIVITY/ FUNCTION	CORRESPONDING ACTIVITY – SPACE OR ROOM OR ELEMENT
B. OUTDOOR ACTIVITIES	Only superficial list:
1. CAR CARE	Garage, car-port, car-space, visitors car-space, cupboards, workshop etc.
2. DRYING CLOTHES	Drying space, lines, "whirlie", balcony, terrace.
3. SITTING	Patio, balcony, terrace, grass.
4. PLAYING	Hard and soft areas/space.
5. STORING	Space for tools, bicycles, toys etc.
6. GARDENING	Space to grow grass, flowers, vegetables and trees.
C. OTHER TECHNICAL FUNCTIONS	
1. ENVIRONMENTAL/SERVICES	Chimney, flues, ducts, tanks, meters, central heating,radiators, refuse bin, ventilators, lights, windows etc.
2. SHELL/STRUCTURE	Walls, windows, doors, columns etc.

Reference to this ergonomic data is given to Sub-Section 2.4 (Table 2.2), where a representative library of indoor house planning elements is developed.

2.3. Environmental and Other Requirements for each Domestic Spatial Activity.

Within this project and for the resulting design system, environmental and other additional design requirements for activity – spaces are assumed to be known and specified either by the designer himself or provided by some external source (client), that is, it is an operation external to the design system, which possibly takes place prior to the design stages at which this system will be operative.

It is also assumed that the designer, i.e. the user of the system starts off using the system with at least a "bubble–diagram" or a first idea of a possible inter-relationship of planning elements, and therefore it is not necessary to include for example association matrices within this system for inter-element or inter-activity – space relationships. It would, however, be useful, at an early stage to have design information for the activities and sub-activities, and any other design information, accessible to the designer within the design system. This would no doubt expedite necessary information retrieval.

Reference is made to Sub-section 4.2; The Analysis Process.

2.4. Associated Library of House Planning Elements.

Based on the list of domestic spatial activities and functions, and the sub-activities and ergonomic data referred to earlier it was possible to systematically evolve a representative list of house planning elements associated with the sub-activities and activities. Some elements necessarily appear under several activities. The elements are coded as to whether they are movable (M) or fixed (F). These states refer to the condition of the elements in the actual finished building, as to whether an occupant can readily move them around or whether they are fixed to the fabric or structure of the building so as to make them "immovable". Only elements consuming functional floor space are included. The representation is made large enough to enable a large as well as a small house to be designed (Table 2.2).

Table 2.2. Activities, Sub-activities and House Planning Elements.

DOMESTIC ACTIVITY/ FUNCTION (ACTIVITY–SPACE IN BRACKETS)	SUB–ACTIVITIES	ASSOCIATED ACTIVITY SPACE OR FUNCTION ELEMENT OR FLOOR–SPACE CONTENT. (ONE OR SEVERAL ITEMS PER TYPE AND ONE OR SEVERAL VERSIONS PER TYPE).
A. INDOOR ACTIVITIES		
1. SLEEPING ONLY (VARIOUS TYPES OF BEDROOMS)	Lie in Bed	Bed (M) (Single,double or child).
	Get to Bed/Get Up	Floor Space.
	Dress/Undress/ Put away clothes for the night	Armchair (M) Easychair (M) Diningchair (M) Stool (M) Wheelchair (M).
	Read in Bed	Reading Light.
	Put things away	Bedside table (M).
	Store Clothes	Chest (M) (Diff. sizes), Wardrobe (M).
	Make Bed/Air Bedclothes	Floor-space.
	Clean	Floor-space.
	Nurse Ill Person	Floor-space.
	Walk to bed/ away from bed	Circulation – Space.
	Dressing/Make-up	Dressing-Table (M).
		Fixed versions of above elements, (study desk/chair).

Table 2.2. (Continued).

2. EATING (DINING–ROOM OR SPACE)	Sitting at table/eating	Dining-table (M) (Various sizes) Dining–chairs (M) Stool (M).
	Getting seated/ Getting up	Floor-space.
	Serve Food	Floor-space, Circulation-space.
	Coming to table/ Leaving table	Circulation-space.
	Storing Cutlery and dishes	Dresser (M) Overhead cupboard (F).
	Sitting at Breakfast Bar	Breakfast-bar (F).
3. MAKING FOOD (KITCHEN; POSSIBLY SEPARATE UTILITY KITCHEN)	Clean, Rinse or washing food	Utility Sink (F).
	Preparing Food	Worktop (F).
	Cooking/Baking	Cooker (F) Hob (F) Oven (F) Microwave (M).
	Washing Dishes	Sink (F) Dishwasher (M).
	Storing food and kitchen utensils	Base Cupboards (F) Overhead Cupboards (F) Drawer Units (F) Food Cupboard (F) Fridge (M) Worktop with drawers (F) Pan Cupboard (F) Upright Freezer (M) Fridge-Freezer (M) Chest Freezer (M).
	Bring in Food/ Take away Rubbish	Circulation-space.

Table 2.2. (Continued).

4. HYGIENIC ACTIVITIES (BATHROOM, WC, SHOWER, SAUNA)	Go to the WC	WC (F).
	Have a bath	Bath-tub (F).
	Have a shower	Shower (Cabinet) (F).
	Washing/Brushing Teeth	Basin (F) Bidet (F).
	Have a Sauna	Sauna-room (F).
	Drying Oneself	Floor-space.
	Grooming	Mirror (M) Equipment.
	Tending Babies	Floor-space Equipment.
	Storing	Base Units (F) Overhead Units (F) Shelves (F) Drawer Units (F) Medicine Cupboard (F
	Walking in and out	Door (F).
5. LIVING (DIFFERENT VERSIONS OF LIVING ROOMS)	Sitting/Talking/ Watching T.V. etc./ Drinking etc.	Settee (M) 2,3,4, Seater. Chairs (M) (as for bedroom) Coffee Table (M) Side Table (M) T V. (M).
	Studying/Writing etc.	Desk/Chair (M).
	Storage	Storage Units (M) Shelves (F) Bookcase (M).
	Playing Cards/ Drawing/Painting	Table (M) Chairs (M).
	Dancing/Playing etc	Floor-space.
	Playing Music	Stereo (M) Piano (M) or organ (M
	Walking to and fro	Circulation-space.

Table 2.2.(Continued).

6. CLOTHING MAINTENANCE	Ironing/Sewing	Ironing/Sewing Cupboard (F) Ironing Board (M) Sewing Table (M) Chair (M).
(UTILITY–ROOM/ WASHROOM)	Washing Clothes	Automatic Washing Machine (F) Tubs (F) Work tops (F).
(Some of these activities could also take place in kitchen, bathroom or living/dining spaces)	Drying Clothes	Drying Cupboard (F) Tumbler Drier (M) Spindrier (M).
	Airing Clothes	Balcony/Space.
	Storing Dirty Clothes	Cupboard (F).
	Mending etc.	Worktops (F).
	Storing Cleaning equipment/detergents etc.	Cleaning Cupboard (F).
7. WORKING		
7.1. PHYSICAL WORK	Cleaning the House	Included under utility space.
(Hobby-room/workshop etc.)	Do it yourself work/ Handywork/ Maintenance	Worktop (M) Cupboards (F) Shelves (F).
7.2. MENTAL WORK (Study (-space)) (Could be part of bedroom or living-space).	Studying/Reading Writing etc.	Desk/Chair (M) Bookcase (M,F).
8. PLAYING (Playroom or space in other area)	Various Forms of Playing	Floor-space Table (M) Chairs (M).

Table 2.2. (Continued).

9. STORING		
9.1. SPACE FOR FOOD (Food-store)	Storing Food	As Kitchen or Separate food-store for long term storage.
9.2. SPACE FOR CLOTHES	Storing -Linen	Linen-Cupboard (F)
	Storing every-day Clothes and Shoes	Cloak (-unit) (F) Drawers (M)
(Clothing/Linen-store)	Storing Old Clothes, Bed-clothes etc.	Wardrobes (M/F) or Clothing-store.
9.3. SPACE FOR FUEL	Storing Coal/Coke/wood/Peat (Solid Fuel)	Fuel-store or Cupboards (F).
(Fuel-store)	Storing Oil/Paraffin/Gas (Liquid)	Tank, fuel-store or cupboards (F).
9.4. SPACE FOR SPORTS EQUIPMENT (Sports-equipment Store)	Storing Tools, Sports equipment, Travelling Equipment Etc.	Sports-equipment Store or Cupboards/Shelves (F)
9.5. SPACE FOR OTHER STORAGE ITEMS	Storing Cleaning items	See Utility Room.
(Cupboards/Shelves etc.)	Storing other, Superfluous items as need arises	Cupboards (F) Shelves (F) Units (M).
10. CIRCULATING	Passing in and out of rooms	Doors (F).
(Corridors, floor-space, stairs, lifts, ladders, doors)	Passing between furniture or rooms	Widths of circulation space (1 person, 2 person, restricted) (M).
	Passing between floors	Stairs (F) Lifts (F) Ladders (M) Ramps (F).

Table 2.2. (Continued).

11. ENTERING/LEAVING		
11.1. TRANSITION OUTWARDS	Going in and out	Front-door (F) Back-door (F).
(Vestibule, Lobby, Door)	Storing Clothes and shoes	Cloak (M/F) Shelves (M/F) Shoerack (M/F).
11.2. TRANSITION INWARDS	Storing/Ornaments	Table (M) Chest (M).
	Sitting	Chairs (M).
(Hall)	Storing Clothes and shoes	As Vestibule.
	Grooming	Mirror (M/F).
C. OTHER,TECHNICAL FUNCTIONS		
1. ENVIRONMENTAL/ SERVICES	Dispose of Effluent Gases, Air etc. Supply Air	Chimney (F) Flues (F) Ventilators (F).
	Conceal Services/ Distributing	Ducts (F) Stacks (F).
	Store Energy/Fluid	Cold Water Tank (F) Immersion Heater (F).
	Emit Heat	Radiators (F).
	Heating	Central Heating Units (F).
	Recording Energy Consumption	Meters (Electrical and Gas (F).
	Dispose of Rubbish	Refuse Bin (M).
	Supplying Light	Electric Light Fittings (M/F) Windows (F).

Table 2.2. (Continued).

2. CONTAINING ACTIVITIES/ SUPPORTING STRUCTURE	Same	Load-Bearing Walls (F) Non-load -bearing walls (M/F) Windows (F) Doors (F) Columns (M/F) (Classified as walls) External Walls (M/F) Internal Walls (M/F).

Elements, as well as being either fixed (F) or movable (M), or a combination of the two states (M/F), may have several variations of the basic shape, depending on the purpose for which the element is going to be used. For example, there are several types of chair. Next, for each particular purpose the element may exist in a range of sizes. Single beds, for instance, are manufactured to several different dimensions. Elements, of course, are also often repeated or used for more than one particular activity. A dining chair, for instance, will often be used as a study chair in conjunction with a desk or table. This sort of data can be used when cataloguing the house planning elements with a code for each one (See Sub-section 4.3.1 , Design Level 1).

Having identified various elements that may potentially constitute a house plan (Table 2.2), a next step of the work was to decide on a unique diagrammatic symbol for each element, so that the interpretation of layouts would be facilitated, and to specify their exact dimensions. Again, the various mentioned ergonomic data were used for this (2.16 – 2.33), but a limited number of references were the main sources (2.34 – 2.60) in constructing the library of house planning elements, showing symbols and dimensions of the elements (Fig. 2.2). It was necessary to use some discretion in the choice of symbolics and dimensions within this library, since the elements eventually would be stored and manipulated using a computer. It was also decided to limit the library of elements evolved (Table 2.1) for use in the present project, since within the finished design system such a library, if not complete, would be extendable by users of the system.

The symbols used can be developed as shown in Fig. 2.3. This type of symbolism was found useful not only to identify elements in building up a plan graphically, but also for the consequent computer graphics application of the design system. Letters were found particularly useful as an aid to distinction between otherwise similar graphic symbols (Fig. 2.3).

Information on space required in front of, around, and between elements was mostly retrieved from the sources mentioned earlier (2.34 – 2.60), and most of such spaces are also shown in Fig. 2.2.

From Fig. 2.2 it can be observed that elements shown so far fall into three categories:

1. Single elements.

2. Macro-elements; defined as two or more elements that always occur together as shown, e.g. desk and chair.

3. Groups of elements built up from the library of single elements.

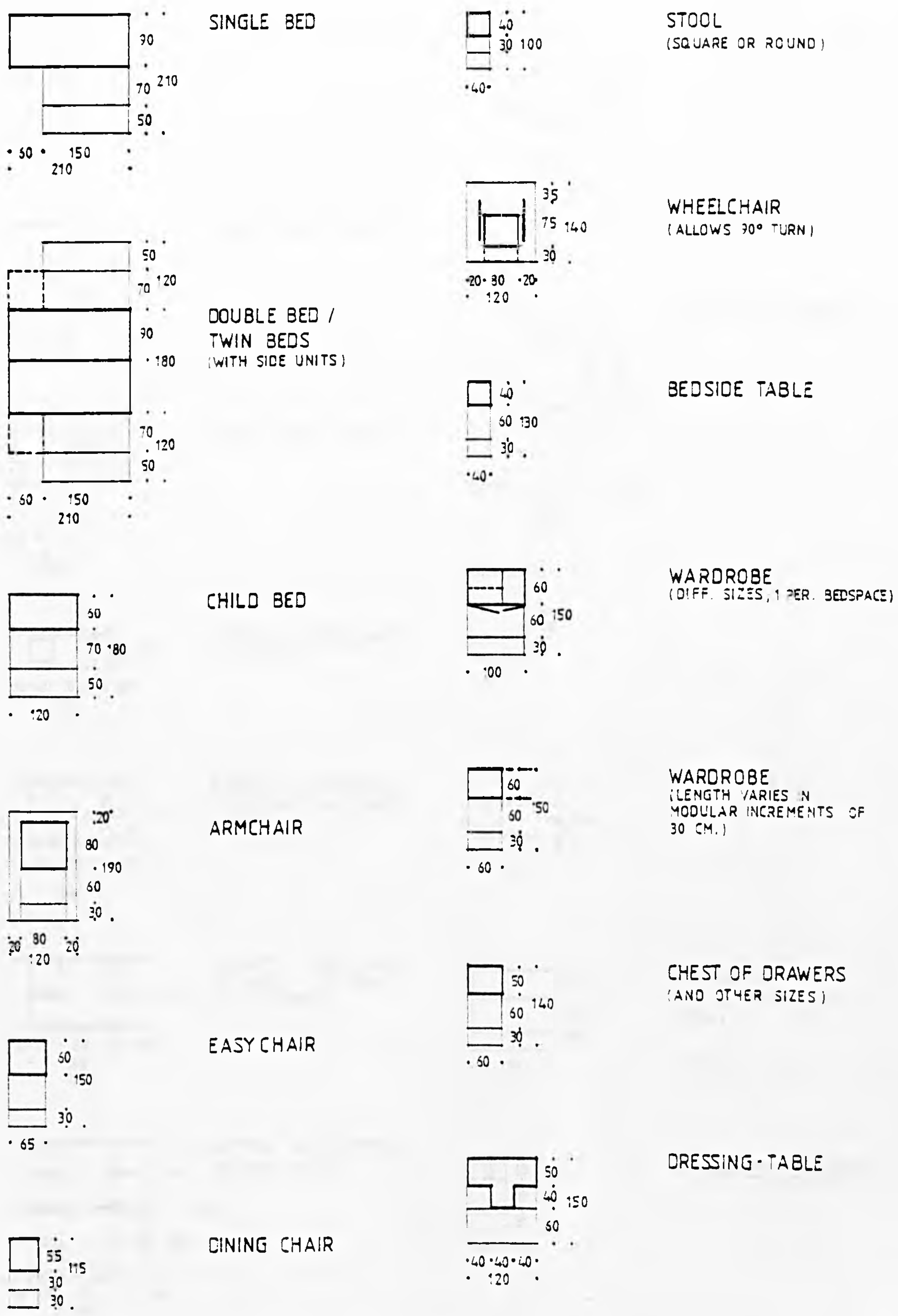


Fig. 2.2. Library of Typical Furniture and Equipment.

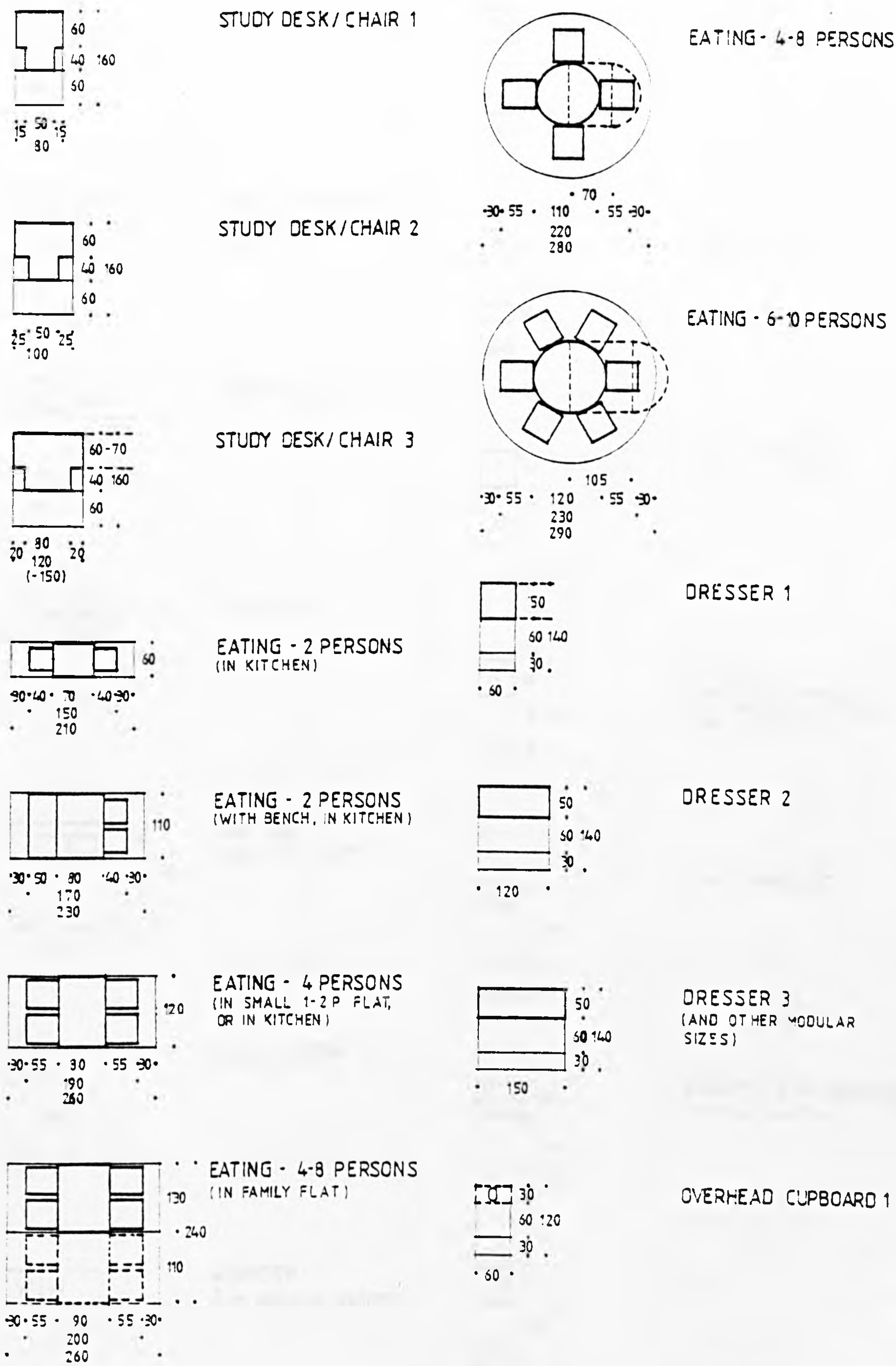


Fig. 2.2. (Continued).

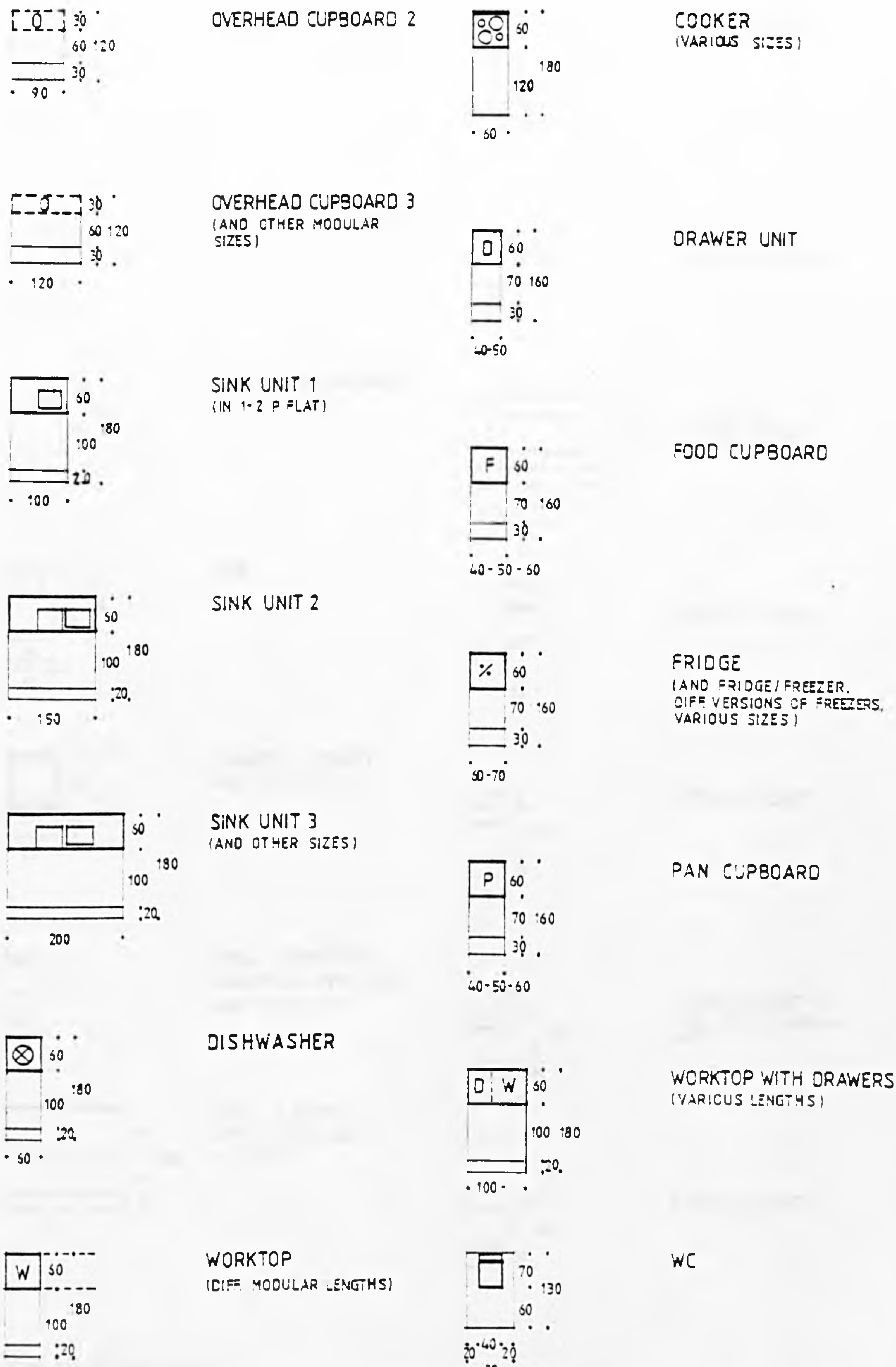
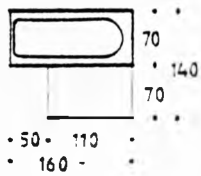
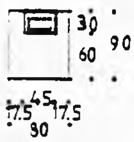


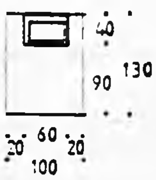
Fig. 2.2. (Continued).



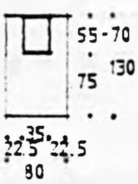
BATHTUB
(VARIOUS SIZES AND TYPES)



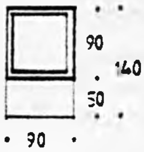
SMALL WASH-HANDBASIN



LARGE WASH-HANDBASIN
(AND OTHER SIZES)

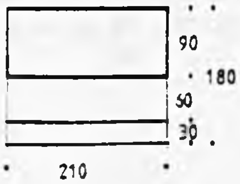


BIDET

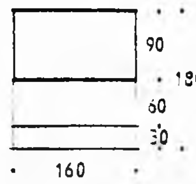


SHOWER (-CABINET)
(AND OTHER SIZES)

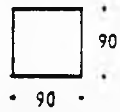
SMALL BATHROOM
OVERHEAD CUPBOARD
(AND OTHER SIZES)



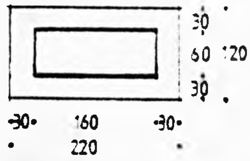
SOFA - 3 SEATER
(OTHER SIZES, ALSO
4 SEATER)



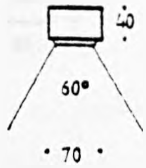
SOFA - 2 SEATER



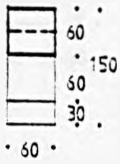
COFFEE TABLE
(MAINLY CORNER TYPE)



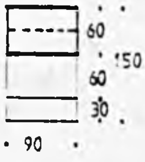
COFFEE TABLE
(AND OTHER SIZES)



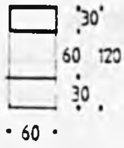
TV
(AND OTHER SIZES)



STORAGE UNIT 1



STORAGE UNIT 2
(AND OTHER MODULAR
SIZES)



BOOKCASE UNIT 1

Fig. 2.2. (Continued).

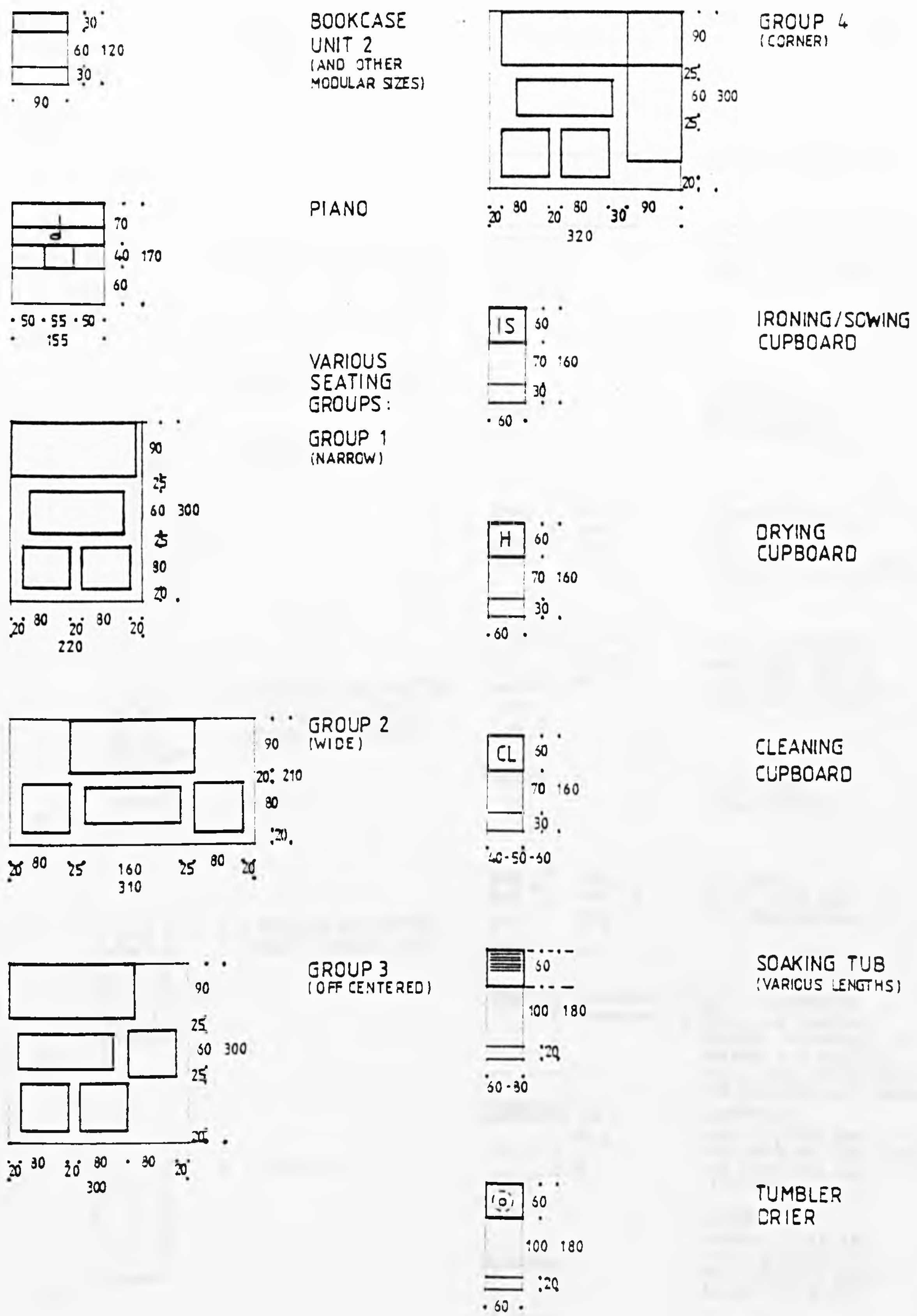
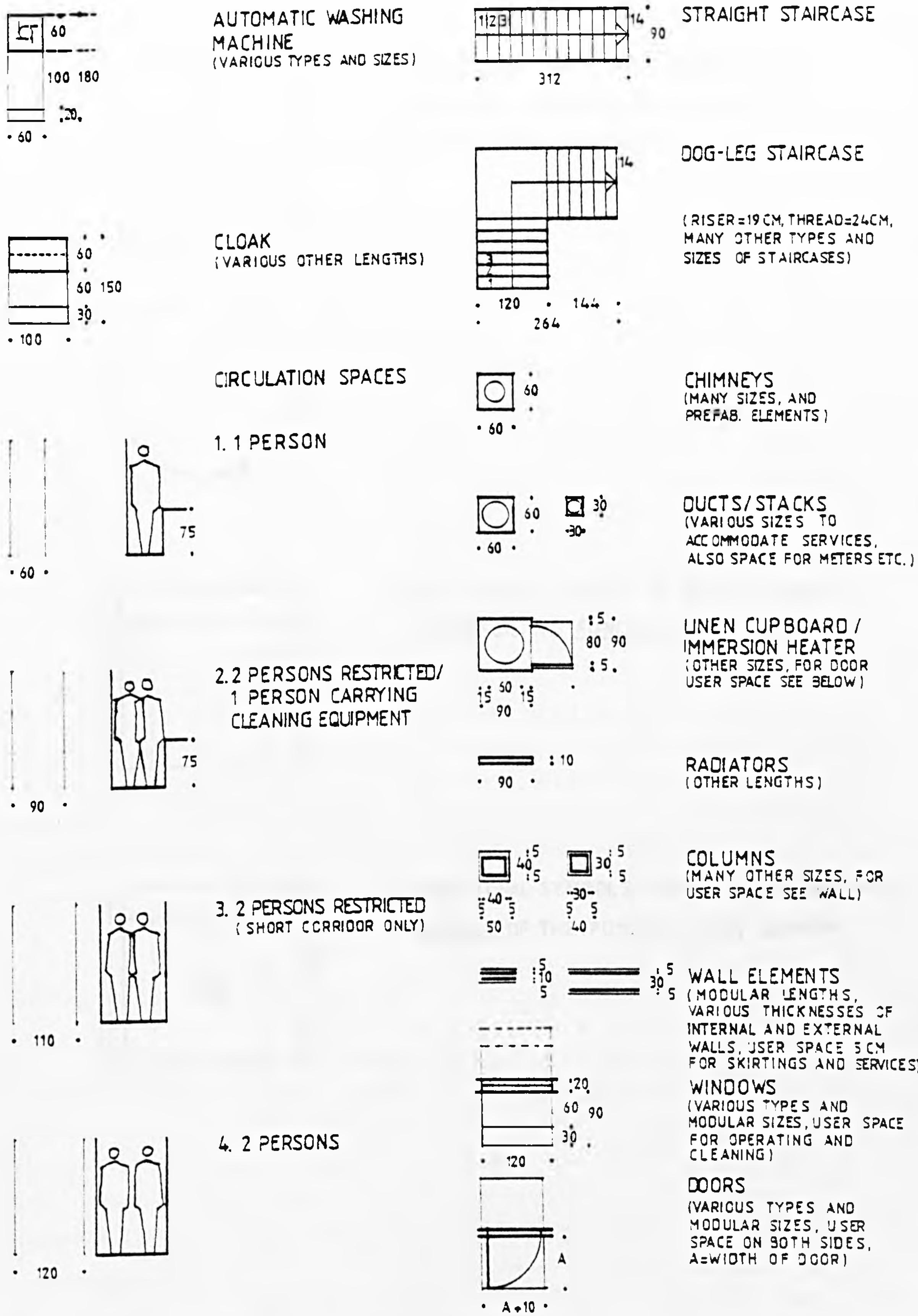
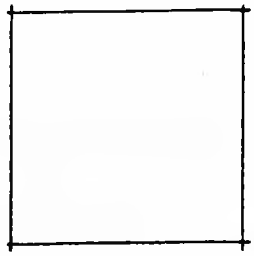


Fig. 2.2. (Continued).

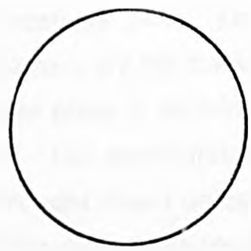


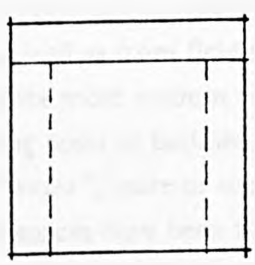
NOTE: SCALE 1:100, ALL SIZES NOMINAL AND GIVEN IN CENTIMETRES.
IF USER SPACE (FAINT LINE) SHOWN AS 2 AREAS, THE AREA NEAREST SOLID ELEMENT (HEAVY LINE) IS ESSENTIAL USER SPACE, THE OTHER PREFERRED ADDITIONAL USER SPACE.

Fig. 2.2. (Continued).

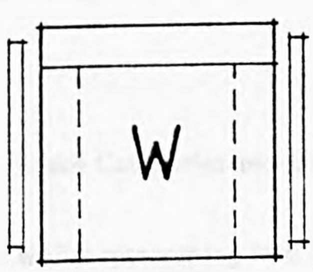


1. SYMBOLS REPRESENTING BASIC SHAPES (SQUARES, RECTANGLES, CIRCLES, ORTHOGONAL POLYGONS).





2. ADDITIONAL SYMBOLS TO BASIC SHAPES REPRESENTING FUNCTION OF AN ELEMENT.



3. ADDITIONAL SYMBOLS REPRESENTING FURTHER DETAILS OF THE FUNTION OF AN ELEMENT.

Fig. 2.3. Use of Element Symbols.

Elements were limited to rectangles, circles or orthogonal polygons.

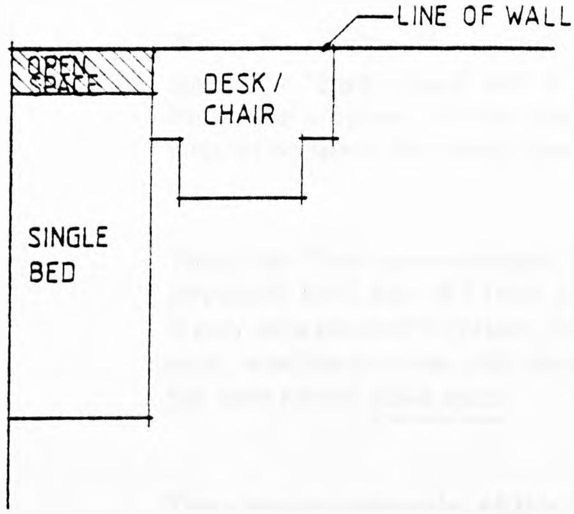
2.5. Rules for the Combination of Elements.

To a non-biased observer it must appear that when designing a house plan, the designer in actual or physical terms "assembles" house planning elements to form a homogeneous plan. This assembly is a two-dimensional manipulation process where the manipulations are his manual design techniques. The process of making a plan will often take place in certain successive stages of build-up, modifications and completions. The manipulation and assembly of elements, like many other processes, cannot be brought about unless there are rules for this assembly. In the context of house planning, such rules are basically concerned with spaces and distances between elements. These spaces and distances are based on ergonomic and anthropometric data referred to earlier (2.34 – 2.60). Such data arise mostly from laboratory experiments normally carried out at various Building and Ergonomic Research Institutes, as well as from field surveys in the housing sector.

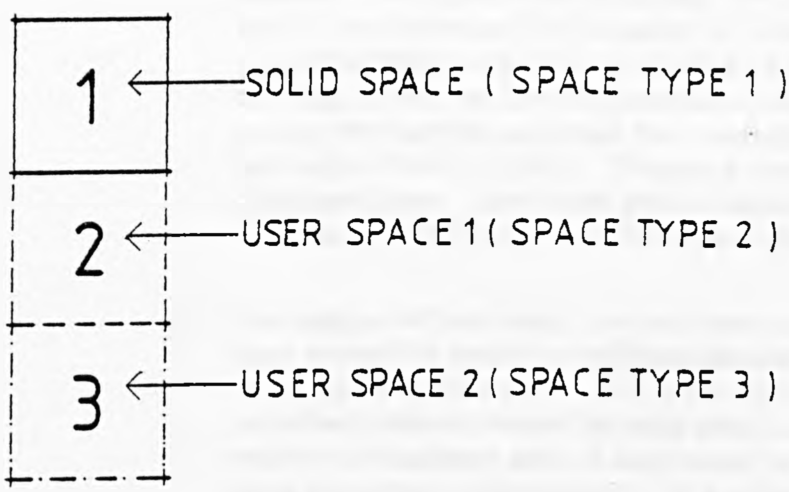
Since most modern houses, both private and public sector ones, due to ever escalating costs of building, mostly contain minimal or marginal spaces, that is, there is no "extra", spare or superfluous floor-space present once all the furniture and surrounding spaces have been taken into account, the distances recommended by the institutes mentioned above are all more or less minimum distances. It is therefore important that domestic spaces should be adaptable and planned for optimum efficiency. This can best be assured by systematising the design techniques employed.

2.5.1. Space Categories and Distances.

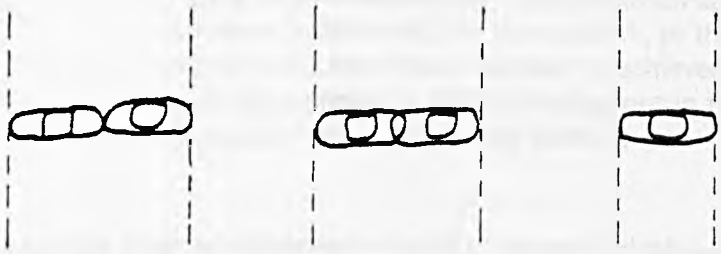
Whilst researching into finding a method for the automatic generation of furniture layouts using computer graphics (this type of generation is not an object of the present research), it was noted that the floor space of a house plan comprises three or four distinct types of spaces, made up from 2—D floor-planning elements such as furniture, walls, doors and windows, as well as circulation space between elements and between activity spaces, and finally, free or wasted space, the latter often being present because it is usually more practical and economical to make rooms rectangular in plan rather than multi-node polygonal or circular. In this system the floor space has been categorised into the following space types (See also Fig. 2.4):



1. PART OF A ROOM LAYOUT SHOWING "OPEN" OR "WASTED" SPACE (SPACE CATEGORY Ø).



2. A TYPICAL ELEMENT SHOWING SPACE CATEGORIES.



3. CIRCULATION SPACE (SPACE CATEGORIES 2 AND 3).

Fig. 2.4. Space Categories.

Space Type Ø : This is the portion of an activity-space which is free, wasted or "open" space, that is, it serves no apparent functional purpose. It falls into the same category as circulation space (See space type 2).

Space Type 1: This is the floor space occupied by the projection of the physically solid part of a floor planning element, whether it may be a piece of furniture, fixed or movable, a wall, door, window or other solid element. This space type has been named solid space.

Space Type 2: There are two categories of this type of space:

2.1. Minimum or essential user space around a solid element. This type of user space may serve one or both of two purposes: one, as space for allowing the solid element to function, e.g. space for a door to swing, or two: as space for a person to use, service or clean the element, e.g. space for a seated person's bent legs in front of a chair. This space type is called user space 1, and exists around and abutting an element, as well as necessarily between elements.

2.2. This category of user space 1 is circulation space, that is, space needed for people to trafficate between elements or between activity spaces. This space type could really be called an element where the solid part is missing. The width of a circulation space is determined but its length varies according to requirements. In practice it was decided to include wasted space (Type Ø) to this category.

Space Type 3: This is an additional space type allocation abutting the minimum space type 2 or user space 1, so that a better user or circulation space standard is achieved, e.g. additional space for a person to stretch his legs out in front of a chair. This space type is called user space 2.

The various types of spaces were found to be sub-dividable, according to their associated functions or purposes, into a set of functions, which, when listed, clarified the interaction between elements, and formed the basis for a possible theory of automatic generation of elements, as well as providing a checking for "manual" manipulation of elements. The various functions can be summarised as shown in Table 2.3.

From the earlier ergonomic data (2.16 – 2.60), it was found that each side of an element usually has one particular type of function or activity taking place

Table 2.3. Types of Functions and Associated Spaces .

FUNCTION CODE	ASSOCIATED SPACE CATEGORIES
F.Ø	Undefined or open space.
F.E	Solid space.
F.U	User space.
F.E.(X).U	User space belonging to element E.(X).
F.E.U.P. (1, 2 or 3)	Space for use of element by people (1, 2 or 3).
F.E.U.F	Space for element itself to function.
F.E.U.C.	Space for people to clean or service element.
F.E.U.Ø./ F.E.U.O	A special case of F.E.U where user space distance l = Ø. It also means that this element side is indifferent to adjacent elements, or unrelated to them.
F.Ei.Ej.U	User space between two or more related elements. This space or distance has usually resulted from an overlapping of their individual user spaces, or is based on the "connectivity" between two elements.
F.C	Space required for circulation of people. Different width of spaces are required. Same type as F.E with specifiable length of element.
F.C.P	An undergroup of F.C. User space for an activity unrelated to any element, e.g. dancing.

NOTE: F.E.U = minimum distances.
F.Ei.Ej.U = maximum distances.
l = User distance; the distance from the sides of an element to the extreme sides of its user space.

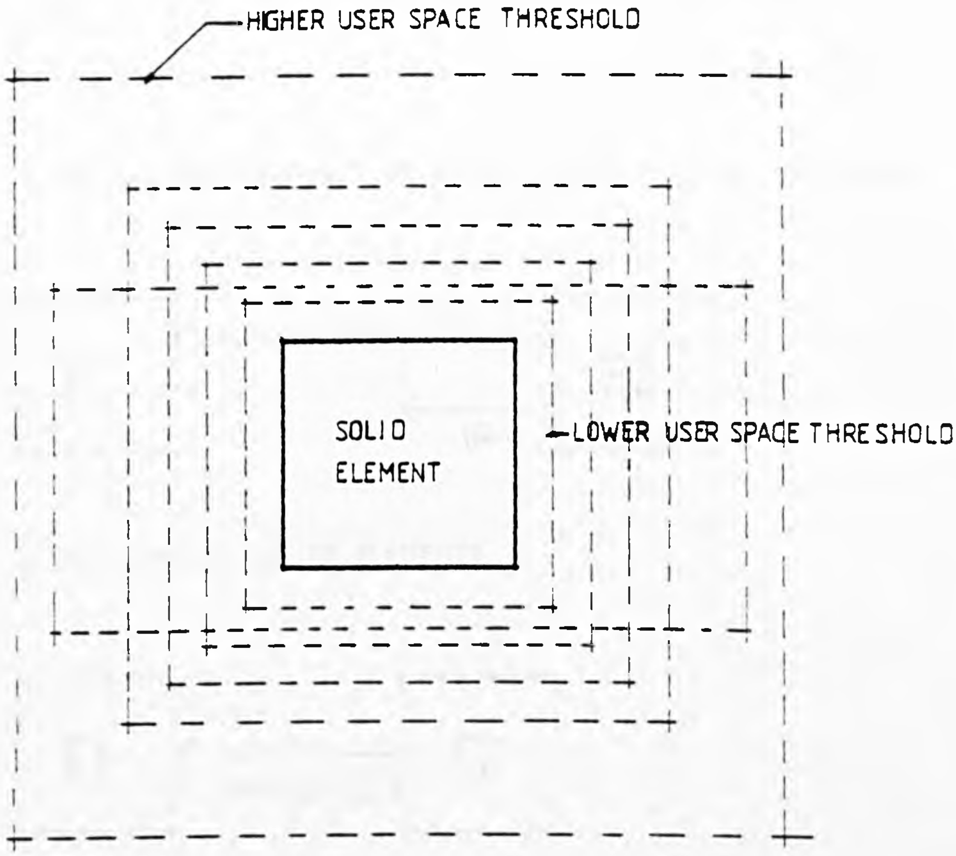
adjacent or contiguous to it, but sometimes other functions can be found next to it. It was also found that types of function can be further sub-divided into various associated distances. For instance, consider the front side of armchair which has already been used as an example. When a person sits down in it he requires a functional space in front of that side for his legs. Next, the distance of space required for his legs depends on whether he bends, folds or stretches his legs out. So in this case there is an l.F.E.U.P (Using symbols from Table 2.3 and l = distance) for the leg space which again is given a value by its various distances l.F.E.U.P. 1, 2 or 3 (1, 2 or 3 represents bending, folding or stretching of legs respectively).

In order to make a rule for the combination or assembly of elements one needs to know the particular minimum distance for a function which is the maximum of all the minimum distances associated with possible functions or activities which may occur next to or contiguous to the side of an element or between nearest sides or points of two or more elements. This type of functions and distances could be worked out in complete detail and it follows then, of course, that there will be not just one particular or single user space surrounding an element, but a whole set of such user space domains (Fig. 2.5). These domains, or a particular domain for a given instance of functions, act as "buffer zones" when an element interacts with other elements. A particular type of domain would be one to cater for space needed to displace an element fractionally or obliquely, as is necessary with chairs. One could even talk of domains around a group of elements which would allow for different versions of rearrangements of that group. The latter type of domain would facilitate the creation of adaptable or multi-purpose activity spaces.

However, a detailed investigation was then made of the conditions that occur when two such domains or buffer-zones (user areas) of two elements meet or interact with one another. This occurs of course when two elements are being manipulated by the designer. Note that this still refers to minimum distances.

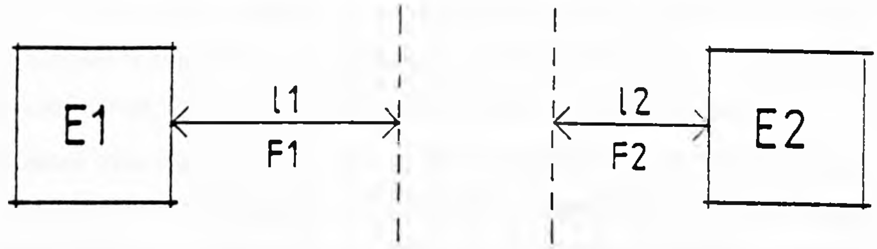
It was, not unexpectedly, found that there was a range of minimum distances that could occur, their limits being determined by an upper and a lower threshold distance (Fig. 2.5). These various domains or distances that occur between two elements could be called the bordering or adjacency conditions, or the connectivity factor between those two elements.

Fig. 2.6 shows some of these bordering conditions, as well as the symbols used. If the two functions determining l1 and l2 always occur simultaneously then obviously l required between the opposite sides of E1 and E2 is l1 + l2.

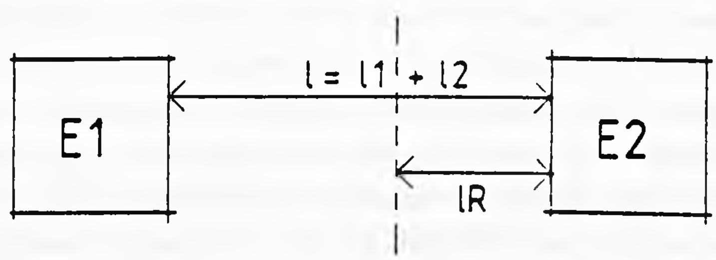


NOTE: THE SOLID ELEMENT MAY HAVE A NUMBER OF SUCCESSIVELY LARGER OR DIFFERENTLY SIZED USER SPACES, RANGING FROM A LOWER TO A HIGHER THRESHOLD SIZE, EACH SPACE CORRESPONDING TO THE SPACE NEEDED FOR A PARTICULAR ACTIVITY ASSOCIATED WITH THE ELEMENT.

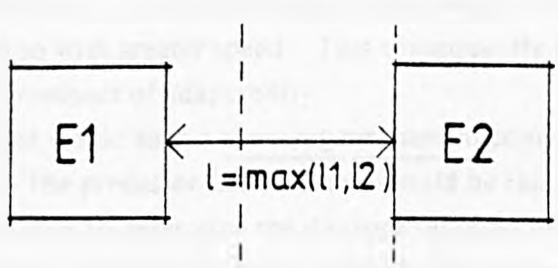
Fig. 2.5. User Space Domains.



1. TWO ELEMEMENTS APART FROM EACH OTHER (NOT WITHIN RANGE).



2. SIMULTANEOUS USE OF ELEMENTS.



3. NON-SIMULTANEOUS USE OF ELEMENTS.

KEY:

l1 = Distance associated with function F1.
l2 = Distance associated with function F2.
l = Distance between E1 and E2.
F1 = Function associated with E1.
F2 = Function associated with E2.
E1 = Element 1.
E2 = Element 2.
lR = Range of change of l.

Fig. 2.6. Bordering Conditions.

Otherwise, if the two functions occur non-simultaneous the I becomes max (I1, I2). In the real life situation it is of course never quite as clear cut as outlined. What was found to happen is that there is a probability or frequency as to whether F1 and F2 are simultaneous or not, and it is this probability that determines I and I_r.

Suppose that the architect has a system available within which he can manipulate elements on a planning board (a gridded magnetic board with cut-out planning elements made of rubber and silicon) or on a computer graphics screen; i.e. the system allows him to move elements from one position to another. If he brings them too close together, he will have broken a distance rule for their combination. On the other hand he might have left them very far apart, so as to make the use of space less economical (See Sub-Section 4.4 for the Evaluation Model and area efficiences). It is, given any large sample of elements, quite impossible for the designer to remember all the distance rules off the top of his head, so unless he continuously and time consumingly looks up pertinent references, such as The New Metric Handbook or Neufert's Architects' Data (2.61, 2.62), to check for these rules, he would inevitably make rule errors. However, if the design system does the rule checking for him and advises him on these matters so that he can quickly take corrective actions in the event of rule-breaks, he not only designs according to the required functional rules, but also does so with greater speed. This consequently raises the quality of the design, particularly in respect of adaptability.

What would such a checking-mechanism comprise (thinking in terms of a computer) ? The processor (an assistant) would be required to inspect a distance cum probability matrix to determine the distance required between two opposing sides of two bordering elements in a given situation, and subsequently inform the designer if a rule had been broken, and, if it had been, suggest remedial action. Such a matrix could also be made to indicate whether two sides (of two opposing elements) were compatible, i.e. whether they could be allowed to remain adjacent to one another at a particular distance or within a certain distance range.

The simplest and most practical specification of the user space dimension required in front of a side of an element is to assign only one value to it; this value being the maximum distance required in front of that side, having considered all the other possible occurring functions and associated minimum distances. This maximum assigned distance in actual fact is the largest of all possible minimum distances that might take place adjacent to the side in question. Such data is to a certain degree available from ergonomic sources (See Fig. 2.2), and this is one reason why such a particular approach was chosen, rather than to devise a completely detailed function method, which also would be a tremendously ardous and time-consuming task with doubtful accuracy expectancy. Furthermore, a detailed function – adjacency analysis requires probability data as input, which does not exist at this point in time; so although a system can and has been devised in principle, based on a functional probability principle, there are no readily available data for instant reference at present.

Further to the rules of distances between elements, rules are needed as to which space-types might be permitted to overlap. This can be shown in a permissibility table (Table 2.4). When, according to such a table, refined to greater or lesser detail, a decision has been taken as to whether or not two or any adjacent space-type elements should be permitted to overlap, the processor must, if overlap is permitted, calculate the permitted distance between the two elements, or if overlap is not permitted, give a warning to that effect. If the two elements are not permitted to overlap but nevertheless abut or be contiguous to one another, then l = (l1 + l2), which is the permitted minimum distance between the elements. If they are permitted to overlap, then the minimum distance will be l = max (l1, l2).

The question of distances between elements was looked further into by considering the different types of adjacency or distance "cases" possible (Fig. 2.7). It was found that with rectilinear shapes there are basically three pertinent cases of adjacencies; two for orthogonal arrangements and one for non-orthogonal arrangements. Another special case is where an element is not rectangular; here a circular element only is considered. Polygonal elements, orthogonal or non-orthogonal will fall into the same sort of pattern as for rectilinear shapes. Rectangular elements have been labelled with sides and nodes as shown (Fig. 2.8). Referring to Fig. 2.7, distance cases can be summarised as follows:

A. Orthogonal Arrangements:

1. Side to Side Relationship:

This is the case used in Table 2.4, where l becomes either max (l1, l2) for non-simultaneity of use and (l1 + l2) for simultaneity of use.

2. Node to Node Relationship:

In this case it can be seen that the minimum or shortest distance between two elements E1 and E2 becomes a distance between nearest nodes. This happens when two pairs of sides of the two elements E1 and E2 are adjacent to one another at the same time; in this case E1.S2 – E2.S4 and E1.S1 – E2.S3. A triangle is thus formed with sides:

l1 = l. (E1.S1 – E2.S3)
l2 = l. (E1.S2 – E2.S4)
l3 = l. (E1.N2 –E2.N4).

l3 is the shortest node distance between elements E1 and E2 and is the hypothenuse of the triangle mentioned above. The value of the hypothenuse will now become:

Table 2.4. Space Overlap Permissibility Table.

SPACE TYPES		OPEN	SOLID	USER	
				I	II
OPEN		Y	Y	Y	Y
SOLID			N	Y or M	Y
USER	I			Y or M	Y if P.S. $\leq$ P.S.T. N if P.S $>$ P.S.T. or M
	II				Y or M

KEY:

Y = Yes
N = No
M = Manual (Designer's decision).
P.S = Probability of simultaneousness
P.S.T = Probability threshold value, e.g. 50%.

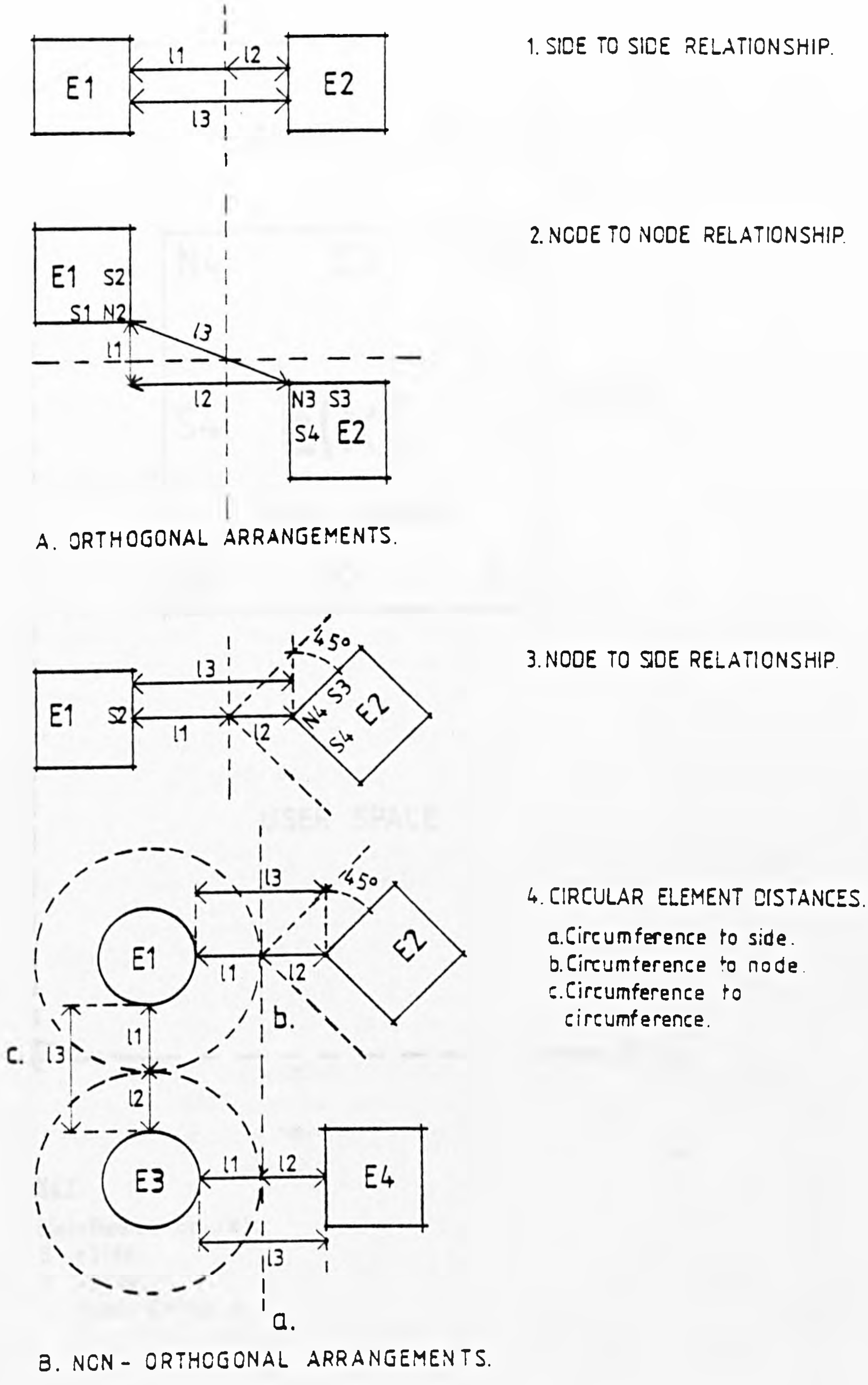
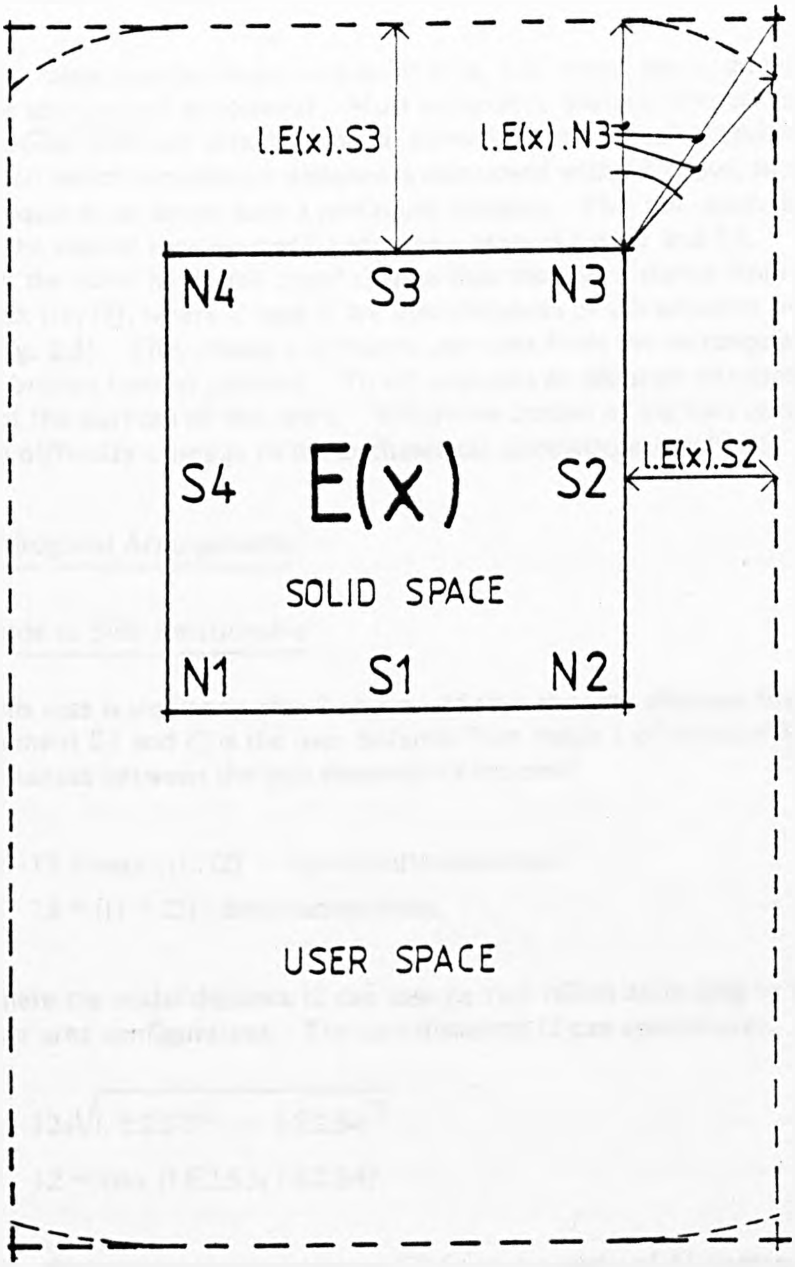


Fig. 2.7. Adjacency (Distance) Cases.



KEY:

E(x)=Element no. (x)..
S =Side.
N =Node.
l =User distance.

Fig. 2.8. Element Labelling.

$13 = (\sqrt{11^2 + 12^2})$.

This raises another important point (Fig. 2.8) which has to do with the shape of the user area of an element. Most ergonomic sources referred to earlier presuppose that user areas around an element are rectangular, and this is the basis upon which a minimum distance is composed with 13 above, to check whether 13 is equal to or above such a minimum distance. This minimum distance, of course, is the sum of the two nodal user area distances for E1 and E2.
On the other hand one could assume that the user distance from a node is max (l1, l2), where l1 and l2 are user distances of the adjacent side to the node (Fig. 2.8). This creates a different user area from the rectangular one (shown in broken lines at corners). To set user area or distance standards is however not the purpose of this work. Whichever option of the two outlined is chosen, no difficulty arises as to the arithmetical calculations involved.

B. Non-orthogonal Arrangements:

3. Node to Side Relationship:

This case is similar to case 2 above. If l1 is the user distance from Side 2 of element E1 and l2 is the user distance from Node 4 of element E2, the minimum distances between the two elements l3 become:

1. l3 = max (l1, l2) - non-simultaneousness.
2. l3 = (l1 + l2) - simultaneousness,

where the nodal distance l2 can assume two values according to assumption of user area configuration. The two distances l2 can assume are:

1. $l2 = \sqrt{l.E2.S3^2 + l.E2.S4^2}$
2. l2 = max (l.E2.S3, l.E2.S4).

The above assumes that element E2 forms an angle of 45 degrees with element E1, that is, the continuation of sides E2. S3 and E2.S4 both form internal angles of 45 degrees with the continuation of E1.S2.

C. Circular Element Distances:

4. Three cases exist:

a. Circumference to side.
b. Circumference to node.
c. Circumference to circumference.

Distances from nodes and sides are calculated as in cases 2 and 3 above (l2). User distance from circumference of circle is assumed to be uniform all around (l1). For all cases (a - c), the resultant distance between elements will be (l3):

1. l3 = max (l1, l2) 2. l3 = l1 + l2.

These are the same values as in case 1, orthogonal arrangements.

A special case of user space occurs when the user space is below an element top surface (or other surface of an element) (Fig. 2.9). This means that another element of height less than the height below the mentioned surface, or its user space, may occupy the user space below the surface. Such user spaces are usually "filled" with another element which is present permanently; e.g. study desk and chair. Two such inter-dependent elements are named macro-elements, (See Section 4.3.1; Design Level 1), and are usually in this system defined as one element, the reason for this being that no computing methodology is then necessary for their combination.

A special case of distance calculation applies when combining elements and their user spaces with circulation spaces only (Fig. 2.10). Two cases occurs:

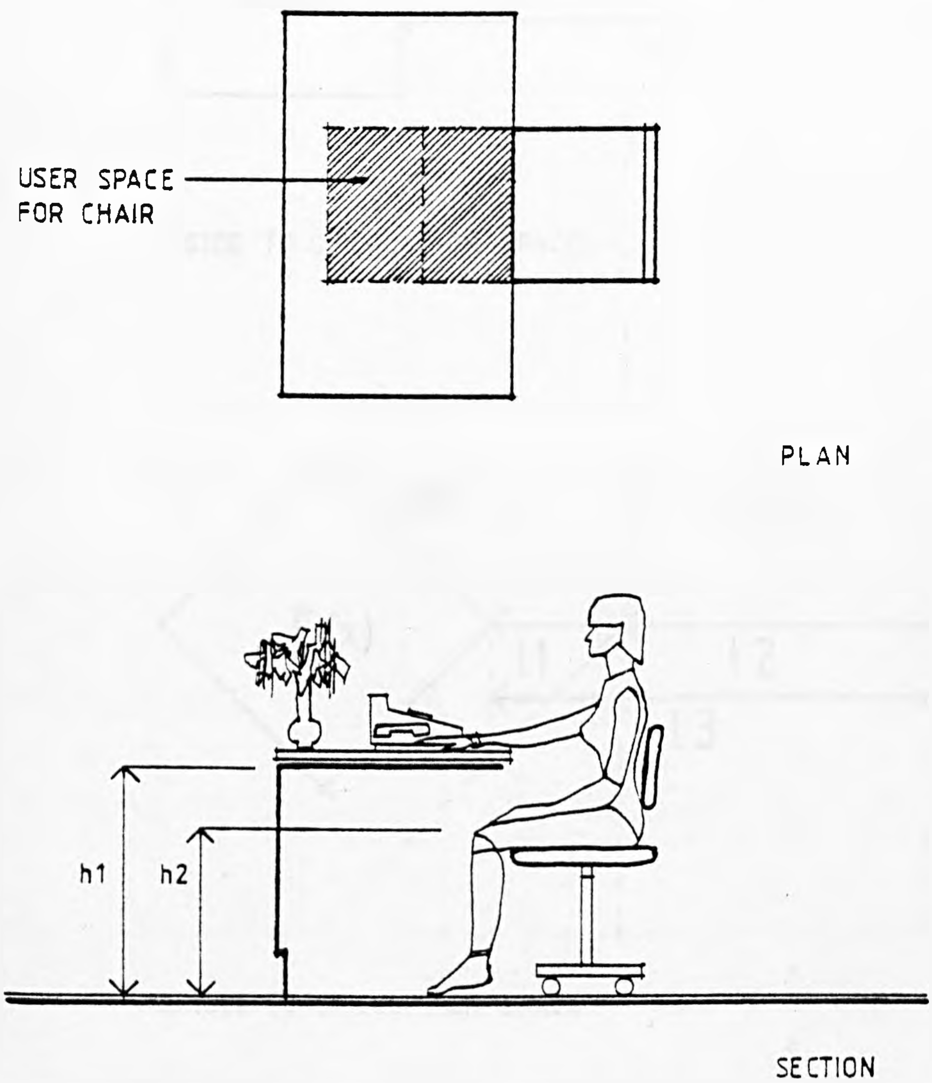
1. Side to Circulation Space.
   Distance calculation as in case 1 for orthogonal arrangements.
2. Node to Circulation Space.
   As in cases 2 and 3 above.

The decision as to whether a user space or distance to an element side or node should be permitted to overlap another similar space could be taken broadly according to the Space Overlap Permissibility Table (Table 2.4). However, the data stored on user spaces can be more precisely specified for each side and node (Fig. 2.11).

For each distance an an attribute can be attached Y or N deciding overlap permission or not. Decision is then made according to the Overlap Permissibility Table. The Y or N attributes may be supplanted by a manual (interactive) decision (Y or N) by the designer and again the Overlap Permissibility Table decides. Distance calculations are carried out as per. distance cases described above.

In order for the Permissibility Table to know the definition of solid, user, undefined and circulation spaces, these were defined with reference to the nodes and sides of elements, broadly, as follows (Fig. 2.11):

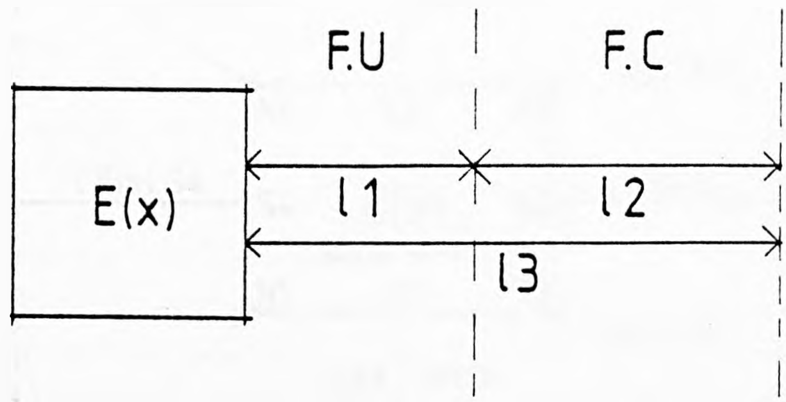
1. Solid Space:
   Normally, the space enclosed by the element sides and nodes, except where a user space occurs below an element.
2. User Space:
   The bounding space around an element defined by the lines parallel to element sides, at the user distance from the element sides and optionally adjusted at the corners by the nodal user distances. The user space could be defined as sub-element $E'(X)$ and its sides and nodes annotated as for its solid element.
3. Circulation Space:
   An element of defined width (l.c) between two parallel lines of an unspecified length. In distance calculations a circulation space is treated in the same way as user space.



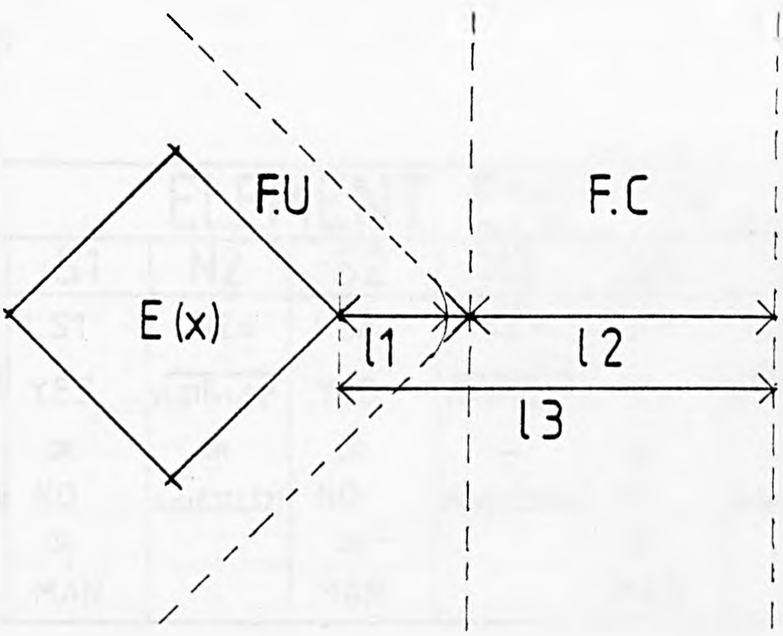
KEY:

h1 = FLOOR TO UNDERSIDE OF TABLETOP HEIGHT.
h2 = FLOOR TO KNEE HEIGHT.

Fig. 2.9. User Space below Elements (Example).

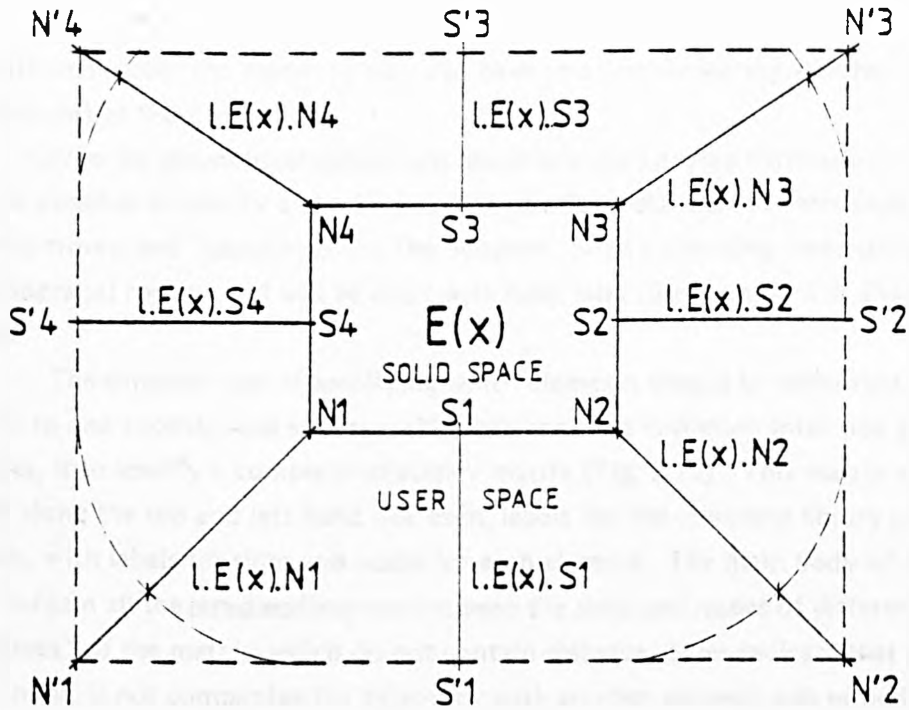


1. SIDE TO CIRCULATION SPACE.



2. NODE TO CIRCULATION SPACE.

Fig. 2.10. Combining User and Circulation Spaces.



ELEMENT E(x) (M OR F)							
N1	S1	N2	S2	N3	S3	N4	S4
l.N1 = $\sqrt{l.S1^2+l.S4^2}$ OR max(l.S1,l.S4)	l.S1 YES OR NO OR MAN	l.N2 = $\sqrt{l.S1^2+l.S2^2}$ OR max(l.S1,l.S2)	l.S2 YES OR NO OR MAN	l.N3 = $\sqrt{l.S2^2+l.S3^2}$ OR max(l.S2,l.S3)	l.S3 YES OR NO OR MAN	l.N4 = $\sqrt{l.S3^2+l.S4^2}$ OR max(l.S3,l.S4)	l.S4 YES OR NO OR MAN

KEY:

E(x) = Element no. (x).
S = Side.
N = Node.
M = Movable element.
F = Fixed element.
l = User distance.
YES = Overlap with another element permitted.
NO = Overlap with another element not permitted; touching only allowed.
MAN = Manual overlap decision.

Fig. 2.11. User Distance Specifications.

As mentioned earlier the elements may also have an attribute stating whether they are moveable (M) or fixed (F).

Given the geometrical definitions above and the Overlap Permissibility Table, it is now possible to specify a checking mechanism for distances between elements which are being moved and "assembled" by the designer. Such a checking - mechanism is a design appraisal routine and will be dealt with fully later (Sub-section 4.4; Evaluation Model).

The simplest way of specifying which elements should be permitted to be adjacent to one another, and subsequently their required minimum inter-side and nodal distances, is to specify a complete adjacency matrix (Fig. 2.12). This matrix would contain along the top and left hand side each, labels for the complete library of single elements, with labels for sides and nodes for each element. The main body of the matrix would contain all the permitted distances between the sides and nodes of different elements. The "boxes" of the matrix which do not contain distance values indicate that an element side or node is not compatible for adjacency with another element side or node. As mentioned, it is also possible to have a factor of probability or frequency attached to each distance value, denoting the likelihood of that particular adjacency occuring. Adjacency probability factors will be further dealt with elsewhere (See Sub-section 4.5; Evaluation Model).

The employment of a complete adjacency matrix was abandoned because of the long time needed to input distances and probabilities. It was decided that the previously described method of defining types of spaces, or, specifying distances adjacent to sides and nodes of an element, was more economical than a complete adjacency matrix, because a matrix of adjacency and all distances between elements, could, if necessary, be generated when needed (See Sub-section 4.4).

So far, mostly <u>minimum distances</u> between elements have been examined (See F.E(X).U; Table 2.3). The elements spoken of in this connection have been <u>unrelated,</u> that is, no <u>maximum distances</u> had to be specified between the elements. However, some elements are <u>related</u> in such a way that one element should not be farther away from another than a certain maximum distance, otherwise the two elements would not function together as intended. For instance, a chair and a coffee table should not be so far apart as to make it impossible for a person in the chair to reach over and pick up his coffee cup (See F.Ei.Ej.U; Table 2.3). It could perhaps be said that a checking mechanism must first check if two elements have broken any minimum distance rules, next, check if the two elements are related, and finally, check if a maximum distance has been broken (Fig. 2.13).

The inclusion of I.F.Ei.Ej involves adding attributes E(X1) - E(XN) to appropriate element sides, and associated I.Ei.Ej distances, which are the maximum distances that particular element side can be from the appropriate opposite sides of other elements. The distinction between maximum and minimum distances and related and unrelated elements was found to be more valid in principle, rather than warranting application in practice. Later, it was decided that the designer's intuition, and the checking of minimum distances only, was necessary.

ELEMENTS		E1								E2
	SIDES/ NODES	N1	S1	N2	S2	N3	S3	N4	S4	
E1	N1		l0	l1	l2	l3				
	S1			l4						
	N2									
	S2									
	N3					l5				
	S3									
	N4						ln			
	S4									
E2										
E3										

Fig. 2.12. Element Adjacency Matrix.

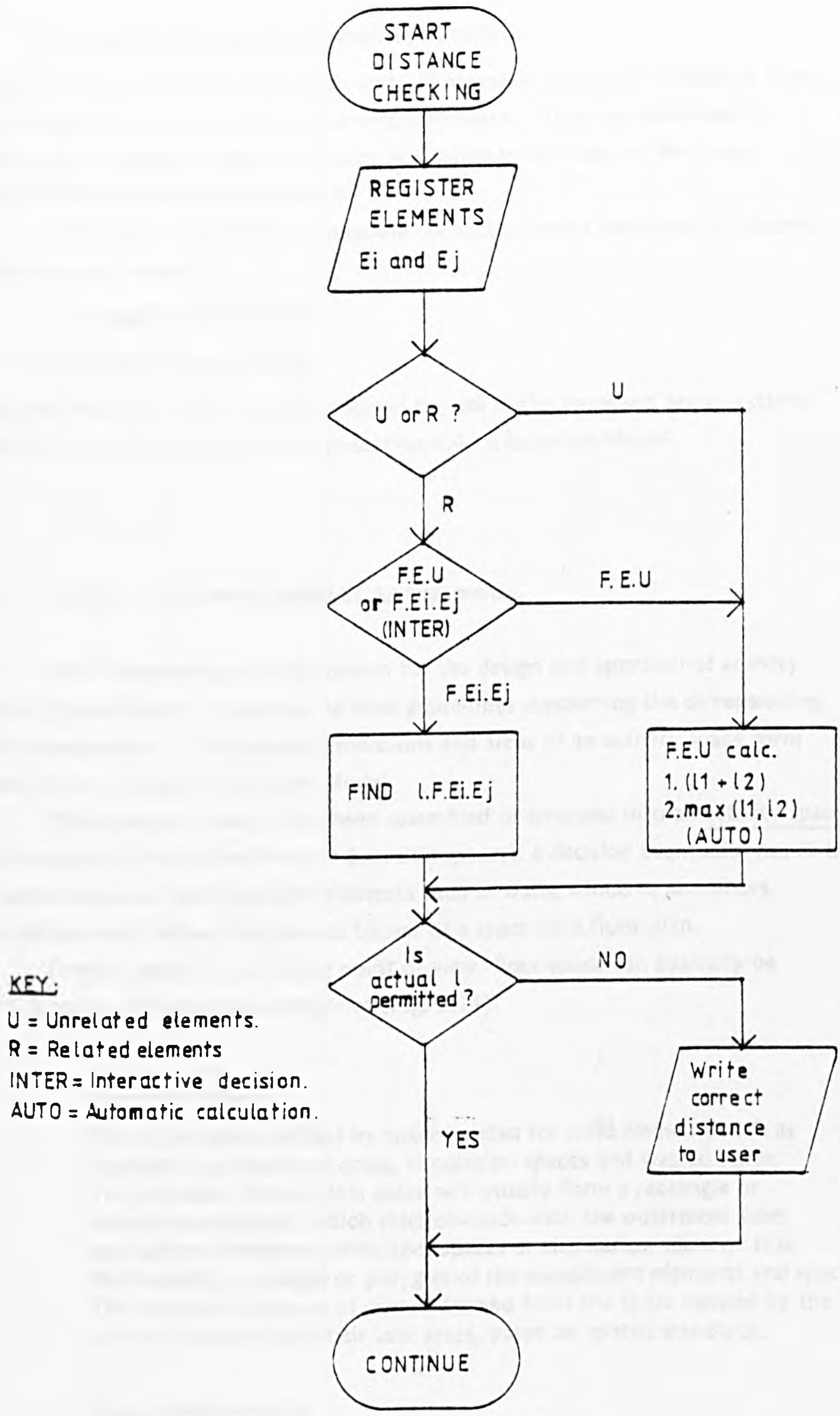


Fig. 2.13. Distance Checking Procedure.

This Sub-section can be summarised as follows:

A single element is defined by its name, state of movability, and user distances from each side and node, which forms a bounding user space. This user space can be contiguous to or overlap other user spaces, according to the rules of the Space Overlap Permissibility Table (Table 2.4).

It is evident that there is a possible conflict between two types of element interaction rules, namely:

1. Distance Calculations.
2. Space Type Overlaps.

It was found that the latter was better suited for use in the proposed design system, but this will be treated in depth in Sub-section 4.4; Evaluation Model.

2.5.2. Rules for the Dimensioning of Arrangements.

When developing a design system for the design and appraisal of activity spaces and house plans it is essential to have guide-lines concerning the dimensioning of such arrangements. The various dimensions and areas of an activity space form the basis of the proposed Evaluation Model.

When single elements have been assembled or arranged into an activity space (See Sub-section 4.3 for other levels of domestic spaces), a decision eventually has to be taken as to locational positioning of elements such as walls, windows and doors. The latter elements define the physical barrier of a space on a floor plan.

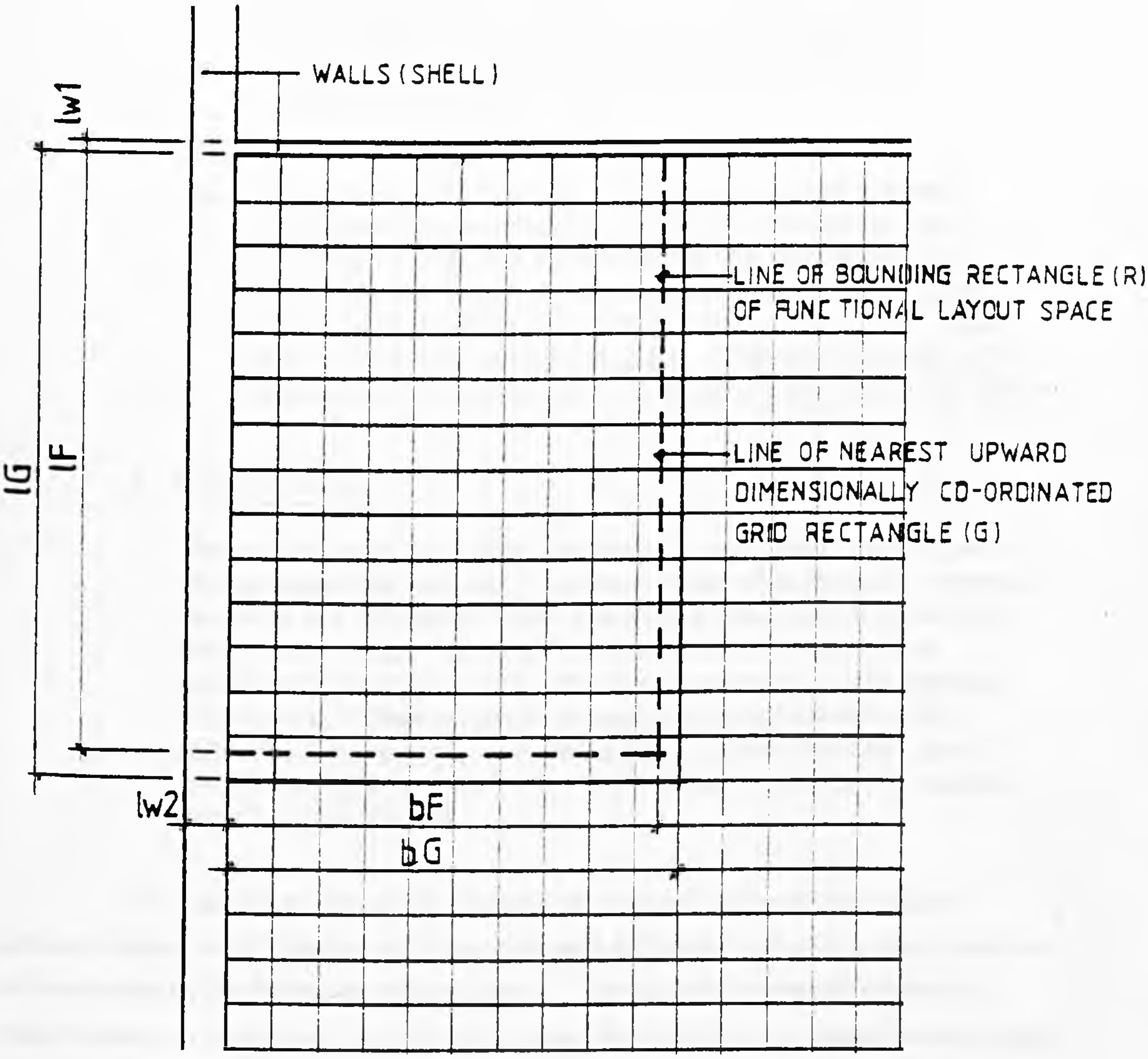
From a space dimensioning point of view, floor-space can basically be defined in terms of three space categories (Fig. 2.14):

1. Functional Space:

   This is the space defined by space needed for solid elements such as furniture and their user areas, circulation spaces and wasted space. The perimeter lines of this space will usually form a rectangle or orthogonal polygon, which sides coincide with the outermost sides and nodes of element solids, user spaces or circulation spaces. It is the bounding rectangle or polygon of the constituent elements and spaces. The functional space is of course derived from the space needed by the activity elements and their user areas, based on spatial standards.

2. Space between Walls:

   This may be of two kinds:



KEY:

lw = Width of walls.
lF = Length of R.
bF = Breadth of R.
lG = Length of G.
bG = Breadth of G.

Fig. 2.14. Dimensioning of Arrangements.

2.1. If no dimensionally co-ordinated planning grid is used, space between walls will usually equal functional space plus the user areas for walls, that is, space for skirting boards, radiators and so forth.

2.2. If a dimensionally co-ordinated grid of any kind is being used, space between walls will usually be multiples of grid modules. In this case the functional space perimeter has been adjusted (usually expanded rather than contracted) to concur with the dimensional grid of sizes, 3M, 6M, 9M, 12M and so forth, or a tartan grid (2.63). This grid could be as fine as described or so coarse as to be called a zone (1M = 100 mm).

3. Space for Walls:

Whereas the functional space (expanded, contracted or actual), or adjusted space between walls, can be considered as the solid elements, user areas and circulation space, the walls are the shell or structure or fabric of the house. The walls fulfil a different function than the elements and spaces within the functional space, in the context of this work. There is usually no particular space allocated for walls on a dimensionally co-ordinated grid, unless a special type of 10—20 tartan grid is employed (2.64). Grids will be further treated under Sections 3 and 4.

It is possible to juxtapose probable dimensions of functional spaces (activity-spaces) with dimensionally co-ordinated rectangles to derive a practicable set of dimensionally co-ordinated activity-spaces. The actual dimensions of activity-spaces would, in actual fact, be adjusted so that the bounding rectangles would concur with the nearest upward-sized grid rectangles. Conversely, a set of dimensionally co-ordinated rectangles could be tested for adaptability by investigating how many types and versions of functional activity spaces would fit into them, that is, the dimensions of their sides would have to be smaller or equal to those of the given rectangle (See also 2.65 – 2.67).

By using a metrically gridded magnetic planning-board and rubber-silicon cut-out elements certain tentative experiments were carried out concerning grids, assembly—techniques and adaptability of spaces (2.68). A similar technique includes a glass plate with lighting underneath and onto which can be fastened gridded tracing paper sheets. Cut-out elements can then be manipulated on the paper as above. For both of these two techniques, solutions can be recorded on photographs or slides. The two techniques were important transitional steps under the circumstances, towards a computer graphics design system.

Two designs, one for a large detached dwelling house and one for a combined electrical shop and dwelling, both located in Norway, were undertaken incidentally during this research project. Both buildings have now been completed. The opportunity was taken to design both buildings with particular attention given to the assembly idea of design and dimensionally co-ordinated grids. Otherwise, both buildings were designed to comply with Norwegian building standards and regulations and the house design had to comply with standards set forth by the Norwegian State House Bank (2.69 – 2.76).

It is not intended to use the two above designs as resultant examples of the proposed design system, since the designs were not carried out in a controlled manner and strictly according to the system. However, drawings are included in the external supplements to the thesis, and their inclusion is purely made to demonstrate that some practical experience was obtained during the research project, and that subsequent models were proposed not only from a theoretical point of view, but also with some basis in real design problems.

SECTION 3: AN INVESTIGATION OF EXISTING DOMESTIC DESIGN SYSTEMS AND THEORIES

3.1.	The Norwegian State House Bank System	S3.2
3.2.	The Norwegian Building Research Institute Systems	S3.9
3.2.1.	The Svennar System	S3.9
3.2.2.	The Björkto System	S3.12
3.3.	The Swedish Building Research Institute Systems	S3.25
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AN INVESTIGATION OF EXISTING DOMESTIC DESIGN SYSTEMS AND THEORIES.

This section briefly describes existing domestic design systems and theories related to functional planning that were found to be relevant to the proposed system. Shortcomings of existing systems have already been suggested in Sub-section 2.1, and the object of this investigation was to extract information from such existing systems that might be of consequent use in this work. It was found that none of the investigated systems offered a comprehensive, flexible and practical answer to the designers problem. However, useful insights were gained which influenced the subsequently advanced system.

3.1. The Norwegian State House Bank System.

The DNSH is the only major building society in Norway and drawings for standard houses have formed an important part of the bank's activity (3.1, 3.2). A wide range of design standards for such standard houses have been issued (3.3 — 3.7). In 1973 a design system was developed (3.8), for the generation of a whole range of categorised and diversified standard house drawings (3.9 – 3.11), as well as an aid for designers involved in house design and residential area planning. The aim was to create a system that would combine rational planning and production of units with great choice and adaptability to existing and future individual requirements. A major consideration was the anticipated rationalisation of drawing work for standard houses, since all schedules and details can be standard for the whole system. Drawings for every new house type constitute simply an instruction for the assembly of components. The system was chiefly concerned with detached houses, but other variants such as terraced houses and tenements were also generated.

The house types were timberframed and timber-clad with hipped roofs and basements in concrete. The structural module was 1200 mm and the main constructional elements were:

- Load-bearing roof trusses c/c 1200 mm, spanning 7.2 m, or 3.6 m if only one half of the truss is used.
- Load bearing external walls with two timber-studs at 1200 mm, giving good flexibility for insertion of windows and doors, standard width 11M.
- Standard floor joists at 600 mm c/c, spanning 3.6 or 2.4 m
- Posts and lintel system in the basement as centre support for joists.

- Strip foundations in the long direction of the house or floor directly on the ground.

Prefabricated chimneys were used. Plumbing and ventilation ducts were placed at non-changeable parts of the house, as was electrical circuits and installations.

The planning module or grid was 24 M x 36 M (M = 100 mm). This size was derived from functional studies described earlier (3.12). Primary activities were:

- sleeping.
- making food.
- eating.
- personal hygiene.
- mixing with family and guests.
- possibility to be alone.

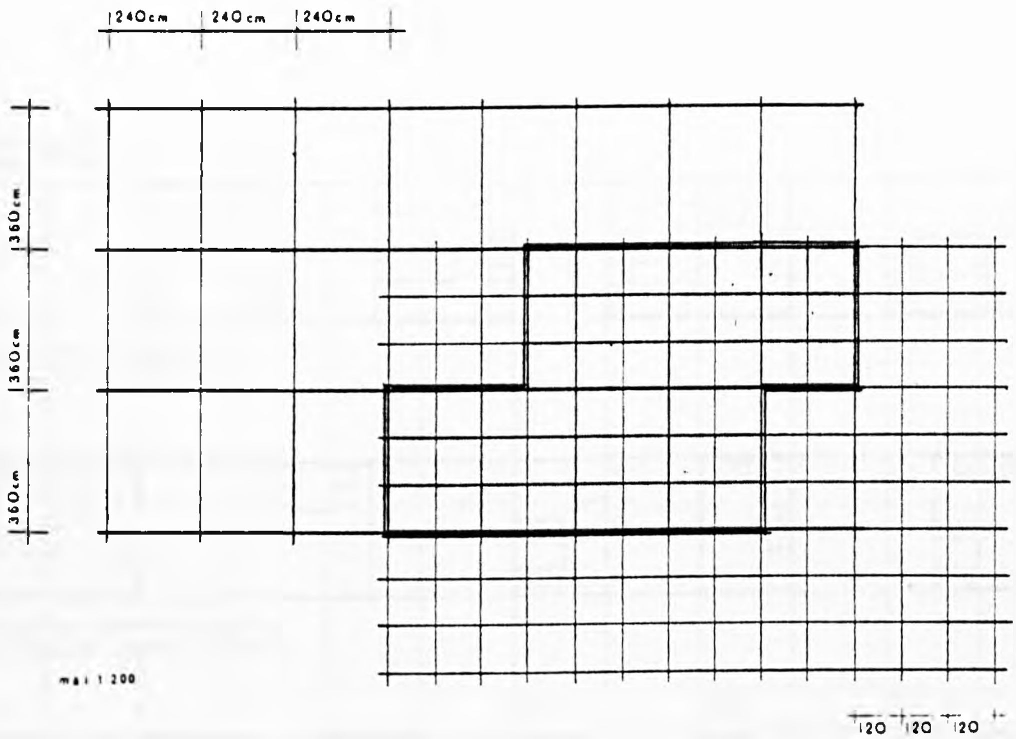
The planning and structural (constructional) modules or grids are shown in Fig. 3.1.

The functions fall into three groups: User rooms, sub-servient rooms, and passage areas. Fig. 3.2 shows how the sizes of various "standard" rooms relate to the 24 M x 36 M planning grid. Rooms have been given sizes to ensure that they are generally adaptable to accept a range of different furniture and fitting layouts, that is, they can be used for a variety of activities as demands change. Fig. 3.3 shows examples of how rooms can be assembled into a plan in relationship to the planning grid and how auxilliary rooms, external seating areas and entrance areas can be added to the main body of the plan.

Fig. 3.4 shows how a plan principle is determined. Fixed elements of the plan, such as entrance lobby, stairs and duct zones for kitchen, bathroom and washroom are organised in a particular system for each plan principle. Location of the fixed elements determines the capacity for adaptability of the plan. A standard house plan can then be built up in a three phase procedure:

1. Determination of plan principle.
2. Determination of area of plan.
3. Site suitability.

Fig. 3.5 shows how a smaller house type can be extended and how internal changes can be made to the plan by re-arranging non-structural elements of the plan when changing demands and economy warrant this.



Modulnett for romsoner:
24M x 36M
Modulnett for konstruksjon:
12M x 12M

Når romsonene settes sammen til planer, vil de passe inn i modulnettet. Når de forskjellige bygningskomponenter settes sammen, vil de følge linjen i modulnettet.

Note: When the planning modules are assembled into plans they will fit into the planning grid. When the various building components are assembled they will follow the lines of the structural grid.
The structural grid fits into the planning grid.

Fig. 3.1. Planning, Structural and Constructional Grids of the DNSH – system. After DNSH (3.13).

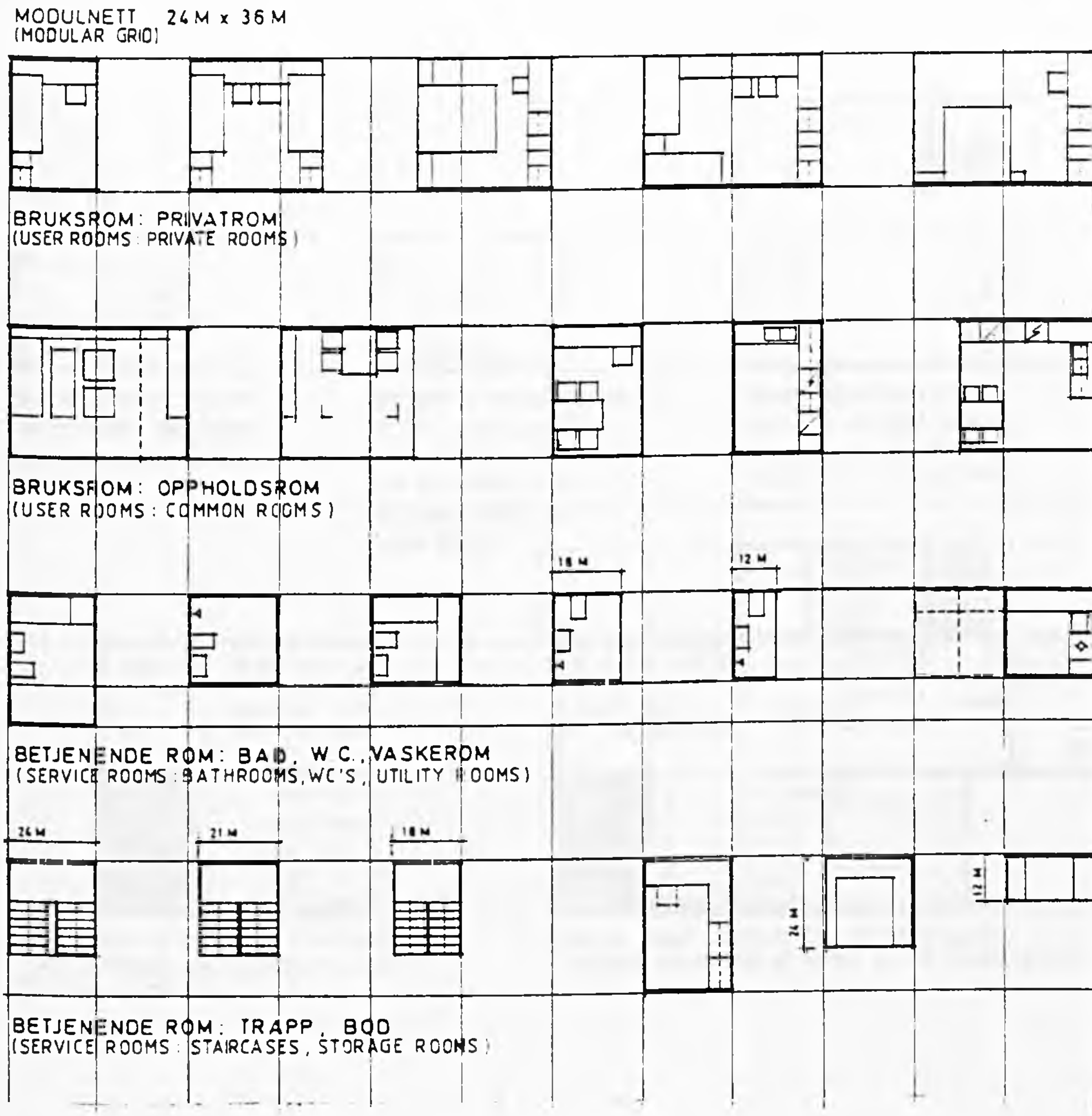


Fig. 3.2. Room Sizes and the Planning Grid of the DNSH – system.
After DNSH (3.14).

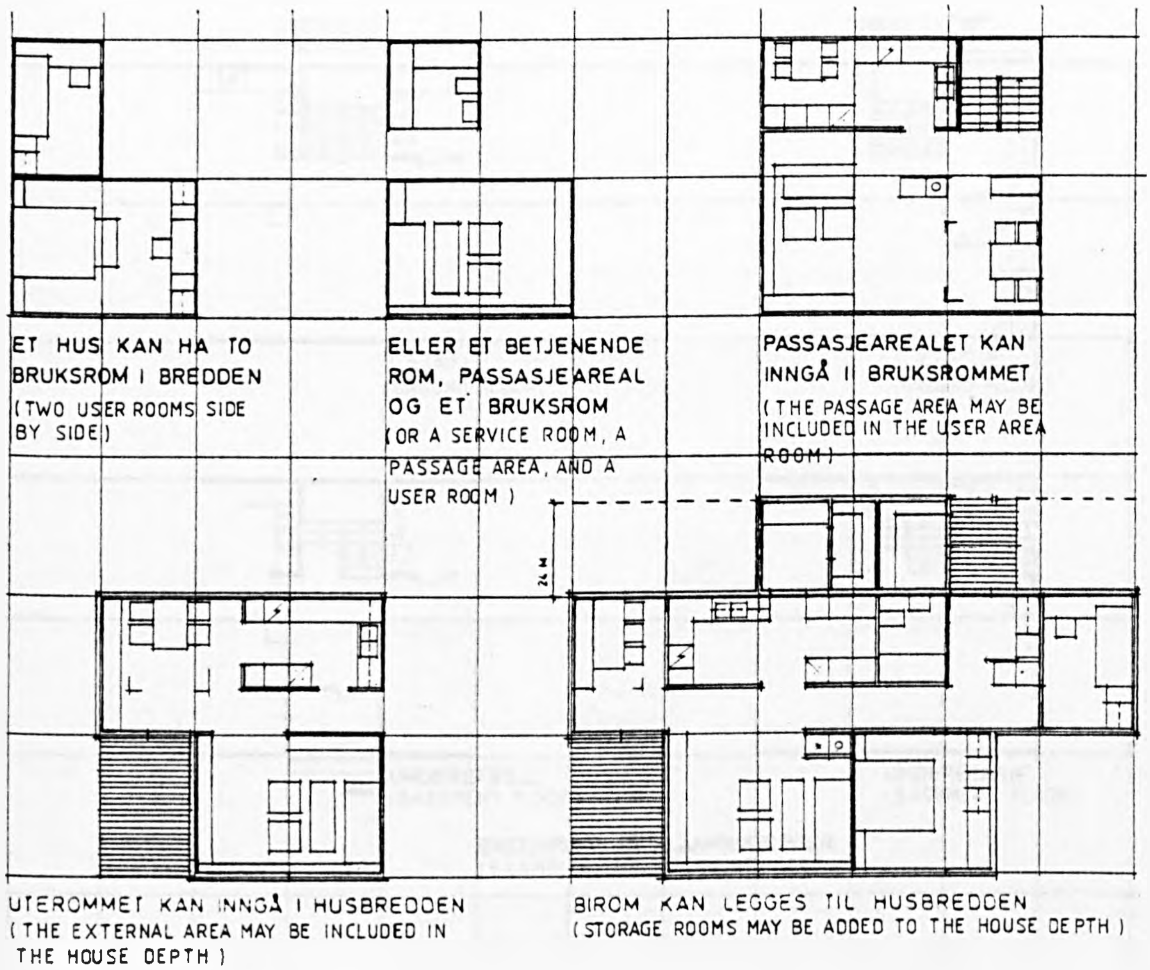


Fig. 3.3. Examples of Room Assembly of the DNSH – system.
After DNSH (3.15).

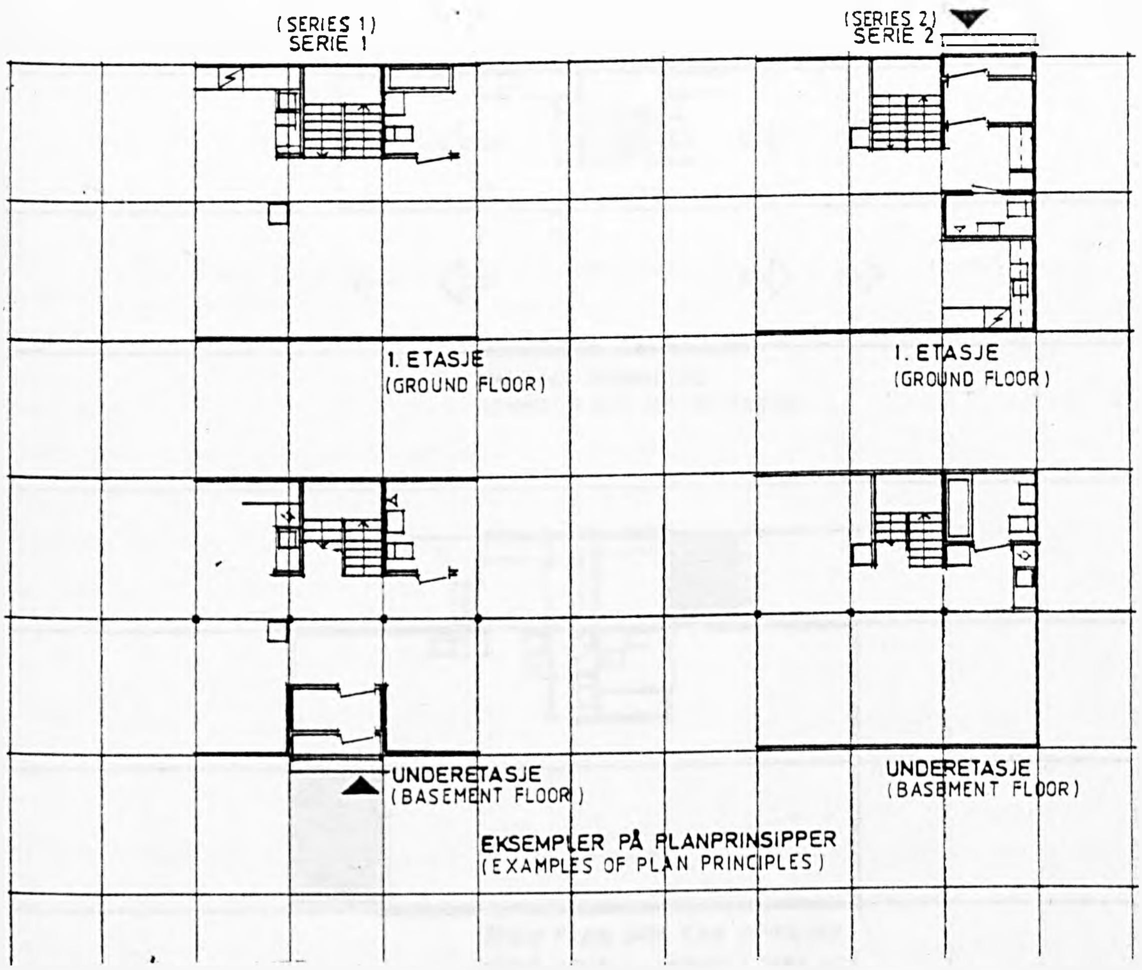


Fig. 3.4. Examples of DNSH Plan Principles. After DNSH (3.16).

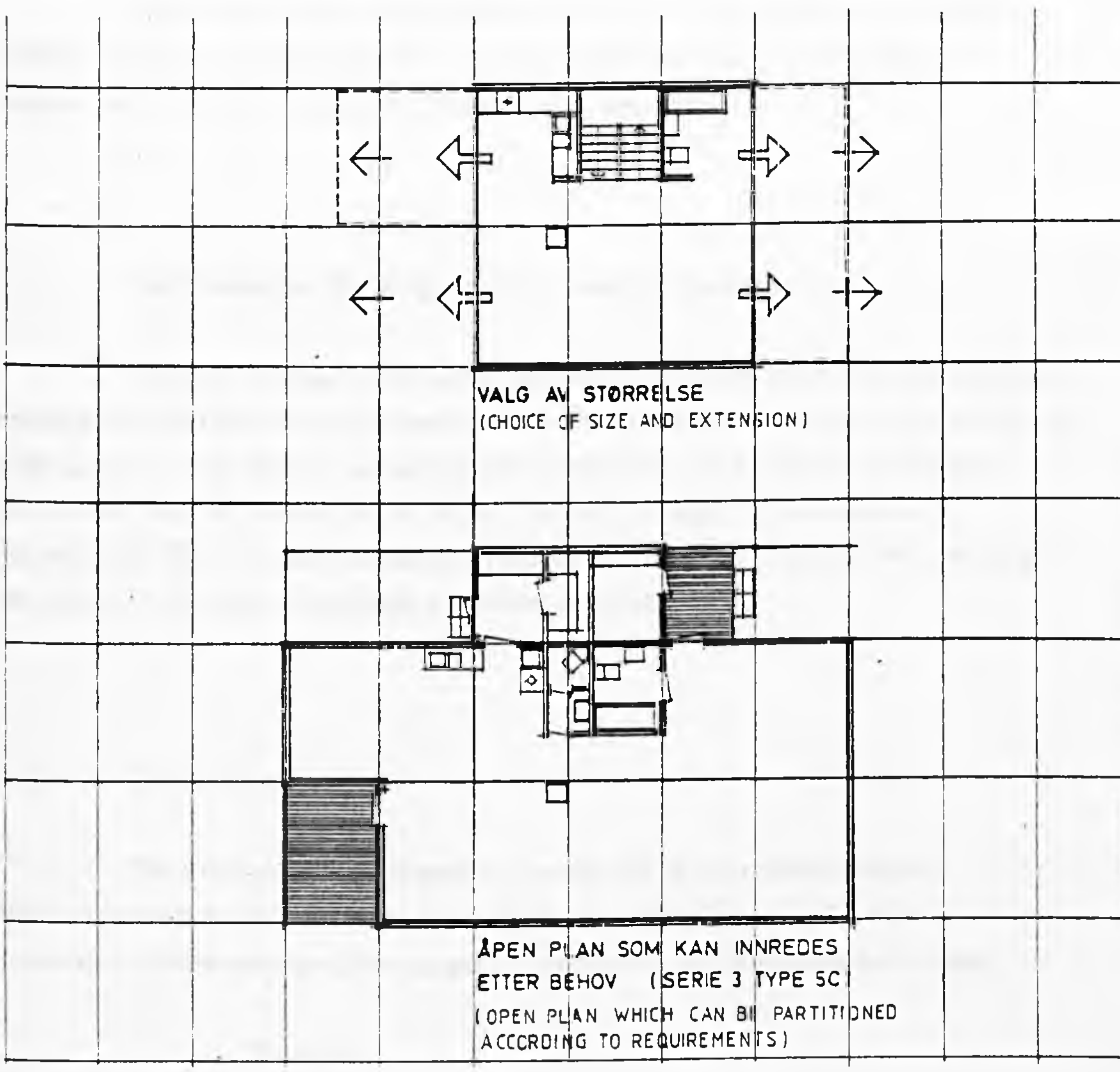


Fig. 3.5. Choice of Size, Extension, Division of Plan and Internal Re-arrangements of the DNSH – system. After DNSH (3.17).

Each plan type is supplemenetd by 4 alternative plan variants. Plans are arranged into series according to their plan principles, sizes and site suitability, and include external spaces, which will not be described here. Clients can thereby choose a type and size that will suit their economy and site.

The system relies on conventional drawing techniques and contains no method of appraising floor plans. The functional and structural premise of the system limits versatility of plan forms by being too rigid.

3.2. The Norwegian Building Research Institute Systems.

The NBI amongst other activities undertakes laboratory and other studies relating to furniture and space needed in the home. These ergonomic and functional data appear as part of their comprehensive publication Building Research Series, and is the result of a co-ordinated research activity within the Scandinavian countries (2.18). No definite design systems have emerged from the NBI, although two functionally related methods are worth studying.

3.2.1. The Svennar System.

The Svennar System is mostly a result of the data given in many NBI data sheets on spatial standards in the home. The following 10 main domestic activities emerged from population statistics and anthropometric data:

- Sleeping
- Eating
- Occupying oneself with others
- Occupying oneself alone
- Making food
- Personal hygiene
- Tending to Clothes
- Cleaning
- Storing
- Circulating.

Each of the activities were analysed in detail and a number of Sub-activities listed.

Based on these a corresponding number of furniture or spaces were listed. Environmental requirements were also considered for each activity. The next progressive step in the analysis was to specify a number of activity-elements (corresponding to the term activity-spaces referred to in the proposed system), being dimensioned rectangles or polygons containing the necessary furniture for particular activities and patterns of movement within the dwelling. It was an objective to design adaptable activity-elements. The following dimensioned main groups of activity-elements were listed (several of each):

- Space for sleeping
- Space for eating
- Space for sitting
- Free floor space
- Working space
- Space for making food
- Space for personal hygiene
- Space for washing clothes
- Space for storing (split into groups)
- Circulation areas
- Doors
- Stairs
- Windows.

Furniture and other elements were dimensioned and in a limited fashion user areas were also shown. Examples of activity elements are shown in Fig. 3.6. Furniture and fittings and activity-elements were combined in a variety of ways in each case, into the following room plan categories:

- Bedrooms (1 - person, 2 - person, couples).
- Livingrooms (1 - 2 person flats, 3 - 5 person dwellings).
- Kitchens (1 - 2 person dwellings: L - shape, 1- sided plan, 2 - sided plan.
  3 - 5 person dwellings: L - shape, 1 - sided plan, U - shape, 2 - sided plan, deep 2 - sided plan with space for eating at window, U - shape with space for eating, 2 - sided plan with space for eating at window, L - shaped with utility space.
  Large dwellings: L - shape, U - shape).

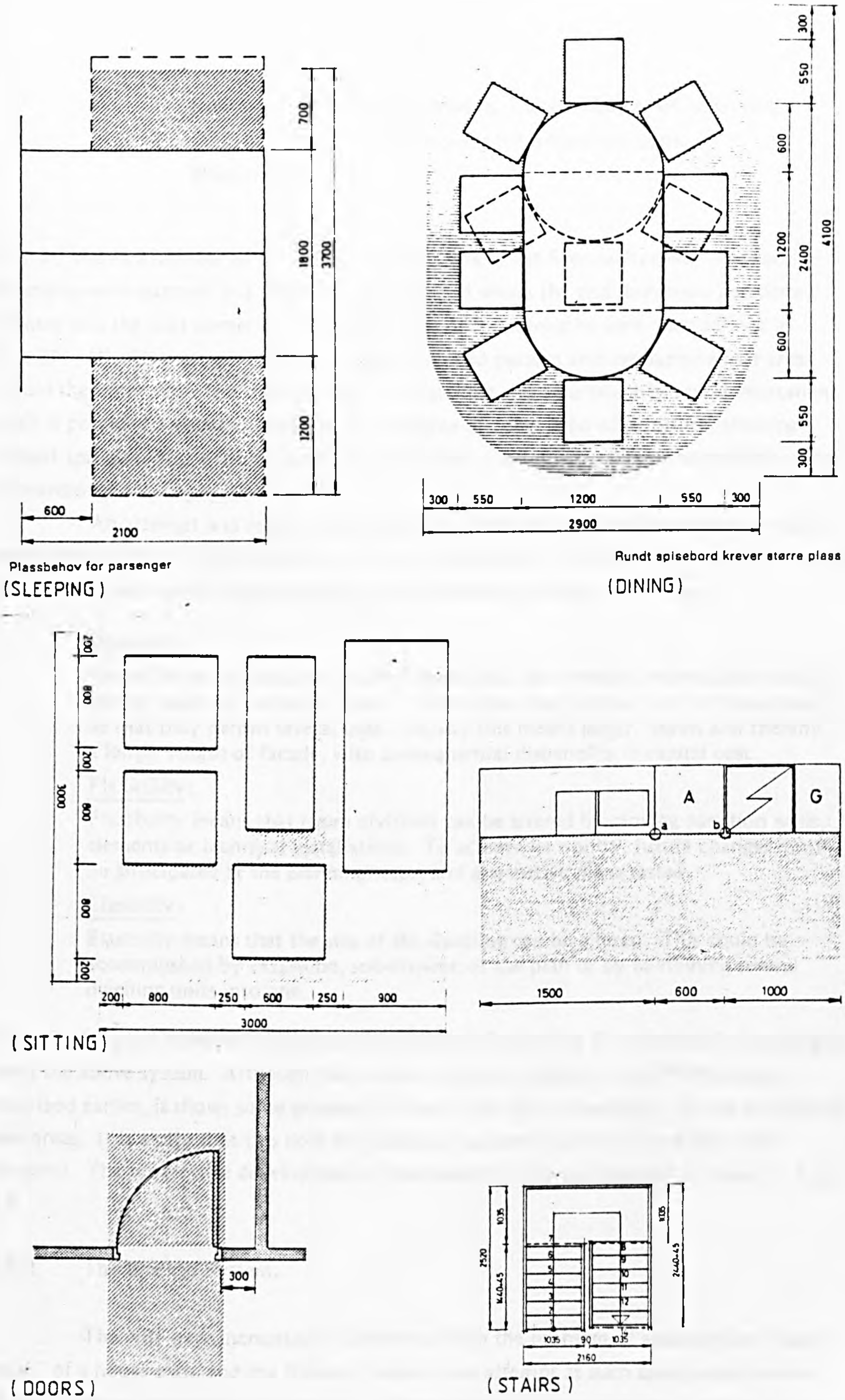


Fig. 3.6. Examples of Activity-elements of the Svennar System.
From Svennar, E. (3.22).

- Sanitary rooms (Bathrooms, shower rooms, WC's, saunas, bathrooms for wheelchair users).
- Washrooms.

Fig. 3.7 shows a number of examples of room plans of the Svennar system. The room examples were adapted to a 3M x 3M modular grid where the grid lines were positioned 50 mm into the wall elements. The dimensions of room lengths were then defined as (n x 3M - M). User areas were shown with a hatched pattern and overlapping user areas would therefore show in a darker tone. The hatching was a particularly useful instrument since it provided a visual impression of the degree of congestion of furniture, allowing instant appraisal of the room layout by the designer, and this would not be possible using conventional drawing symbols.

An attempt was made to progress into designing complete house plans using the room plans evolved. Adaptability was the main qualitative criterion set for such floor plans. Adaptability was said to be obtainable by the following different objectives:

Generality:

Generality as a house plan quality means that the dwelling without any changes can be used in a variety of ways. This implies that rooms must be dimensioned so that they permit several uses. Usually this means larger rooms and thereby a longer length of facade, with consequential disbenefits in capital cost.

Flexibility:

Flexibility means that room divisions can be altered by moving partition walls, elements or technical installations. To achieve flexibility, future changes must be anticipated at the planning stage, and alternative plans tested.

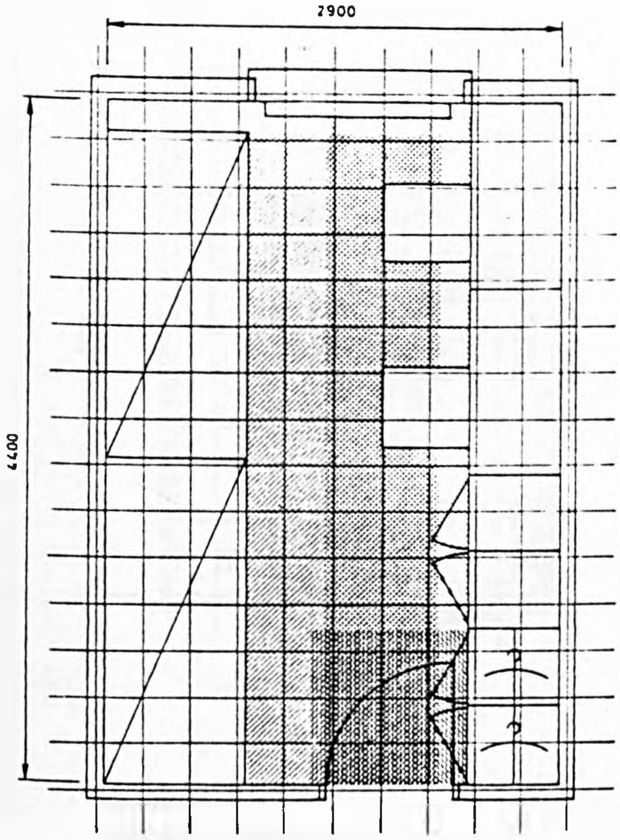
Elasticity:

Elasticity means that the size of the dwelling can be altered. This could be accomplished by extension, sub-division of the plan or by combining several dwelling units into one.

Fig. 3.8. shows an example of ground floor and first floor plans of a terraced house designed using the above system. Although the Svennar system is similar to the DNSH system described earlier, it shows some promise of visual floor plan appraisal by the use of hatched user areas. It is a pity that this does not show on the complete floor plans that were designed. The progressive development of the system can be summarised or shown in Fig. 3.9.

3.2.2. The Björkto System.

The NBI were increasingly confronted with the problem of assessing the "usable value" of a house plan, and the Björkto System is an attempt at such an appraisal method (3.24). Various unsuccessful attempts had been made in many countries at devising appraisal methods, and these had taken various forms:



SOVEROM FOR TO PERSONER

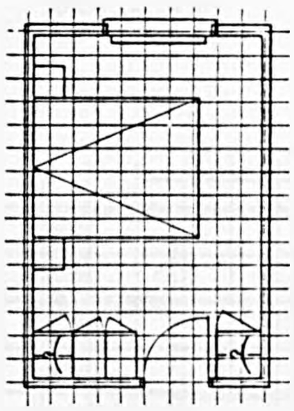
Fasadebredde 2,9 m
Dybde 4,4 m
Areal 12,8 m²

Rommet kan ikke deles, heller ikke bruksmessig, slik at de to beboerne kan disponere hver sin del av rommet.

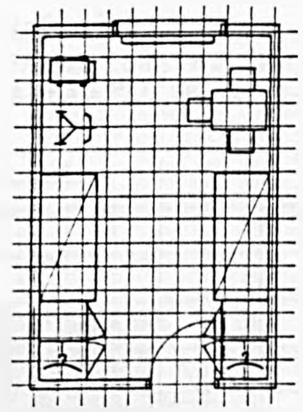
Det kan romme to sengeplasser i dybden, to doble garderobeskap på tilsammen 2000 mm × 600 mm og to arbeidsplasser, hvorav den ene med godt dagslys fra venstre.
Fritt gulvareal 5,6 m², men med en lang-smal og lite hensiktsmessig form.
En av beboerne kan være rullestolbruker.

BEDROOMS FOR TWO PERSONS:

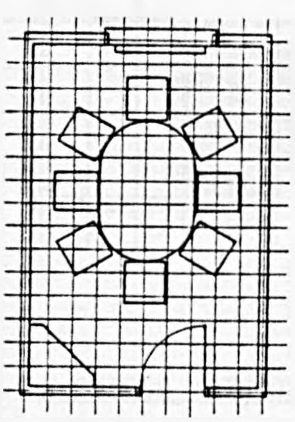
FACADE LENGTH = 2.9 m
DEPTH = 4.4 m
AREA = 12.8 m²



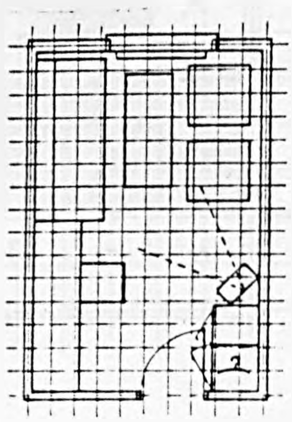
ADAPTED AS MASTER BEDROOM



ADAPTED AS BED / PLAYROOM FOR TWO CHILDREN



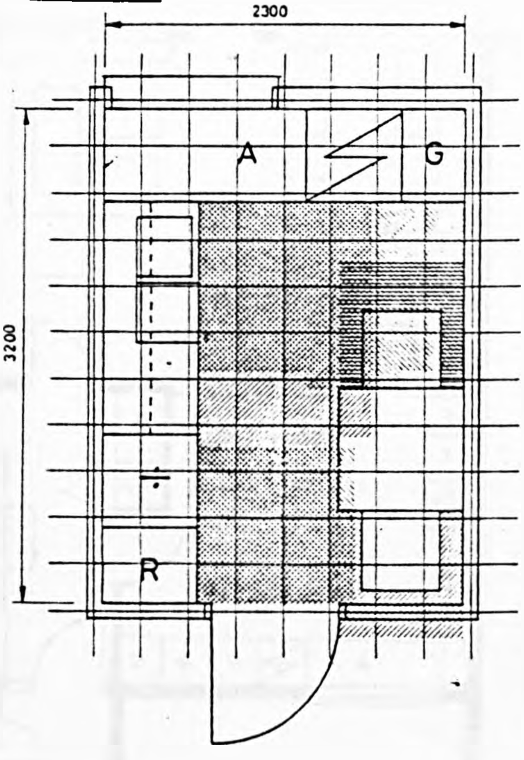
ADAPTED AS DININGROOM FOR 8-10 PEOPLE



ADAPTED AS BEDSITTER

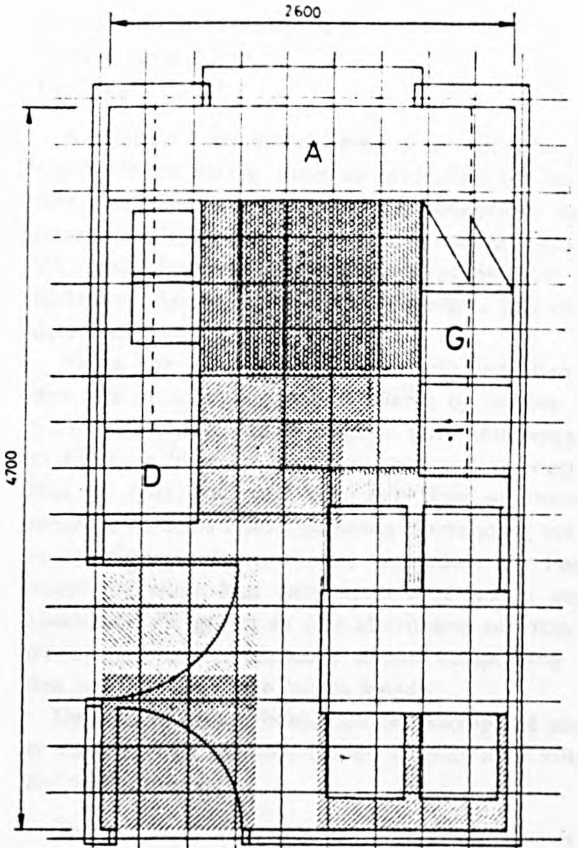
Fig. 3.7. Examples of Room Plans of the Svennar System.
After Svennar, E. (3.23).

KITCHENS:



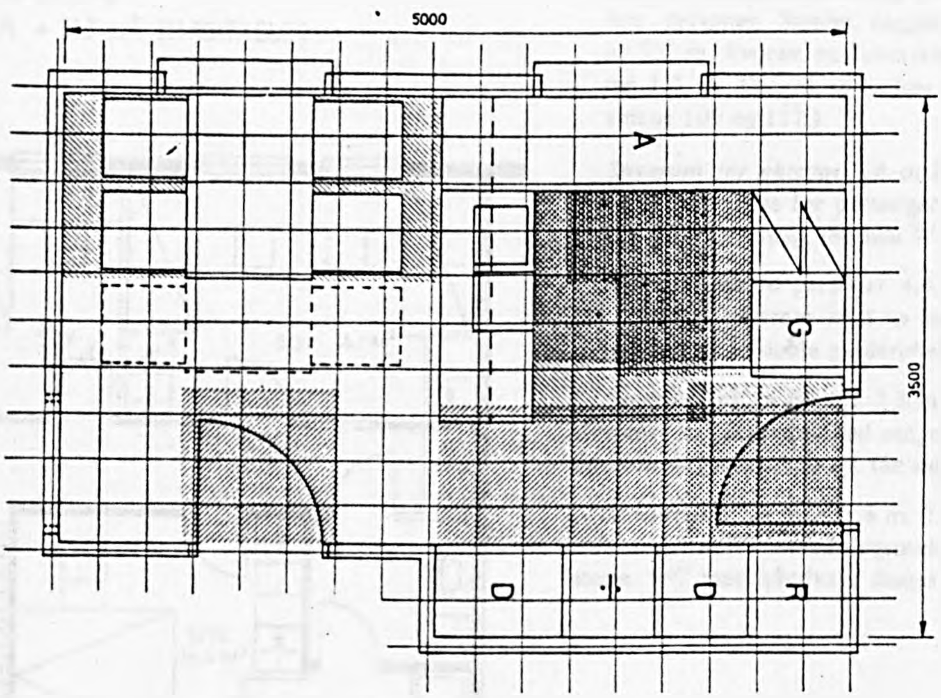
L-SHAPED:

FACADE LENGTH = 2.3 m
DEPTH = 3.2 m
AREA = 7.4 m^2



U-SHAPED:

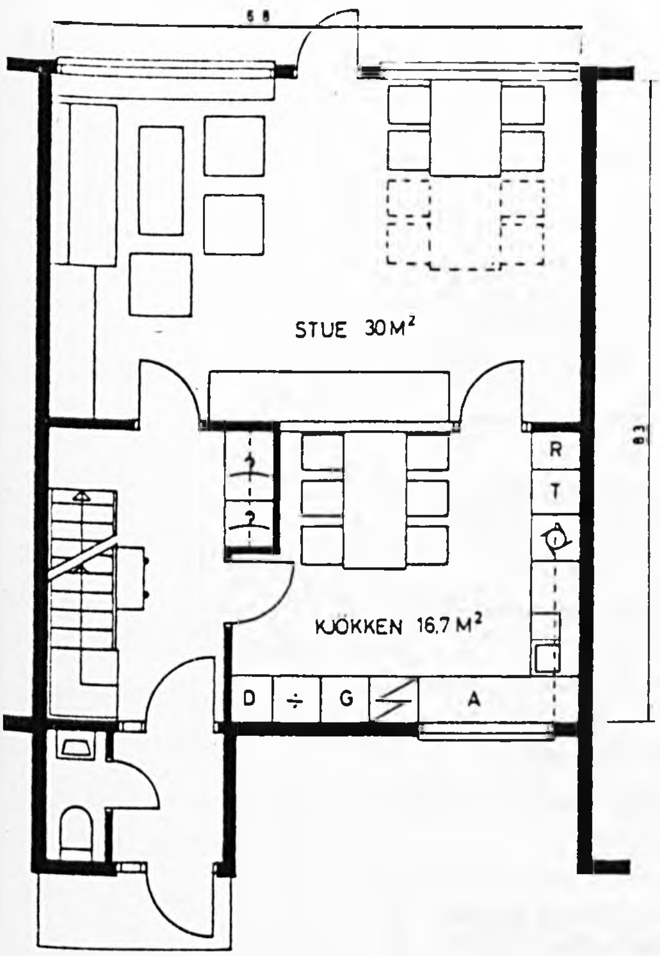
FACADE LENGTH = 2.6 m , DEPTH = 4.1 OR 4.7 m
AREA = 10.7 OR 12.2 m^2



U-SHAPED WITH DINING AREA:

FACADE LENGTH = 5.0 m
DEPTH = 2.9 m - 3.5 m
AREA = 16.0 m^2

Fig. 3.7. (Continued).



TERRACED HOUSE:

FACADE LENGTH = 6.8 m
DEPTH = 8.3 m
AREA = 113 m^2 (HABITABLE)

REKKEHUS

Fasadebredde, netto 6,8 m
Dybde, netto 8,3 m
Leieareal 113 m²

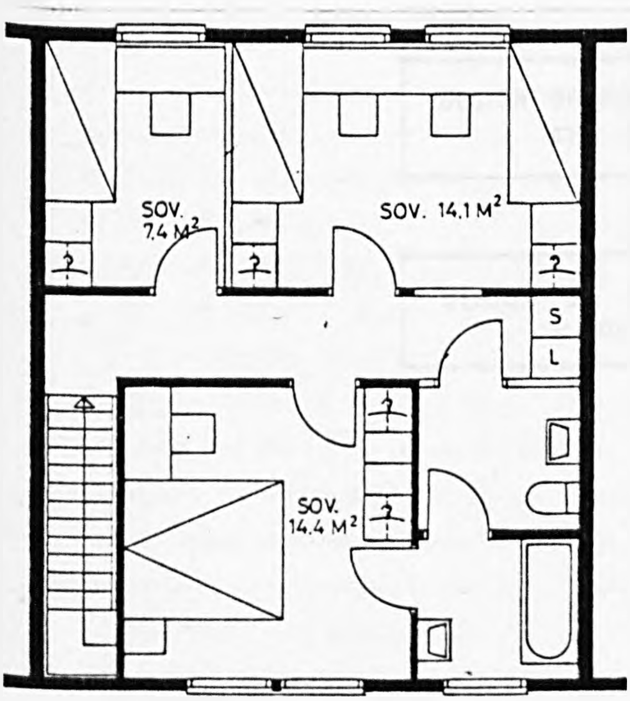
Rekkehus i to etasjer med stue, kjøkken og entré i første etasje, soverom med plass for inntil fem personer i annen etasje. To sanitærrom med flere innredningsmuligheter finnes i annen etasje, WC med håndvask i første etasje. Vaskemaskin og tørkeskap finnes i kjøkkenet og boder i helt eller delvis utgravd kjeller.

Huset kan tilpasses beboernes vekslende behov dels ved at rommene kan møbleres og brukes på flere måter, dels ved at enkelte lette skillevegger er flyttbare (markert på tegningene ved at veggen ikke er fylt). Ved små endringer kan soveromsarealene fordeles etter familienes størrelse og sammensetning, sanitærrommene innredes på flere måter, og stuen kan være åpen eller lukket mot kjøkkenet. På grunn av den alternative soveromsinndeling blir korridoren i annen etasje lang – den strekker seg i hele husets lengde.

De enkelte rom er hentet fra de eksemplene som er vist i forrige kapittel, i noen tilfeller med mindre tillempninger.

Stue 6,8 m × 4,4 m. 30 m². Stuen har plass for stor sittegruppe, spiseplass for inntil åtte til ti personer og 4,7 lm veggplass for oppbevaringsmøbler. Det er ca. 10 m² fri gulvplass. (Se side 101.)

Kjøkken 4,4 m × 3,8 m. 16,7 m². Rommet har plass til kjøkkenutrustning for en husholdning på fem personer. Samlet vegglengde for innredning er 7,0 m, hvorav vaskemaskin og tørkeskap opptar 1,2 m. Det er spiseplass for 6 personer. (Se sidene 109 og 117.)



Soverom for ektepar 3,8 m × 3,8 m. 14,4 m². Rommet har plass for parsenger, toalettbord og to doble garderobeskap. (Se side 95.)

Soverom for to personer 4,4 m × 3,2 m. 14,1 m². Delbart soverom med to sengeplasser, to arbeidsbord og to doble garderobeskap. (Se side 90.)

Soverom for en person. 2,3 m × 3,2 m. 7,4 m². Rommet kan innredes med sengeplass, arbeidsbord og dobbelt garderobeskap. (Se side 86.)

Sanitærrom 2,0 m × 3,8 m. 7,6 m². To sanitærrom med flere innredningsmuligheter i annen etasje. WC med håndvask finnes i første etasje.

Fig. 3.8. Floor Plans Designed Using the Svennar System. From Svennar, E. (3.24).

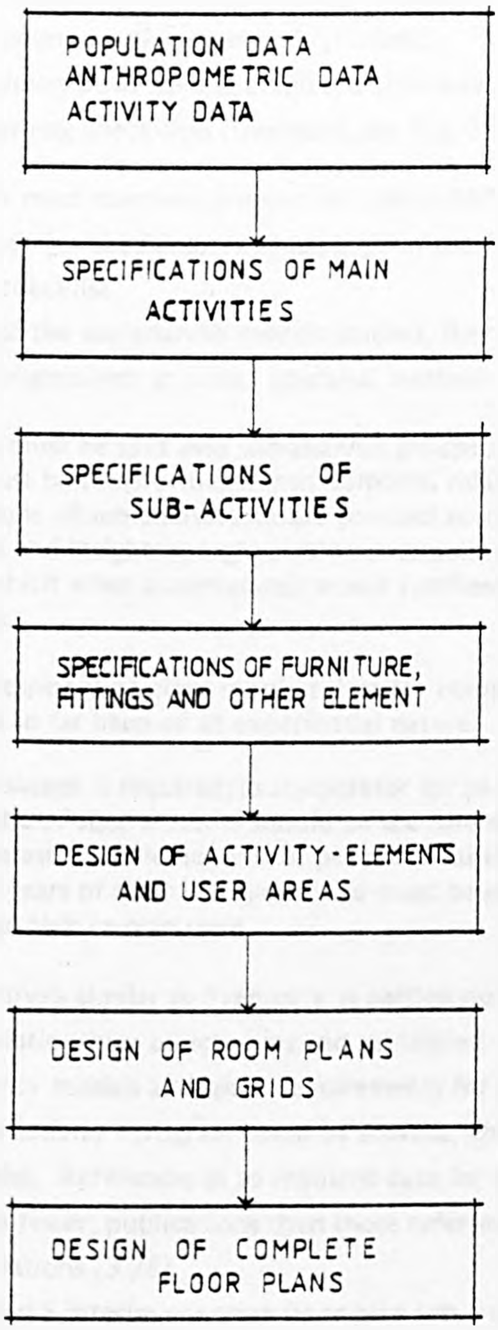


Fig. 3.9. Development of the Svennar System.

- Graphical analyses (France and Germany).
- Mathematical calculations (Germany).
- Attribution of points; ranking methods (U.S.A.).
- Economic ranking methods (Finland).
- Opinion polls among architects (Norway; see Fig. 3.10).
- Planning check-lists (Denmark, see Fig. 3.11).

The latter above was the most concrete proposal to date (1963). Desirable characteristics are pre-defined with space for checking. A rough type of plan quality evaluation was also included on the Danish checklist.

On the basis of the sub-analysis models studied, Björkto put forward the points he regarded as essential ingredients to a plan appraisal method:

1. A method must be split into sub-analysis groups as part of the total analysis. Results must be transformable into numbers, relations or concrete observations. Investigations of sub-analyses should proceed according to current relevant techniques and insights, progressively constructing a multitude of such sub-analyses, which when accumulated would synthesize into a total appraisal of the plan.

2. Logical assessment of plans requires data for comparison, that is norms. These have so far been of an experiential nature.

3. A model concept is required; as comparator for plan appraisals. The main characteristic of such a model should be the intention of providing satisfaction for the greatest possible number of people or families during the greatest number of years of their life cycles, and must be easy to adjust to each particular design task or plan type.

An activity analysis similar to Svennar's is carried out, resulting in an activity - model, describing interrelationships of activities and associated areas needed (See Fig. 3.12 for examples of sub-activity models and space requirements for some furniture. Björkto outlined how a complete activity - program could be created, which would form the skeleton of the plan appraisal model. References as to required data for an activity - program were made to similar, although fewer, publications than those referred to in Section 2, as well as relevant building regulations (3.28).

Björkto specified 5 interim concrete floor plan sub-analysis areas and demonstrated these using a specific flat floor plan. The sub-analyses were mainly of a graphical nature. Drawings and plan-analyses were transferred to plastic film, and by use of an overhead projector, the sub-analyses could be studied singly or in conjunction with one another by super - imposing sheets. It was the intention (subsequently unrealised) to transform the requirements of the sub-analyses into practical aids such as templates, planning elements on tape, check-lists and so forth.

The 5 sub-analyses were:

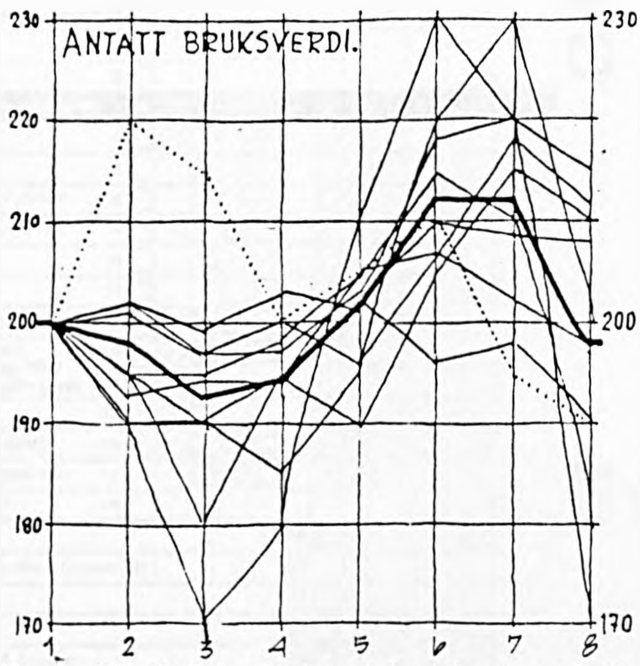


Fig. 1. Når 10 Oslo-arkitekter skal uttale seg om bruksverdien av 8 leilighetsplaner, synes oppfatningene å divergere like mye som hos menigmann.

(DIVERGENCE IN ARCHITECTS' SUBJECTIVE APPRAISALS OF 8 APARTMENT PLANS)

Fig. 3.10. Assumed Usable Value of Floor Plans among Architects. After Björkto, R. (3.25).

SBI HUSKELISTE for familieboligens funktionskrav

VURDERINGSSKEMA for familieboligens brugsværdi

☐ Primære krav

☐ *Sekundære krav*

Andre muligheder for opfyldelse af primære og sekundære krav er vist som fri felter

For hvert krav noteres om dette er: ikke opfyldt ÷, opfyldt O, bemærkelsesværdig (god) løsning +

rum nr | antal sengepladser

BEBOELSESRUM: A Opholdsstue, B *Opholdsstue 2*, C Forældresoverum, D Soverum, E Soverum, F, G *Køkken/spisekøk.*

BIRUM: H Forstue/gang, J Vindfang, K WC, bad

L, M UDENOMSRUM

÷ O + hver linie

ENDELIG VURDERING
1 uacceptabel
2 acceptabel — under middel
3 acceptabel — middel
4 acceptabel — over middel

rum ialt | senge ialt | boligareal brutto | netto | udenomsrums bruttoareal

Plandisposition - opfyldes krav om A B C D E F G H J K L M — hver gruppe — *Bemærkninger*

1 Ingen installationer på væg mod beboelsesrum
2 Adgang fra forstue og tilstødende gang
3 *Kontakt køkken → spisepl. Kontakt køkken → udenomsrum (M)*
4 *God beliggenhed for udlejning*
5 *Dør til terrasse / have*

Plandisposition

Rumfunktioner - opfyldes krav om plads til A B C D E F G H J K L M

6 Opholdsgruppe
7 Radiogrammofon *TV*
8 Spisebord med 5-7 stole, G: *spisekøk. 5 pladser*
9 Reol A: 35×135, ellers 35×105 *35×135*
10 Opbevaringsmøbel 65×165
11 Arbejdsbord 65×115, A: *85×155*
12 Seng(e) C: 200×210, D&E: 1 eller 2 stk. 100×210
13 Klædeskabe 1-sengsrum 65×105 løse og/eller
14 2-sengsrum 65×165 *65×210* indbyggede
15 *babyseng 70×120*
16 *skuffemøbel (C,D,E: 55×105 eller toiletbord)*
17 *alternativ møblering (C: 2×1seng, D: spisepl. osv)*
18 *supplerende møblering (A: f. eks. piano)*

Beboelsesrum + køkken

BEBOELSESRUM Køkken G

19 Friareal udfor arbejdsplads min. 100
20 Kosteskab 60×60 (enten i køkken (G) eller i forstue (H))
21 Underskabe 300×60
22 Overskabe 260
23 Køkkenbord, 410 cm bordforkant incl. komfur
24 Frastilling på begge sider af komfur og vask
25 Madskab (ventileret til det fri) 60×60
26 Køleskabselement 60×60 *60×70*

Køkken

27 At tage overtøj af og på ca. 3,5m² (i forstue (H) og/eller vindfang (J))
28 Garderobeskab 65×120 (i forstue (H) og/eller vindfang (J))

BIRUM WC, bad

29 WC, håndvask, brusebad, plads til badekar
30 *separat wc med håndvask*
31 *vaskemaskine eller andre supplerende installationsgenstande / møbler*
32 *vindue*

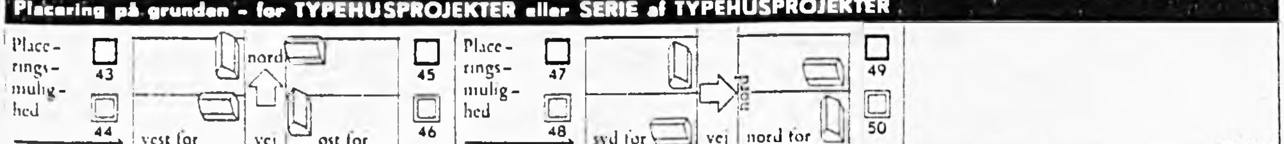
Birum

UDENOMSRUM OG GARAGE

33 Viktualier
34 Cykler
35 Tøjvask og indendørs tøjtørring (i bad (K) eller udenomsrum (M))
36 (Fyr og brændsel)
37 Skarnkasse
38 *pulterrum*
39 *haveredskaber og -møbler*
40 *værksted*
41 *garage*
42 (Senere udbygningsmulighed på grunden af evt. mgl. udenomsrum og garage, pkt. 33-41)

Udenomsrum og garage

Placering på grunden - for TYPEHUSPROJEKTER eller SERIE af TYPEHUSPROJEKTER



SBI 1959

Fig. 2. Denne danske sjekkliste for småhus omfatter så vel boligens som omgivelsenes egenskaper.

Fig. 3.11. House Planning Checklist. After SBI. In Björkto, R. (3.26).

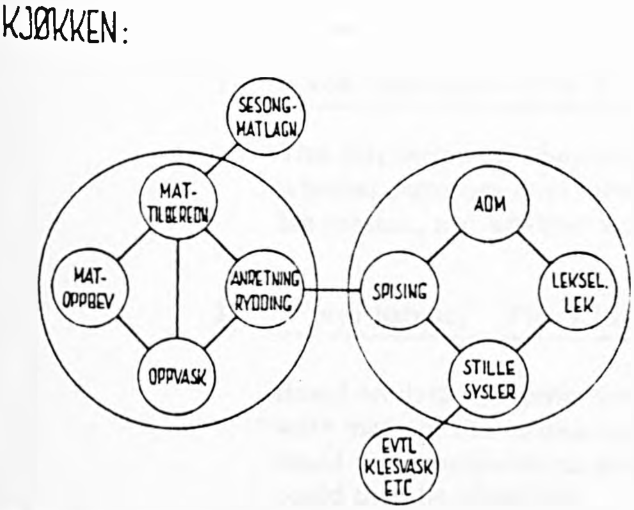


Fig. 3. Kjøkkenets primære, veldefinerte oppgaver er vist i sirkelen til venstre. Sirkelen til høyre antyder bioppgaver som er vel kjent, men ikke klart definert.

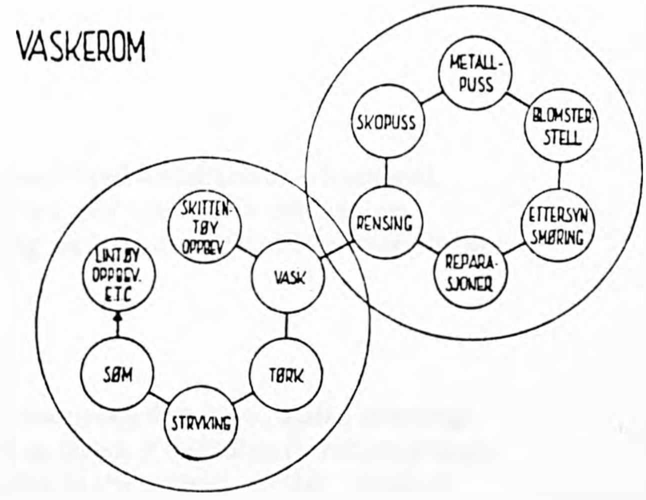


Fig. 4. Vaskerommets primære oppgave er klesvasken. Men det er også andre oppgaver i boligen som med fordel kan konsentreres her. Disse oppgaver har hittil vært nokså hjemløse i boligplanen.

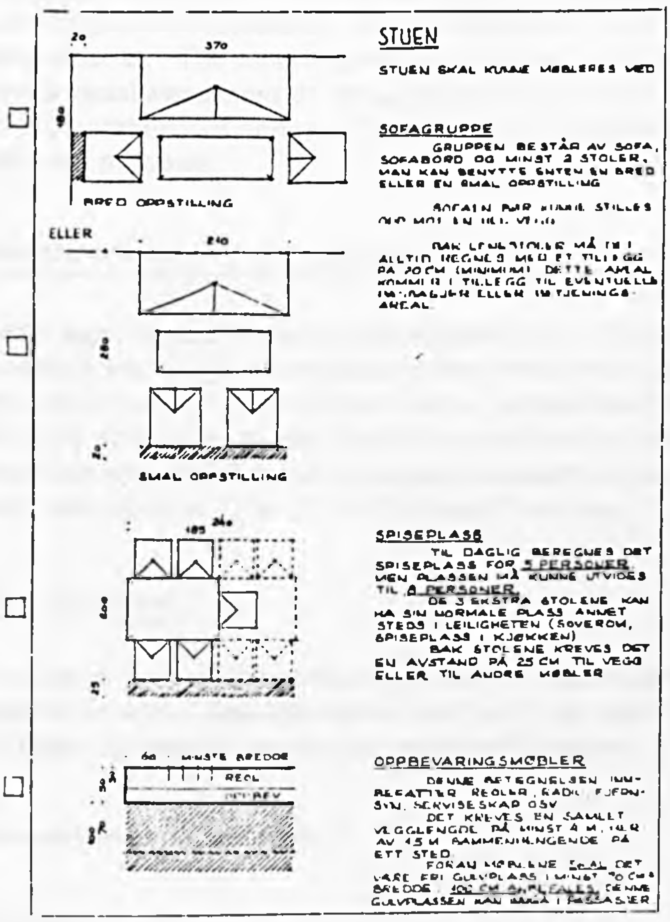


Fig. 6. Krav til møbleringsmuligheter i stuen ifølge BD blad 1 703. Det er valgfrihet mellom to typer av sofagrupper. Det kunne vært ønskelig med plass som tillot begge oppstillingsmuligheter, slik at stuen ikke ble bundet til bare det ene alternativ.

Fig. 3.12. Activity Models and Space Requirements. After Björkto, R. (3.27).

1. Fixed Installations (Fig. 3.13):

This test shows up whether desired fixed installations are present, whether statutory requirements are met and which deficiencies are present, and whether working areas have correct inter-relationships.

2. "Furnishability" (Fig. 3.13):

Based on data and dimensions concerning furniture, scaled drawings were made in the various rooms to check if desirable furniture groups could be accommodated according to the activity-model. Defects could then be identified.

3. User Areas (Fig. 3.14):

User areas were shown in a different shade from furniture, thereby illustrating new circumstances and correlations of the plan characteristics. The superimposition of the various sub-analyses permits visual assessment of the acceptability of overlaps of space, and the suitability of non-used floor areas for other desirable or additional purposes.

4. Circulation Areas (between rooms; Fig. 3.15):

Several aspects are affected by this sub-analysis; Efficiency of circulation routes, good circulation route interactions, good divisions of floor areas into activity-areas, possible conflicts between stationary activity areas and circulation areas and so forth. The total circulation area could be calculated and compared to an experiential norm, calculated as 12 to 27% of the total floor area.

5. Room Relations:

This type of analysis concerns comparison of the actual room connections with a desirable association matrix or activity-diagram. This topic is presently beyond the scope of this work.

Other sub-analyses proposed were:

- checklists
- adaptability of the rooms and floor plan
- provision of auxilliary rooms
- relationship to sun and climate
- the environment around dwellings.

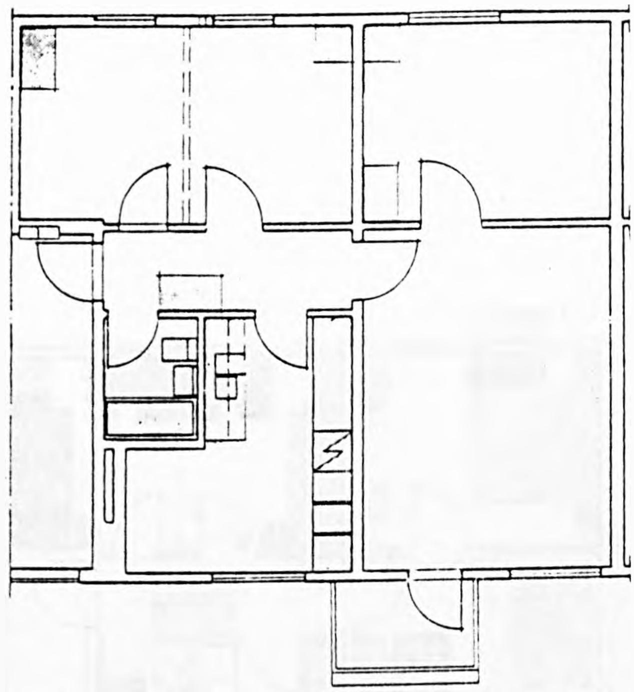


Fig. 7. Kontroll av fast innredning. Registrerte mangelforhold er på originalen angitt ved farge.

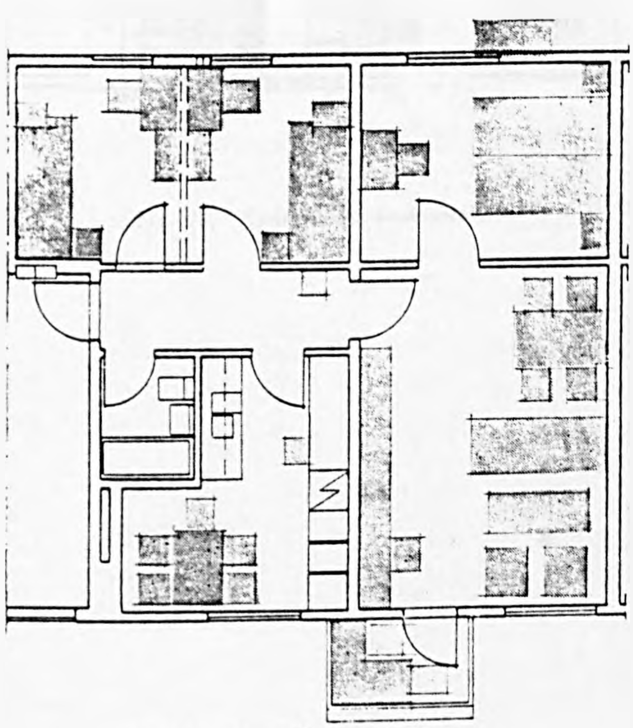


Fig. 8. Kontroll av møblerbarhet.

Fig. 3.13. Sub-analyses on Fixed Installations and Furnishability of the Björkto System. After Björkto, R. (3.29).

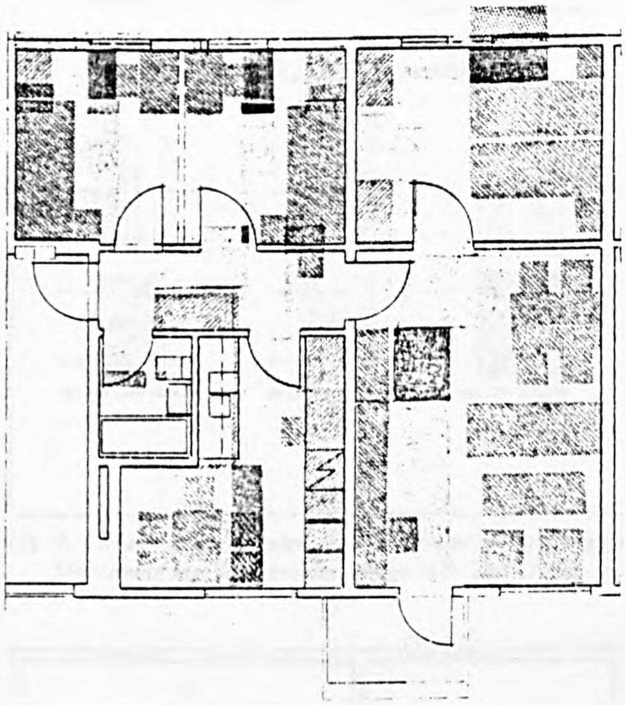


Fig. 10. Kontroll av bruksarealer.

Fig. 3.14. Sub-analysis for User Areas of the Björkto System.
After Björkto, R. (3.30).

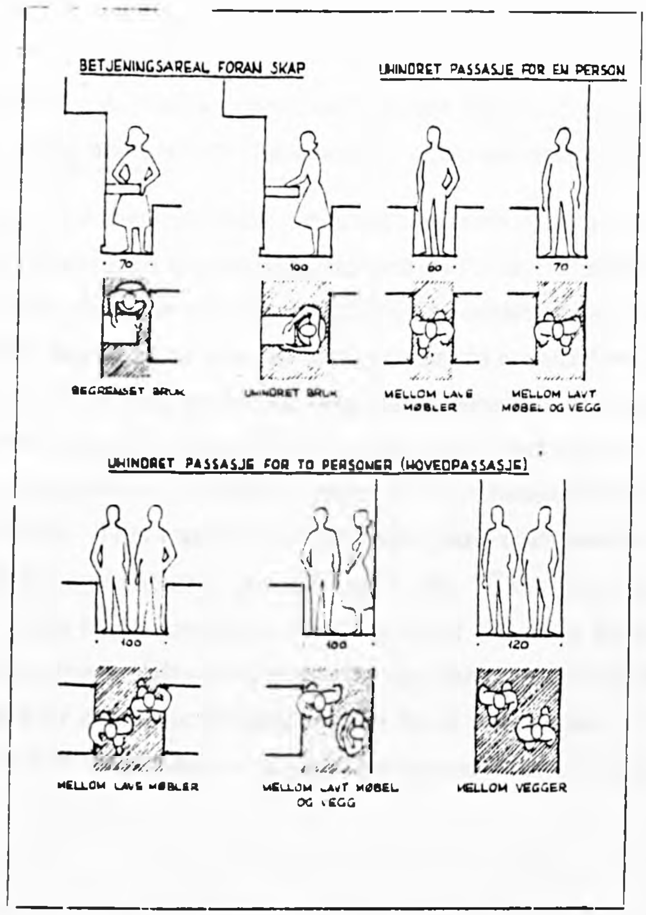


Fig. 9. Krav til gangarealer og bruksarealer mellom vegger, innredning og løse møbler ifølge BD blad 1703.

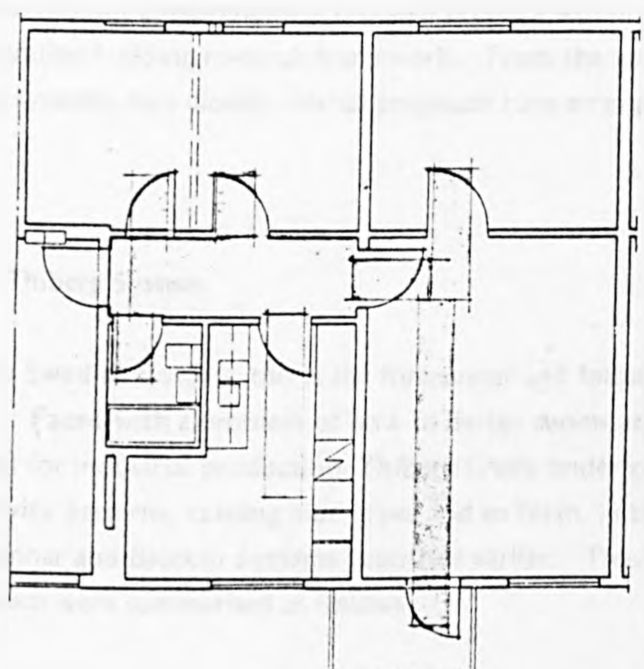


Fig. 11. Kontroll av trafikkarealer; her beregnet til ca. 13,5 % av totalarealet som skal betjenes.

Fig. 3.15. Sub-analysis for Circulation Areas of the Björkto System. After Björkto, R. (3.31).

An important sub-analysis indicated was the distribution of functional areas within the dwelling plan, which there was no concrete proposals for.

However, it was suggested that the bedroom areas could be compared to living areas, or the dining area in relation to the seating area and so forth. Probably, such data would establish "normal" area distribution proportionality numbers to represent a sub-analysis model. Such norms would act as comparators to results from other floor plans. If the architect generates new solutions, such appraisals will help to ensure that desirable features of previous plans are retained in the new ones.

Björkto concludes by offering a system for synthesising the sub-analyses into a meaningful whole. This was done by arranging sub-analyses into 5 principal groups both for internal and external spaces (Fig. 3.16). Examples were given on the various sub-analysis areas to be contained within each of the main groups (Table 3.1). It was pointed out that the activity-model should be changeable in time as living standards and patterns of domestic behaviour vary from year to year. Further, the model should not be so rigid as not to permit unconventional plan solutions.

3.3. The Swedish Building Research Institute Systems.

The SIB carries out comprehensive research projects within the Scandinavian co-operative building research framework. From the point of view of functional design systems, two closely related proposals have emerged.

3.3.1. The Sven Thiberg System.

Of the two Swedish systems, this is the forerunner and foundation of the latter system (3.34). Faced with a problem of how to design rooms and house plans (blocks of flats) for industrial production, Thiberg firstly undertook studies on population data, activity patterns, existing plan types and so forth, in the same line of enquiry as the Svennar and Björkto Systems described earlier. The resulting aims for a design system were summarised as follows:

1.1. Programmed room functions (dimensioned) for a series of rooms and auxilliary rooms (stores etc.) must be specified.

OVERSIKT OVER PLANANALYSEOMRÅDER
(PLAN ANALYSIS AREAS)

GRUPPER (GROUPS)	INNENDØRS (INTERNAL)	UTENDØRS (EXTERNAL)
DIMENSJONSMESSIGE FORHOLD (DIMENSIONAL ASPECTS)	A	F
POSISJONSMESSIGE FORHOLD (POSITIONAL ASPECTS)	B	G
ANDRE MILJØSKAPENDE FORHOLD (KLIMA, LYS, LYD, MATERIALSTRUKTURER) (ENVIRONMENTAL ASPECTS)	C	H
STELL OG BRUKSFORHOLD (MAINTENANCE AND USER ASPECTS)	D	I
KOSTNADS- OG KVALITETSFORHOLD (COST AND QUALITY ASPECTS)	E	

Fig. 18. Plananalyseområdene kan inndeles i 5 hovedgrupper vertikalt og 2 hovedgrupper horisontalt. Hver gruppe omfatter en mengde analyseoppgaver.

(NOTE: EACH OF THE 5 PLAN ANALYSIS AREAS INCLUDE MANY SUB-ANALYSES - SEE TABLE 3.1).

Fig. 3.16. Main Sub-analysis Groups of the Bjorkto System.
After Bjorkto, R. (3.32).

Table 3.1. Examples of Sub-analysis Areas within Groups of the Bjõrkto System. After Bjõrkto, R. (3.33).

Tabell 2. Eksempler på plananalyseområder innenfor gruppene:

A- *Dimensjonsmessige forhold ved arealer innendors.*	B- *Posisjonsmessige forhold ved arealer innendors.*	C- *Diverse miljømessige forhold innendors*
A_0*) Relative arealfordelingsforhold	B_0*) Romrekkefølge	C_0 Varmeforhold
A_1*) Fast innredning	B_1*) Romsamvirkninger	C_1**) Ventilasjonsforhold
A_2*) Møbleringsarealer	B_2*) Romatskillelser	C_2**) Akustiske forhold
A_3*) Bruksarealer	B_3*) Planfleksibilitet (D_3)	C_3 Fargeforhold
A_4*) Trafikkarealer	B_4*) Romfleksibilitet (D_4)	C_4**) Belysningsforhold
A_5 Vindusåpninger	B_5**) Romorientering/sollys	C_5 Materialstrukturer
A_6 Veggåpninger	B_6 Dag/natt fordeling	C_6
A_7 Tilknytningspunkter for elektriske installasjoner	B_7 Voksne/barn fordeling	C_7
A_8	B_8 Arbeid/rekreasjon	C_8
A_9	B_9 Representasjon/privatliv	C_9
Flateproporsjonsvirkninger	Volumsamvirkninger	Miljøvirkninger

(SEE FIG. 3.16 FOR CLARIFICATION)

1.2. Specifications of frequently occurring planning patterns for the organisation of room functions.

1.3. Specifications for a number of frequently occurring plantypes, firstly for industralised blocks of flats of rectangular shape.

2.1. Specifications for a number of frequently occurring structural and constructional Building systems.

2.2. Specifications for a number of frequently occurring technical installation systems.

A preferred dimensional system (modular grids) would have to be tested against the conditions of point 1.1 above. Fig. 3.17 shows how dimensioned room functions were adapted to a 3M constructional grid. This dimensional adjustment results in a number of standard room plans, which would have to adhere to the conditions of 1.3, 2.1 and 2.2. Plan variants not agreeing with the 3M module would be discarded. This dimensional exercise produced the following criteria for the design system:

1. A system of preferred room sizes.
2. Standard room plans.
3. Examples of dimensional adjustments.

Fundamental weaknesses of the system were indicated as:

1. The work is limited to the housing sector, particularly to rectangular plans in blocks of flats.

2. The background material is not completely reliable; partly based on experience, partly on laboratory data.

3. The dimensional adjustments of room plans are subject to subjective judgements on the part of the designer (this may not be disadvantageous, but variable).

The method assumes that "known" functional requirements are to be satisfied and that it is the technical solution which is the main objective; that is, "form follows function".

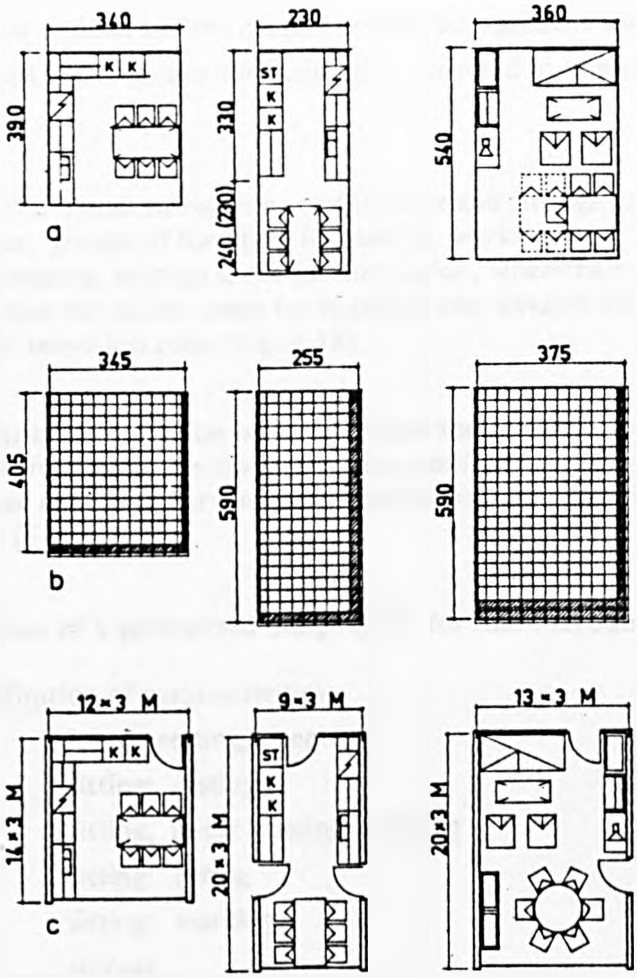


Fig. 10. Tilpasning av funksjonsbestemte rom til modulmål og preferansemål.

Fig. 3.17. Adaptations of Dimensioned Room Functions to Modular and Preferential Dimensions; S. Thiberg System. After Thiberg, S. (3.35).

3.3.2. The Alice Thiberg System.

This system was produced by the wife of Sven Thiberg, perhaps explaining the close connection between the two Swedish systems of the SIB. The aim of the planning of dwellings was defined as "the creation of the best possible socio-physical conditions for habitations" (3.36), and the main points covered by the study were as follows:

1. Details of dimensions referring to furniture and fittings; user areas; groups of furniture for storing, working, eating, sleeping, seating; space for circulation, wheelchair space, space for doors, space for radiators and window sills, space for television zone (Fig. 3.18).

2. Principles of combination of furniture for the composition of furniture groups, positioning of doors and combination of user space and space for circulation and doors and examples of these (Fig. 3.19).

3. Description of a generalized design guide for room layouts.

   3.1. Definition of main activities:
   - lying: resting, sleeping
   - sitting: resting
   - sitting, lying: resting, sleeping
   - sitting: eating
   - sitting: working
   - storage.

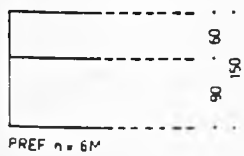
   3.2. Choice of 6 standard furnishing squares for furniture groups (Fig. 3.20) and examples of their use (Fig. 3.21).

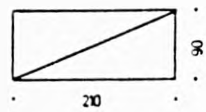
   3.3. Full scale laboratory tests of the use of the furnishing squares (Fig. 3.22).

   It was found that the chosen furnishing squares had optimum dimensions for variations of layouts within them.

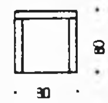
4. The design of a series of room layouts showing the application of the design guide in the dimensioning of rooms intended for residential purposes. Based on activities and number of people in a dwelling, a method was presented for the calculation of room contents, subsequently detailed into furniture content required for each room. Room content was specified in levels

FURNITURE, SYMBOLS WITH DIMENSIONS





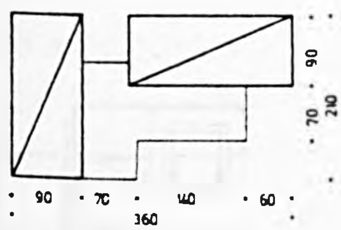
*Säng, soffa / Bed, settee**



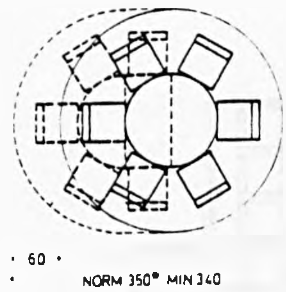
*Fåtölj / Armchair**

Furnishing zones

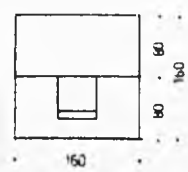
FURNITURE AND GROUPS OF FURNITURE WITH USER DIMENSIONS



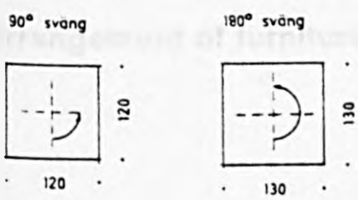
Arrangements of beds



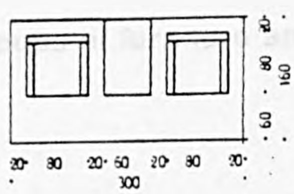
Dining areas

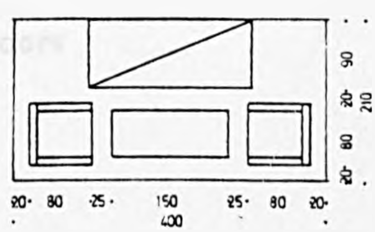


Work spaces

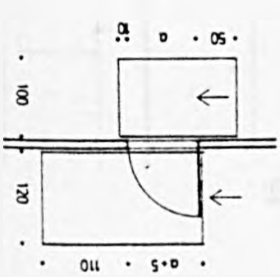


Turning space for wheelchairs

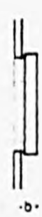




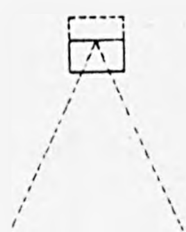
Seating groups, suites



Free space around door



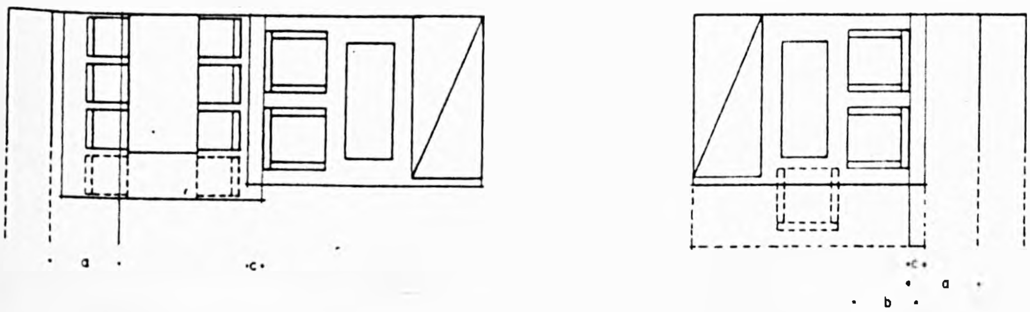
Radiator and window sill



Television zone

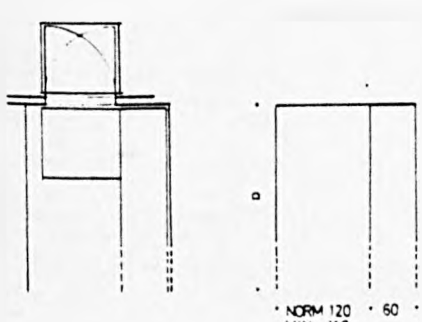
Fig. 3.18. Examples of Dimensioning of the A. Thiberg System.
After Thiberg, A. (3.37).

PRINCIPLES OF COMBINATION, EXAMPLES



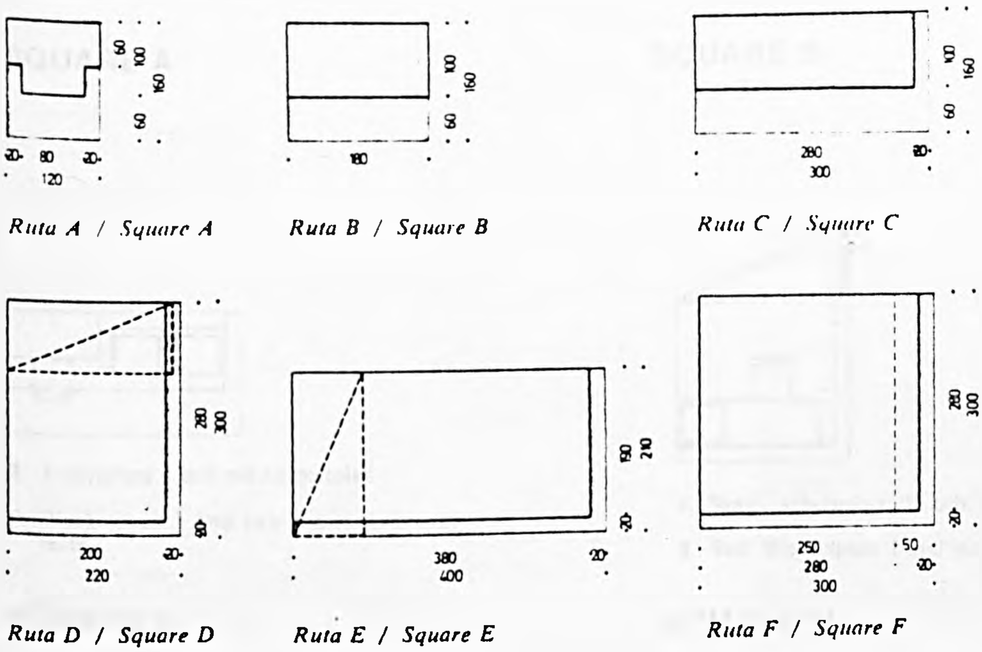
Composition of furniture groups

Arrangement of furniture or groups of furniture and doors



Combination of user space and space for circulation and doors

Fig. 3.19. Examples of Principles of Combination of the A. Thiberg System. After Thiberg, A. (3.38).

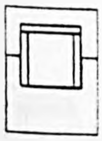


FIGUR 2 / FIGURE 2

Generella möbleringsrutor.

Standardized furnishing squares.

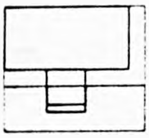
Fig. 3.20. Standard Furnishing Squares of the A. Thiberg System. From Thiberg, A. (3.39).



1. Fristående fåtölj

1. Free-standing armchair

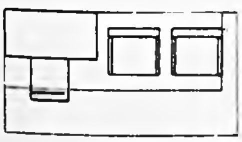
SQUARE A



3. Arbetsplats 3

3. Work space 3

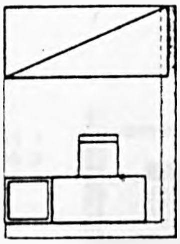
SQUARE B



9. Arbetsplats 1 och två karmstolar

9. Work space 1 and two chairs with arm-rests

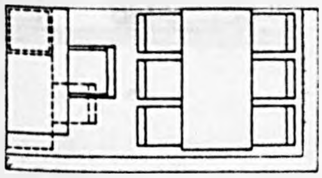
SQUARE C



8. Säng, arbetsplats 1 och förvaring (60)

8. Bed, Work space 1 and storage (60)

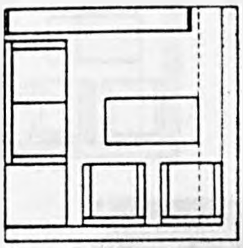
SQUARE D



8. Matgrupp 3 och arbetsplats 3 eller arbetsplats 1 med förvaringsenhet (60)

8. Dining area 3 and Work space 3, or Work space 1 with storage unit (60)

SQUARE E



5. Tvåsittssoffa, två fåtöljer, låga bord (60×120 och 80×80) och bokhylla (djup 30).

5. Settee (two-seater), two armchairs, low tables (60×120 and 80×80) and book-case (depth 30)

SQUARE F

Fig. 3.21. Examples of Use of Furnishing Squares of the A. Thiberg System. From Thiberg, A. (3.40).

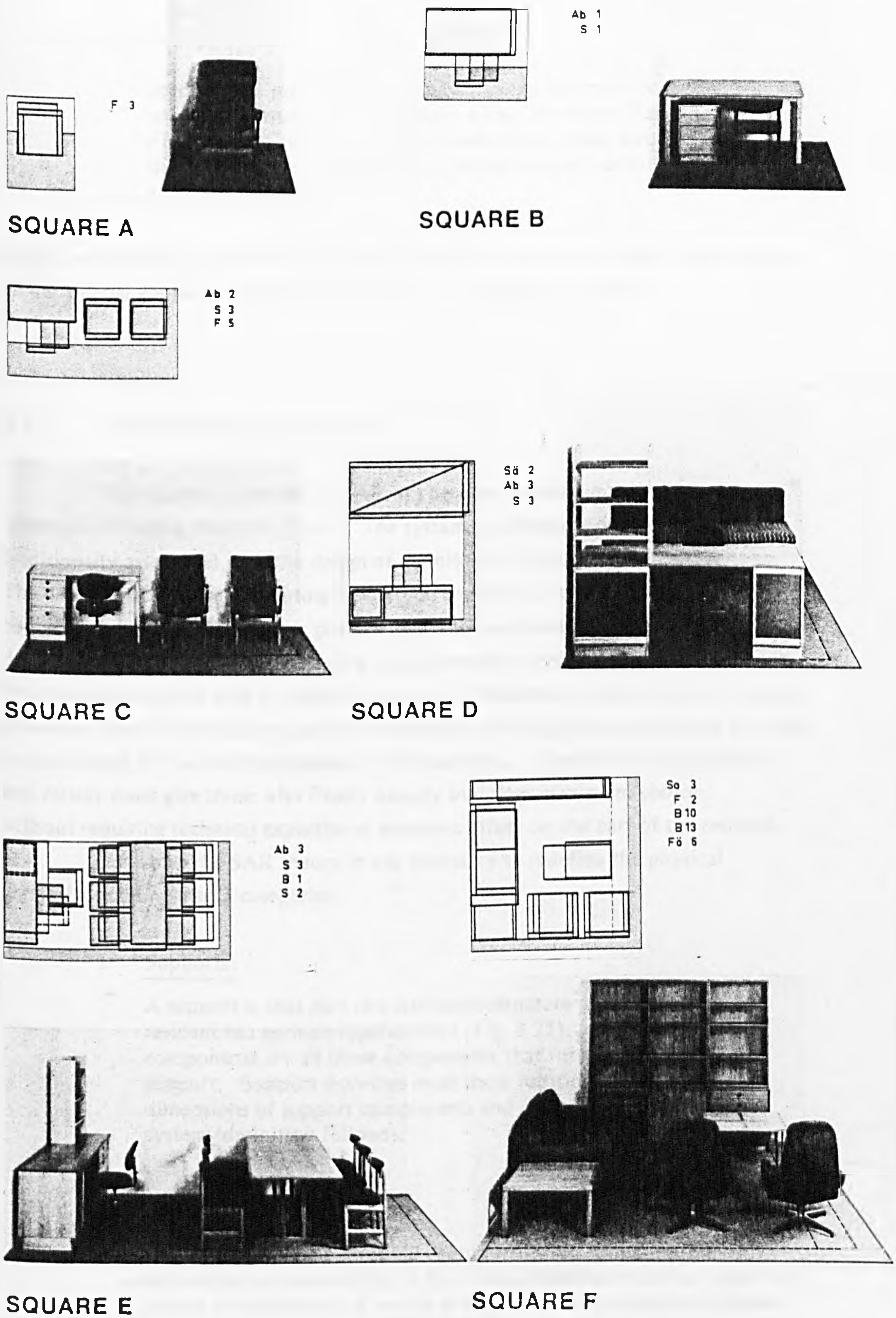


Fig. 3.22. Examples of Laboratory Tests on the Use of the Furnishing Squares of the A. Thiberg System. From Thiberg, A. (3.41).

according to number of people occupying the room or scope of activities that could take place within the room (Table 3.2, Fig. 3.23). Given a number of restrictions, room layouts were then designed for bedrooms and livingrooms of various categories and sizes (Fig. 3.24).

Again, an interesting facet of the system was that user areas were shown on the plans, giving a visual appreciation of possible areas of congestion or conflict.

3.4. The Habraken (SAR) System.

This Dutch system of the SAR has become popular in a number of countries, including the U.K. (3.45). The system was developed to solve problems traditionally associated with the design of mainly industrialised mass housing. The design process in mass housing is based on the floor or the unit plan, this plan being used repetitiously in larger projects. It was maintained that most of the design effort is directed toward finding a good enough solution to justify repetition. The Habraken system aims at designing a physical framework, within which a number of variant floor plan solutions can become realizable throughout the building life span, and according to the changing needs of the occupants. In real terms, adaptability and variety must give those who finally occupy buildings maximum choice without requiring technical expertise or excessive effort on the part of the resident.

To evolve the SAR theory it was necessary to redefine the physical parts of a building into 2 categories:

1. Supports:

   A support is that part of a habitable structure over which the resident has no individual control (Fig. 3.25). Support components are all those components that form part of the support. Support drawings must show location and nominal dimensions of support components and of the zone and margin system (definition follows).

2. Detachable units:

   Detachable units are movable components over which the resident has individual control (Fig. 3.26). Detachable units can be shown on a chart or indicated in a zoning analysis, in which case their location in relation to the zone and margin system is also noted (see below).

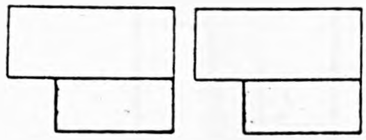
Table 3.2. Furniture Content of Rooms; A. Thiberg System. From Thiberg, A. (3.42).

Furniture content	Rooms in dwellings ≥ 2 rooms + kitchen									One-room dwelling			
	One-bed room, level			Two-bed room, level		Living room with dining area, level		Living room (sitting room) without dining area, level		Temporary dwelling, level		Permanent dwelling, level	
	1	2	3	1	2	1	2	1	2	1	2	3	4
Beds, No.	1	1	1	2	2	—	—	—	—	1	1	—[a]	1[b]
Work space 1 (Square A), No.	1/0	1	1/0	1/0	1	—	—	—	—	—	—	—	—
Work space 3 (Square B), No.	—	—	0/1	—	—	—	—	1/0	1/0	1[c]/0	1[c]/0	1[d]/0	1[d]/0
Dining area 1 (2 persons), No.	—	—	—	—	—	—	—	—	—	—	1	—	—
Dining area 2 (4 persons), No.	—	—	—	—	—	—	—	—	—	0/1[c]	0/1[c]	0/1[d]	0/1[d]
Dining area 3 (6 persons), No.	—	—	—	—	—	1	—	—	—	—	—		
Dining area 4 (8 persons), No.	—	—	—	—	—	—	1	—	—	—	—		
Free-standing armchair (Square A), No.	0/1	1	0/1	0/1	1	—	—	—	—	—	—		
Seating group 1 (Square B), No.	—	—	1/0	—	—	—	—	0/1	0/1	1	1		
Bed combined with Seating group 1, No.	—	—	—	—	—	—	—	—	—	—[e]	—[e]		
Suite 1 (Square D), No.	—	—	—	—	—	1/0	1/0	1/0	—	—	—	1/0	1/0
Suite 2 (Square E), No.	—	—	—	—	—	0/1	0/1	0/1	—	—	—	0/1	0/1
Suite 3 (Square F), No.	—	—	—	—	—	—	—	—	1	—	—	—	—
Low storage, 6 × 6 dm, No.	1	1	1[f]	2	2	—	—	—	—	1[f]	1[f]	—	1[b]
High storage, depth 6 dm, dm	—	—	12	—	—	30 (18 + 12)	30 (18 + 12)	30 (18 + 12)	30 (18 + 12)	18 (6 + 12)	18 (6 + 12)	24 (6 + 18 (12 + 12)	24 (6 + 18) (12 + 12)
High cupboard[g] 6 × 6 dm, related to number of beds, No.	1	1	1	2	2	—	—	—	—	1	1	1	1

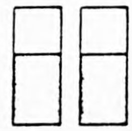
a) Part of suite
b) In alcove
c) In normal alternative choice between Work space 3 and Dining are 2 should be permitted
d) Choice between Work space 3 and Dining area 2 should be permitted
e) Or bed + Seating group 1 combined to form suite
f) Not included in minimum alternative
g) High cupboard in or outside room

Two-bed room

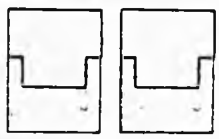
Nivå 2 / Level 2



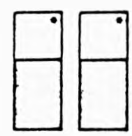
Säng / Bed



Låg förvaring, 6 dm / Low storage, 6 dm



Ruta A / Square A



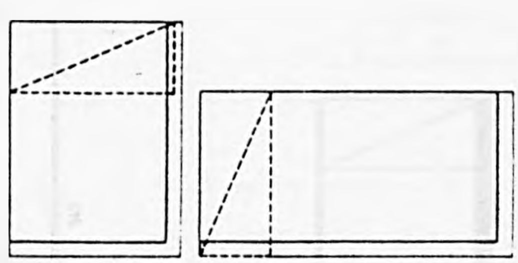
Högskåp, 6 dm / Tall cupboard, 6 dm

* i eller utanför rummet
** ingår ej i min. alt.
*** valfrihet i möbleringen mellan skrivplats 3 och matgrupp 2 bör finnas.

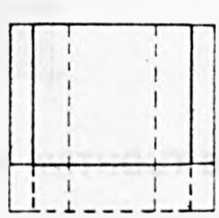
* in or outside room
** not included in minimum alternative
*** choice of furniture between Work space 3 and Dining area 2 should be possible.

Living room with dining area

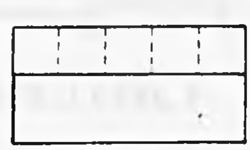
Nivå 2 / Level 2



Ruta D eller ruta E / Square D or Square E



Matgrupp 4 / Dining area 4



Hög förvaring, 30 dm / High storage, 30 dm

Fig. 3.23. Examples of Room Content of the A. Thiberg System. After Thiberg, A. (3.43).

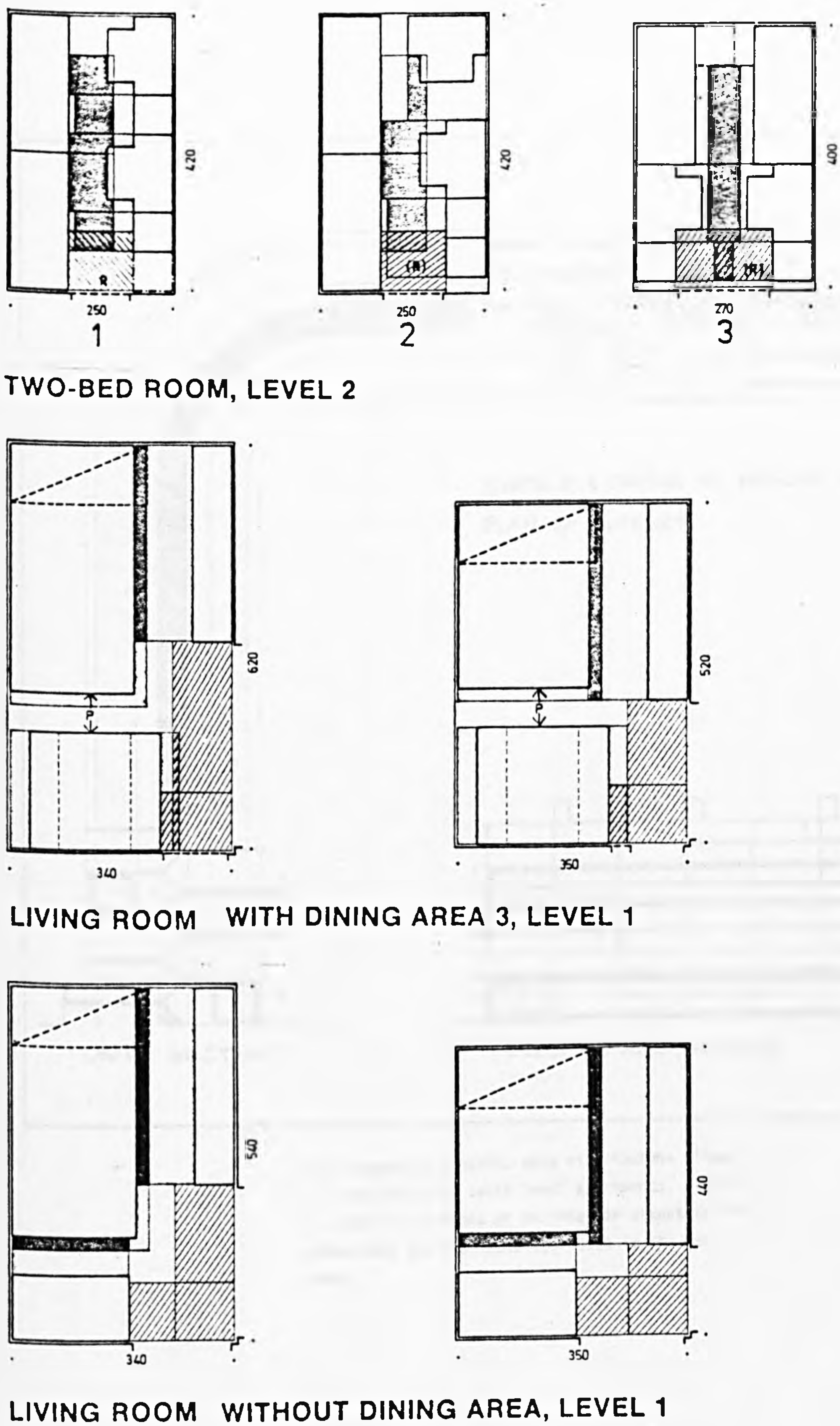
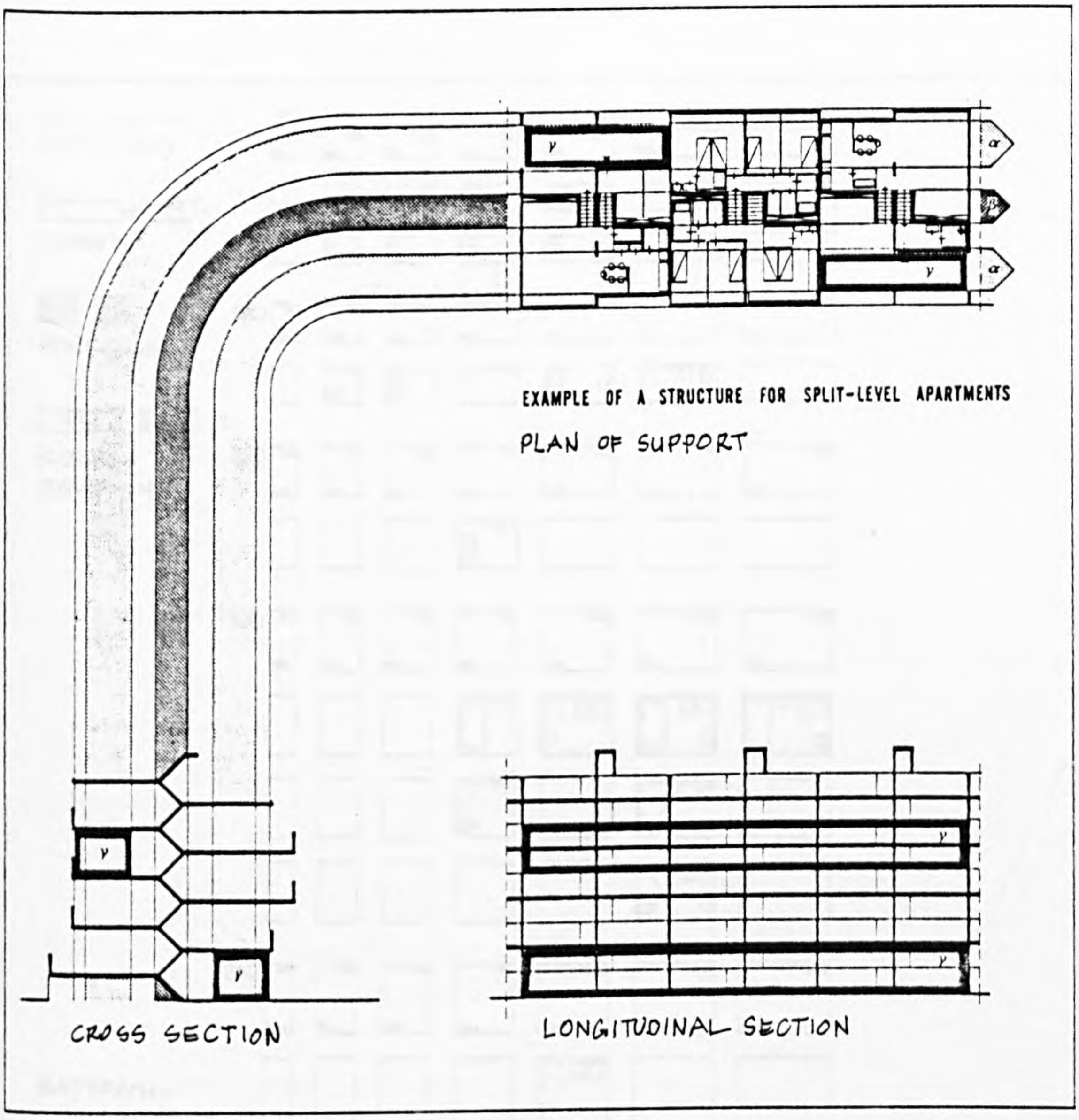


Fig. 3.24. Examples of Room Layouts Using the A. Thiberg System.
After Thiberg, A. (3.44).



This support's specific zone distribution allows for the design of split level apartments. Access to these is by means of an interior street in the gamma zone and a private staircase in the beta zone.

Fig. 3.25. Principle of Support Drawings of the Habraken System. From Habraken, N. J. et al. (3.46).

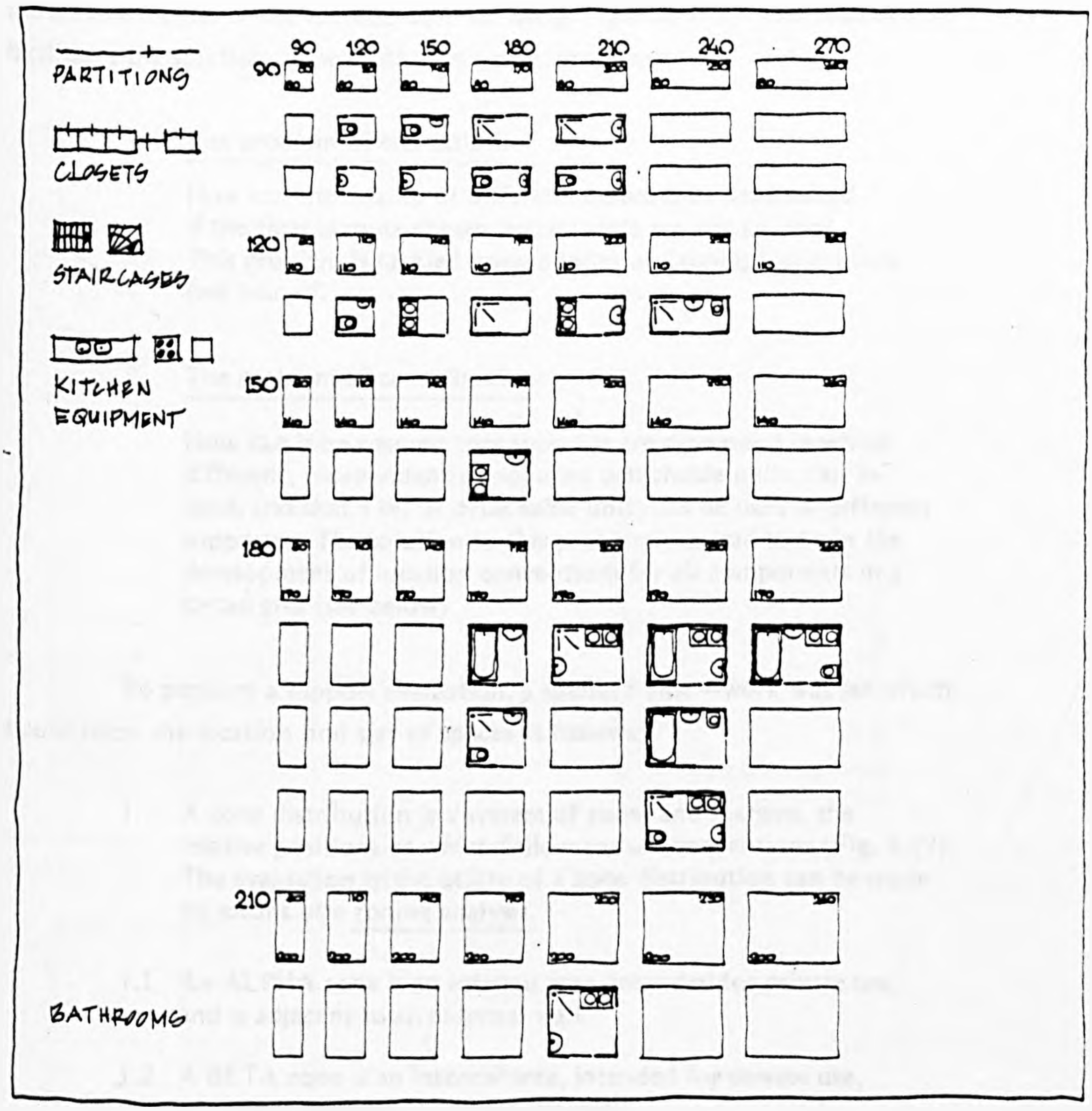


Fig. 3.26. Principle of Detachable Units of the Habraken System.
From Habraken, N.J. et al. (3.47).

The systems theory approach indicates that there is a close relationship between the different parts of the method used for designing supports. This relationship facilitates the solution of two different design problems:

1. <u>The problem of evaluation:</u>

   How can the quality of different supports be determined if the final layouts chosen by residents are not known? This problem is tackled using a series of "zoning" operations (see below).

2. <u>The problem of co-ordination:</u>

   How can it be ensured that supports are developed in which different, independently produced detachable units, can be used, and that a set of detachable units can be used in different supports. The solution to this problem was said to lie in the development of location conventions for all components in a tartan grid (see below).

To perform a support evaluation, a spatial frame —work was set which would allow the location and size of spaces as follows:

1. A zone distribution is a system of zones and margins, the relative positions of which follow certain conventions (Fig. 3.27). The evaluation ofthe utility of a zone distribution can be made by means of a <u>zoning analysis.</u>

1.1. An ALPHA zone is an internal area, intended for private use, and is adjacent to an external wall.

1.2. A BETA zone is an internal area, intended for private use, and is not adjacent to an external wall.

1.3. A GAMMA zone can be internal or external, but is intended for public use.

1.4. A DELTA zone is an external area intended for private use.

1.5. A MARGIN is an area between two zones with the characteristics of both of these zones.

1.6. Spaces can further be classified into general purpose spaces, special purpose spaces and service spaces, each to be located in the zone and margin space system (zone distribution).

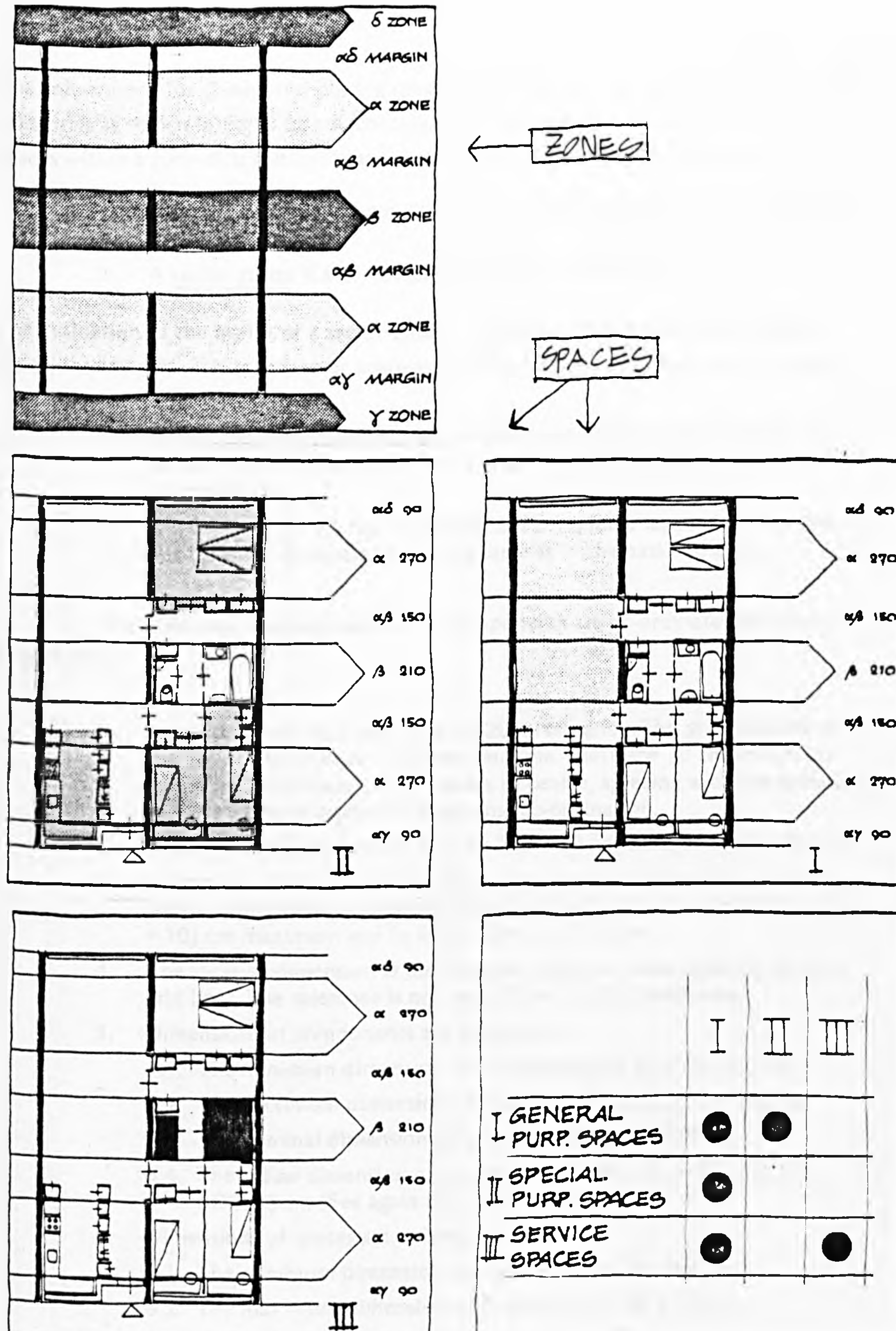


Fig. 3.27. Location of Zones in the Habraken System.
From Habraken, N.J. et al. (3.48).

The conventions for coding and placing spaces in a zone distribution fall into three main categories as shown in Fig. 3.28. According to the locations and interconnections of spaces within a zone distribution, space classifications can be defined as follows (Fig. 3.29):

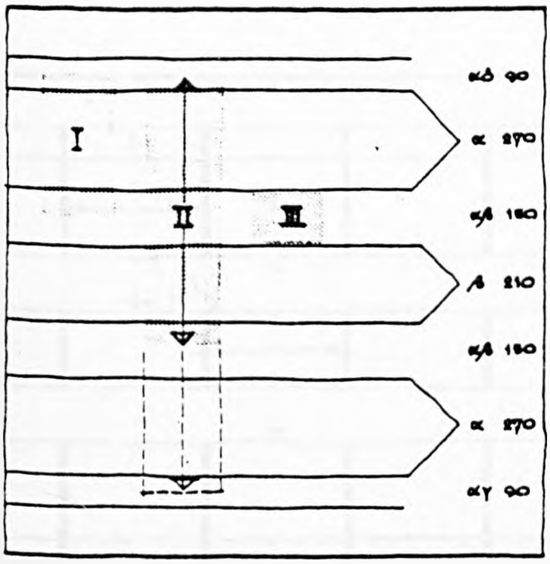
1. A sector is a part of a zone and its adjoining margins that can be planned freely.
2. A sector group is a combination of connected sectors.

The evaluation of the utility of a sector group, depends on the development of basic variations and sub-variations (sector analysis), which are defined as follows (Fig. 3.30):

1. A basic variation indicates the position, in a specific sector group, of a certain group of functions, which together form a dwelling program (combination).
2. A sub-variation of a basic variation is a completed layout in which the positions of the functions are the same as in the basic variation.

The horizontal location and size of components are co-ordinated as follows (Fig. 3.31):

1. Layouts should be drawn on a 10/20 tartan grid. This grid is based on the 1M x 1M (100mm x 100mm) module. Both the 10 cm and 20 cm bands are 30 cm apart, from centre to centre, agreeing with the preferred module for international dimensional co-ordination.
2. Faces of components always occur in the 10 cm band of the 10/20 grid.
3. A nominal dimension is a multiple of the module of the grid, (n x 30). Actual dimensions of elements and spaces will then vary between (n x 30 + 10) cm maximum and (n x 30 - 10) cm minimum.
4. The locating dimension is the distance from the component to the next grid line. The tolerance is not part of the locating dimension.
5. Dimensions of components are as follows:
   5.1. The minimum dimension of a component is (n x 30 - 10) cm.
   5.2. The maximum dimension of a component is (n x 30 + 10) cm.
   5.3. The nominal dimension of a component is (n x 30) cm.
   5.4. The actual dimension of a component is (n x 30 + 10 - LOC. 1 - LOC. 2) cm (See again Fig. 3.31).
6. Dimensions of spaces are as follows:
   6.1. The minimum dimension of a space is (n x 30 - 10) cm.
   6.2. The maximum dimension of a space is (n x 30 + 10) cm.
   6.3. The nominal dimension of a space is (n x 30) cm.
   6.4. The actual dimension of a space is (n x 30 - 10 + LOC. 1 + LOC. 2) cm.



Now that the categories of space have been defined we can investigate the relationship between their location and size, and the zone distribution.

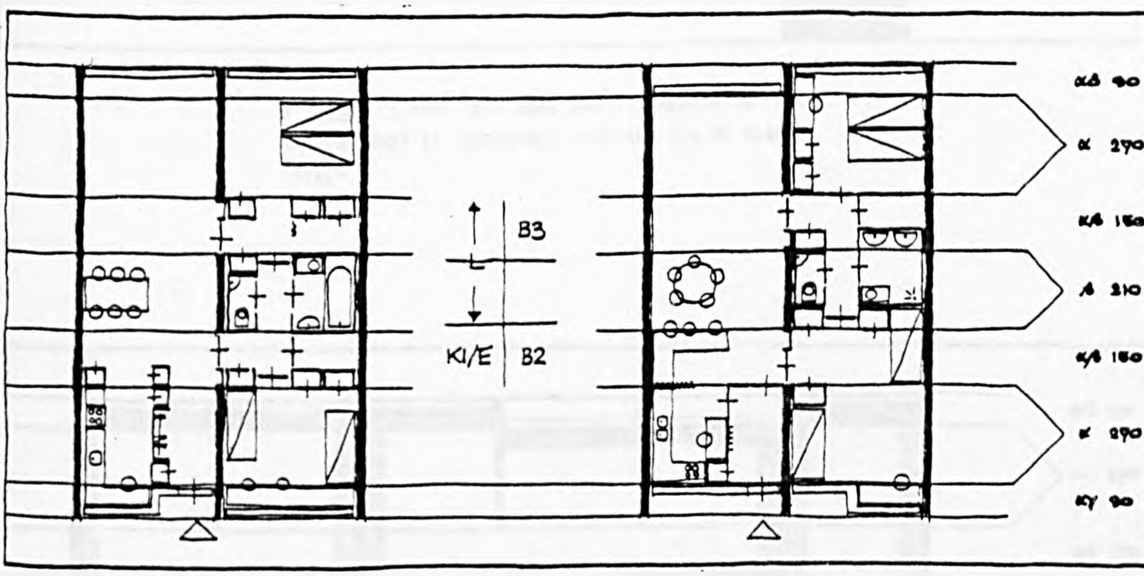
In every zone distribution <u>three primary positions can be distinguished:</u>

POSITION 1: A SPACE WHICH OVERLAPS THE ZONE AND ENDS IN THE ADJACENT MARGIN.

POSITION 2: A SPACE WHICH OVERLAPS MORE THAN ONE ZONE AND ENDS IN A MARGIN.

POSITION 3: A SPACE WHICH BEGINS AND ENDS IN THE SAME MARGIN.

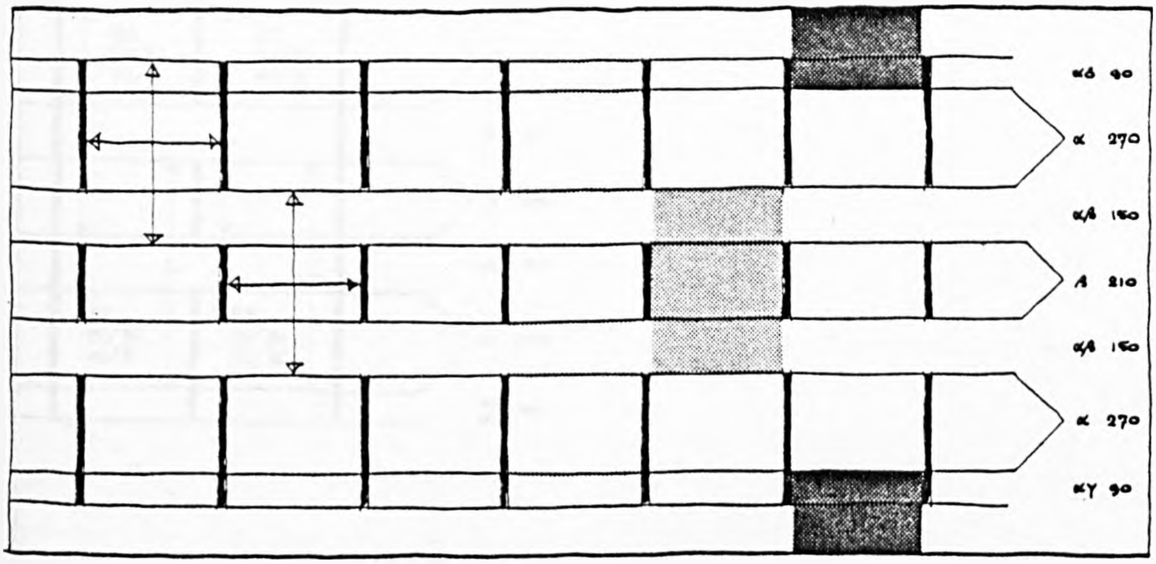
All three positions conform to the general rule: spaces always end in a margin.



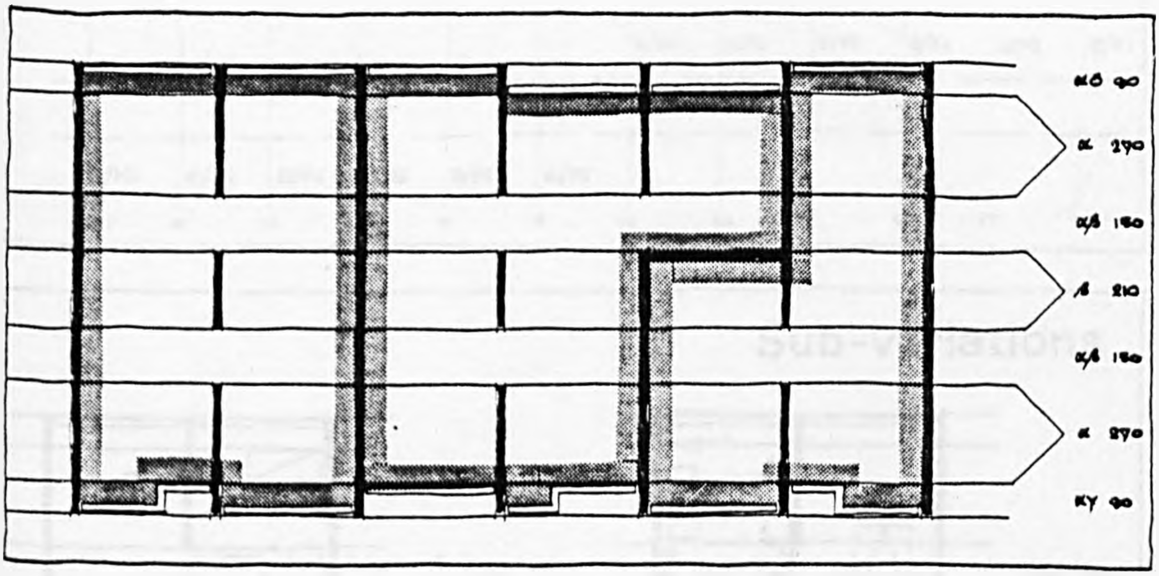
CODING SYSTEM:

L	LIVING ROOM
B	BEDROOM
B1	SINGLE BEDROOM
B2	DOUBLE BEDROOM
B3	MASTER BEDROOM
K	KITCHEN
KI	KITCHEN FOR COOKING
K2	EAT-IN KITCHEN
E	ENTRANCE
b	BATHROOM
St	STORAGE
G	GARAGE
ETC.	

Fig. 3.28. Conventions for Placing and Coding Spaces in the Habraken System. From Habraken, N.J. et al. (3.49).

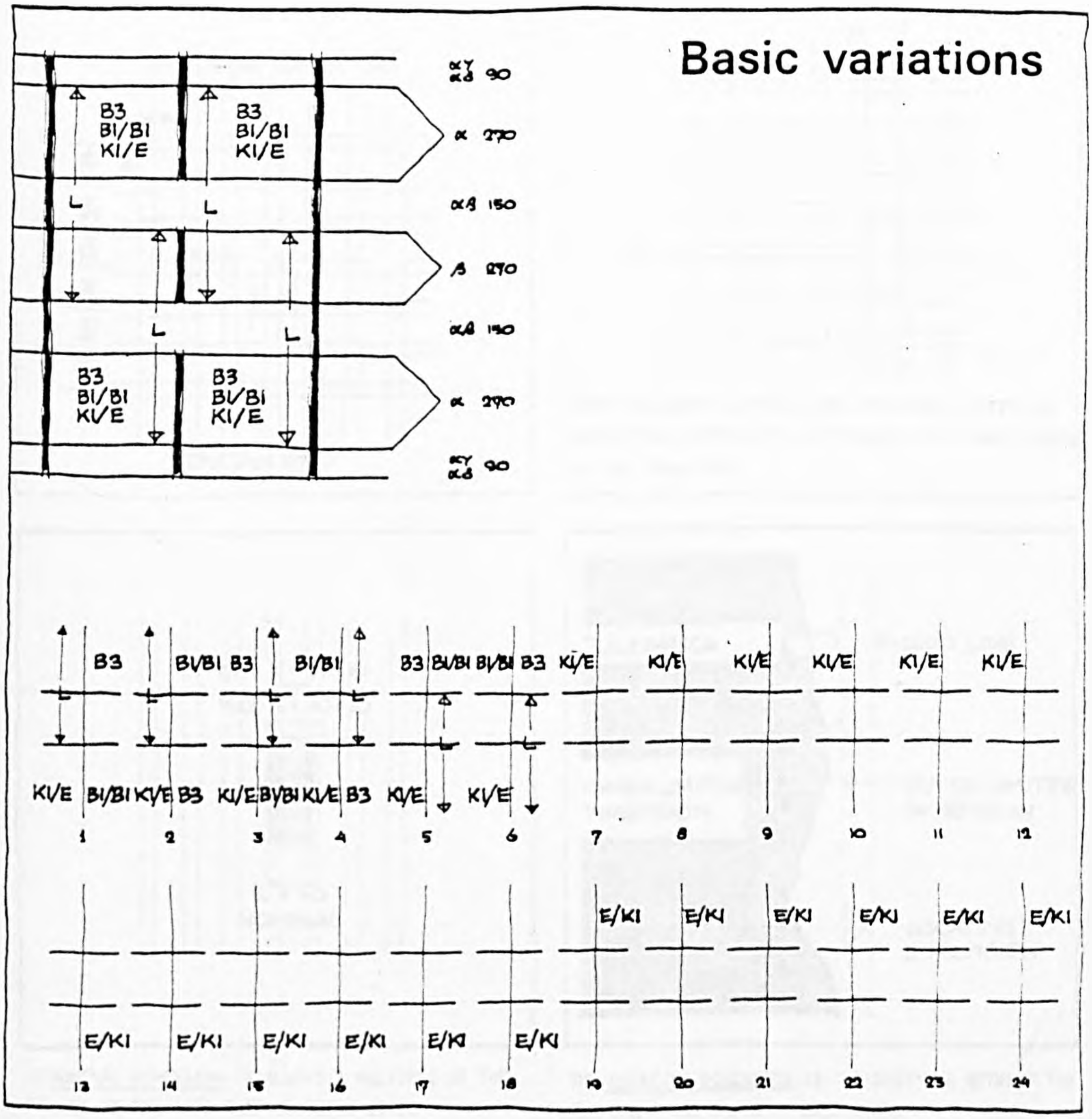


A SECTOR IS PART OF A ZONE AND ITS ADJOINING MARGINS THAT IS COMPLETELY OPEN AND CAN BE PLANNED FREELY.



A SECTOR GROUP IS A COMBINATION OF INTERCONNECTING SECTORS.

Fig. 3.29. Sectors and Sector Groups in the Habraken System.
From Habraken, N.J. et al. (3.50).



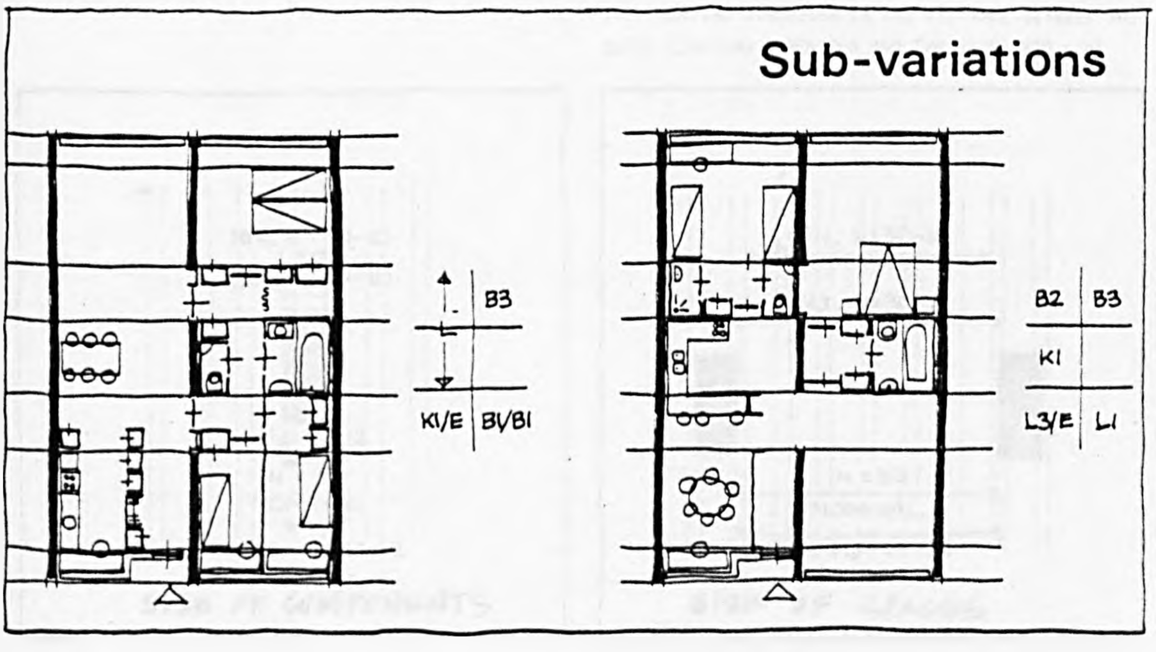


Fig. 3.30. Principle of Basic Variation and Sub-variation of the Habraken System.
From Habraken, N.J. et al. (3.51).

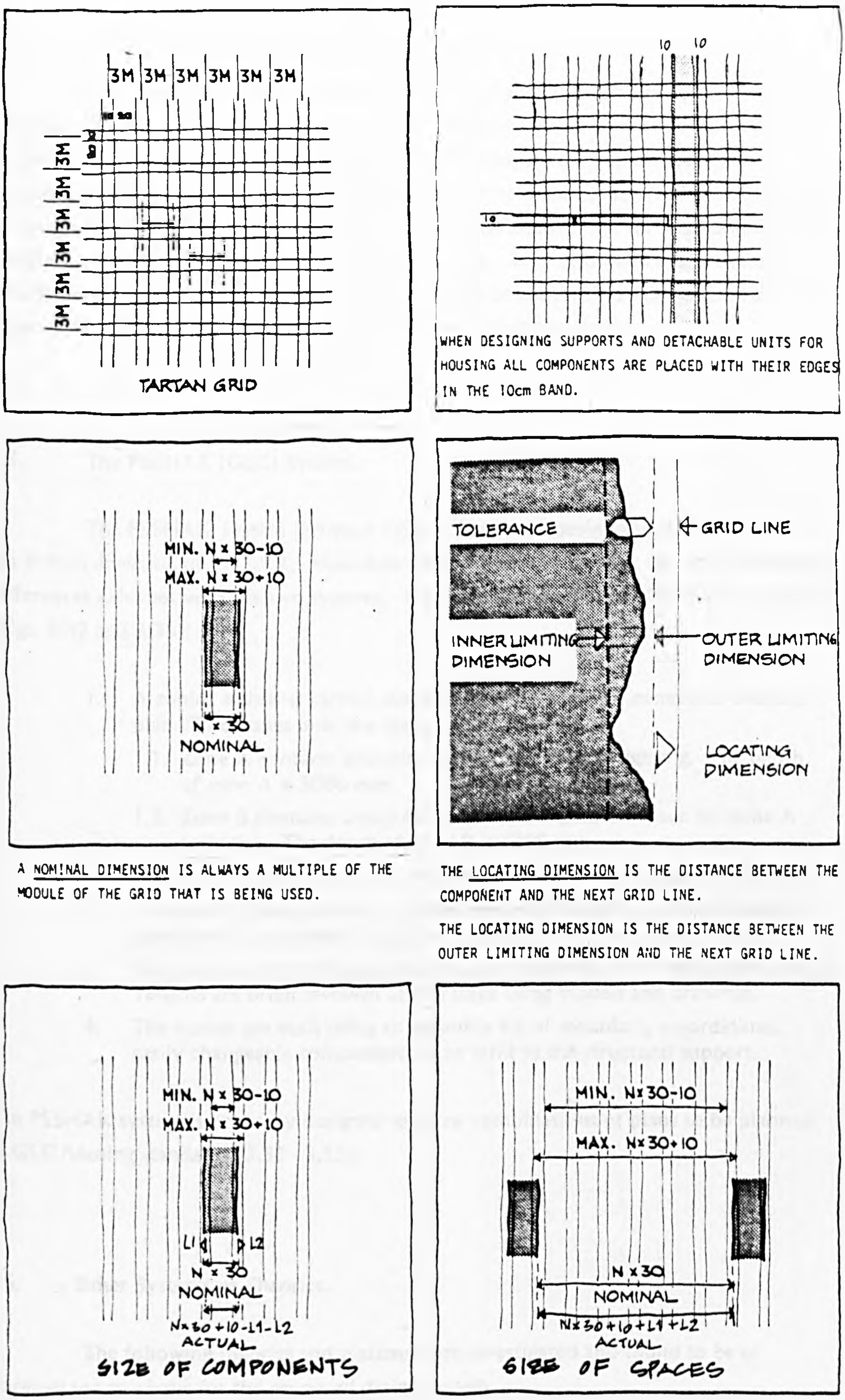


Fig. 3.31. Location and Size of Components in the Habraken System.
After Habraken, N.J. et al. (3.52).

The Habraken concepts allow the design of a support system which can be grouped into sectors. Analyses can be made of zones and sectors. From the analyses a number of basic variations of solutions can be evolved, which may be developed into complete plans or sub-variations. The possibilities inherent in a support system to generate, via the analyses, a number of sub-variations, giving maximum scope for adaptability for the residents, determine the utility of the support system. The Habraken design system is wholly dependent on manual and graphic techniques of the synthesis design process and involves no mathematical evaluation at the appraisal design process.

3.5. The PSSHAK (GLC) System.

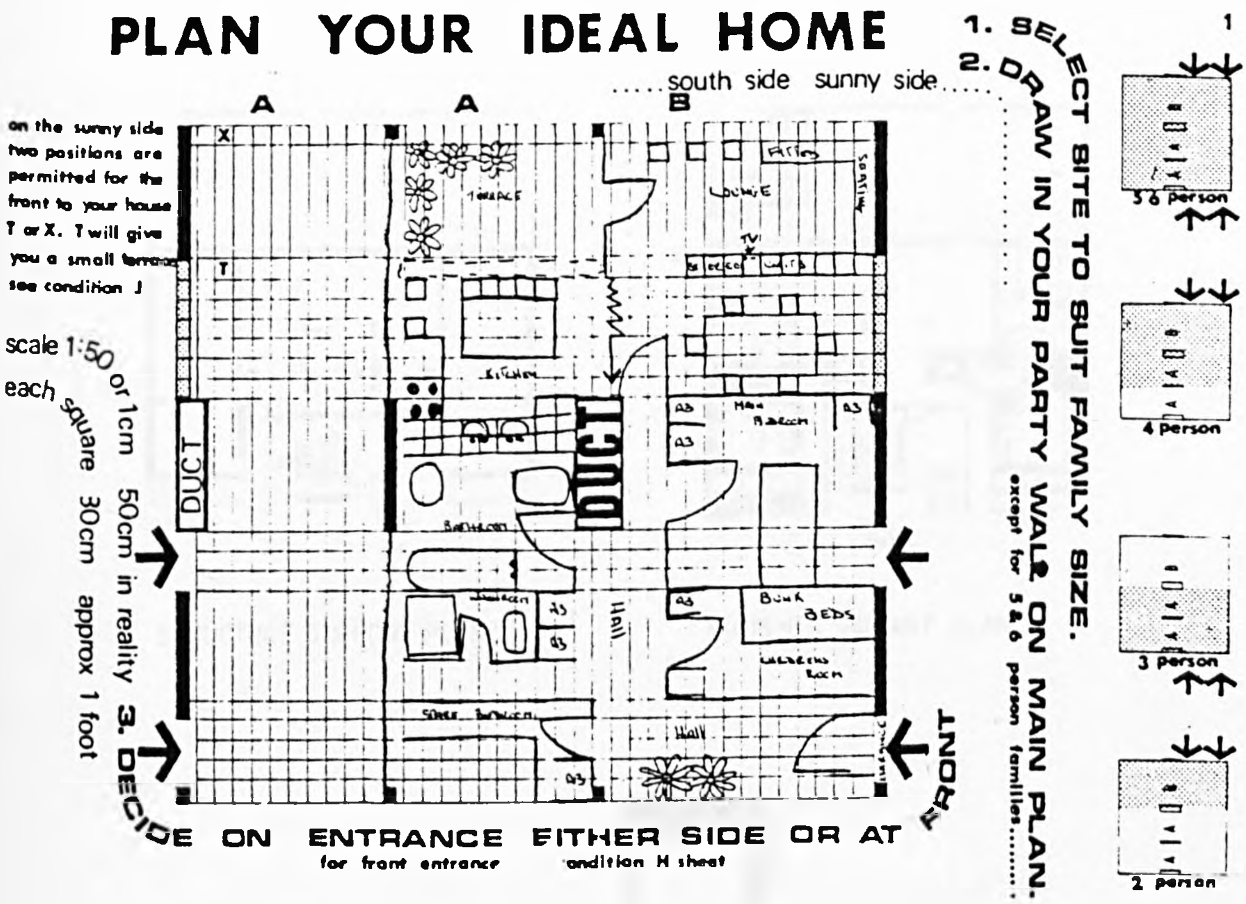
The PSSHAK system (Primary System Support Housing and Assembly Kits) is a British diversion of the SAR, Habraken design system. However, certain fundamental differences exist between the two systems. The main elements of the PSSHAK system are (Figs. 3.32 and 3.33):

1. A zoning analysis is carried out to determine width of zones and width of plan. Two zones only are used:
   - 1.1. Zone A contains activities that require natural lighting. The depth of zone A is 3000 mm.
   - 1.2. Zone B contains utility functions and expansion space for zone A activities. The depth of zone B is 4300 mm.
   - 1.3. Both types of zone may have bay widths of 3000 mm or 3900 mm.
2. A support is designed on a 100/200 mm modular grid, which includes loadbearing components, external doors and windows, and services.
3. Plan variants are developed, showing the possibilities of the support system. Tenants are often involved at this stage using models and drawings.
4. The houses are built using an assembly kit of modularly co-ordinated, easily changeable components as an infill to the structural support.

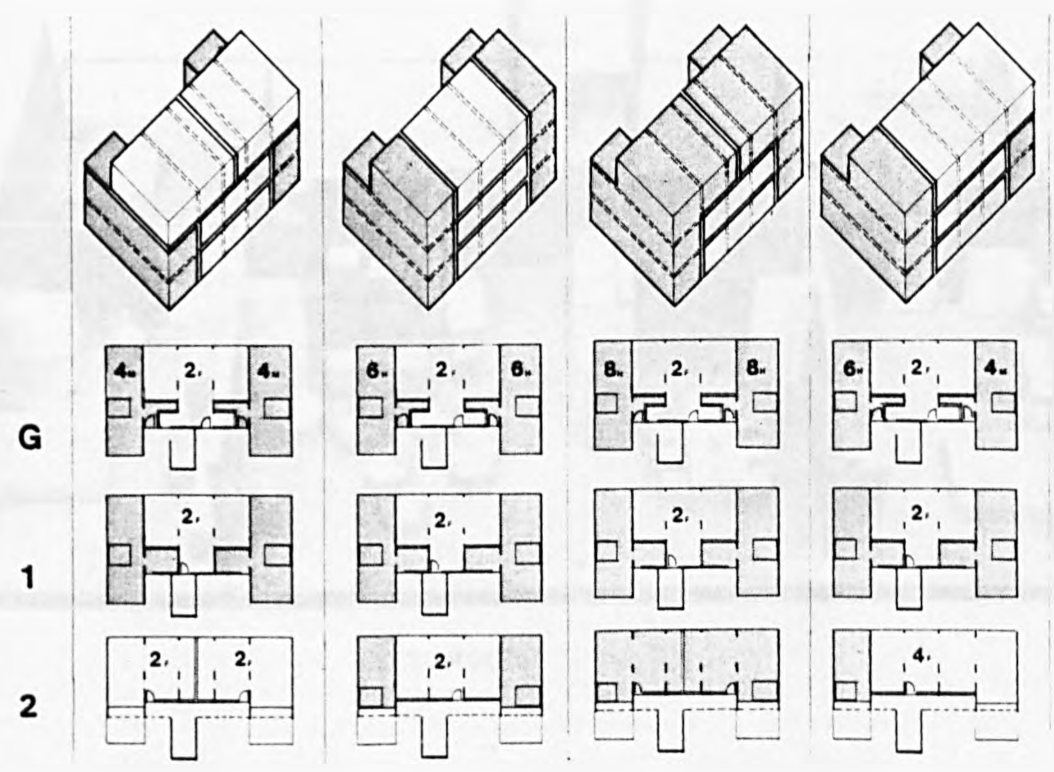
The PSSHAK system is primarily designed to allow combinations of plans to be planned to GLC housing standards (3.53 - 3.58).

3.6. Other Systems or Theories.

The following theories and systems were investigated and found to be of marginal use as a basis for the proposed design system:



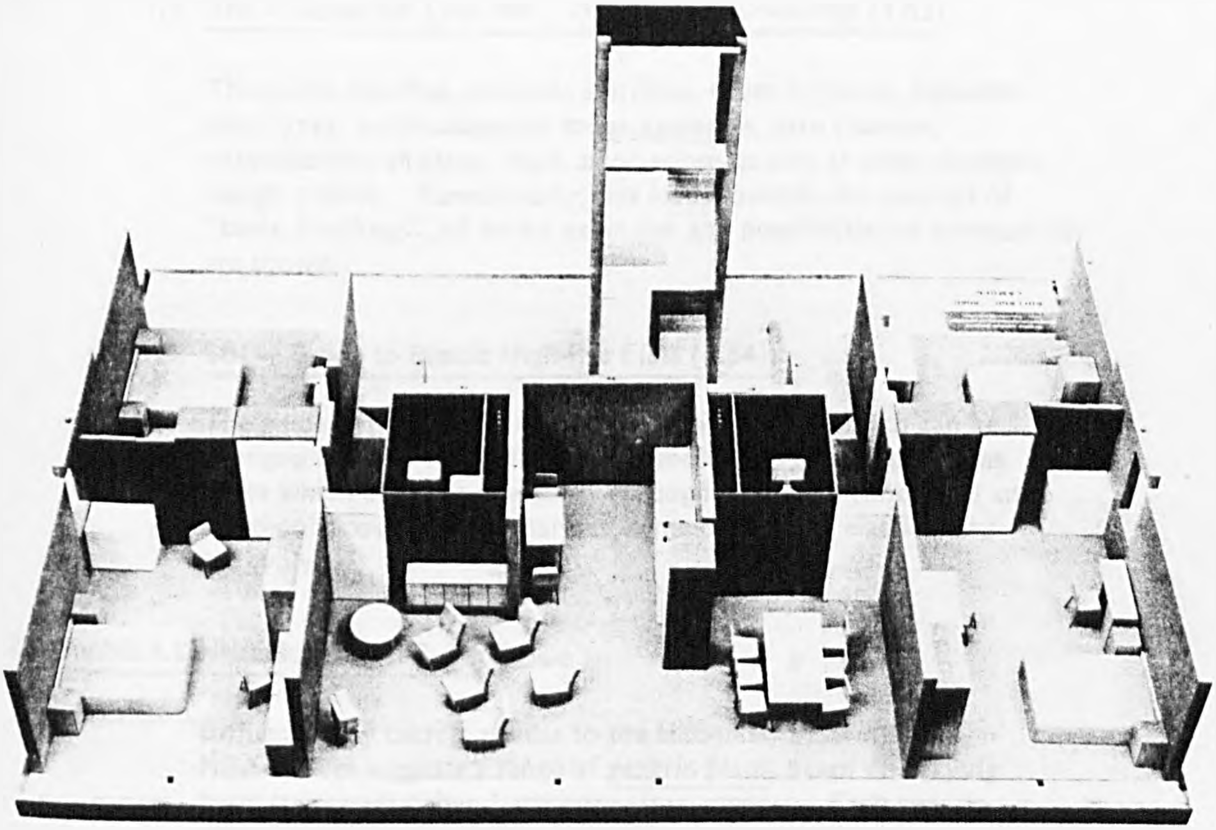
TENANTS' PLAN



DESIGNER'S VARIANTS

Fig. 3.32. Plans Showing Tenants' Plan and Designer's Variants Using the PSSHAK System for the Adelaide Road Scheme. In Habraken, N.J. et al. (3.59).

STRUCTURE SUPPORT PLAN FINISHED VARIANT PLAN



KIT MODEL

Fig. 3.33. Examples of Structure Support Plan, Finished Variant Plan and Kit Model of the PSSHAK System. In Habraken, N.J. et al. (3.60).

1. Danish Building Research Institute Theories:

1.1. The Rasmussen - Vedel - Petersen Theory (3.61):

This system uses the same premises as the Svennar and Björkto systems described earlier. Through a series of functional tests of adaptability of rooms by means of their capacity to contain large numbers of furniture groupings, a "usable value" is derived (no method specified). Plans possessing a high usable value would be suitable for rational and industrial production of house types.

1.2. SBI Standard House Evaluation Guide (3.62):

This evaluation guide offers a number of checklists, room association diagrams and furniture and furniture groupings intended to assess (graphically) a floor plan. The guide contains appraisal suggestions on a number of aspects other than functional ones. The guide is similar to the Svennar System, mentioned above.

1.3. SBI – Guide for Low-rise, High-density Dwellings (3.63):

This guide specifies domestic activities, room contents, domestic plan types, multi-adaptable room examples, plan changes, extendability of plans, room associations as well as other domestic design criteria. Functionally, this leads towards the concept of "basic dwellings", of which examples and possibilities of extensibility are shown.

1.4. SBI – Guide to Elastic High-rise Flats (3.64):

The guide defines flexible dwelling plans as those which can be changed to allow for different uses and elastic dwelling plans as those which can be extended. Through a series of functional and socio-politico-economic analyses, some criteria for elastic plans are evolved.

2. The NBA Design Guides (3.65, 3.66):

Influenced by factors similar to the Habraken System, the NBA system suggests a range of generic plans, based on varying basic staircase/kitchen/bathroom arrangements. Each generic plan can be developed into a number of plan variants (cf. Habraken's supports, variants and sub-variants), called a range of plans. Plans can then be adapted to take into account modular co-ordination and functional space requirements, also shown in the guide. The guide presents a logical and coherent approach to the design of dwellings.

3. Open Systems Building (3.67, 3.68):

This system advocates open systems building, defined as the design of buildings from available components. Through a complete analysis of building products, the design process stages, building systems classifications and functional sub-analyses, a series of open systems designs are exemplified. It is a useful guide to realise the context of functional studies within the complete design procedure. Closed systems buildings are conversely designed from a specific range of products.

4. The RH Building System (3.69):

This building system devised by the Norwegian house building firm Ringsakerhus is similar in approach and end result to the DNSHsystem referred to earlier, although on a smaller scale. Preferred room modules form the basis of prefabricated building elements.

5. The Bredberg Evaluation System (3.70):

This Swedish SIB System provides a matrix of activities and number of persons within households. Using a scale of functional qualities ranging from A to C, room layouts and positions are assessed. The scale of qualities is based on a graduated range of room sizes and their possibilities of containing furniture groups. The difference between this system and the Svennar system, for example, is that it provides an approximate method of evaluation rather than a graphical assessment of room layouts only. The method refers to the quality of a floor plan as a standard of utility.

6. A German Building Research Institute Evaluation Method (3.71):

This German method of the IFB offers a procedure for assessing the optimality of a floor plan in terms of function, hygiene, socio-psychological factors and social factors. A point-system from 0—3 is awarded to each room and the plan as a whole, according to the degree of optimalisation on the various aspects of evaluation. Spatial standards and size of rooms are important criteria. An average is calculated to give the point-value of the plan as a whole. This system shows promise in method, but fails to examine each evaluation aspect in sufficient detail. For example, functional worth is mainly evaluated in terms of room area in proportion to total floor area. Adaptability in terms of possible furniture arrangements is not considered. The functional room assessment is similar to the Danish checklist referred to in the Björkto system above (Sub-sub-section 3.2.2).

7. A Portuguese System (3.72):

This study by Portas is based on a comparative analysis of floor space standards for different countries. Domestic activities were reviewed in the light of modern activity patterns and a monographic analysis is divided into 16 functions, where the required functional data, the standard equipment and anthropometric requirements are examined, in order to establish minimal floor space requirements.
Inter-relationships and connections between activities were taken into consideration. Two housing standards were proposed, based on the synthesis of the monographic study, and a table of recommended minimal floor spaces per dwelling was laid out.

8. The Building Systems Development Approach (3.73 – 3.75):

The BSD system is based on an examination of flexible housing in Sweden and other countries. The Tenets of functionalism, minimum floor space, multi-function rooms, flexibility of movable partitions and elasticity by extension are all denied in favour of what the authors call adaptability. Their definition of adaptability implies a new use of space in dwellings, in terms of allowance of a variety of interconnections between rooms, no built-in furniture and a wide range of alternative uses of space. The analysis avoids a detailed study of activities, required furniture and spaces, yet postulates objectives similar to those resulting from such studies, without a detailed back-up.

3.7. Other Sources.

Sources were consulted which contained detailed standards on anthropometrics, functio-spatial standards, and house design. These have already been referred to in Section 2. Most of these sources commence with activity studies and progress through spatial standards to activity-spaces, room layouts and house design. The principal references are listed below, in order of estimated usefulness:

1. The Building Research Series : Architects' Data Sheets of the NBI (3.76).
2. Neufert's Architects' Data (3.77).
3. The AJ and the New Metric Handbooks (3.78, 3.79).
4. The New Scottish Housing Handbook (3.80).
5. The MHLG Design Bulletins (3.81 – 3.83).
6. Human Dimension and Interior Space; an American source (3.84).

7. The Australian Handbook of Dwelling Design and Construction (3.85).

8. Building Regulations (3.86, 3.87).

3.8. Summary.

Shortcomings of existing systems and proposals for objectives of a tentative novel design system have already been listed in Sub-section 2.1. Based on such proposals and the functional investigations described in Sections 2 and 3, the skeleton of a model for a new design system would be:

1. At the Analysis Process:

   Compilation of an information source or design guide, readily available for the designer.

2. At the Synthesis Process:

   A computer graphics system to enable the architect to create and manipulate design elements to form plans.

3. At the Appraisal Process:

   A computer-based evaluation model to enable numerical and graphical evaulation of layouts, preferably given to the designer as instantaneously as possible, i.e. dynamically linked with the Synthesis Process. If a design "error" was made during the Synthesis Process, such instantaneous evaluation feedback would facilitate immediate design correction.

   There is an obvious need for such a numerical appraisal technique for layouts, since this is completely lacking in the existing design systems that were studied, and its presence would lead to improved control over the exact use of different floor space categories and areas.

SECTION 4: THE PROPOSED MODELS OF THE DESIGN SYSTEM

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THE PROPOSED MODELS OF THE DESIGN SYSTEM.

4.1. Introduction.

Based on the functional investigations and factors described in Sections 2 and 3, it is now possible to define elements of an emerging flexible design system for the Analysis, Synthesis and Appraisal of domestic activity spaces and house plans, with attention given to marginal spaces and adaptability. In addition to the objectives for the system given in Sections 2 and 3, two main targets were set in the development of the design system:

1. It must be flexible in terms of manipulation of shapes and of jumping back and forwards in the design sequence, so as to aid the synthesis process.
2. It must provide appraisal mechanisms for architectural arrangements, better than the manual ones used at present.

In order to devise a flexible system, it is essential to form a new philosophy with regard to the components of domestic floor plans. The functional investigations showed that conventionally a floor plan is sub-divided into a set of room plans. However, it has been observed that a floor plan is (consciously or unconsciously) built up (assembled) in certain stages, graduating from single elements to progressively larger "groups" of elements. Such stages of assembly of a floor plan are not at present defined or developed, the reasons being mainly:

1. A theory of keeping libraries of planning elements at the various design assembly stages has not existed before.

2. A definite theory of rules for the combination of planning elements has not existed before, although certain theories of combination of elements have been developed for automatic assembly of elements using the computer (4.1 – 4.3). These theories make use of an association matrix, which, when specified, indicates the degree of nearness or connectivity between elements (Fig. 4.1). Such theories are reasonably inflexible, since the matrix must be changed every time a different layout is desired. Designers usually oppose this approach, because they feel it inhibits the creative aspect of combining elements.

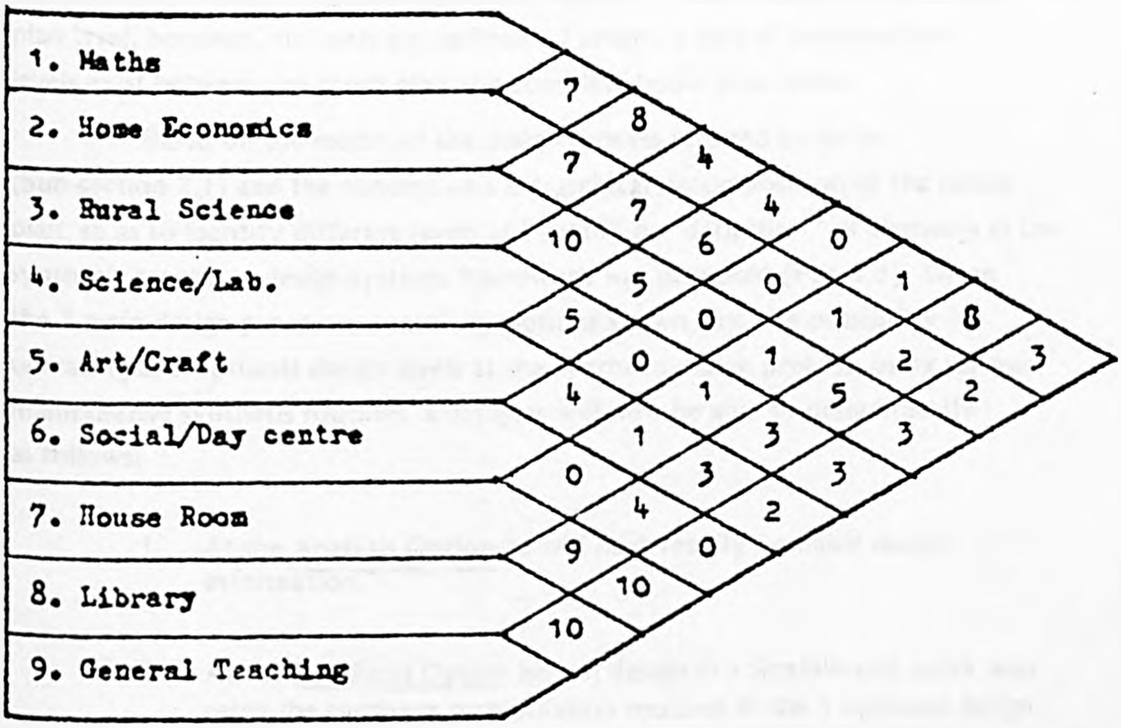


Fig. 4.1. Example of Use of the Association Matrix.
After ABACUS (4.4).

3. No well known controlled experiments of assembling a floor plan in stages have previously been carried out. Such assembly stages shall, in what follows, predominantly be called design levels or levels only.

Certain theories of planning levels have existed because they related to definite scales or levels of planning. These levels were usually employed within economic and land-use planning. The SAR system referred to in Sub-section 3.4 also shows the use of planning levels (Fig. 4.2). Below floor plan or room plan level, however, no levels are defined. Further, a lack of intermediate levels exist between the room plan and complete house plan levels.

Based on the model of the design process referred to earlier (Sub-section 2.1) and the concept of a hierarchical decomposition of the house plan, so as to identify differing levels of "detail" or "definition" of elements at the synthesis process, a design systems framework was proposed (Fig. 4.3). Given the 3 main design processes or activity options shown, and the possibility of operating at 5 optional design levels at the synthesis design process, using various manipulative synthesis routines, a designer will now be able to design ideally as follows:

1. At the Analysis Option he will have readily available design information.

2. At the Synthesis Option he can design in a flexible and quick way using the synthesis manipulation routines at the 5 optional design levels.

3. At the Appraisal (Evaluation) Option, layouts can be evaluated graphically and numerically.

4. The system is flexible in allowing the designer to alternate between Design Options in the design sequence and between Design Levels at the Synthesis Option.

The systems flowchart shown in Fig. 4.3 serves as a basis and framework for the detailed description of the complete system, which is the subject of the rest of this section (4.6).

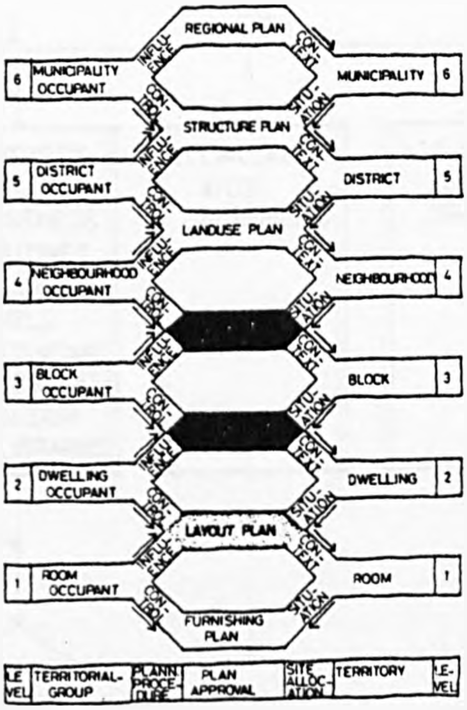


Fig. 4.2. Planning Levels. From SAR (4.5).

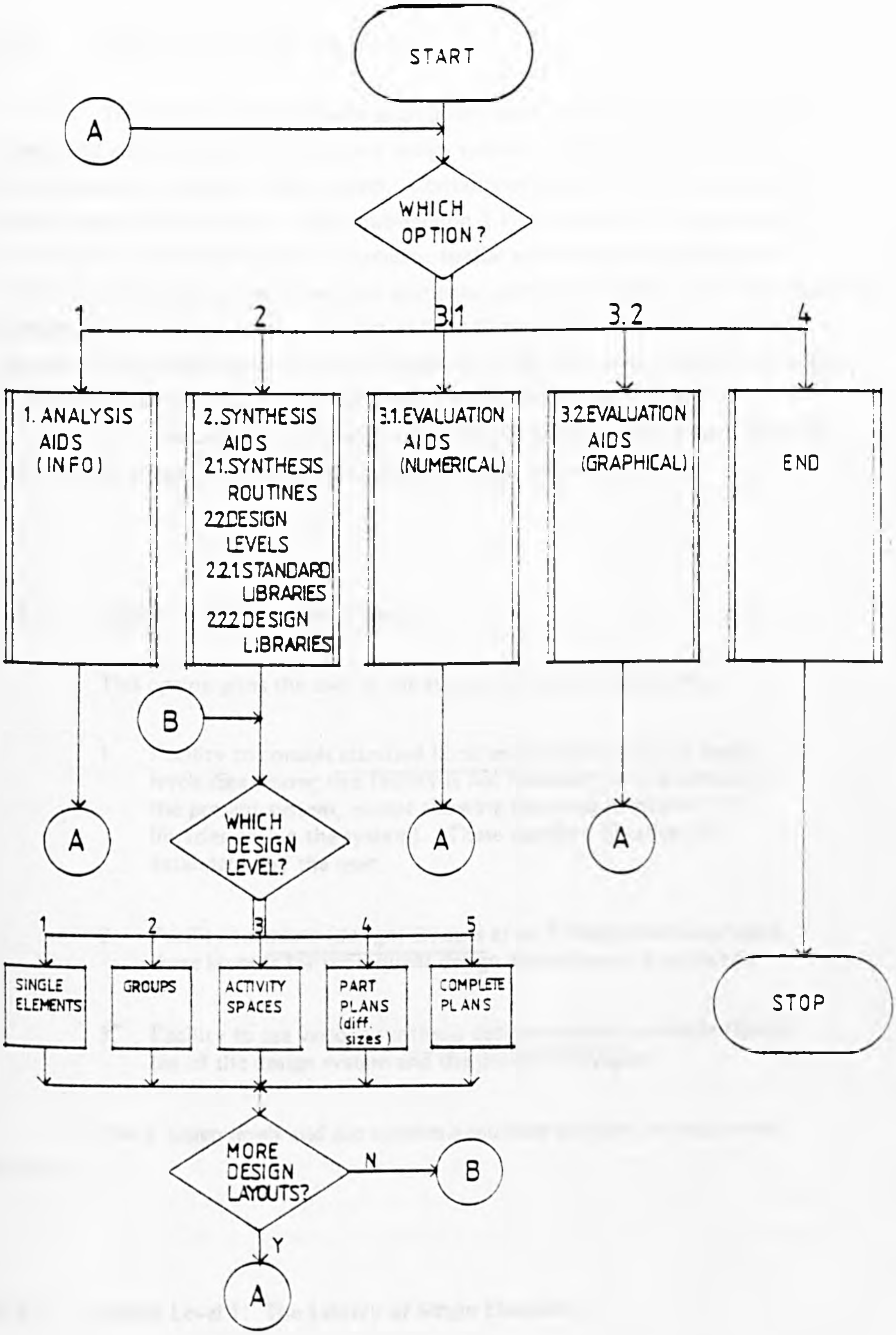


Fig. 4.3. Overall Flowchart Showing Sequence in the Proposed Design System.

4.2. Option 1: The Analysis Process.

This option should be seen as an information bank on aspects of house design and application of the proposed design system. The information bank is extendable by the user of the system. Contents of such an information source have already been referred to under Sub-section 2.1. Examples of house design information could include a list of domestic spatial activities and requirements with cross-reference to their associated elemental content (furniture and other elements), planning and building regulations, a list of "good" house planning check-points, technical information referred to earlier, and any other information suitable at stages C (Outline Proposal) and D (Scheme Design) of the RIBA Plan of Work.

It is unnecessary to implement the analysis option in the present research, but it would be useful for architects using the design system in practice.

4.3. Option 2: The Synthesis Process.

This option gives the user of the system the following facilities:

1. Facility to consult standard libraries of layouts at all 5 design levels (See below; this facility is not necessary to implement in the present system, except allowing for subsequent entry of libraries within the system). These standard libraries are extendable by the user.

2. Facility to create (design) layouts at all 5 design levels and store these layouts for subsequent design alterations and appraisals.

3. Facility to use various synthesis design routines to enable flexible use of the design system and the design of layouts.

The 5 design levels and the synthesis routines will now be dealt with in turn.

4.3.1. Design Level 1: The Library of Single Elements.

This extendable library stores information on single elements and macro-elements referred to earlier under Sub-section 2.4. The elements are coded, dimensioned in millimetres, contain certain attributes, and are defined with space categories on different "overlays" (Fig. 4.4). There are two immediate design advantages to this overlay concept:

1. The space types of a single element, an activity-space, a part-plan and so forth, may be displayed one by one.

2. Activity-spaces or floor plans may be overlayed on top of one another. This overlay concept is a critical and important facility for the designer, since at present the equivalent can only be achieved through superimposing sheets of tracing or plastic paper containing the plans, on top of one another. Use of computer graphics, however, allows any plan overlay permutation desired, quickly, and neatly, which is important for the design of layouts on intermediate floors, since it is necessary to keep a detailed track of what is aligned immediately above or below the layout concentrated upon, particularly structural elements.

For coding system, reference is made to Section 8. Retrieval of elements are enabled by calling their names. Further information on the design of layouts and the use of the system implemented on the computer can be found in Sections 7 – 10. This section deals primarily with the conceptual framework and aspects of the design system. The library of single elements is extendable by the systems users, i.e., the creation of additional elements is possible.

4.3.2. Design Level 2: Groups of Elements.

A group arrangement of elements corresponds to one domestic activity or function only, for instance a seating area in a living space (Fig. 4.5). A group is created by combining elements from the Level 1 standard library of elements. Group layouts will therefore be defined on several overlays also, since the space categories of single elements are specified on separate overlays. Coding of groups will ensure they are recognised as level 2 layouts. Combination of elements adhere to the rules of combination, discussed in Sub-section 2.5 and further in Section 5.

Level 2 facilities are:

1. Possibility of consulting a standard library of groups. This would act as a design guide for the user.

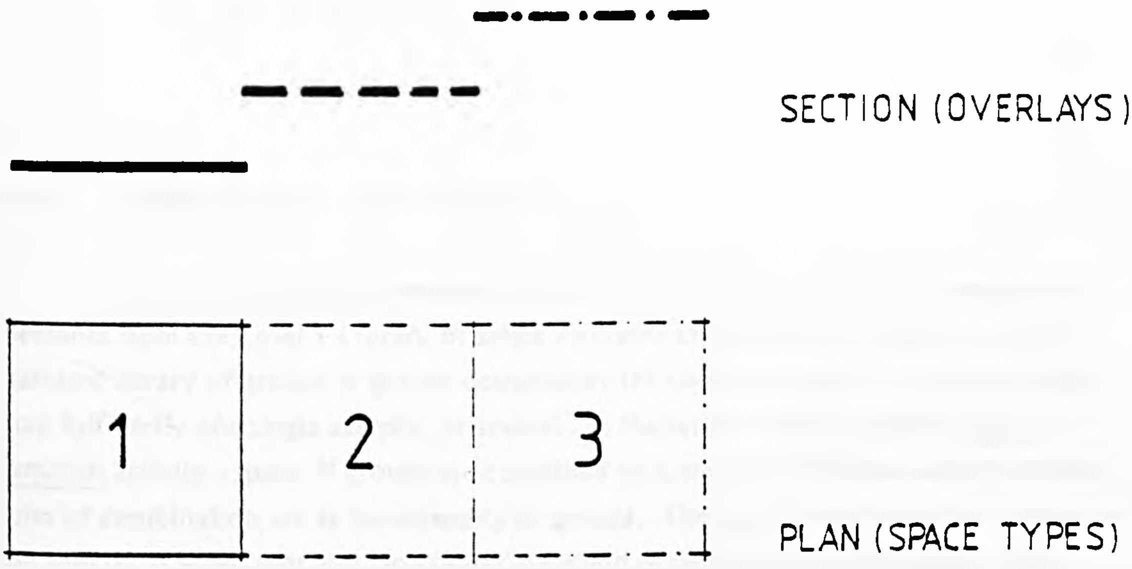


Fig. 4.4. Graphical Example of a Level 1 Single Element and the Overlay Concept.

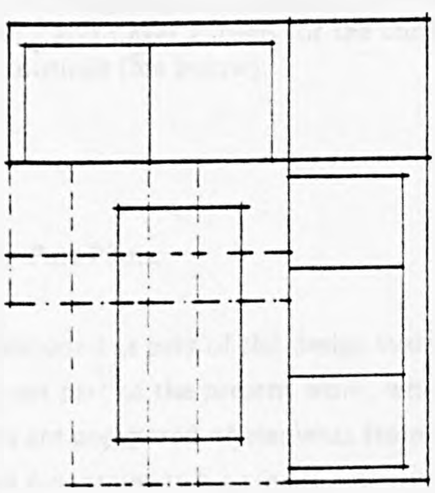


Fig. 4.5. Example of a Level 2 Group.

2. Possibility of designing and amending Level 2 groups using the Level 1 library of single elements, the rules of combination of elements, and the synthesis routines (See below).

4.3.3. Design Level 3: Activity Spaces.

An activity-space corresponds roughly to a room layout, and is composed of elements from the Level 1 Library of single elements and/or groups from the Level 2 standard library of groups or groups designed by the user at Level 2. An activity-space may fulfil only one single activity, or several. In the latter case it is called a multi-function activity - space. If groups are combined to form multi-function activity spaces, rules of combination are as for assembly of groups. The total area of an activity space is the sum of its solid, user and circulation areas and is called its functional area. Walls, doors, windows and open space may also form part of the activity - space area. Usually, an activity space is delimited by the bounding rectangle of its composite Level 1 or Level 2 elements (Fig. 4.6).

Level 3 facilities are:

1. Possibility of consulting a standard library of activity spaces, which would constitute a design guide for activity spaces.

2. Possibility of designing and amending Level 3 activity spaces, using elements from Level 1 and Level 2, rules for the combination of elements, and the synthesis routines (See below).

4.3.4. Design Level 4: Part Plans.

Part plans are included as part of the design system, although practical implementation of this level is not part of the present work, which concentrates on Level 3 activity spaces. Part plans are composed of elements from Levels 1, 2 and 3, according to choice of inclusion. Level 4 contains two or more activity - spaces grouped together as one unit, and movable as one unit, as layouts of other levels are. Part - plans are on a graduated scale of sizes, definable by the user. In this respect Level 4 could be sub-divided into several sub-levels; 4.1, 4.2 and so forth. The coding system would allow for such sub-level definitions (See Section 8). Fig. 4.7 shows examples of the concept of part plans.
It is anticipated that the library of standard part plans would not be extensive, since a

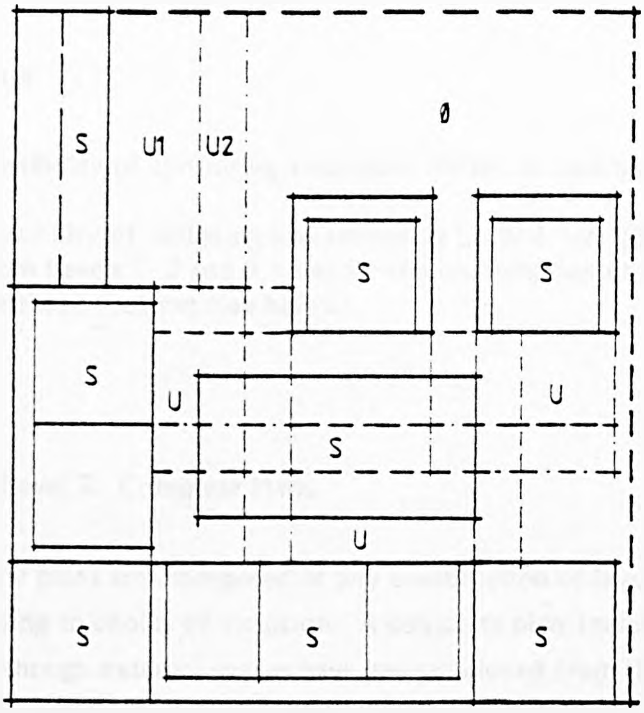


Fig. 4.6. Example of a Level 3 Activity Space.

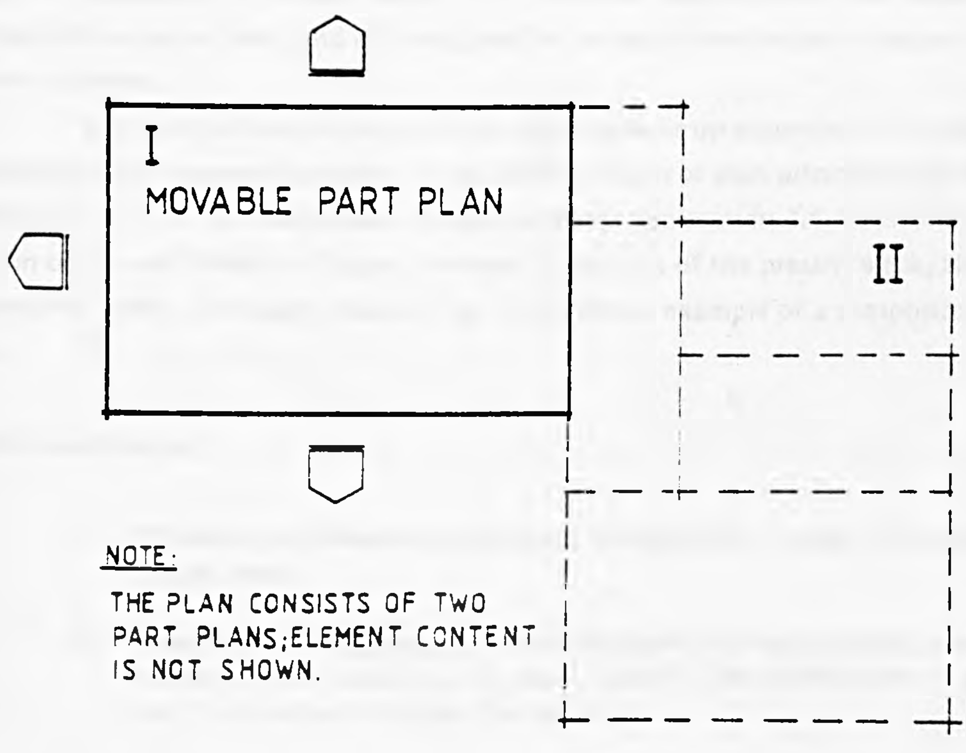


Fig. 4.7. Example of the Concept of Level 4 Part Plans.

part plan is fairly unique to each house design, whereas at the other levels, standard solutions can, possibly with adjustments, be used for a wide variety of designs.

Level 4 facilities are:

1. Possibility of consulting a standard library of part plans.

2. Possibility of designing and amending Level 4 part plans, using elements from Levels 1, 2 and 3, rules for the combination of elements, and the synthesis routines (See below).

4.3.5. Design Level 5: Complete Plans.

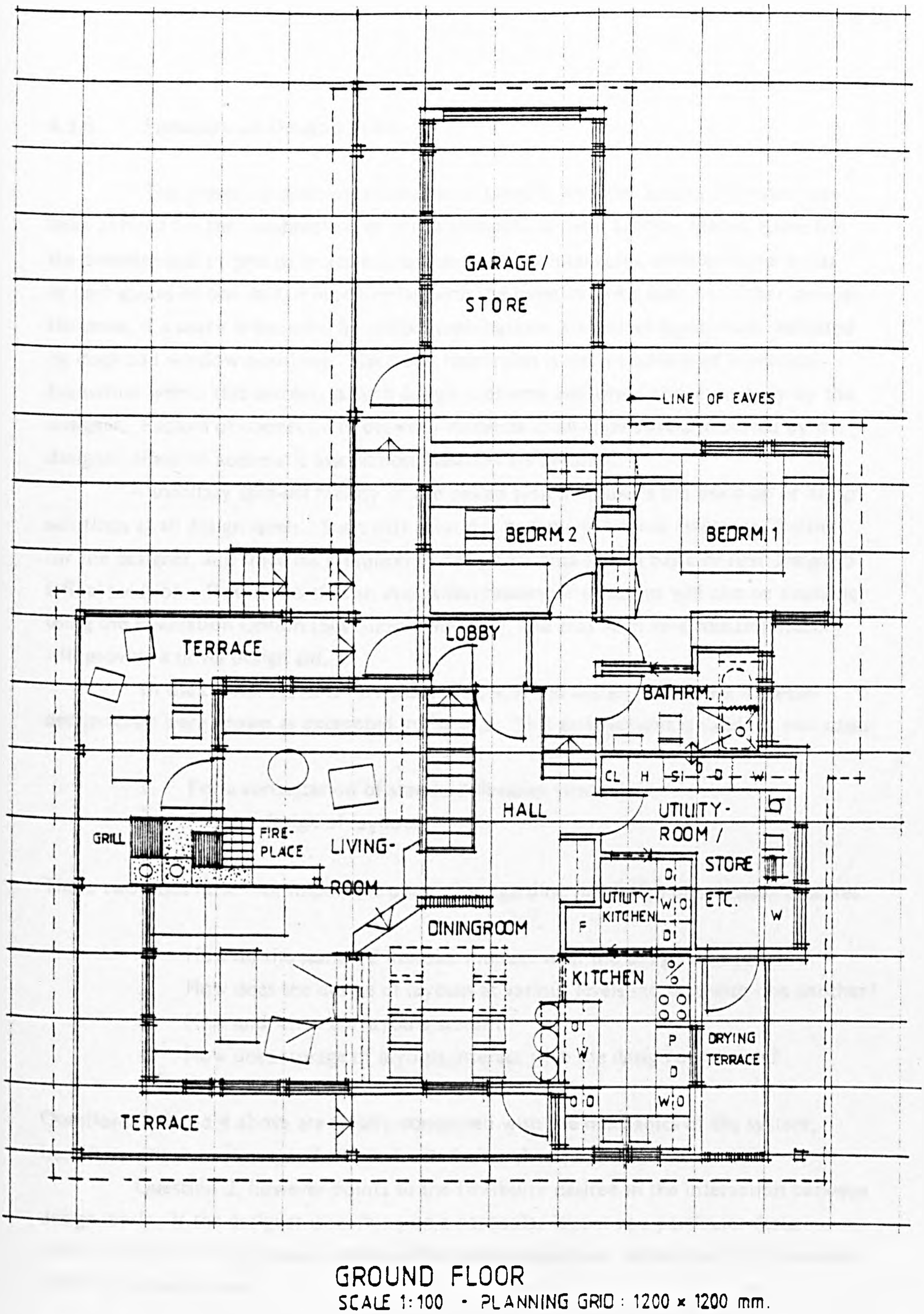
Complete plans are composed of any combination of layouts from Levels 1, 2, 3 and 4, according to choice of inclusion. A complete plan includes both internal and external spaces, although external spaces have been excluded from the present project. By external spaces is meant the activity spaces immediately adjacent to and functionally linked to the inside of a house plan, for example, patio, terrace, drying area for clothes, entrance area etc. The complete internal plan includes the functional spaces of Levels 1, 2, 3 and 4 as well as interior and exterior walls, windows, doors and other, fixed elements. Again it is possible to sub-divide Level 5. One sub-level would include the house plan as bounded by external walls, and the next one for the addition of external space to the former sub-level.

A standard library of house plans could be built up according to a certain morphology, for example according to the DNSH system of plan principles (See Sub-section 3.1; 4.7) or the NBA system of generic plans (Sub-section 3.6;4.8). The construction of a Level 5 library of plans, however, is not part of the present work, although allowed for within the design system. Fig. 4.8 shows an example of a composite complete plan.

Level 5 facilities are:

1. Possibility of consulting a standard morphological library of complete house plans.

2. Possibility of designing and amending Level 5 complete plans, using elements from Levels 1, 2, 3 and 4, rules for the combination of elements, and the synthesis routines (See below).



NOTE: THE ABOVE FLOOR PLAN WAS DESIGNED USING THE LIBRARY OF HOUSE PLANNING ELEMENTS AND BY PAYING PARTICULAR ATTENTION TO THE "ASSEMBLY" IDEA OF DESIGN. USER SPACES NOT SHOWN. SEE SUB-SECTION 2.5.

Fig. 4.8. Example of a Composite Level 5 Complete Plan.

4.3.6. Summary of Design Levels.

The present project concentrates on Level 3, Activity Spaces and rules have been defined for the combination of single elements to form activity spaces. Rules for the combination of groups or activity spaces follow similar rules, since extreme solids or user spaces of one layout may overlap with the same extreme spaces of other layouts. However, if a space is bounded by walls, combinations with other layouts are restricted by door and window positions. The latter restriction is not a problem of numerical evaluation within this system, as such design problems are solved conventionally by the designer. Factors of connectivity between elements at all Levels are also solved by the designer, since no automatic association matrixes are involved.

A corollary spin-off facility of the design system in use is the build-up of design solutions at all design levels. Such past solutions become in a sense reference libraries for the designer, and trace his evolution of design variants from a basic or first design to a final solution. This means that an evaluation history of solutions will also be available, using the Evaluation Option (See Sub-section 4.4), and that such an evaluation history will provide a novel design aid.

In the overall systems flowchart (Fig. 4.3) the design interaction between design levels were shown as excerpted in Fig. 4.9. This arrangement is valid for two cases:

1. For a consultation of standard libraries (stored).
2. For the design of layouts.

These two cases raise four important questions regarding the design of synthesis features:

1. How do the standard libraries interact with the design of layouts?
2. How does the design of layouts at various levels interact with one another?
3. How and when are layouts stored?
4. How does storage of layouts interact with the design of layouts?

Questions 1, 3 and 4 above are closely concerned with the mechanics of the system, i.e. the synthesis routines, and will be treated after these, in Sub-section 4.3.9.

Question 2, however points to the flexibility desired in the interaction between design levels. If the designer is working on a particular layout at a particular design level, he may want to do one or more of the following actions, whilst still being involved with the former layout:

1. Create and/or amend another layout:
   1.1. At the same level.
   1.2. At a different level.

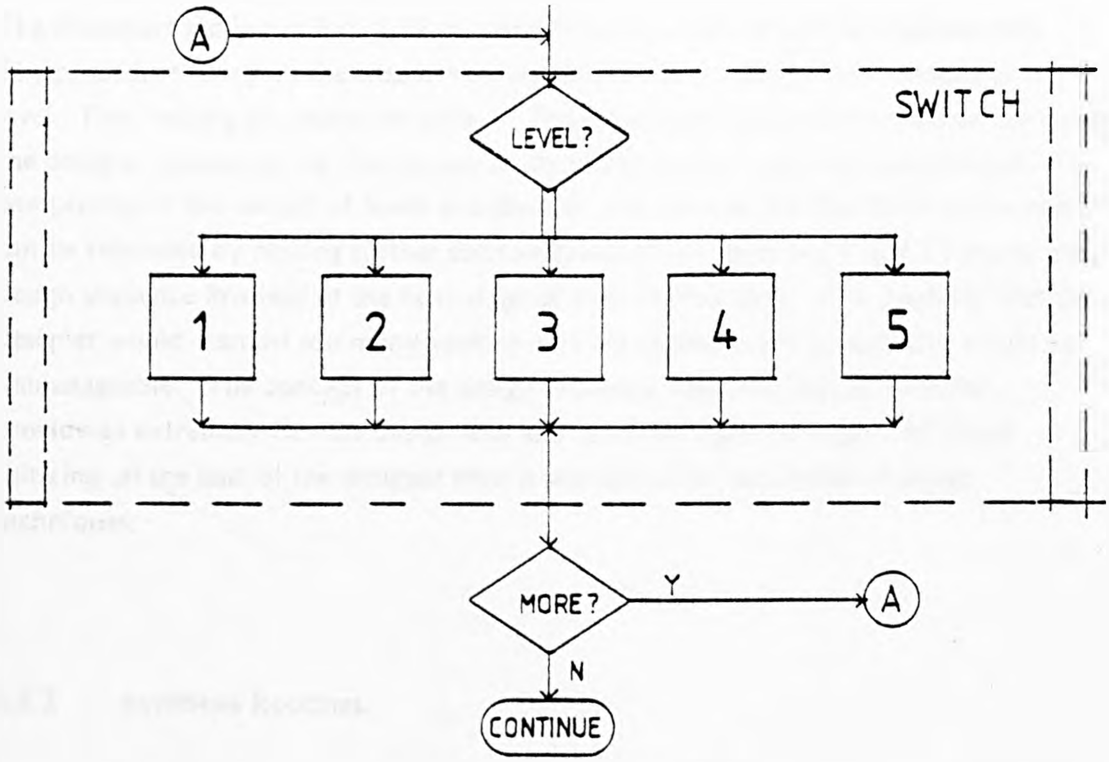


Fig. 4.9. Interaction between Design Levels.

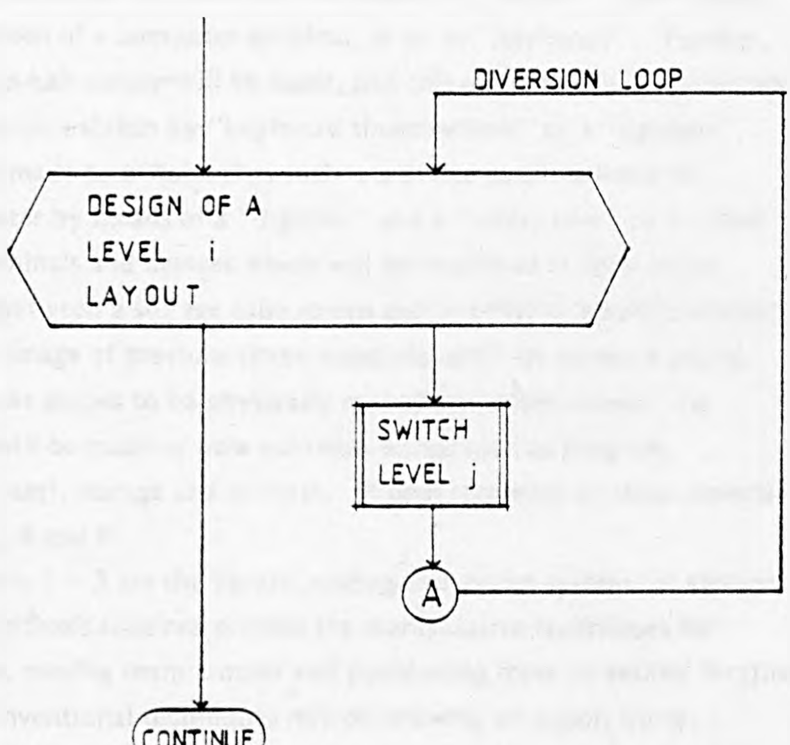


Fig. 4.10. Switching of Layouts and Levels.

The flowchart section in Fig. 4.10 indicates how the above would be implemented. The procedure is in fact the creation or amendment of layouts within layouts, at any level. This nesting process is iterative. Once the design diversion is deemed concluded, the designer returns to the first layout at the design level at which he commenced. The complexity of this switch of levels and layouts, and thereby the flexibility of the system can be enhanced by nesting further such switches within switches, Fig. 4.11 shows the design sequence involved at the next stage of such re-iterations. It is doubtful that the designer would warrant too many such re-iterative stages, as the complexity would be unmanageable. The concept of the design sequence described would, however, provide an extremely flexible design tool and facilitate a greater degree of lateral thinking on the part of the designer than is possible using conventional design techniques.

4.3.7. Synthesis Routines.

At this stage in the description of the design system, it is no longer possible to conceptualise the model only. It was clear that a computer graphics system would be required to implement the system. Therefore, frequent reference will be made to hardware and software components of the system hereafter.

As regards hardware, reference will be made to a "screen", which simply means the graphics screen of a computer terminal, or to its "keyboard". Further, use of the words "cross-hair cursor" will be made, and this refers to the device which aids position of shapes on a screen by "keyboard thumbwheels" or a "lightpen". Reference will also be made to a "tablet", which is a device to allow input of shapes into the computer by means of a "digitiser" and a "tablet pen", or to other types of computer terminals and devices which will be explained as they occur. There is a distinction between a storage tube screen and a refresher graphics screen; the former retains the image of previous shape locations until the screen is paged, whereas the latter allows shapes to be physically moved across the screen. As regards software, use will be made of now common words such as program, sub-routine (of a program), storage and so forth. Proper reference to these aspects are given to sections 7, 8 and 9.

Whereas levels 1 – 5 are the library, coding and design system for elements of a house plan, the synthesis routines provide the manipulative techniques for creating such elements, moving them around and positioning them in desired locations and storing them. Conventional techniques rely on drawing on paper, using overlays, using cut-out shapes to move around on a planning board and so forth. Using computer graphics, however, it is possible to manipulate shapes on a screen.

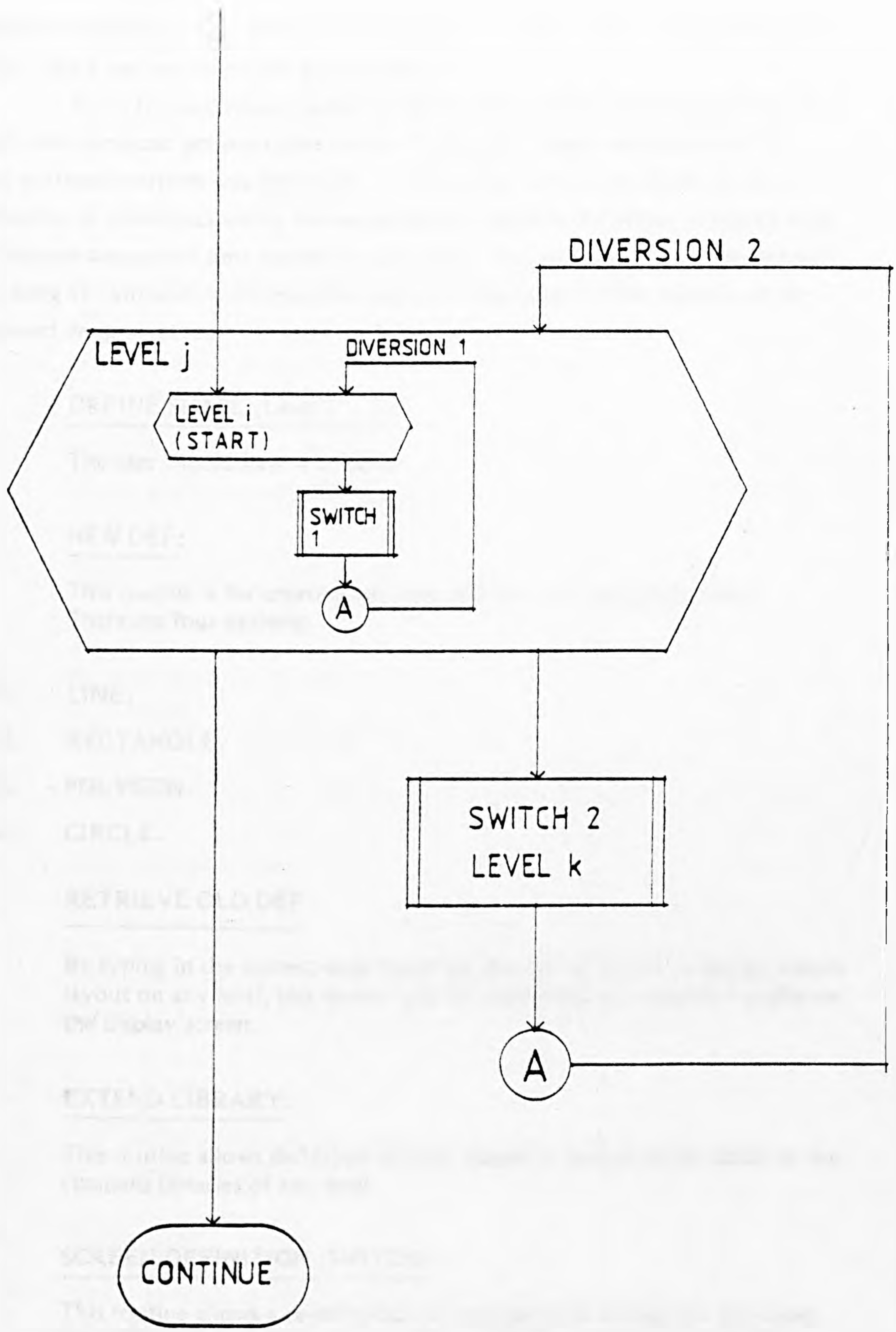


Fig. 4.11. The Concept of Reiterative Layout and Level Switching.

Refresher graphics, as mentioned, allows shapes to be seen moving physically on the screen, like a modern television game system.

From the experience gained using the planning-board technique and the GAEL 4A computer program (See Section 7), the main objective established for ideal synthesis routines was flexibility. Flexibility here can be taken to mean the ability to move backwards, forwards and sidewards in the design sequence with a minimum amount of time wasted at each step. The earlier studies suggested the following 16 synthesis routines as the main and ideal ones for the purpose of the proposed design system:

1. DEFINE SHAPE (Level 1 – 5):

The user should have 4 options:

1.1. NEW DEF:

This routine is for creating any new definition on any design level. There are four options:

1.1.1. LINE.

1.1.2. RECTANGLE.

1.1.3. POLYGON.

1.1.4. CIRCLE.

1.2. RETRIEVE OLD DEF:

By typing in the correct code name for any stored library or design history layout on any level, this layout may be positioned at a desired position on the display screen.

1.3. EXTEND LIBRARY:

This routine allows definition of new shapes or layouts to be added to the standard libraries of any level.

1.4. SCREEN DEFINITION (SWITCH):

This routine allows a re-definition of arrangements already on the screen or addition of new layouts at any level. This routine is also useful if part of a plan needs to be moved as one element, or if groups or activity spaces need to be altered whilst having the whole plan displayed.

2. DRAW SHAPE:

The user has three options:

2.1. DRAW MENU:

This routine causes a specified number of elements on any level from the standard libraries or design layouts to be drawn on a small area of the screen (upper and lower part strip) called the Menu Area. The scale of the shapes would be smaller than the normal design scale elsewhere on the screen.

2.2. DRAW ON PLANNING AREA:

This routine draws shapes from any level to any scale on the main part of the screen. Rotation and reflection of shapes should be possible.

2.3. HARDCOPY:

The screen layout may be copied using the following devices:

2.3.1. Tektronix 4631 Hardcopy Unit.

2.3.2. Calcomp Drum Plotter.

2.3.3. Photographic, film or video recording.

2.3.4. Tektronix Cassette Recorder.

2.3.5. Flat-bed plotter with interchangeable pens for line thickness and colour.

3. PICK (FROM MENU):

This routine allows the user to choose shapes or layouts from the menu area using either a lightpen (if refresher graphics is used) or a thumbwheel cross-hair cursor (if a storage tube terminal is used), and position the chosen shape or layout on the planning area of the screen.

4. MOVE SHAPE:

This routine allows the user to move already positioned layouts at any level to new positions, and rotate or reflect layouts.

5. EDIT SHAPE:

This routine allows the user to alter previously defined library or design layouts on any level. The user can change any definition specification of layouts such as dimensions, line type, origin, name, dashed lines as per LINCOD specifications on any overlay level (See Routine 13 below).

6. GRID (AXES):

This routine allows a specification of a dimensionally co-ordinated grid to any module, which can be drawn on the planning area of the screen to desired line specification on any overlay level, and onto which layouts at any design or overlay level can be positioned. The grid would co-incide with international modular co-ordination dimensions. Simplified, this routine could allow dimensionally co-ordinated x— and y — axes to be drawn on the screen; positioning of elements being enabled by the horizontal and vertical lines of a cross-hair cursor. Grids or axes would allow house plans to be dimensionally co-ordinated.

7. SCALING (WINDOWING):

This routine allows the user to define layouts at any scale (e.g. 1:5, 1:10, 1:20, 1:50, 1:100, 1:200, 1:500, 1:1000 etc.). This routine is syncronized with the GRID routine.

8. TEXT:

This routine enables the user to add text to a layout at any level to a desired lettering size. Lettering is useful for denoting symbols on single elements, room names, floor levels and so forth. Location of text is optional and overlay level can be specified.

9. DIMENSIONING:

This routine allows automatic dimensioning of layouts on any overlay level, temporary or permanently displayed, in millimetres.

10. ORIGIN:

This routine enables display of a layout's origin. This enables positioning and re-positioning of a layout.

11. ADJUST DIMENSIONS:

This routine is useful for adjusting dimensions of a functional layout space to the nearest GRID line used. The following options should be available:

11.1. AUTOMATIC ADJUSTMENT:

This routine effects automatic rounding of dimensions to the nearest grid line used.

11.2. EXPAND:

This routine enables the user to interactively expand the perimeter of a layout to the nearest or any grid line above the actual layout dimensions.

11.3. CONTRACT:

This routine enables the user to interactively decrease the perimeter of a layout to the nearest or any lower grid line dimension.

12. PUSH APART:

This routine is useful for inserting walls or similar elements between two functional spaces. Consider two contiguous activity spaces. Their functional perimeter lines at the line of contact will concur. By pointing to the contiguous line with a light pen or cursor, the user should be able to move the two lines and thereby the complete layouts apart by a specified width to accommodate the walls. It should be possible to move one or both layouts. This option is useful when manipulation of elements and spaces has resulted in a desired relational plan, at which stage there is a need to interject walls and other elements.

13. OVERLAY LEVEL:

This routine enables the designer to perform two important tasks:

13.1. LAYOUT OVERLAY:

This routine enables the user to specify parts of elements, e.g. user areas, to be stored and drawn on different overlay levels. This allows viewing of any composition of overlays that form part of an element. For instance, when a floor plan has been completed, it is no longer necessary to keep the user areas displayed and so these overlays can be removed, leaving the solids displayed.

13.2. DESIGN OVERLAY:

This routine enables the user to overlay one layout or plan at any level on top of another layout. For instance, this is useful when designing an upper floor plan of a house. The top floor plan can then be overlayed on the floor plan below to aid the designer in the design of the top floor plan.

14. ZONES:

This routine enables specification of zones according to the Habraken-system described in Sub-section 3.4, and would allow a zoning analysis. Two options should be available:

14.1. AUTOMATIC ZONING:

This routine causes zoning lines to be drawn on the screen area according to a standard zoning library. This type of zoning would be useful for standard housing.

14.2. INTERACTIVE ZONING:

This routine enables the user to specify zone widths interactively.

15. AUTOMATIC GENERATION:

Automatic generation of elements is not part of the present project. If implemented, automatic generation would cause a set of specified elements to be positioned into several possible layouts based on the rules for combination. Solutions would be drawn in the main area of the screen, the idea being that such solutions or permutations may aid the designer towards a solution. Automatic generation makes use of an adjacency or association matrix or is based on attributes linked to sides of elements. A certain amount of work was done on automatic generation of elements, but resources prevented a further investigation.

16. STORAGE OF LAYOUTS:

Three routines are desired:

16.1. STORAGE OF STANDARD LIBRARIES:

This routine stores layouts on any level, according to code-names given, in standard solution libraries for consultation by the designer.

16.2. STORAGE OF DESIGN SOLUTIONS:

This routine stores design solutions at any level, according to code-names given, in a history file of design layouts for consultation by the designer.

16.3. DELETION:

Since storage of layout is automatic, this routine allows the user to delete unwanted layouts from storage.

4.3.8. Aspects of Synthesis Routines.

A number of flowchart specifications were undertaken on the above synthesis routines (4.9). However, existing computer software was obtained which satisfied most of the proposed routines, thereby dispensing with further such specifications (see section 7).

A number of questions were raised in Sub-subsection 4.3.6, concerning the interaction between the stored standard library definitions as well as stored design layouts, and the design of layouts at any design level. Further the question arose as to how and when layouts are stored. These questions can be answered as follows:

1. Storage of layouts is instantaneous as described under synthesis routines. Geometric data on layouts are kept in file under the name given to the layout, and as such the way in which the name is coded indicates the type and level of the layout.

2. In Sub-sub section 4.3.6 was also discussed the interaction of layouts at various levels and this was shown in Figs. 4.9 – 4.11. If, when designing at a particular level, the designer wishes to define a new layout at the same or another level, and chooses to retrieve a layout from the standard library or the library of design layouts at the chosen level, instead of creating a new layout at that level, the procedure can more properly be shown in Fig. 4.12.

4.3.9. Summary of Synthesis Option.

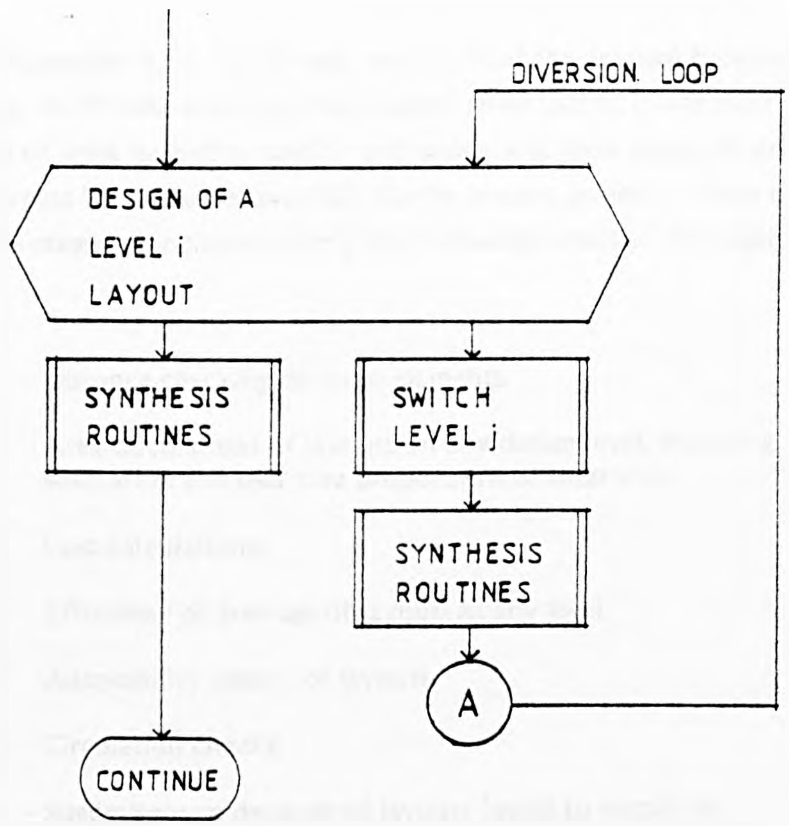
In Sub-section 4.3 has been proposed a conceptual system for designing domestic layouts at 5 optional design levels using a number of proposed storage and synthesis routines, and the interactions of design levels, storage, and synthesis routines.

A limitation of the system is that only orthogonal, 2 - dimensional layouts and shapes are included (circle not to be implemented for evaluation purposes, but available as a shape). Otherwise the Synthesis Option provides a highly flexible and interactive design aid. The implemented system will be discussed in Sections 7 - 10.

4.4. Option 3: The Evaluation Process.

A number of evaluation measures, manual and automatic, are available for evaluating aspects of designs within Building Economics, Environmental Design and Structures. However, as evidenced by the functional studies of sections 2 and 3, no real objective or numerical method of evaluating the functional aspect of a domestic floor plan exists. A plan is usually assessed subjectively and visually only on functional aspects, and further calculations of overall floor areas and cost may be carried out. Appraisal measures usually establish norms for "good" or "bad" design, which can be compared to new designs. An evaluation measure "history" is thus constructed, which enhances "good" design. Since no functional evaluation measures exist, no real and controlled enhancements of the spatio-functional aspects of a domestic floor plan can satisfactorily be achieved.

To enhance the evaluation of floor plans as per objectives of Section 2, a number of spatio-functional evaluation routines were proposed (4.10), which can



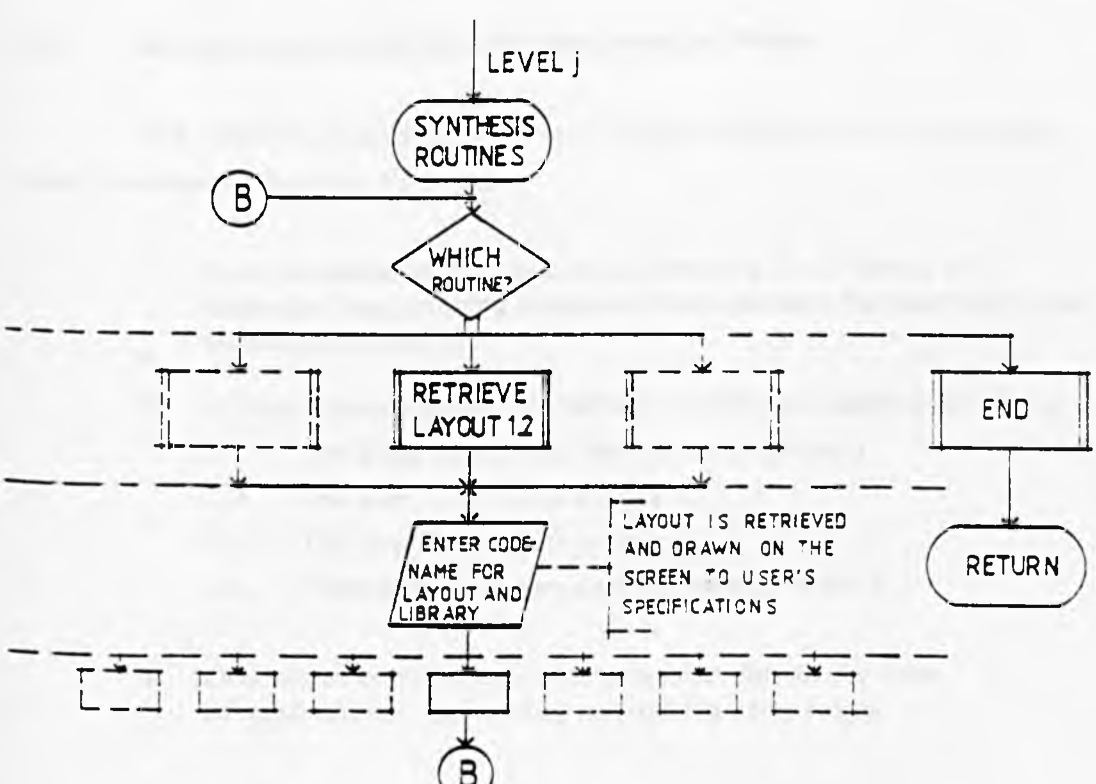


Fig. 4.12. Interaction between Design of Layouts, Levels and Storage.

be found in Appendix A1.1. Although, as a result of the detailed functional investigations, all of these measures were known to be useful, it was soon found that the sheer volume of work needed to specify and implement these measures on the computer, would far surpass the resources available for the present project. These early proposals for evaluation measures included mainly the following aspects. (See again Appendix A1.1):

1. Distance checking between elements.
2. Area calculations of layouts on any design level, including solid areas and user area proportions of total areas.
3. Cost calculations.
4. Efficiency of area use of layouts at any level.
5. Adaptability checks of layouts.
6. Circulation checks.
7 Suggestions to designer of layouts found to match his previous designs.

4.4.1. Background and Objectives for the Evaluation Model.

The following factors are important to the construction of an evaluation model for assessing domestic floor plans:

1. It can be assumed that use can be made of a 2 – D library of domestic floor planning elements which represent furniture and other elements, on level 1.
2. A floor planning element is defined on different overlays as follows:
   - 2.1. The Solid part of the element is on overlay 1.
   - 2.2. The User 1 area is on overlay 2.
   - 2.3. The User 2 area is on overlay 3.
   - 2.4. Other parts of elements are on overlays 4 and 5.
3. Overlaps of elements can take place according to the rules of combination. Solids may not overlap other solids.

4. Using a Tektronix Tablet and graphics screen, layouts may be designed on any level. The method of evaluation will concentrate on level 3 activity spaces, but may be extended.

5. A level 3 activity space is bounded by a rectangle on overlay 6.

6. For experimental and efficiency purposes the method will be restricted to the evaluation of orthogonally arranged layouts, and rectangular and orthogonal polygons used as planning elements.

7. It may be assumed that sometimes open or wasted areas will be contained within the bounding rectangle of an activity space.

A typical activity space representing a bedroom is shown in Fig. 4.13, showing overlays 1, 2, 3 and 6.

Based on the 2–D components of domestic floor space the objectives of a functional evaluation method are set as follows:

1. The efficiency of an activity space should be evaluated in terms of the following factors:

1.1. The nature and efficiency of the overlapping areas between elements.

1.2. The shape and length of the perimeter.

1.3. The proportion of various sub-areas to the total area.

2. The display on the graphics screen of the numerical results of the evaluation calculations, illustrated by graphical output of such results in graphs, histograms and piecharts.

3. The comparison of efficiency evaluation results for several layouts and a build-up of an evaluation history for previous designs to form efficiency norms.

4. An attempt to link evaluation as dynamically as possible to the synthesis design process. Ideally each design "move" should be evaluated instantaneously, so as to prevent inefficient or impractical design moves.

5. The formulation, hypothesis and tests of a tentative manual method of evaluation prior to full computer implementation.

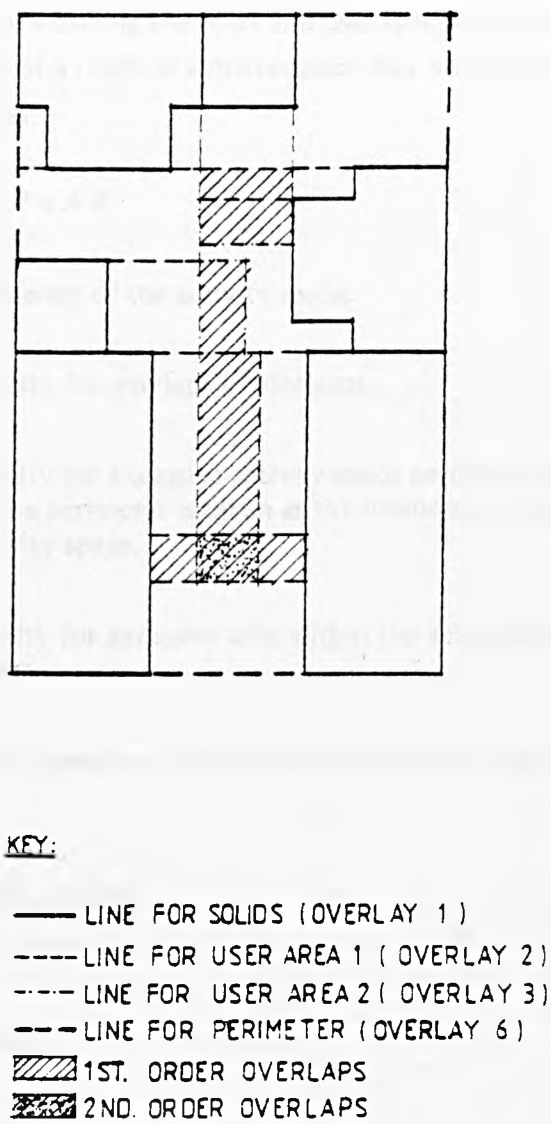


Fig. 4.13. Typical Example of a Level 3 Activity Space.

Further mechanics of the computer implemented evaluation method are contained within Sections 9 — 11.

4.4.2. The Manual Evaluation Method.

This sub-section aims at explaining how a measure of efficiency for level 3 rectangular domestic activity spaces containing orthogonally arranged rectangular and orthogonal polygonal planning elements and user spaces was derived (4.11).

The efficiency of a room or activity-space may be expressed, using three penalty factors, as follows:

$$E = O.P \times P.P \times A.P$$

where E = the efficiency of the activity space.

O.P = the penalty for overlaps of elements,

P.P = the penalty for excessive activity-space perimeter length, where the perimeter is taken as the bounding rectangle of the activity space.

A.P = the penalty for excessive area within the activity space perimeter.

Each of the three penalty factors can be expressed in turn as follows:

(1) $$O.P = \frac{\Sigma\ (A.01 \times W.01)}{A.01}$$

where: $$A.01 = \sum_{y=1}^{n} A^{y}.01$$

where: A.O = the sum of all overlapping areas or the intersection between all pairs of overlapping elements.

01 =		notation signifying that two elements only are overlapping. If the intersection of overlapping areas of three elements is sought, then the index would be 02 and so forth.
y =		index to denote the exact pair of overlapping elements referred to.
n =		the maximum number of overlapping elements.

The total overlapping area of one pair of overlapping elements can be expressed as:

$$A.^{y}01 = \sum_{i=1}^{j} i\, a.^{y}\, 01 \sum i$$

where: a = the overlapping area between two space categories of two overlapping elements.

i = index to denote the particular instance of overlap between two space types only, of two overlapping elements.

6 possible instances are:

1:1
1:2 (2:1)
1:3 (3:1)
2:2
2:3 (3:2)
3:3

The suffix i also denotes that all overlapping areas resulting from an instance of overlap between two overlapping elements are summed up and added to the total of $a.^{y}\,01$, which finally is added to A.01.

j = the number of overlap instances present.

and: w.01 = a penalty weighting factor. Each instance of overlap is assigned a weighting factor which expresses the severity of decreased spatial standard of the activity - space, resulting from the type of overlap incurred. w.01 was given values from 1 - 5 in the preceding manual experiment (Section 5), as shown in Table 4.1, but these values are changeable by the designer.

Table 4.1. Overlap Instance Weighting Factors.

OVERLAP INSTANCE	1:1	1:2	1:3	2:2	2:3	3:3
WEIGHTING FACTOR TYPE	W.1:1	W.1:2	W.1:3	W.2:2	W.2:3	W.3:3
WEIGHTING FACTOR VALUE	5	4	3	3	2	1

Table 4.2. Probability Penalty Products.

INSTANCE	1.1:2.1	1.1:2.2	1.1:2.3	1.2:2.1	1.2:2.2	1.2:2.3	1.3:2.1	1.3:2.2	1.3:2.3
PROBABILITY PRODUCT	p1.1xp2.1	p1.1xp2.2	p1.1xp2.3	p1.2xp2.1	p1.2xp2.2	p1.2xp2.3	p1.3xp2.1	p1.3xp2.2	p1.3xp2.3
	P1.1:2.1	P1.1:2.2	P1.1:2.3	P1.2:2.1	P1.2:2.2	P1.2:2.3	P1.3:2.1	P1.3:2.2	P1.3:2.3

If no overlap penalty is incurred, that is, if no overlapping area is added to A.01, then:

O.P = 1, since $\Sigma(A.01 \times w01) = A.01$.

But even if O.P. min = 1, it is still possible that instances of 3:3 overlaps may have occurred, since w.01.3:3 = 1.

The additive overlap penalty area can now be expressed as:

$$\Sigma(A.01 \times w.01) = \Sigma\kappa\left[\left(\sum_{y=1}^{n} A^{y}.01\right) \times w.01.\kappa\right]$$

where: κ = Suffix to denote that instance overlapping areas are to be multiplied in each case by the appropriate value of w.01; the index 01 meaning that a first order overlap is occurring, i.e., an overlap between pairs of elements only.

The above equation can now be fully expressed as:

$$\Sigma(A.01 \times w.01) = \Sigma\kappa\left[\left(\sum_{y=1}^{n}\left(\sum_{i=1}^{i} a^{y}.01.\Sigma i\right)\right) \times w.01.\kappa\right],$$

and the full expression of the penalty factor for overlaps of elements becomes:

$$Op = \frac{\Sigma\kappa\left[\left(\sum_{y=1}^{n}\left(\sum_{i=1}^{i} a^{y}.01.\Sigma i\right)\right) \times w.01.\kappa\right]}{\Sigma\kappa\left(\sum_{y=1}^{n}\left(\sum_{i=1}^{i} a^{y}.01.\Sigma i\right)\right)}.$$

The penalty weighting system would more appropriately be arranged as shown in Table 4.2. In this case a weighting factor p would be assigned to each space type of every element. If two elements overlap the combined penalty weighting product for such an overlap would be:

$$p1.i{:}2.j = p1.i \times p2.j$$

where: p1.i = the probability of usage of element 1, space type i.

p2.j = the probability of usage of element 2, space type j.

p1.i:2.j = the probability product incurred when element 1, space type i overlaps with element 2, space type j. This could also be called P.01.κ.

If P.01.κ is inserted in the full expression of O.P above, instead of w.01, a more appropriate value for O.P would be obtained, based on all 9 possible overlap instances between two elements and probability or frequency of usage of each space type of an element. A difficulty in implementation of such a probability penalty is the lack of data for probabilities. Such data could only be obtained by equalisation of vast observed data on occupancy of elements' space types. However, the probability option has been included in the implemented evaluation program, as an alternative to the overlap instance weighting factor w.01 (See Section 9).

(2) $$P.P = \frac{P.R}{P.(OPT).A.R}$$

where: P.R = the perimeter of the bounding rectangle of the activity space.

P.(OPT). A.R = the optimum or minimum perimeter needed to form a bounding square containing the area of the activity space.

A.R = index to denote that the perimeter is associated with the area within the actual bounding rectangle of the activity space.

But:

$$P.(OPT).A.R = +\sqrt{A.R} \times 4,$$

and: $$P.R = 2l.R + 2b.R$$

where: A.R = the area within the bounding rectangle of the activity space.

l.R = length of the bounding rectangle (long side).

b.R = breadth or width of the bounding rectangle (short side).

The perimeter penalty factor now becomes:

$$P.P = \frac{2l.R + 2b.R}{+\sqrt{A.R} \times 4}.$$

P.P has a minimum value of 1 when the bounding rectangle of the activity space is a square, which will give the least wall length if walls were to circumscribe the activity space.

(3) $$A.P = \frac{A.R}{A.F.(max).(OPT)}$$

where:	A.F. (max). (OPT)	=	a theoretical value representing the resulting functional area within the polygon containing all elements of the activity space, and where no overlapping areas or wasted space are present.
	F. (max). (OPT)	=	index to denote that this is a functional area, that is, a polygon is formed around the resulting activity space, and this polygon has a maximum and optimum value. This index will be written as FMO in the following, or E. (TOT).

But A.FMO (=A.E. (TOT) can be expressed as:

A.FMO = A.S + A.U. (TOT)

where:	A.S	=	the total area of all the solids within the bounding rectangle of the activity space (space type 1).
	A.U. (TOT)	=	the total area of all the user spaces, or space types 2and 3, within the activity space, when no overlaps are taking place.

A.R. can be fragmented similarly as:

	A.R	=	A.S + A.NS
where:	A.NS	=	the total non-solid area within the activity space (A.R–A.S).
But:	A.NS	=	A.E. (UNION) – A.S + A.BR
where:	A.E.(UNION)	=	the union of elements within the activity space.
	A.BR	=	the free or wasted area, i.e. space type $\emptyset$, within the bounding rectangle of the activity space.
But:	A.E. (UNION)	=	A.FMO – A.01 + A.02
where:	A.02	=	the intersection of three overlapping elements, or, a second level overlap, or an overlap of the second order. It was found that this was the highest order of overlap occurring in domestic orthogonal layouts. However, it is easily possible to allow for higher orders of overlaps in the calculations, if this should prove necessary (See Appendix A1.2).

The above formula has been demonstrated graphically and mathematically elsewhere, and can be taken as common knowledge.

The total expression for the area within the bounding rectangle of the activity space now becomes:

$$
\begin{aligned}
A.R. &= \{A.S + A.NS\} \\
&= \{A.S + [A.E.(UNION) - A.S + A.BR]\} \\
&= \{A.S + [(A.FMO - A.01 + A.02) - A.S + A.BR]\} \\
&= \{A.S + A.U.\,(TOT) - A.01 + A.02 + A.BR\}.
\end{aligned}
$$

The penalty factor for excessive area within the activity space hence becomes:

$$
\frac{A.R}{A.FMO} = \left\{ \frac{A.S}{A.FMO} + \frac{A.U.(TOT)}{A.FMO} - \frac{A.01}{A.FMO} + \frac{A.02}{A.FMO} + \frac{A.BR}{A.FMO} \right\}.
$$

The ratios of each component of A.R to A.FMO are expressed because in calculations it is useful to get a picture of all these relationships and express them numerically and graphically. It is not possible at this point to predict a minimum value for A.P, but the lower it gets, the higher the efficiency of the activity space becomes.

By using a slightly different procedure, $^{A.R}/A.FMO$ can be derived as follows:

A.E. (UNION) = A.OU + A.NO

where: A.OU = the union area of overlapping element areas.

A.NO = the non-overlapping areas of elements.

But, as has been demonstrated numerically and graphically:

A.OU = A.01 – 2A.02,

hence: A.E. (UNION)= A.01 – 2A.02 + A.NO

But: A.R = A.E. (UNION) + A.BR,

hence A.P can now be expressed as:

$$\frac{A.R}{A.FMO} = \left\{ \frac{A.01}{A.FMO} - \frac{2A.02}{A.FMO} + \frac{A.NO}{A.FMO} + \frac{A.BR}{A.FMO} \right\},$$

which allows a comparison of the ratio containing A.NO with the other components of A.R/A.FMO.

The full expression of the efficiency of an activity space can now be written as:

$$E.R(1) = \left\{ \frac{\Sigma k \left[\left[\sum_{y=1}^{n} \left(\sum_{i=1}^{i} a^{y}.01.\Sigma i \right) \right] \times W.01.k \left(\text{or } P.01.k \right) \right]}{\Sigma k \left[\sum_{y=1}^{n} \left(\sum_{i=1}^{i} a^{y}.01.\Sigma i \right) \right]} \right\} \times \left\{ \frac{2l.R + 2b.R}{+\sqrt{A.R} \times 4} \right\} \times \left\{ \frac{A.S}{A.FMO} + \frac{A.U(TOT)}{A.FMO} - \frac{A.01}{A.FMO} + \frac{A.02}{A.FMO} + \frac{A.BR}{A.FMO} \right\},$$

or:

$$E.R(2) = \left\{ \frac{\Sigma k \left[\left[\sum_{y=i}^{j} \left(\sum_{i=1}^{j} a^{y}.01.\Sigma i \right) \right] \times W.01k \left(\text{or } P.01.k \right) \right]}{\Sigma k \left[\sum_{y=i}^{n} \left(\sum_{i=1}^{j} a^{y}.01.\Sigma i \right) \right]} \right\} \times \left\{ \frac{2lR+2b.R}{+\sqrt{A.R} \times 4} \right\} \times \left\{ \frac{A.01}{A.FMO} - \frac{2A.02}{A.FMO} + \frac{A.NO}{A.FMO} + \frac{A.BR}{A.FMO} \right\},$$

where: R = index denoting that the associated variable, E, is in respect of the bounding rectangle of the activity space.

The minimum values of E.R (1) and E.R (2) occur when each of the positive components have their minimum values and each of the negative components have their maximum values. The optimum value of E.R would occur when the greatest degree of area compactness and perimeter length economy of an activity-space occurred, at the cost of the least degree of sacrifice of comfort or spatial standards. The smaller the value of E.R, the greater the efficiency of the activity space, although this does not mean that E.R = 0 is perfect or possible.

4.4.3. Summary of Evaluation Option.

The above described manual method of evaluating the efficiency of floor usage of design level 3 activity spaces is described in further detail in Section 5 and its implementation is undertaken in Sections 9 – 11.

The evaluation method would work at higher and lower design levels as follows (not implemented in the present work):

1. If the bounding rectangles of layouts of other levels are specified on particular overlays, then E.R can be calculated for any layout on any design level. However, bounding rectangles for layouts on other levels than the evaluated one, would have to be ignored by the method. If E.R were calculated for all levels, then its values would fall into ranges of norms, corresponding to each level.

2. E.R at higher design levels than 3, could be taken as an average of the E.R's of all constituent level 3 activity spaces.

However, resources of time prevented the detailed implementation of refinements 1 or 2 above. Such refinements would of course, be essential for use of the method for the design and evaluation of domestic floor plans by architects in practice. The test of this project is to prove the viability and benefit of the evaluation method.

4.5. Summary of the Proposed Design System.

The design system detailed above and elsewhere is thought to act in conjunction with other design systems or to be complemented as follows:

1. The synthesis option could be extended to include 3 – dimensional elements; this would allow 3—D design.

2. The evaluation option could be extended to include 3– D functional aspects, in the event of the implementation of 1 above.

3. The design system's evaluation routines might, if the system works with other design appraisal routines on aspects of structures and environmental design, complement these as novel evaluation measures.

It is therefore important to see the present work in a larger context; as follows:

1. The ideal functional design system proposed in this work is implemented partially on:

    1.1. Synthesis Aspects.

    1.2. Evaluation Aspects.

2. The implemented parts of the system are experimental.

3. An ideal house design system would contain, after validation:

    3.1. The ideal and complete functional design system as described in this section.

    3.2. Complementary 3—D synthesis routines and evaluation routines on other design aspects.

However, implementation of CAAD evaluation techniques on structural and environmental aspects is often a straight transcription of existing manual techniques, the novelty in this case often being the implementation of techniques. Hence such implementations can be done relatively quickly. The functional techniques described in the present work represent original advances in design methods, and their validation and implementation must therefore be expected to take longer to establish than those of the former techniques.

SECTION 5: AN OBJECTIVE MANUAL EVALUATION EXPERIMENT

5.1.	Background and Objectives	S5.2
5.2.	Step by Step Evaluation Procedure	S5.2
5.3.	Results and Conclusions	S5.6

AN OBJECTIVE MANUAL EVALUATION EXPERIMENT.

This section describes a manual evaluation experiment involving the evaluation of efficiencies of rectangular domestic activity spaces containing orthogonally arranged rectangular and orthogonal polygonal planning elements (5.1).

5.1. Background and Objectives.

This manual evaluation experiment was undertaken to test and validate the viability and usefulness of the evaluation method described in Sub-section 4.4. A sample of 21 two - person bedroom layouts at level 3 was chosen for the manual test run (See Appendix A2.1, Fig. A2.1 for layouts; and 5.2). Fig. 5.1 shows a typical bedroom layout from the sample. Fig. A2.2 shows the planning elements used as standard room content for the whole sample of bedrooms, and Table A2.1 shows the sub-areas of the planning elements used. Parameter symbols used are as in Sub-section 4.4,except additional ones which are defined. A wall user space shown of 50 mm was not used, as all calculations are based on areas within the bounding functional rectangle of rooms.

5.2. Step by Step Evaluation Procedure.

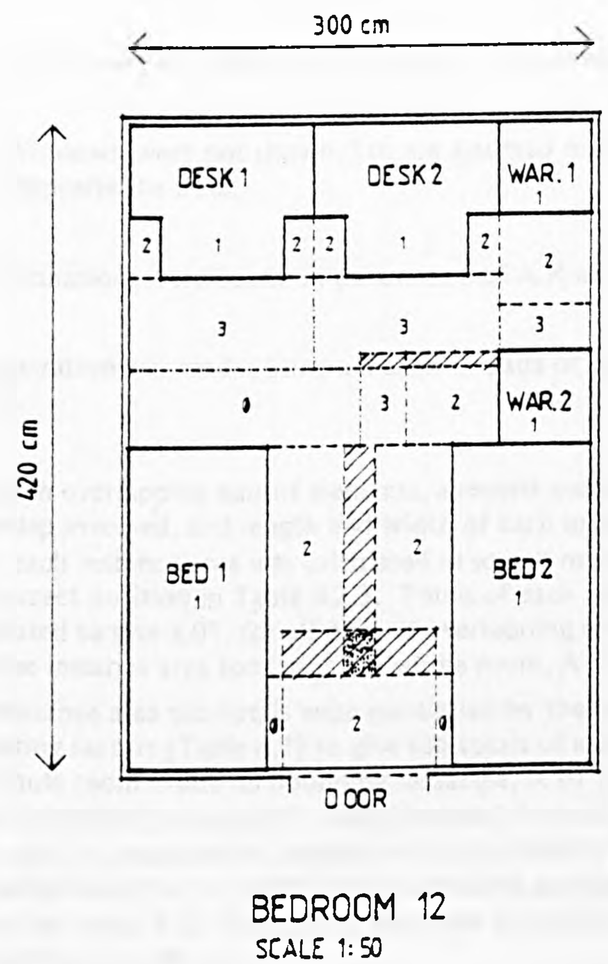
The manual evaluation test runs of the 21 bedroom sample can most expeditiously be illustrated by including a typical evaluation run of one of the two person bedrooms (See Appendix A2.2). The manual evaluation run was carried out in the following steps.

Step 1: The room layout was drawn to scale 1:50 on mm graph paper (See again Fig. 5.1 for the example bedroom). The following line and alphanumeric symbols were used:

1. Solid lines for space category 1 solid elements on overlay level 1.

2. Different types of dashed lines for space categories 2 and 3 element user spaces on overlay levels 2 and 3.

3. Hatching for 1st.order overlap areas.



NOTE: SEE ALSO TEXT AND APPENDIX A2.1 AND A2.2.

Fig. 5.1. Typical Bedroom Layout from the 21 Bedroom Sample.
After Thiberg, A. (5.3).

4. Hatching and dotting for 2nd. order overlap areas.

5. Solid lines for the functional bounding rectangle on overlay level 6.

6. Elements were labelled by name.

7. Space types were indicated (1, 2, 3 and 0 for wasted area).

8. Doors were indicated with a break in the bounding rectangle.

9. Windows were not shown, but are assumed to be positionable on the wall opposite the door.

All calculations were based on parameters of A.R and P.R.

Step 2: A registration was made, using a matrix of pairs of overlapping elements (Table A2.2).

Step 3: For each overlapping pair of elements, a record was made of the instance types of overlap involved, and length and width of each instance area was measured. Next each instance area was calculated in square metres and the value entered in the correct position in Table A2.3. Totals of each instance area category were calculated to give a.01, for all pairs of overlapping elements, and summed up to give the instance area totals for the whole room, A 01.

The instance area sub-totals were multiplied by the correct overlap penalty weighting factors (Table 4.1) to give sub-totals of a.01 x w.01 and a total for the whole room inside its bounding rectangle, A.01 x w.01. The total of 2nd. order overlapping areas A.02, was calculated, but not split into overlap instance area types or penalised by penalty weighting factors, the reason for the latter being that all overlap areas are being completely penalised at all orders of overlap when A.01 for pairs of elements is penalised. All values were entered in Table A2.3 as shown.

Step 4: Recordings, measurements and calculations were then carried out to obtain values for the parameters listed on the data sheet (Table A2.4), these parameters being necessary for subsequent calculations of the efficiency factor E.R and its components. Table 5.1 briefly defines each parameter and states method of calculation. No calculations involving F, (R + 5), and G have been carried out so far, but appropriate parameters are shown in Table 5.1.

Step 5: Ratios and components of E.R were then calculated as per Table A2.5, and the total of E.R was obtained for each room layout.

Table 5.1. Evaluation Area and Perimeter Parameters.

TYPE OF PARAMETER	UNIT	SYMBOL	NAME/DEFINITION	METHOD OF CALC. *	EQUIVALENT
AREA	M^2	A.R	Area inside R*	M	I.R x b.R *
"	"	A.R + 5	Area inside (R + 5) *	M/C	(I.R+0.1) x (b.R+0.1)
"	"	A.G.	Area inside G *	M/C	I.G x b.G
"	"	A.BR	Wasted area inside R	M/C	A.R – A.E. (UNION)
"	"	A.BR + 5	Wasted area inside (R + 5)	M/C	
"	"	A.BG	Wasted area inside G	M/C	
"	"	A.F	Area inside F * (= A.E. (UNION))	C	A.R – A.BR
"	"	A.01	Sum of 1st. order overlaps inside R	M	
"	"	A.02	Sum of 2nd. order overlaps inside R	M	
"	"	A.0U	Union area of overlaps inside R	C	A.01 – 2A.02
"	"	A.03	Intermediate overlap area calc.	C	A.01 – A.02
"	"	A.S	Sum of solid areas inside R	C	Constant = 6.58 for 21 bedrooms
"	"	A.U. (TOT)	Sum of user space areas inside R	C	Constant = 5.84 for 21 bedrooms
"	"	A.FMO	Sum of solid and user space areas inside R	C	A.S + A.U.(TOT) = 12.42 for 21 bedrooms
"	"	A.U. (UNION)	Union area of user spaces inside R	C	A.U. (TOT) – A.03
"	"	A.E. (UNION)	Union area of elements inside R	C	A.R – A.BR = A.FMO – A.03
"	"	A.NSR	Non-solid areas inside R	C	A.R – A.S = A.E (UNION) – A.S + A.BR
"	"	A.NSR + 5	Non-solid areas inside (R + 5)	C	A.R + 5 – A.S
"	"	A.NSG	Non-solid areas inside G	C	A.G – A.S
"	"	A.NSF	Non-solid areas inside F	C	A.F – A.S
"	"	A.NO	Non-overlapping area of A.E. (UNION)	C	A.E. (UNION) – A.OU
PERIMETER	M	P.R	Perimeter length of R	M	2 I.R + 2 b.R
"	"	P.F	Perimeter length of F	M	Sum of sub-sides
"	"	P.R + 5	Perimeter length of (R + 5)	M	2 (I.R + 0.1) + 2 (b.R + 0.1)
"	"	P.G	Perimeter length of G	M	2 I. G + 2 b. G

* KEY:

M	=	Manual measuring from activity space plan and subsequent calculation
C	=	Calculation using known parameters
R	=	Bounding rectangle of activity space
R + 5	=	Bounding rectangle of activity space enlarged by 5 cm on all sides
G	=	Bounding rectangle of nearest upward grid lines of R
F	=	Bounding orthogonal polygon of activity space
I	=	length of R
b	=	breadth of R

Only 4 out of the 21 bedrooms had overlap instances involving solids overlapping with user spaces. These overlap areas are covered by A.E.(UNION), since all possible overlap permutations involving space types 1, 2 and 3 are taken into consideration by this parameter. A solid to user space overlap is of course more serious than a user to user space overlap, and hence is penalised more heavily.

Understandably, no solid to solid (1:1) overlap instance occurred in the sample, since the layouts were all sensibly designed. The calculation method would allow for 1:1 overlap instances to happen, but the penalty involved would be so high as to make such overlaps prohibitive. In the subsequent computer evaluation (See Sections 9 - 10) 1:1 overlaps are not permitted, that is, the user is warned if making such a mistake.

5.3. Results and Conclusions.

Numerical evaluation results for the 21 bedrooms are contained in Appendix A2.3, Tables A2.6 - A2.8; as recorded and calculated in the manual step by step test run procedure.

Eight graphs (Figs. 5.2 - 5.9), showing relationships of the various components of E.R to each other, were drawn up using the numerical evaluation results for the 21 bedrooms. Using the evaluation graphs as a basis, descriptions and conclusions from the manual evaluation experiment are as follows:

GRAPH 1: Each bedroom layout was taken in the sample order as given, and E.R, Σ(A.01 x w.01)/A.01 (O.P), P.R/(+$\sqrt{\text{A.R}}$ x 4) (P.P) and A.R/A.FMO(A.P) were plotted for each layout.

GRAPH 2: The rooms were sorted in order of increasing A.R and a new graph plotted, using a different scale to amplify fluctuations. Graph 2 shows that the largest contributor to E.R is O.P, that is, the overlap area penalty factor or component. When E.R increases, i.e., when the efficiency is lowered a corresponding increase is shown in O.P, implying too much overlap penalty is incurred.

The perimeter penalty factor (P.P) appears to have very little influence on E.R in this layout sample, but this is obviously because most of the rooms were fairly square in shape.

A correlation is shown between E.R and A.P, in that the efficiency decreases (E.R increases) when A.P increases. This is because the furniture and user-space content was constant for the whole sample of layouts, hence, any increase in A.R above an optimum value, would result in lower efficiency.

GRAPH 3: Every component of A.R/A.FMO(A.P) in both of the E.R(1) and E.R(2)

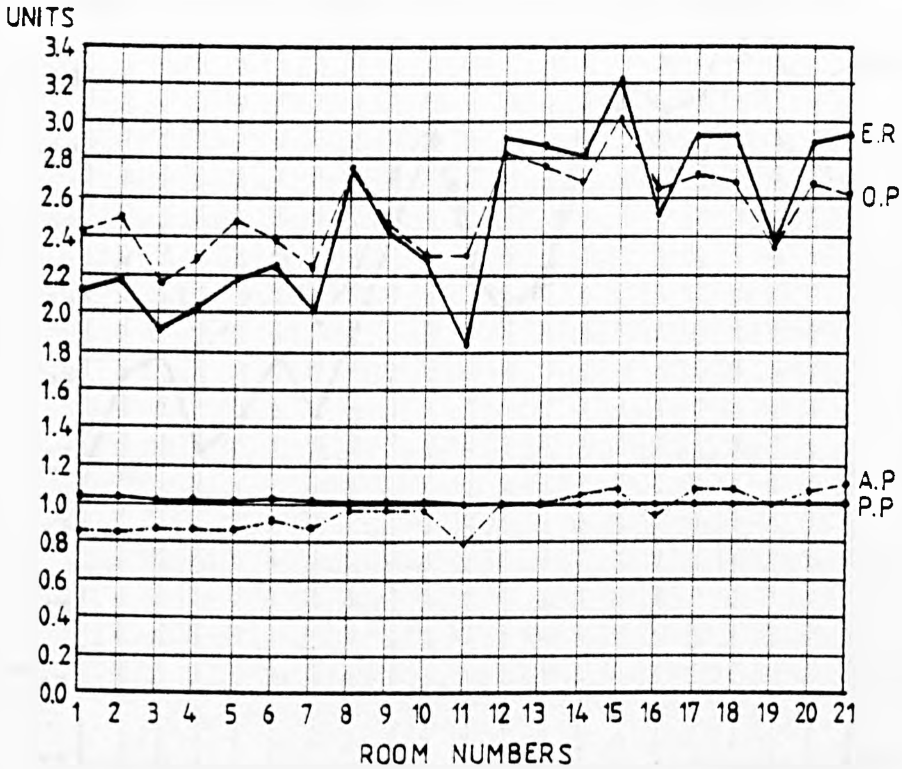


Fig. 5.2. Evaluation Graph 1.

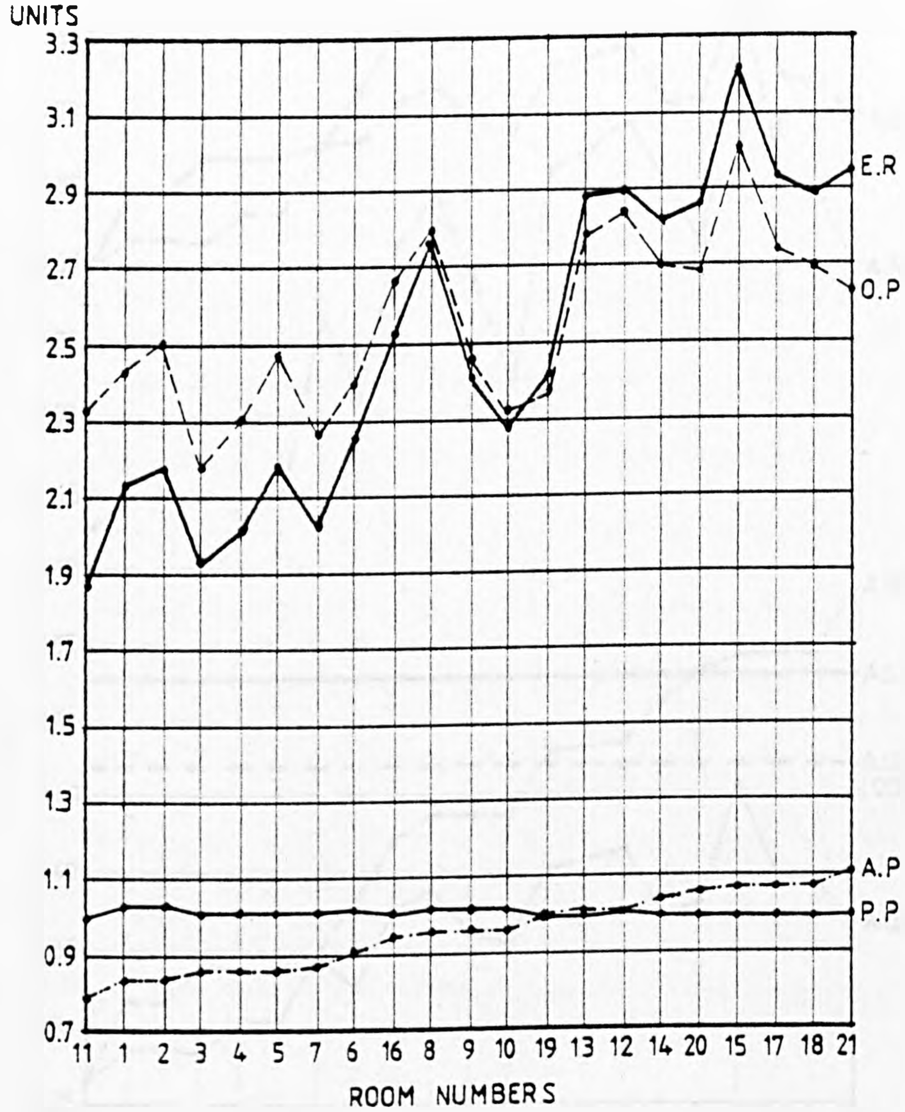


Fig. 5.3. Evaluation Graph 2.

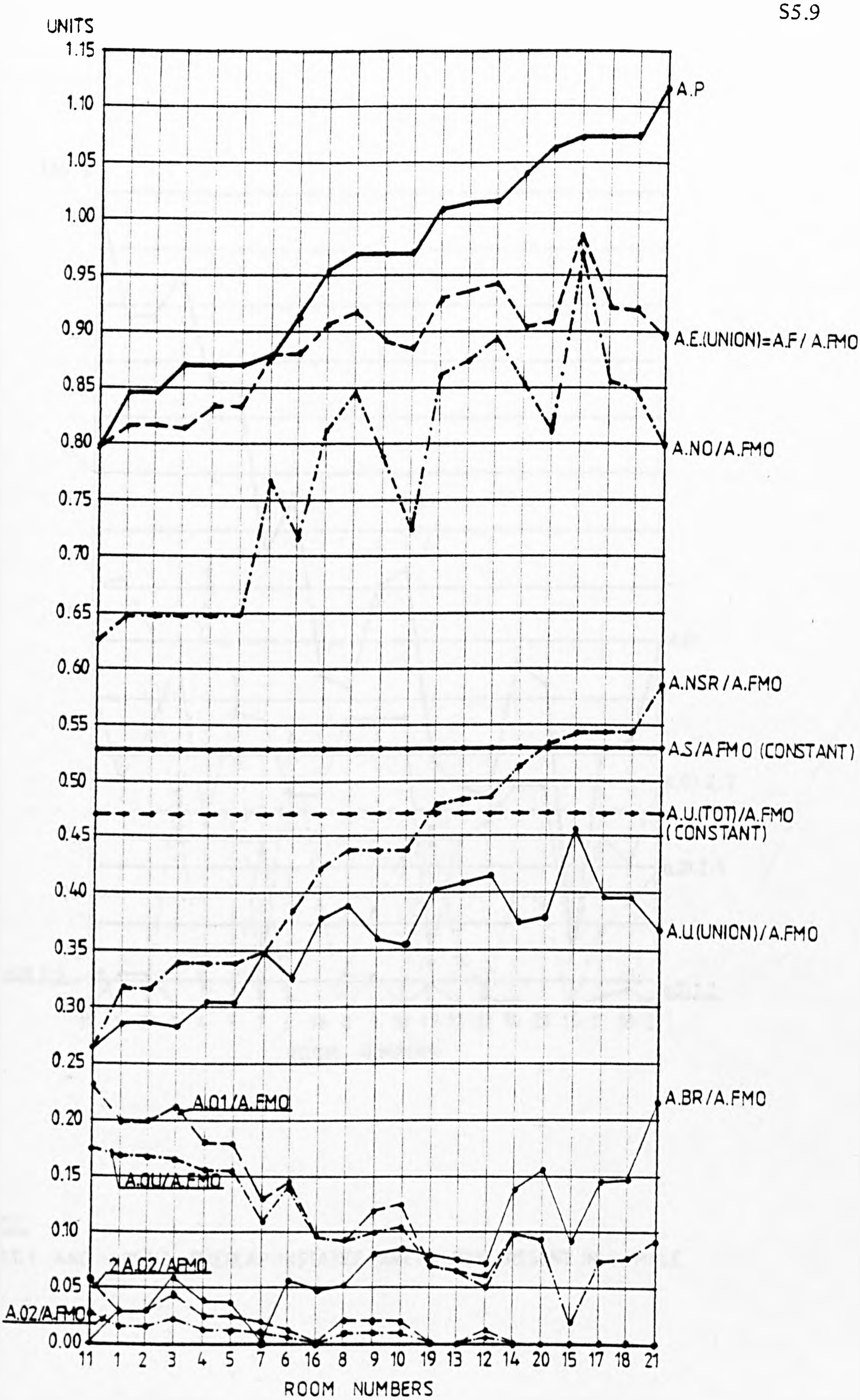
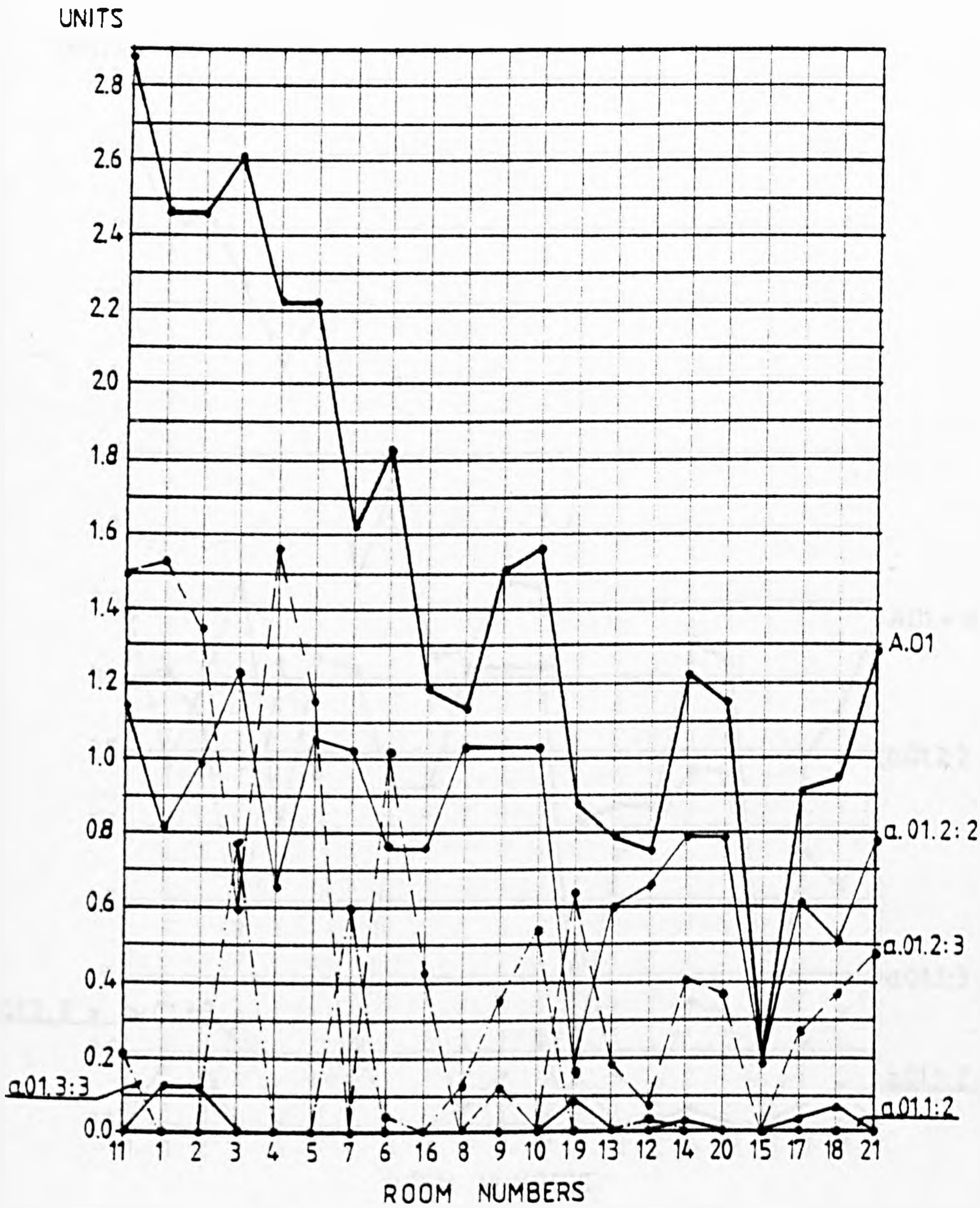


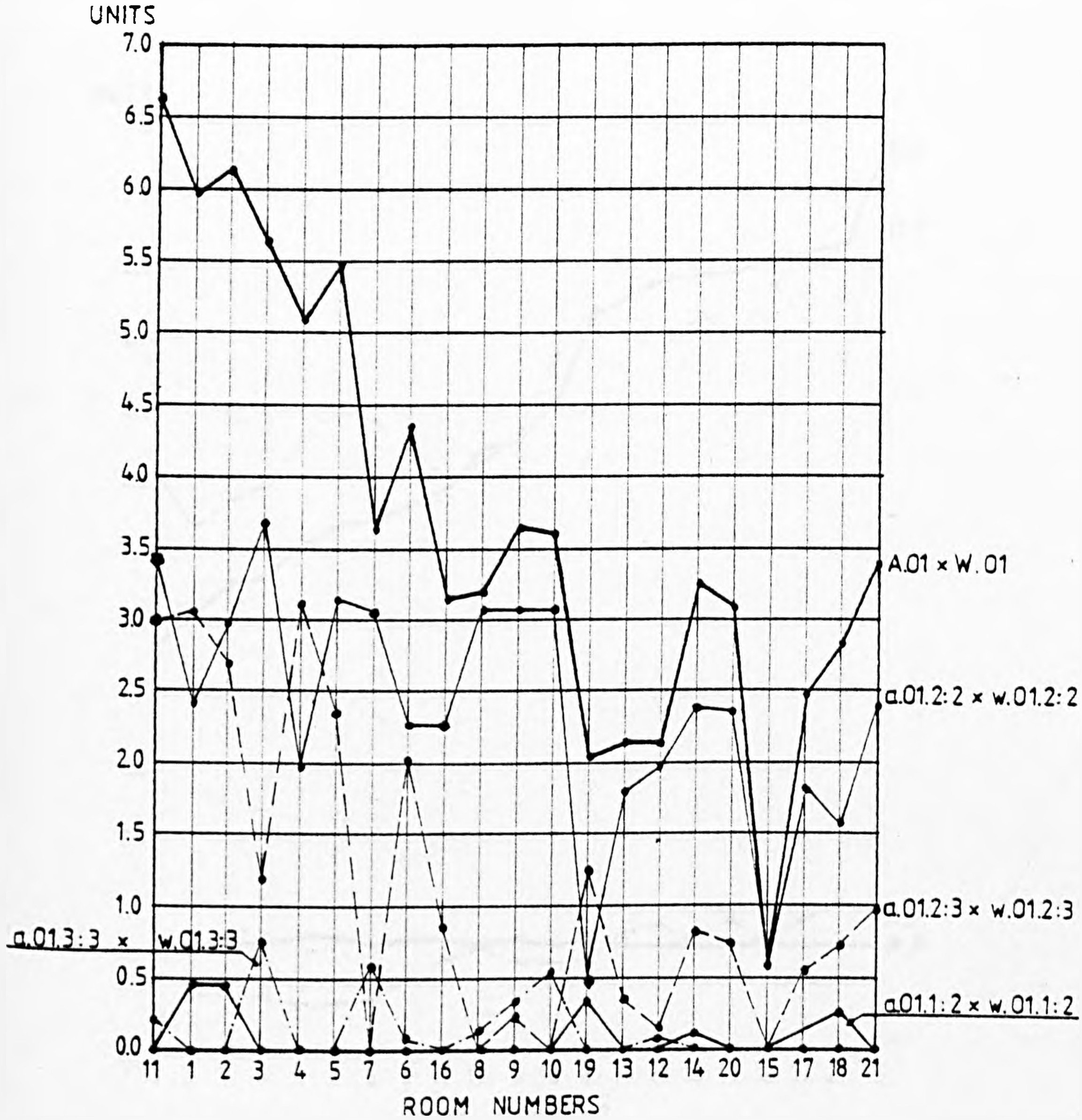
Fig. 5.4. Evaluation Graph 3.



NOTE:

a.01.1:1 AND a.01.1:3 OVERLAP INSTANCE AREAS NOT PRESENT IN SAMPLE.

Fig. 5.5. Evaluation Graph 4.



NOTE:

SINCE NO a.01.1:1 AND a.01.1:3 OVERLAP AREAS ARE PRESENT (SEE FIG. 5.5), THERE ARE NO CORRESPONDING a.01.1:1 × w.01.1:1 AND a.01.1:3 × w.01.1:3 PENALTY OVERLAP VALUES IN THE SAMPLE.

Fig. 5.6. Evaluation Graph 5.

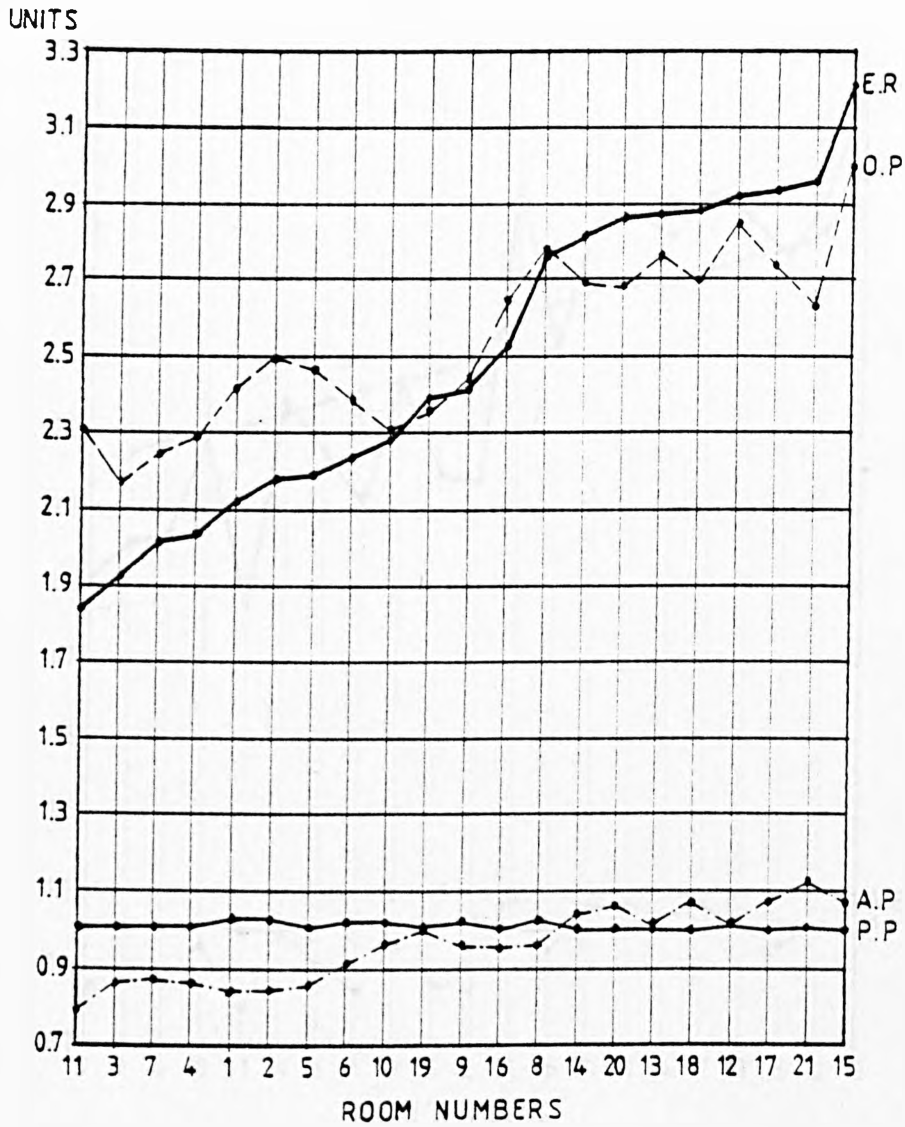


Fig. 5.7. Evaluation Graph 6.

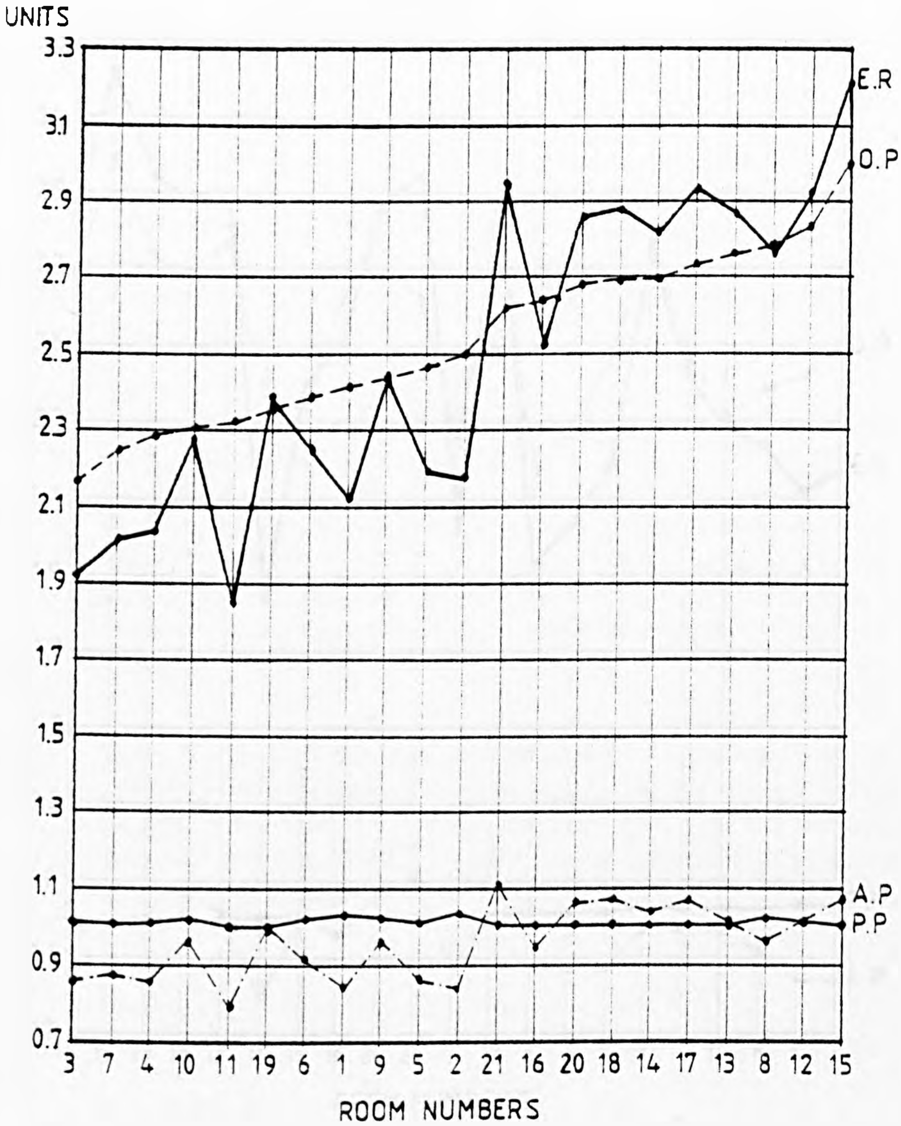


Fig. 5.8. Evaluation Graph 7.

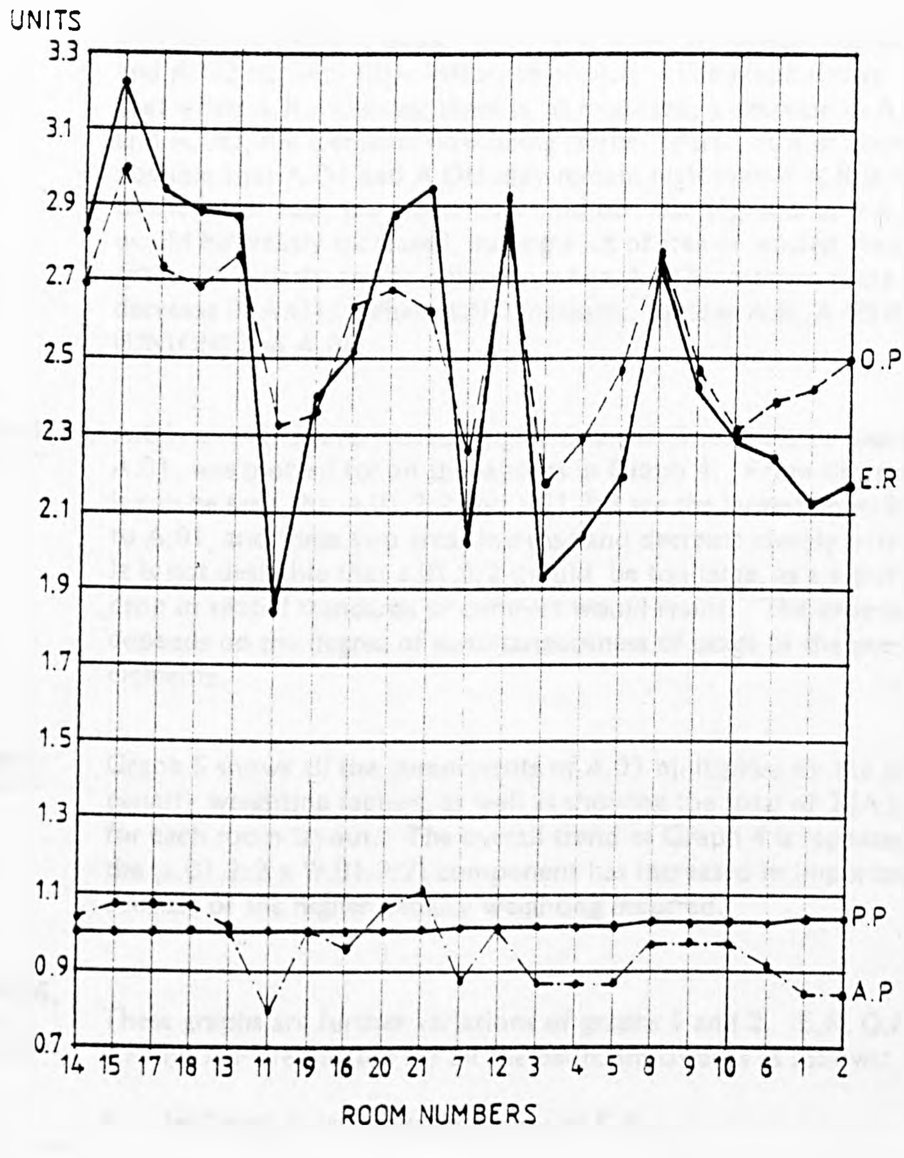


Fig. 5.9. Evaluation Graph 8.

formulas were plotted in Graph 3. Since A.S was constant for all the layouts, the interesting fluctuations were those of A.NSR, the non solid area within R. A.NSR was most influenced by A.E (UNION), or A.F, thereby reducing A.BR in importance in this sample. A.E. (UNION) was most influenced by A.NO, the non-overlapping element areas. A.O1 and A.OU are closely correlated. and A.O2 has very little influence on A.R. The graph shows that when A.R increases, there is, as expected, a decrease in A.O1 and A.OU, the elements now being farther apart. It is of course possible that A.O1 and A.OU may remain high even if A.R is high. In the latter case, the elements would be close together and A.BR would be greatly increased, leaving a lot of free or wasted area of floor space. Similarly and corollorary, when A.NO increases, there is a decrease in A.O1. When A.NO increases, so does A.R, A.NSR, A.E. (UNION) and A.BR.

GRAPH 4: A.01, as well as every occurring component instance area overlap of A.01, was plotted for all the layouts in Graph 4. From this graph it can be seen that a.01.2:2 and a.01.2:3 are the largest contributors to A.01, and these two areas increase and decrease closely with A.01. It is not desirable that a.01.2:2 should be too large, as a significant drop in spatial standards or comfort would result. The drop in comfort depends on the degree of simultaneousness of usage of the overlapping elements.

GRAPH 5: Graph 5 shows all the components of A.01 multiplied by the appropriate penalty weighting factors, as well as showing the total of Σ(A.01 x W.01) for each room layout. The overall trend of Graph 4 is repeated, but the (a.01.2:2 x W.01.2:2) component has increased in importance, because of the higher penalty weighting incurred.

GRAPHS 6, 7 and 8: These graphs are further variations of graphs 1 and 2. E.R, O.P, P.P and A.P are plotted for all the bedroom layouts as follows:

1. In Graph 6, in increasing order of E.R.
2. In Graph 7, in increasing order of O.P.
3. In Graph 8, in increasing order of P.P.

No further observations can be made from these graphs, except that observations and conclusions from Graph 2 are reinforced.

The above manual experiment shows clearly that the evaluation method described in Sub-Section 4.4 is fully viable. The numerical and graphical evaluation results from the 21 bedroom test run portray a complex picture of the nuances and interrelationships involved in the floor area and efficiency component variables of layouts. When evaluating a layout or comparing several layouts, using the proposed evaluation method, a suitable procedure for use of the method would be:

1. Determine overall efficiency by looking at E.R and its components O.P, P.P and A.P.

2. Compare values from (1) with established norms or other layouts.

3. Determine abnormal value occurrences of O.P, P.P or A.P.

4. Look at sub-components and ratios of O.P, P.P or A.P, to determine the cause of abnormal values.

5. Take corrective actions by amending the layout(s) so that less penalty is incurred, thereby increasing the efficiency of the layout(s).

6. Iterate synthesis and evaluation processes, until a satisfactory solution of layout(s) is found.

The user may not wish to make full use of all the numerical evaluation data, if he so chooses, but the overall values should give indications of the layout efficiencies involved and suggest corrective design actions. Quite apart from the sensibility of the evaluation method, an important point of its implementation is that it gives the designer, in addition to his own critical and subjective design appraisal, an additional, novel, and optional means of further evaluating room layouts. Further, the evaluation method can be extended by including other efficiency measures such as for instance:

1. E.R could be supplemented by an occupancy efficiency factor of area per person available, say.

2. Layout perimeter dimensions may be compared against a library of other such layout dimensions to determine the adaptability of layouts.

3. Probabilities of usage of elements can be included for a more accurate calculation of O.P (See Section 9.).

The manual evaluation experiment suggests two important further actions to be taken:

1. The validity of the proposed evaluation method must be tested by comparing results from the manual evaluation experiment with subjective evaluations on the same sample of bedroom layouts.

2. Clearly, the magnitude of the calculation task involved in applying

the evaluation method in the manual test run of the 21 bedrooms, makes it obvious that the method can only be practicably implemented, in conjunction with the Synthesis Option (Sub-section 4.3), by using the computer.

3. The complexity involved in analysing the numerical data from evaluation runs as described, suggests that evaluation results should optionally be graphically displayed to the designer, that is, the numerical data should be presented in the form of graphs, histograms and piecharts. Such graphical conveyance of data would greatly facilitate the interpretation of these data.

SECTION 6: A COMPARATIVE SUBJECTIVE EVALUATION EXPERIMENT

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A COMPARATIVE SUBJECTIVE EVALUATION EXPERIMENT.

6.1. Introduction.

Following the outline (6.1) and subsequently the detailed specification and manual demonstration (6.2) of the proposed method of evaluating efficiencies of rectangular domestic activity spaces containing orthogonally arranged rectangular furniture and user spaces, it was important to test the relevance of this method before it could become a fully operational CAAD program. For this purpose an experiment was constructed using the following approach (6.3):

1. By using the results of the manual evaluation run as a benchmark or reference statistic (See Section 5).

2. By carrying out a subjective evaluation test among architectural staff and students, using a selective sample of bedroom layouts from the manual evaluation run sample.

3. By investigating the level of agreement among the experiment subjects and subsequently comparing ranks of the subjective and objective tests.

The most significant outcome of the investigation were:

1. No significant agreement amongst test subjects was found. This result is extremely important, since it proves the unreliability of subjective layout assessments of this nature.

2. Consequently, no positive rank correlation between subjective responses and the objective evaluation results could be tested, as expected.

6.2. Test Methods and Conditions.

Two tests were used:

1. The manual evaluation run of 21 bedroom layouts, which test method and conditions have been described earlier (Section 5).

2. A subjective evaluation test among 18 architectural staff members and 38 architectural students of this school. A questionnaire was written based on the simplified efficiency formula (See Appendix A3.1, Table A3.1):

$$E.R = O.P \times P.P \times A.P$$

where:

E.R = the efficiency of an activity space.

O.P = the penalty measure for overlaps of elements.

P.P = the penalty for excessive activity space perimeter length.

A.P = the penalty for excessive area within the activity-space perimeter.

Eight rooms were chosen from the 21 bedroom layouts and divided into pairs. Pairs were formed on the basis that both rooms in a pair should have identical perimeter sides, i.e. identical "shells", Appendix A3.1, Table A3.2 shows a table of the room pairs and their data from the manual evaluation run, and the layouts are also shown graphically in Fig. A3.1. The four questions that the test subjects were asked about the 4 pairs of room layouts, Questions 2,3(a), 3(b), and 4, relate to the efficiency measure formula as shown in Table 6.1 (See again questionnaire, Table A3.1).

The perimeter efficiency measure was not included as a separate question, as it was thought that a subjective assessment of this measure was impracticable. It was, however, referred to in question 4. Any bias concerning this efficiency measure was thought excluded by keeping the shell of both rooms of a pair, as mentioned, identical. The 38 students answered the questions under controlled conditions in one room and used a pencil only. They were given on average 20—30 minutes to complete the questionnaire. The students were chosen from years 3—6, as students in those years were assumed to be competent at reading and interpreting 2—D plan layouts. The 18 staff members completed the questionnaire in non-controlled conditions, in their offices or at home.

6.3. Results, Analysis and Correlation of Tests.

Three main statistical methods of analysis of the subjective test results and of the correlation between the manual and subjective results were employed as follows:

Table 6.1. Relationship between Subjective Test Questions and Efficiency Measures.

QUESTION NO.	EFFICIENCY MEASURE *
2	O.P
3 (a)	A.P
3 (b)	A.P
4	E.R

* Note: See Sub-Section 4.4 for explanation of these measures.

Table 6.2. Locations of Subjective Results Tabulations.

QUESTION NO.	APPENDIX NO.
2	A3.2.1
3 (a)	A3.2.1
3 (b)	A3.3.1
4	A3.3.1

6.3.1. Subjective Test Sample Agreement Tests.

This statistical test (6.4) was applied to the subjective responses of Questions 3 (b) and 4, as shown in Appendix A3.3.3, in the following sequence:

Step 1: The total subjective or observed rankings were taken from Appendix A3.3.1, Tables A3.7 to 9 (Roi). The sums of these rankings were checked against the following formula for the total of rankings ($R_{TOT.}$), to ascertain their correctness:

$$R_{TOT} = \frac{mn\ (n+1)}{2}$$

where: m = no. of subjects or judges.
n = no. of room layouts to be assessed.

Step 2: The expected ranking for each room layout under the null hypohesis of no agreement, or total indifference, was calculated as:

$$R_{Ei} = \frac{m\ (n+1)}{2} \quad \left(= \frac{R_{TOT}}{n}\right).$$

Step 3: The difference (d) between the expected and the observed ranking was calculated for each room layout as follows:

$$d_i = R_{Ei} - R_{o_i}.$$

Step 4: The sum of the squared differences (S) was now calculated as:

$$S = \sum_{1}^{i} d_i^2 .$$

where: i = the number of room layouts.

Step 5: The maximum possible sum of the squares of the differences between the expected and observed rankings (S_{max}), is given by:

$$S_{max} = \frac{m^2\ (m^3 - n)}{12} .$$

Step 6: As a measure of the degree of agreement between the judges, a ratio (W), known as the Coefficient of Concordance, was calculated as:

$$W = \frac{S}{S\ max.}$$

This ratio will vary for different samples between zero and 1, where zero signifies complete raudomness in the allocation of rankings and 1 signifies complete agreement among the judges.

Step 7: W was tested for significance, using Snedecor's distribution for F, as follows:

1. A "continuity correction" was applied to W, making the ratio ($\overline{W}$):

$$\overline{W} = \frac{S - 1}{S_{max} + 2}.$$

2. The F-value was calculated as:

$$F = \frac{(m - 1)\ \overline{W}}{1 - \overline{W}}.$$

3. The degrees of freedom (f) were calculated as:

3.1. The degrees of freedom for the greater estimate:

$$fg = (n - 1) - \frac{2}{m}, \text{ and :}$$

3.2. The degrees of freedom for the lesser estimate:

$$fl = (m - 1) \times fg.$$

4. The F – tables were entered with the obtained values for fg and fl (6.5), and the appropriate values for F were read off both at the 1% and the 5% significance levels. The obtained F is significant at the given level if it is equal to or greater than the table value, meaning that W is correct. This test is good at the 1% level, but better at the 5% level.

6.3.2. Comparative Result Figures and Graphs.

The results for the 8 selected bedrooms from the manual method of evaluation are tabulated in Appendix A3.1, Table A3.2. Subjective results are tabulated in the Appendices for the different questions as shown in Table 6.2. The evaluated efficiency measures of the CAAD – method as well as the subjective ranking figures for all questions were converted into percentile values for ease of comparison between room layout rankings. The rank totals were obtained according to standard statistics (e.g. 6.6). An explanation of ranking totals and the percentage calculations would be beyond the scope of this thesis. The subjective percentile values were now used to construct the comparative Graphs 1 – 7 (See Fig. 6.1). The meanings of the graphs are as follows:

Graphs 1–4: For Questions 2 and 3 (a), for both staff and students, and for each pair of room layouts, comparative percentages of rankings between manually calculated evaluation figures and subjective responses, are shown. As for all graphs, subjective rankings are shown in tone and evaluation method ranking without shading. Pairs and rooms are indicated.

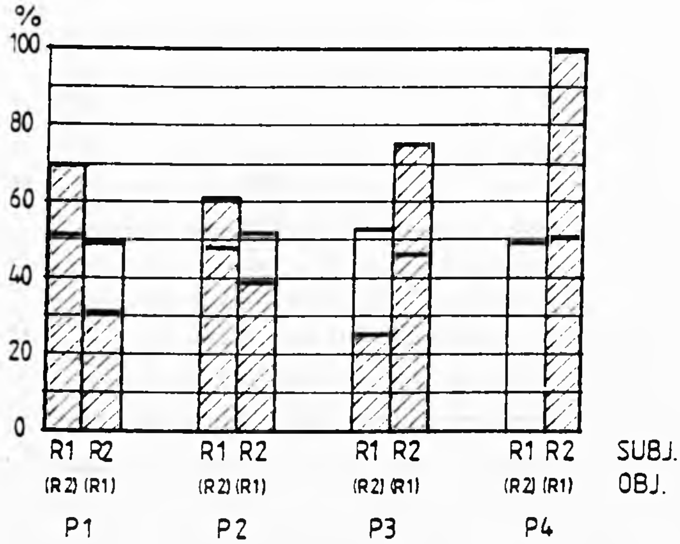
Graphs 5–7: For Questions 3(b) and 4, for all 8 room layouts, a similar comparison to the one shown in Graphs 1 – 4 (Fig. 6.1), was shown. Rooms are indicated as well as ranking orders for both the CAAD – method and subjective responses.

Only an aggregate of 15 of the subjects'forms were accepted for Question 3(b), as for the others, answers appear to have been limited to room layouts chosen in Question 3(a), which was not the intention. For Questions 2 and 3(a) the above was the only method of analysis finally used, although normal distribution calculations were carried out (Appendix A3.2.2), with negative results.

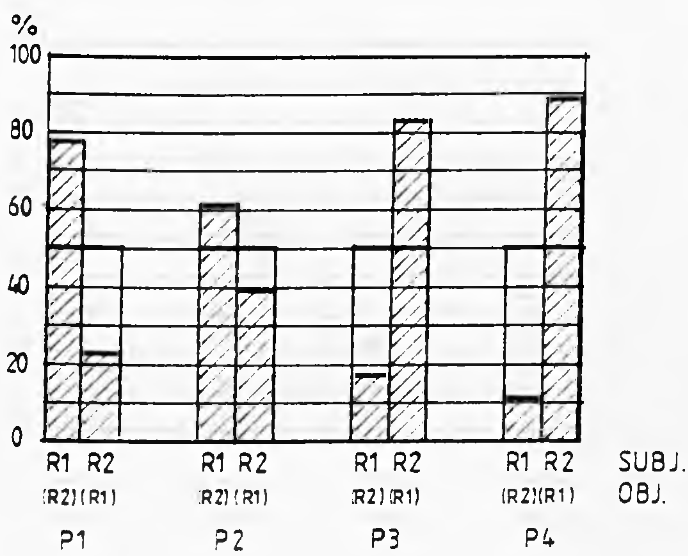
6.3.3. Rank Correlation Tests.

This correlation test between subjective and objective rankings was applied to Questions 3 (b) and 4 in the following steps (6.7):

Step 1: A scoring sheet was used to record rankings for all the 8 bedroom layouts (See Appendix A3.3.2, Tables A3.10 and A3.11). For the CAAD method the 8 bedrooms were (objectively) ranked from 1 – 8 for Question 4, but for Question 3 (b) where the objective



GRAPH 1 - QUESTION 2 (O.P)



GRAPH 2 - QUESTION 3(a) (A.P)

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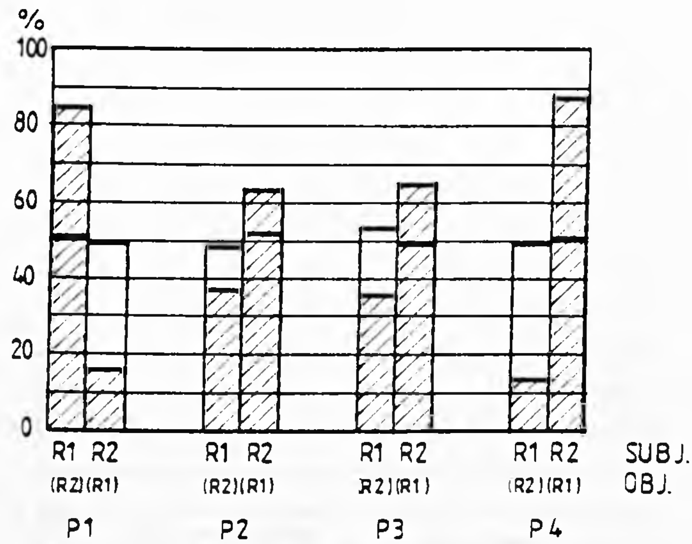
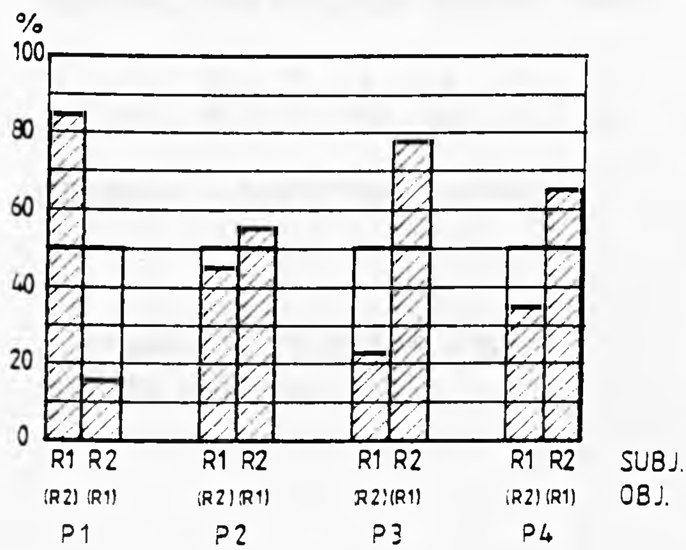
KEY: R = ROOM.
P = PAIR.
SUBJ. = SUBJECTIVE RESULTS (SHADED).
OBJ. = OBJECTIVE RESULTS (NON-SHADED)

Fig. 6.1. Objective and Subjective Evaluation Test Comparative Result Graphs.



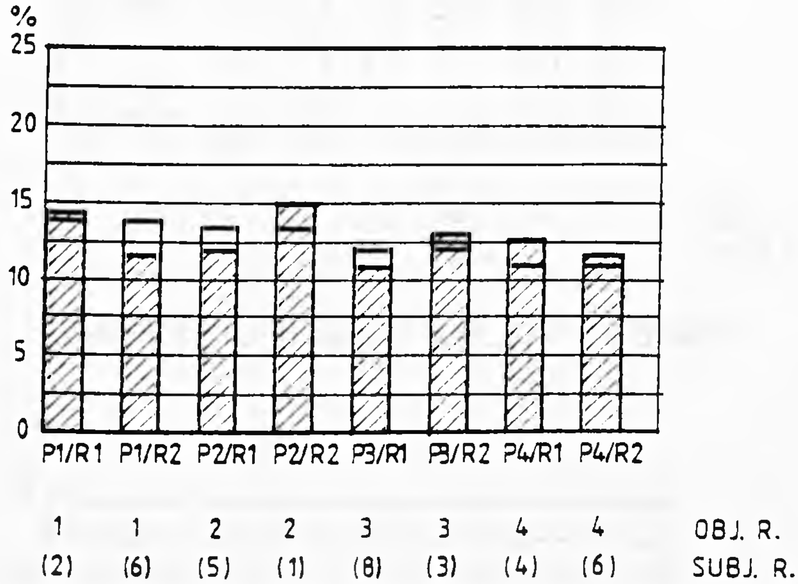
GRAPH 3 - QUESTION 2(O.P)



GRAPH 4 - QUESTION 3(a)(A.P)

38 STUDENTS

Fig. 6.1. (Continued).



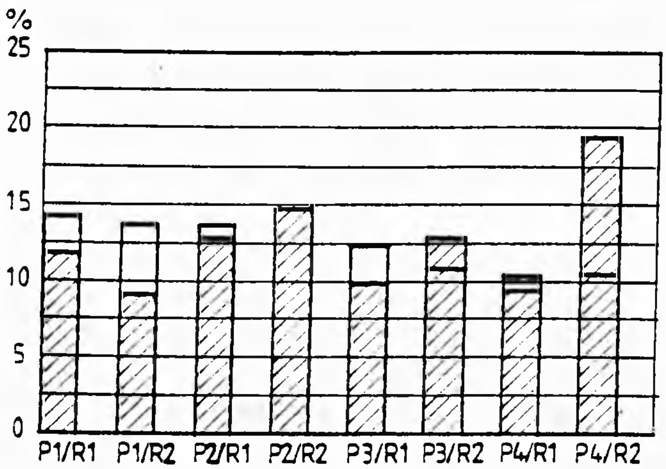
GRAPH 5 - QUESTION 3(b) (A.P)

6 STAFF + 9 STUDENTS = 15
(STATISTICAL METHOD)

KEY:

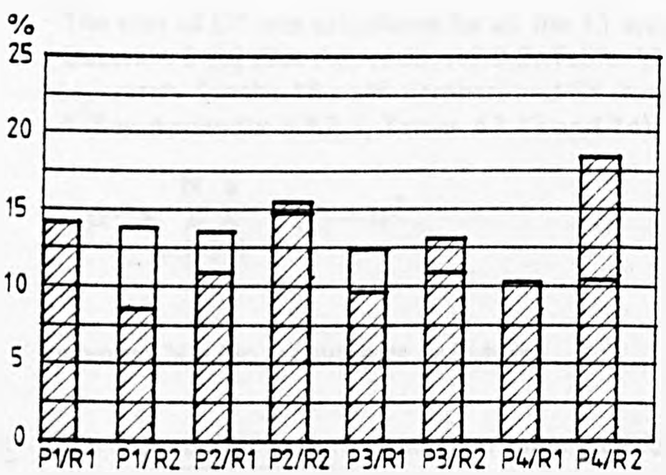
OBJ. R. = OBJECTIVE RANKING.
SUBJ. R. = SUBJECTIVE RANKING.

Fig. 6.1. (Continued).



2	3	4	1	5	6	8	7	OBJ. R.
(5)	(8)	(3)	(2)	(6)	(3)	(7)	(1)	SUBJ. R.

GRAPH 6 - QUESTION 4 (E.R) - 18 STAFF



2	3	4	1	5	6	8	7	OBJ. R
(3)	(8)	(5)	(2)	(7)	(4)	(6)	(1)	SUBJ. R.

GRAPH 7 - QUESTION 4 (E.R) - 38 STUDENTS

Fig. 6.1. (Continued).

ranking was equal for both rooms in any pair, a "Tied" ranking of 1.5 for pair 1 rooms, 3,5 for pair 2 rooms, and so forth, was given. The test subjects were, for both Questions 3 (b) and 4 , asked to rank the rooms they considered "best" from 1 – 4; a "Tied" rank of 6.5 was therefore attributed to the remaining four rooms to obtain 8 rankings. For each Subject person, and for each room layout, the following subtraction was performed:

$$T_i - i$$

where: T_i = subjective ranking for one room.

i = objective (CAAD) ranking.

Step 2: For each subject person, a measure of deviation (D^* for Question 4 and D^{**} for Question 3 (b)), was calculated as:

$$D^* = \sum_{i=1}^{8} (T_i - i)^2 .$$

The sum of D^* was calculated for all the 15 accepted forms for Question 3 (b) (See Appendix A3.3.2, Table A3.12), and separately for the 18 staff members and 38 students for Question 4 (See Appendix A3.3.2, Tables A3.13 and 14), as:

$$\Sigma D^* = \sum_{1}^{N} \sum_{i=1}^{8} (T_i - i)^2 .$$

where: N = No. of subjects or judges.

Step 3: The expected deviation was then calculated for Question 3 (b) as shown in Appendix A3.3.2, as:

$$E\,[D^{**}] = \frac{1}{6}(N^3 - N) - \frac{1}{12}\,\Sigma\,(d_i^3 - d_i) - \frac{1}{12}\,\Sigma\,(fi^3 - fi) .$$

where: N = total number of room layouts.

d_1 = no. of rooms subjectively ranked lowest.

d_2 = no. of rooms subjectively ranked second.

d_i = no. of rooms subjectively ranked on i-th place.

f_1 = no. of rooms objectively ranked lowest.

f_i = no. of rooms objectively ranked on i-th place.

For Question 4, the similar formula was calculated as shown in Appendix A3.3.2, as:

$$E\ [D^*] = \frac{1}{6}\ (N^3 - N) - \frac{1}{12}\ \Sigma\ (d_i{}^3 - d_i),$$

since the last bracket expression came to zero in this instance.

Step 4: The variation of the deviation was calculated for Question 3 (b), as shown in Appendix A3.3.2, as:

$$\mathrm{Var}\ [D^{**}] = \frac{(N-1)N^2\ (N+1)^2}{36}\left[1- \frac{\Sigma(di^3-di)}{N^3-N}\right]\left[1- \frac{\Sigma(fi^3-fi)}{N^3-N}\right].$$

And for Question 4, the similar formula was calculated as shown in Appendix A3.3.2, as:

$$\mathrm{Var}\ [D^*] = \frac{(N-1)\ N^2\ (N+1)^2}{36}\left[1- \frac{\Sigma(di^3 - di)}{N^3 - N}\right].$$

$E\ [D^*]$ and $\mathrm{Var}\ [D^*]$ were both calculated on the assumption that D^* has an approximately Normal distribution, and under the null Hypothesis:

H_o= "no ranking" correlation between objective and subjective results.

Step 5: The mean deviation $\overline{D^*}$ was calculated for Question 3 (b) as shown in Appendix A3.3.2, as:

$$\overline{D^{**}} = \frac{\Sigma D^*}{S}$$

where: S = no. of test subjects for Question 3 (b).

$\overline{D^*}$ was calculated according to the same formula for Question 4, as shown in Appendix A3.3.2, separately for both staff and students.

Step 6: As a consequence from Step 5, the mean value for the variation of the deviation, was calculated for Question 3 (b) and for Question 4, as shown in Appendix A3.3.2, as:

$$\text{Var}\ [\bar{D}*^{(*)}] = \frac{\text{Var}\ [D*^{(*)}]}{S}\ .$$

Step 7: The z-distribution value was then calculated for both Questions 3 (b) and 4, as shown in Appendix A3.3.2, as:

$$z = \frac{E\ [D*^{(*)}] - \bar{D}*^{(*)}}{\sqrt{\text{Var}\ [\bar{D}*^{(*)}]}}\ .$$

Step 8: The z-values for all the calculations were finally compared with a statistical z-or t- distribution table (6.8), which indicated the following:

Reject H_o if:

1. $z > 1.96$ (2.5% significance level).
2. $z > 1.64$ (5% significance level).
3. $z > 1.28$ (10 % significance level).

Otherwise, accept H_o .

The results of this test are shown for both Questions 3 (b) and 4 in Appendix A3.3.2.

This rank correlation test between subjective and objective ranking was done on all the 18 staff members' and 38 students' responses before the aforementioned bias in the answers was discovered, and the accepted number of completed questionnaires were reduced to 15. No significant change in the results of the test occurred as a result of this response selection.

6.3.4. Summary of Analysis and Correlation Tests.

Table 6.3 shows the results of the statistical tests and calculations. These results will be commented upon in Sub-section 6.4 below.

The test to see whether answers for questions 2 and 3 (b) were normally distributed is not included in Table 6.3, but its calculations are shown in Appendix A3.2.2.

It will be seen that the results from Graphs 1 – 4 on sample agreement correlates closely with the normal distribution test for questions 2 and 3 (b).

Table 6.3. Summary of Analysis and Statistical Tests Results.

	PAIR	RANK CORRELATION WITH CAAD METHOD		SAMPLE AGREEMENT	
		18 STAFF	38 STUDENTS	18 STAFF *	38 STUDENTS*
Q.2 (Op)	P1	A (G)	N (G)	N (G)	P (G)
	P2	A (G)	P (G)	N (G)	N (G)
	P3	N (G)	N (G)	P (G)	N (G)
	P4	P (G)	P (G)	P (G)	P (G)
Q.3(a)(Ap)	P1	N (G)	N (G)	P (G)	P (G)
	P2	A (G)	A (G)	N (G)	N (G)
	P3	N (G)	N (G)	P (G)	P (G)
	P4	N (G)	A (G)	P (G)	N (G)
Q.3(b) (Ap)		N (S)		N (S)	
Q.4 (E)		N (S)	N (S)	N (S)	N (S)

KEY:

P = Positive.

N = Negative.

A = Appriximately Positive.

G = From Graphs 1 – 7, Fig. 6.1 (Sample Agreement, Positive if 70% swing in one direction).

S = From Statistical Calculations.

* = Compare with figures for normal distribution as shown in Appendix A3.2.2.

A test was also done for questions 3(b) and 4 to see whether the student mean variance correlated with the staff mean variance, but as no rank correlation between subjective and objective rankings were found, obviously because of no sample agreement, this test was discarded as superfluous, or irrelevant.

6.4. Interpretations of Results.

In order to form any overall conclusions of the tests it was found helpful to make the following observations in respect of the various questions of the subjective test:

6.4.1. Observation 1: Question 2 (O.P).

1.1. Sample agreement tests (Fig. 6.1, Graphs 1 – 4):

1.1.1. As Table 6.3 shows (and as substantiated by the Normal Distribution calculations shown in Appendix A3.2.2), there was no definite sample agreement on responses to question 2 , but:

1.1.2. For Pair 4, both for staff and students, Room 2 was greatly preferred, for staff with as much as 100%. These results suggest an importance of the door user area overlap as discussed below.

1.1.3. For Pair 1, Room 1 was greatly preferred, although according to the CAAD method both rooms were almost equal. Here, "visual simplicity" or "functional simplicity" seems to have been a deciding factor.

1.2. Rank correlation with the CAAD method (Fig. 6.1, Graphs 1 – 4):

1.2.1. There was mostly a negative correlation, possibly because the subjects "measured" other criteria than asked for, or that rooms were too similar to make visual judgements of distinction upon, and:

1.2.2. "Visual tidiness" seem to be a criterion used in the subjective ranking.

1.2.3. For pair 4, room 2 was very significantly ranked first for both staff and students. A possible explanation could be the door swing user area overlap for room 1 which is greater and looks more "messy" than for room 2. As the objective test showed these rooms to have equal efficiency, this may be an indication that overlaps involving doors should be more heavily weighted.

1.2.4. Simple circulation routes seems to have been influential as a criterion in the subjective ranking.

1.2.5. Functional simplicity appears to have been a ranking factor.

6.4.2. Observation 2: Question 3 (a) (A.P).

2.1. Sample agreement tests (Fig. 6.1, Graphs 1 – 4):

2.1.1. Here, the pattern from Question 2 was largely repeated. An oddity is Pair 2 where staff and students, who usually agreed in the ranking, gave different preferences. This is possibly because the two room layouts of Pair 2 are very similar in their plan solution. The difference between rankings for both rooms of Pair 2 is also less.

2.2. Rank correlation with the CAAD method (Fig. 6.1, Graphs 1 – 4):

2.2.1. This question included overlap conflict, as for question 2, but also included the Area efficiency factor (A.P), including best use of available space and least amount of wasted space. Again, very little rank correlation with the CAAD method can be shown.

2.2.2. The objective method ranked both rooms for each pair equal, but equal was not a response option. This could have "thrown" some test subjects.

2.1.3. Again, where visual simplicity can be shown, such rooms were preferred; as for Pair 1/Room 1, Pair 3/Room 2 and Pair 4/ Room 2.

2.1.4. It was interesting that the pattern of response from question 2 was repeated, and that in some cases, as for Pair 4, the graph contracted, i.e. there was not a great swing towards any of the two rooms. This could be because the subjects realised that a room with little or no conflict (overlaps of user areas) nevertheless might have a significant portion of wasted space. This "wasted space" factor seems to have "pushed" the subjective responses more in favour of the objective ranking.

6.4.3. Observation 3: Question 3 (b) (A.P).

The sample here was, as mentioned, reduced to only one mixed batch of 15 staff and students, because some people had ranked the first four room layouts from the four layouts chosen in Question 3 (a), which was not the intention.

3.1. Sample agreement tests (Fig. 6.1, Graph 5; Appendix A3.3.3):

3.1.1. The spread of responses as seen from the graph, and as shown by the calculations, is so great that no sample agreement on the ranking has occurred. This could be because according to the objective method the room layouts were also very equal in area efficiency.

3.2. Rank correlation with the CAAD method (Fig. 6.1, Graph 5; Appendix A3.3.2):

3.2.1. The calculations showed there was no rank correlation between subjective and objective ranking.

3.2.2. Again, the fact that equal was not an option, could have biased the subjective results.

3.2.3. Subjects did not seem fully aware of the fact that room content (furniture) was the same (constant) for all the 8 room layouts, and that obviously the ones with the larger "shells", i.e. larger areas, would have a lower area efficiency. It is quite significant how this point appears to have been missed among subjects.

3.2.4. It is odd that Room 1/Pair 4 now was 4, in front of Room 2, which was ranked 6, whereas both for Questions 2 and 3, Room 2 was always preferred.

3.2.5. The first 4 room layouts ranked subjectively seem to agree reasonably well with the objective ranking, according to Graph 5, Fig. 6.1.

6.4.4. Observation 4: Question 4 (E.R).

4.1. Sample agreement tests (Fig. 6.1, Graphs 6 – 7; Appendix A3.3.3):

4.1.1. The calculations showed no sample agreement on the ranking. This is also reflected by the spread shown in the graphs. Again, this might be due to the relatively equal objective rankings.

4.1.2. Students and staff appear to have followed roughly the same response pattern.

4.1.3. It is significant that Room 2/Pair 4 was ranked 1 both for staff and students, although only ranked 6 objectively. Again the visual "orderliness" of the layout seems to have biased the subjective ranking.

4.2. Rank correlation with the CAAD method (Fig. 6.1, Graphs 6 – 7 ; Appendix A3.3.2):

4.2.1. This question which asked subjects to rank the 4 "best" room layouts according to overall efficiency, including perimeter economy, showed no positive correlation with the objective method in the subjective responses given.

6.4.5. Conclusions.

It is extremely difficult to make definite statements regarding the above observations. The following inferences, however, are justified:

1. The non-correlation between subjective and objective rankings, as caused by the non-agreement between subjects' rankings may be an indication that this type of room efficiency evaluation does not lend itself to subjective "measuring". This would apply to both overall efficiency, overlap penalty, perimeter economy and area efficiency according to the formula:

   $$E.R = O.P \times P.P \times A.P.$$

   If this indeed is the case, as the subjective room layout test suggests, then this is a strong suggestion that this type of room evaluation is best done by objective methods.

For this particular method (See Sub-Section 4.4), it has been shown that computer graphics would be the only practical means of implementation. Hence, priority becomes getting the evaluation routines program operational as soon as possible so that it can be validated by designer users of the program, and the evaluation output compared with the manual evaluation results (Section 5).

2. A possible explanation for the non-correlation between subjective and objective rankings may be that the subjective questionnaire questions may have been ambiguous in wording or simply because the concept of such a room layout test is novel and the terminology, as such, is not established. Or, subjects certainly may have measured other criteria than asked for, such as visual or functional tidiness, circulation problems and other types of more typically conventional room layout assessment criteria.

3. The reasons for the no sample agreement may have been because "equal rankings" was not an option, and, because all the 8 room layouts were fairly similar in objective efficiency, and otherwise equal in a traditional design sense. The wide spread i.e. indifferent ranking would appear to corroborate the latter explanation.

4. The penalty weighting used in the objective room efficiency evaluation is reasonably arbitrary, or rather, perhaps tentative at present (See Table 4.1). However, when the design system synthesis and evaluation routines become fully operational on the computer, the penalty system will also be based on the probability of usage of elemental areas.

No comparisons with the tests outlined in this section and similar tests done by other research workers were possible, since none of the latter could be found. This highlights a difficulty in researching such a novel room evaluation method — it must be proved or disproved by practical use, and refined and developed accordingly.

SECTION 7: ACQUISITION OF EXISTING AVAILABLE SOFTWARE

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7.1.2.	Synthesis Facilities	S7.3
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ACQUISITION OF EXISTING AVAILABLE SOFTWARE.

Having specified a complete house design system suitable for computer graphics implementation (See Section 4), progress could now procede according to the following options:

1. Work from Scratch:

    1.1. Complete software specifications of the analysis, synthesis and evaluation options described in Section 4, followed by:

    1.2. Complete computer programming and CAAD implementation of the software specifications.

2. Use of existing available computer programs:

    2.1. Obtain suitable or near suitable programs for the analysis, synthesis and evaluation options.

    2.2. Amend and complement the suitable programs to enable implementation of the proposed design system, partly or wholly.

Option 2 above was the most optimal strategy to take, given the time and resources available in this particular research project. This section deals with the process of choosing suitable programs and the degree of applicability of the chosen programs.

7.1. Program Requirements.

Suitable programs must provide the following essential facilities for each of the design activity options as described below.

7.1.1. Analysis Facilities.

The program should provide, or it should be possible to complement the program with the following facilities:

1. The facility for the systems author to create written data files.

2. The facility for users of the program to access and read the data files whilst running the program.

3. The facility for users of the program to expand and modify the data files with new or additional information.

The data files would contain the following:

1. Program information.

2. Design information as mentioned in Sections 2,3 and 4.

7.1.2. Synthesis Facilities.

The program should provide the following essential graphics routines:

1. The facility to create geometric shapes.

2. The synthesis facilities described in Sub-section 4.3 necessary to manipulate, edit and dimension the geometric shapes and layouts.

3. The facility to attribute names or definitions to shapes so as to allow the creation of libraries of coded shapes and layouts at the various design levels defined in Sub-section 4.3.

4. The facility to create named layouts at the various design levels using shapes or layouts from other design levels.

5. The facility to create named shape or layout definitions whilst already working at a particular definition at a particular design level (the creation of new definitions within definitions).

6. The facility to text layouts.

7. The facility to draw solid as well as differently specified dashed lines.

8. The facility to adjust shapes to specified visible grids.

9. The facility to set up any shape or layout definition on a number of overlay levels and the possibility to view only specified overlay levels at any given time.

7.1.3. Evaluation Facilities.

The program should provide the following essential facilities as needed by the evaluation method specified in Sub-section 4.4 and Section 5.

1. Efficient measuring of areas of shapes and layouts.

2. Measuring of areas of overlap between shapes.

3. Measuring of perimeter lengths of bounding rectangles and polygons of layouts.

7.2. Program Investigation.

Although a substantial number of graphics programs were reviewed, the search for suitable programs was limited by their availability. The resources available for the research project did not permit the purchase of a large graphics suite of programs. The real search was therefore restricted to packages thought to be available on an inter-college /university basis. Another restriction was that the programs preferably should be compatible with the Tektronix graphics storage tube terminals as well as the RGIT Dec—20 computer system, and written in Fortran. The programs considered were those described below.

7.2.1. Analysis and Synthesis Programs.

<u>1. ABACUS Programs:</u>

The majority of ABACUS graphics software is supported by the general or common basic 2 – D graphics utility manipulation routines contained in the GRAMP Package (GRAphics Manipulation Package; 7.1). The graphics program considered was SPACES 2 (7.2) which is a program for producing sketch layouts of school buildings, as part of the larger SPACES suite of programs (7.3 – 7.5). A later sophistication of GRAMP, GINGER (Graphics INteraction of Graphics Elements; 7.6), was produced for ECOLE 3 (7.7), a program intended for the design and appraisal of buildings at the scheme and detail design stages.

Although suitable for most of the proposed synthesis design options, SPACES 2 did not provide the analysis option required, nor did it operate on overlay levels.

2. EdCAAD/SSHA Programs:

The EdCAAD Unit at the University of Edinburgh has produced, amongst other programs, a House Design Package for the SSHA (7.8 – 7.12) which is supported by the EdCAAD TIGER Graphics (7.13) and Polygon Package (7.14) Systems. The House Design Package provided most of the analysis and synthesis facilities needed, but the overlay concept was not included.

3. CADC Programs:

The CADC has produced the GINO suite of programs, which is a comprehensive graphics package with an almost unlimited range of application possibilities, including architectural design application. The GINO–F routines (7.15) provided nearly all the graphics facilities needed for the analysis and synthesis options, except the overlay concept. Availability was not a great problem since the program became available on the RGIT Dec–20.

4. The Jacobi Program:

The Jacobi Program is a Danish implementation of automatic generation as well as interactive design of house plans (7.16). The graphics program makes use of the overlay concept, but the various overlays are not individually removable. The user is presented with a flexible element menu system on the screen, enabling a high degree of design flexibility. However, availability and compatibility with the Dec – 20 was a problem, and the program operated using a refresher graphics terminal.

5. SAR Programs:

After an early alphanumerical implementation of the SAR design system (See Sub-section 3.4; 7.17) a full scale graphics program was made recently (7.18), named SMOOC. The SMOOC program, whilst providing a flexible design aid for the SAR Design System, was not found suitable for the analysis and synthesis options of the proposed design system. Availability would have been a problem.

6. Eastman Programs:

Charles Eastman has written a number of papers on CAAD, and on spatial synthesis in particular (7.19 – 7.22). However, the Fortran routines studied were not immediately implementable as a graphics synthesis program and lacked a substantial number of the required synthesis facilities. No provision was made for designing using overlays.

7. GAEL 4A:

GAEL 4A is part of the large GAELIC Suite of programs, written by Dr. John Eades of the RGIT, then of Edinburgh University (7.23, 7.24), and later amended and complemented by the Compeda software agency (7.25). GAEL 4A allows use of a wide variety of graphics routines, including most of the synthesis facilities needed for the proposed design system. This program was the only one considered which made use of the overlay principle. In addition GAEL 4A was readily available on the RGIT Dec – 20 system. See Sub-section 7.3 for further details on GAELIC and GAEL 4A.

7.2.2. Evaluation Programs.

1. EdCAAD Programs:

The polygon package mentioned above (7.26) enabled efficient measuring of shape and shape overlap areas and perimeter node co-ordinates.

2. Compeda Programs:

The Dimcheck or Design Rule Checking Program (7.27) was written to check areas and perimeters of layouts created by the GAEL 4A program against default values. The program routines were based on the EdCAAD polygon package routines. The Dimcheck Routines, subject to changes, included most of the area and perimeter calculations needed for the evaluation method of the proposed design system. See Sub-section 7.3 for further details on Dimcheck.

7.3. Program Description and Applicability.

The GAEL 4A and the Dimcheck programs were chosen for the analysis/

synthesis and evaluation options respectively, of the proposed design system. This Sub-section describes briefly the GAELIC suite of programs, and in particular the GAEL 4A and Dimcheck programs, including their availability and compatibility.

7.3.1. The GAELIC Suite of Programs.

The GAELIC suite of computer programs are designed to assist in the production of integrated circuit masks, masks for printed circuit boards and thin and thick film layouts in electronic engineering. The basic aims of the suite are to allow the user to accurately enter the description of a layout into the computer, to interactively check and modify the layout, and, finally, to produce layout drawings (7.28).

The functions of the various programs in the suite are as follows (Fig. 7.1):

1. GAEL 1A:

This program takes a file containing the output from a digitiser, checks for syntax error, and produces a GAELIC language file.

2. GAEL 23:

This program takes a file containing the GAELIC language, checks for syntax errors, and produces a Ring Data Structure file, which can be changed or added to.

3. GAEL 4A:

This program will plot out all or a specified part of the Ring Data Structure layout, on a Tektronix 4010 (or other) Terminal. The program then allows the user to interact with the layout modifying or deleting existing shapes or adding new ones (See below for further details).

4. GAEL 5A:

This program plots all or part of a layout on a CALCOMP incremental plotter.

5. GAEL 6A:

This program extracts all the lines from a Ring Data Structure, joins them together to form polygons, if appropriate, and returns these polygons to the Data Structure.

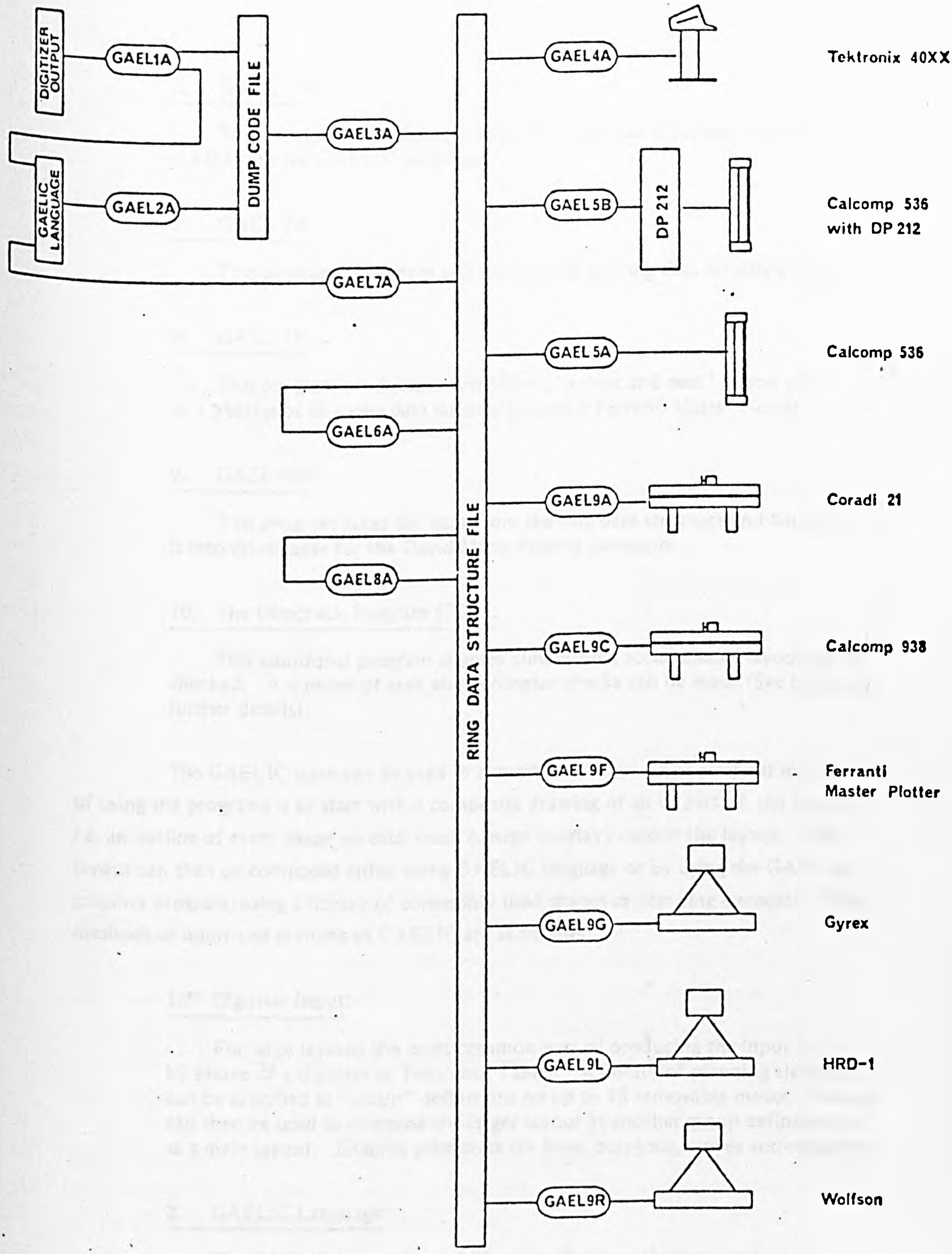

Fig. 7.1. Block Diagram of the GAELIC System. From Eades, J.D. (7.30).

6. GAEL 7A:

This program takes the contents of a Ring Data Structure and converts it back into the GAELIC language.

7. GAEL 8A:

This program rearranges and rationalises the ring data structure file.

8. GAEL 9F:

This program produces a microfilm , a "cut and peel" master plot or a photoplot of a ring data structure, using a Ferranti Master Plotter.

9. GAEL 9D:

This program takes the data from the ring data structure and converts it into drive tapes for the David Mann Pattern Generator.

10. The Dimcheck Program (7.29):

This additional program enables dimensional accuracies of layouts to be checked. A number of area and perimeter checks can be made (See below for further details).

The GAELIC suite can be used in a number of ways. The simplest method of using the programs is to start with a composite drawing of all or part of the layout, i.e. an outline of every shape on each mask (design overlay) used in the layout. The layout can then be composed either using GAELIC language or by using the GAEL 4A graphics program, using a library of commonly used shapes or planning elements. The methods of input and features of GAELIC are as follows:

1. Digitiser Input:

For large layouts the most common way of producing the input is by means of a digitiser or Tektronix Tablet. A library of planning elements can be specified as "group" definitions on up to 15 removable masks. Groups can then be used to compose the larger layout as another group definition or as a main layout. Graphic primitives are lines, polygons, circles and rectangles.

2. GAELIC Language:

The GAELIC Language enables a specification of groups and layouts alphanumerically. It is doubtful whether this facility would be useful or acceptable to architects.

3. Ring Data Structure:

The Ring Data Structure file allows alphanumeric or graphic creation, editing of or additions to layouts.

4. Check Plots:

Plots of the whole or specified parts of layouts can be produced, showing all or a selected number of the masks used. "Windowing" enables accurate layout area specifications for plotting.

5. Interactive Graphics Editing:

GAELIC allows the user to interact with a layout, modifying or deleting existing shapes or adding new ones using a Tektronix graphics terminal (See GAEL 4A below).

6. Final Output:

Layouts can be hardcopied using a plotter or a Tektronix Handcopy Unit.

7. Configurations:

The GAELIC suite is an efficient timesharing system, implementable on all major computer systems.

8. Associated Design Aids:

These include the Dimcheck program already mentioned (Also see below).

The entire GAELIC suite is written in ANSI Fortran IV and implemented on the RGIT Dec – 20 computer system. Following initial use of the programs to ascertain their applicability for the proposed design system and discussions with Dr. John Eades, subsequent permission was obtained from Compeda, the marketing software agency for GAELIC, to use, amend and add to the suite. In return for this facility, Compeda required a copy of the amended and new programs, once the programming work had been done.

Use was made of the programs GAEL 7A and GAEL 23, but these facilities would not normally be required in the proposed design system. However, although the programs GAEL 4A and Dimcheck only, are used in the proposed system, the remainder of the GAELIC suite are still available as options.

7.3.2. The GAEL 4A Program.

The following is a brief description of the GAEL 4A program, chosen for the analysis and synthesis facilities of the proposed design system. Further reference is given to the GAELIC Users Manuals (7.30, 7.31) and Section 10 below.

1. Introduction:

The GAEL 4A program uses any of the Tektronix storage tube graphics terminals with cross-hair cursors to interactively modify and correct a layout held in a data structure file. The user can select which data structure file is to be processed and can select which part of that layout to be edited; i.e., a particular group definition on a particular mask (overlay) at a particular window size. The non-storing cross-hair cursor, controlled from thumb wheels, and simple keyboard commands are used to create, delete and modify layouts.

The storage tube screen is divided into two parts: the right hand edge of the screen is used for messages and is called the "menu area". It contains such information as the lists of masks plotted on the screen, the mask number being modified, and the name of a group when an origin is identified, etc. The remainder of the screen, except for a small area at the top which contains the window size and name of the present layout, is used for drawing and plotting and is known as the "plotting area".

The program command structure is hierarchical in that the user has a choice of options at one level and when one of these is selected, the program drops to a lower level where the user has a different choice of graphical options. The first level is known as the "program command level" and the second as "cursor command level". There is also a third command level beneath cursor level.

The program command level options are concerned with selecting the group definition to be processed, the size of the window, the mask numbers to be plotted, modifying or drawing on an existing data structure, setting modes for plotting, etc. The options are briefly described below.

Two of these options, MODIFY AND DRAW, allow the cross-hair cursor to be displayed and this can be used to identify existing shapes plotted out on the screen, to indicate the coordinates of new shapes to be added or to change the window being plotted etc. This is the lower cursor command level and the options available are briefly described below, as are the sub-cursor command level options.

Certain options are available whenever the cross-hair cursor is displayed on the screen independent of whether the program is at the cursor or secondary command level. These are known as "permanent cursor options" and in general they control the replotting of the current or new window. These options are also briefly described below.

Before the program command level is reached the program must be "initialised" as described below. Fig. 7.2 shows the main logic of the GAEL 4A program and Fig. 7.3 shows a typical MODIFY procedure at the cursor command level.

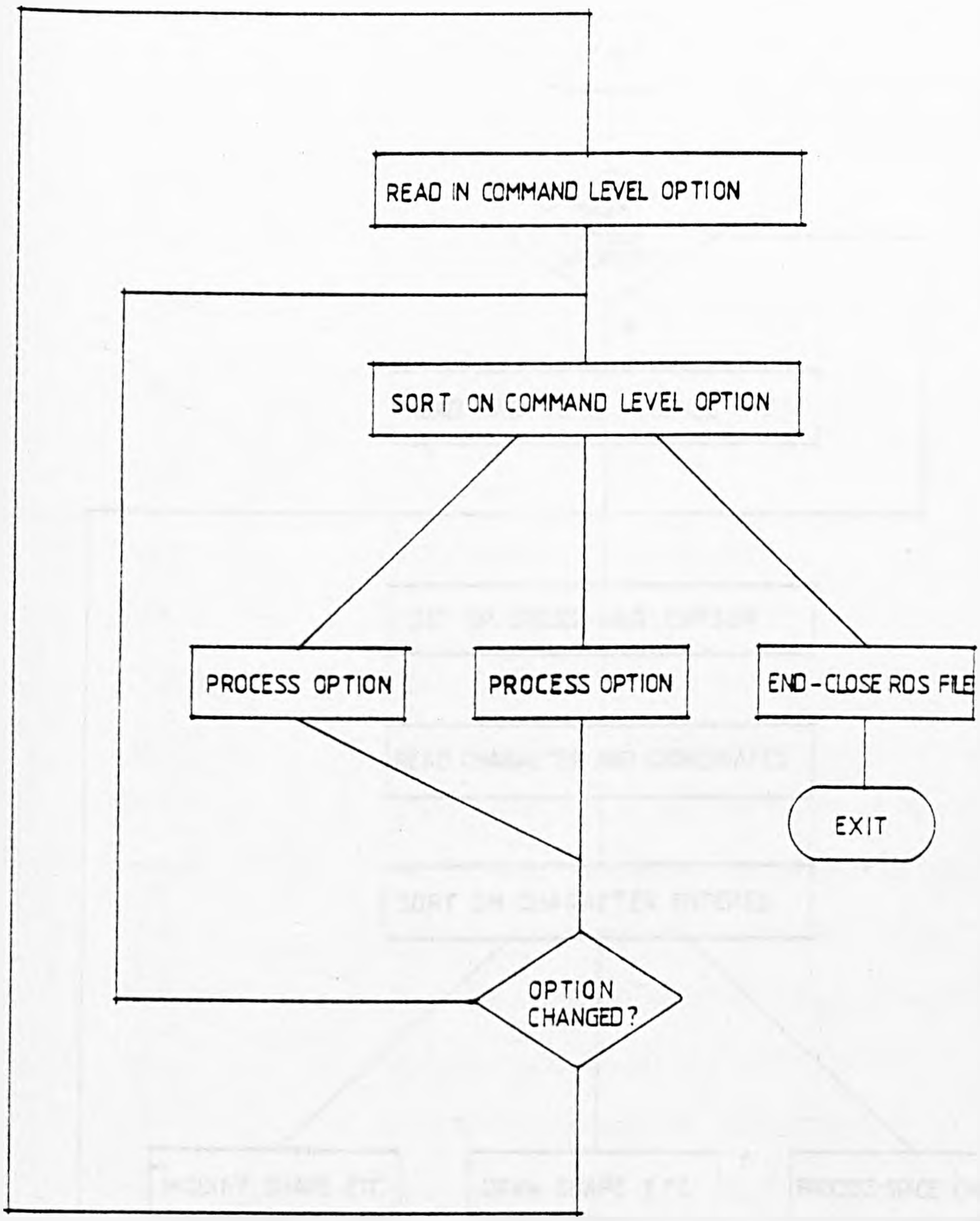

Fig. 7.2. Simplified Flow Diagram of GAEL4A. After Eades, J.D. (7.32).

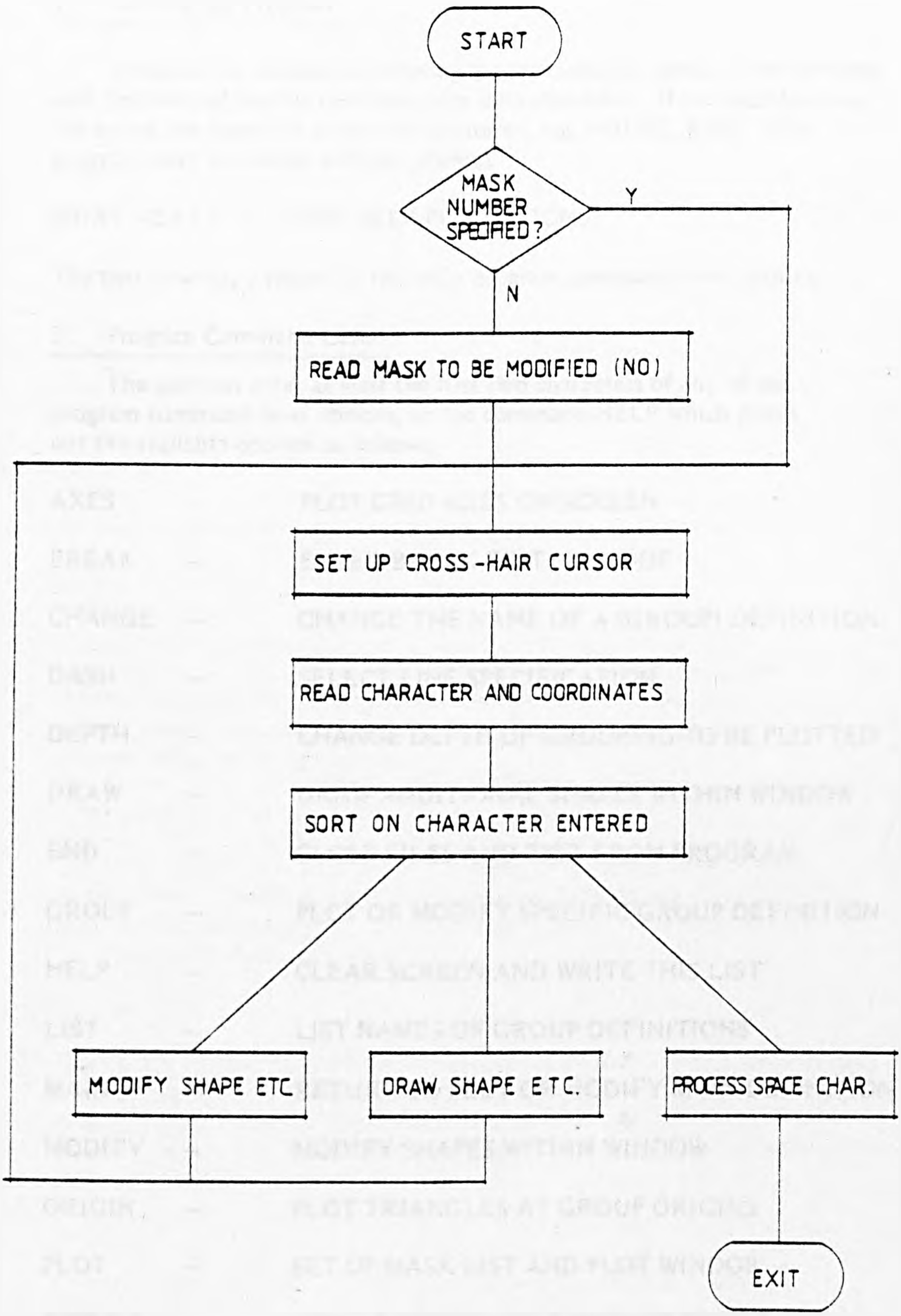

Fig. 7.3. Simplified Flow Diagram of the GAEL4A Modify Procedure.
From Eades, J.D. (7.33).

2. Starting the Program:

Initialisation consists of entering the transmission speed of the terminal and the name of the file containing the data structure. If no data structure file exists, the name for a new file is entered, e.g. HOUSE. RNG. The program next continues with the prompt:

WHAT NEXT ? – TYPE HELP FOR OPTIONS.

The user now has a choice of the main program command level options.

3. Program Command Level:

The user can enter at least the first two characters of any of the program command level options, or the command HELP which prints out the available options as follows:

AXES	–	PLOT GRID AXES ON SCREEN
BREAK	–	ENTER BREAK EDITING MODE
CHANGE	–	CHANGE THE NAME OF A (GROUP) DEFINITION
DASH	–	SELECT LINE SPECIFICATION
DEPTH	–	CHANGE DEPTH OF GROUPING TO BE PLOTTED
DRAW	–	DRAW ADDITIONAL SHAPES WITHIN WINDOW
END	–	CLOSE FILES AND EXIT FROM PROGRAM
GROUP	–	PLOT OR MODIFY SPECIFIC GROUP DEFINITION
HELP	–	CLEAR SCREEN AND WRITE THIS LIST
LIST	–	LIST NAMES OF GROUP DEFINITIONS
MAIN	–	RETURN TO PLOT OR MODIFY MAIN DEFINITION
MODIFY	–	MODIFY SHAPES WITHIN WINDOW
ORIGIN	–	PLOT TRIANGLES AT GROUP ORIGINS
PLOT	–	SET UP MASK LIST AND PLOT WINDOW
REPLOT	–	REPLOT WINDOW FOR PREVIOUS MASK LIST
ROUND	–	ROUND TO NEAREST GRID POINT
SAVE	–	INTEMEDIATE SAVE OF DATA STRUCTURE FILE

TRACK — CHANGE TRACK WIDTH MODE

WINDOW — CHANGE WINDOW SIZE.

Certain of these options have default positions. The following is a description of those options considered to be applicable to the proposed synthesis option.

AXES:

This option allows the user to set up visible grid axes in the x - and y - directions at the edges of the plotting area of the screen, as in a graph. Cross-hair cursor lines can then be used for positioning shapes using the axes as positional aids.

CHANGE:

This option allows the user to change names of group definitions.

DASH:

This option enables specification of lines at particular mask levels according to the "lincod" system (7.34). Mask 1 shapes are always plotted as a solid line. Other mask numbers from 2 — 15 have default dashed lines of various kinds, but any mask lines can be changed using the DASH option.

DEPTH:

This option allows the user to control depth of grouping to be plotted on the screen. Depth refers to the number of times group definitions have been used or plotted within other group definitions. The range is from 1 — 10 with a default value of 1.

DRAW:

This option allows the user to draw new shapes on the screen thereby adding them to the ring data structure. It gives the user the opportunity to design layouts directly on the screen on the mask number or numbers specified. The cross-hair cursor will appear and the various cursor commands described below are available.

END:

This option enables a save of the updated data structure and exit from the program.

GROUP:

This option allows the user to name and create a new group definition, or to change and view an existing one, using the various plot and modify routines available. Other group definitions can be used in the design of the current group definition.

LIST:

This option allows the user to have all group name definitions present in the data structure listed in order of creation. This is particularly useful when a library of shapes or planning elements are used, as it allows "picking" of elements for the design of layouts.

MAIN:

This option allows the user to process the main definition instead of group definitions, but the latter can also be used in the design of the main layout. The group option is preferred in the present design system, as it allows design in an increasing depth of groupings, which is not possible using the main layout option.

MODIFY:

This option allows the user to identify shapes plotted in the window of a group or the main definition and modify or delete them. It is obviously preceded by the plot or replot facilities, otherwise there will be no shapes on the screen to identify. Shapes are identified by positioning the cross-hair cursor at group origins or shape nodes and pressing various keys on the keyboard. These various cursor commands are dealt with below.

The modification only takes place on one user specified mask at a time, and when modifications on this mask are complete, another mask can be specified.

Automatic switching between the MODIFY and DRAW options occurs in the program when the appropriate cursor control level options are exercised (See again Fig. 7.3).

ORIGIN:

This option allows group origins to be marked by small triangles in order to ease their identification by the cross-hair cursor.

PLOT:

This option allows the user to set up a list of mask numbers to be plotted and then plots out those masks for the previously defined window. The masks are then plotted in turn, in the order given.

REPLOT:

This option plots out the window for each of the masks specified by a previous PLOT option. As for the PLOT option, mask numbers plotted are displayed, as is the window size.

Because of the characteristics of the storage tube display, the shapes plotted and messages remain visible until the contents of the complete screen are erased.

ROUND:

This option enables the invisible set-up of a grid to specified x- and y- modules on the plotting area of the screen. The program then automatically rounds all coordinates entered by means of the cross-hair cursor to the nearest grid point. The default grid increments are 1 micron, or 1 mm in the proposed design system. This option is useful for rounding layout dimensions to a modularly co-ordinated grid.

SAVE:

This option enables an intermediate save of the layout data structure up to the point of SAVE execution.

WINDOW:

This option allows a specification of the window of a layout to be viewed. It is effected by entering the desired bottom left hand and the top right hand x - and y - coordinates of the plotting screen area. Experimentation and calculation permits layouts to be drawn to standard architectural scales.

After completion of a main program command procedure the user is returned to the "WHAT NEXT ? " question and is then free to choose from the main program commands or exit from the program by the END command.

4. Cursor Command Level:

The cross-hair cursor controlled by the thumb wheels and the keyboard are used to create, identify and modify shapes. The cursor is set up by either the MODIFY, DRAW and TRACK command level options. At the cursor command level there are a number of options that can be entered that are controlled by single character key-strikes and occassionally by the position of the cross-hair cursor.

Whenever the cross-hair cursor is on the screen there are certain keyboard options available that are mainly concerned with the window plotted, and these are known as "window cursor commands" or "permanent cursor commands".

There are also options available at a lower level which can perform such functions as identifying the nearest point coordinates in the layout, indicating where a polygon should start etc., and these are known as "main cursor commands".

After several of the "main cursor commands" have been selected, further information may be required. For example, when a point on a shape has been identified, the user needs to tell the program if the point or the shape is to be moved, and its new position. This type of facility is accomplished by using the set of keyboard options known as the "subsequent cursor commands".

The various cursor commands are now briefly dealt with (options marked with asterisk are not considered useful for the present system):

4.1. Permanent Cursor Commands:

The keyboard options available are:

J	–	jump back to the window size required to display whole definition.
Q-Q	–	Query incremental distance between two points. Q is pressed with cursor at each point.
U	–	Undefined zoom in or out of the picture. Positive values are specified for enlargements and negative values for reduction. The position of the cursor determines the centre of the changed picture.
V	–	Print out value of nearest co-ordinate to cursor.
W	–	Redraw or change window. The position of the cursor determines the centre of the changed picture.
Z	–	Zoom in by a factor of 2. The position of the cursor determines the centre of the changed picture.
a	–	Plot axes once (only).
d	–	Complement the dashed line swith.
g	–	Complement axes (grid) plotting switch.
t	–	Complement full track switch. *
+	–	Insert mask in plot list.
–	–	Remove mask in plot list.
w-w	–	Define new window by bounding rectangle.
SPACE	–	Return to program command level or ignore shape (previous command).
1-9,O	–	Plot mask once only. Allows non-permanent additions to mask plot list.
o	–	Complement origin switch.

4.2. Main Cursor Commands:

The keyboard options available are:

B — Break layout along line to be defined. *

C — Copygroup. *

F — Find nearest point in definition including groups and repeats (nearest to cursor position).

G — Insert group call. Allows user to position a group (library) shape or layout in the present definition as indicated by the cursor.

I — Identify nearest point in definition excluding groups and repeats. Subsequent options enable modification and re-positioning of shapes etc.

L — Insert line. Enables the creation of a line of specified length and direction.

M — Change mask number. Only one mask is worked on at a time.

] — Move shape to other mask (as specified).

P — Insert polygon. Enables the creation of a polygon, of any type or size. Can also mean permanent dimensioning display.

R — Insert rectangle. Enables the creation of any rectangle.

T — Insert track. *, Can also mean temporary dimensioning display.

. — Insert circle. Allows the creation of circles to specified diameter sizes.

\ — Start line at nearest point in complete definition.

Λ — Insert text. Allows texting of layouts or shapes to specified scale of letters and position in plotting area.

4.3. Subsequent Cursor Commands:

The keyboard options available are:

A — Plot point at end of an angled line. Enables creation of points of an angled line.

D — Draw shape (s) previously modified or specified. D can also mean facility to dimension shapes or layouts when no prior draw commands have been executed. Layouts can be dimensioned in the x- or y- directions separately, or in both directions at the same time, temporarily or permanently on any mask.

E — Exit from polygon with an orthogonal line segment. This option enables the user to close a polygon with an orthogonal line configuration.

H — Move whole of shape horizontally or vertically. Allows any shape or group definition to be moved either parallel to the x-axis only, or parallel to the y-axis only, i.e. orthogonally.

N — Move point to nearest point in definition. This option enables quick creation or repositioning of existing shapes with reference to the existing layout points.

O — Plot point at end of orthogonal line. Used to specify end of line segment or top right hand corner of a rectangle.

S — Substitute new co-ordinate. This option allows correction of incorrectly entered coordinate points.

X — Exit from polygon with an angled line segment. Same as E, except the closing line is angled.

Y — Yank whole shape of an angle. This option allows non-orthogonal re-positioning of shapes.

I — Delete shape. Allows deletion of rectangles, lines and polygons, but not group definitions or circles.

— Substitute coordinates entered by keyboard . This option allows numerical keyboard co-ordinate entry of points rather than by cursor positioning, and is more accurate than the latter.

DEL — Delete text, circle, (track,) or group (definition). Subsequent command to the I (identify) option.

The relationships and command sequences between main and subsequent cursor commands can be found in the GAELIC Users Manual (7.3 5). Some common procedures are shown in Fig. 7.4.

On the 4010, as opposed to the 4014 terminal, lower case keyboard options are not possible, so these are then not available.

5. Applicability of the Program:

The GAEL 4A program does not satisfy the proposed analysis and synthesis requirements of the proposed design system on the following points:

5.1. Analysis Insufficiencies:

The program does not provide the facility to employ information data files as described (See sub-section 7.1.1).

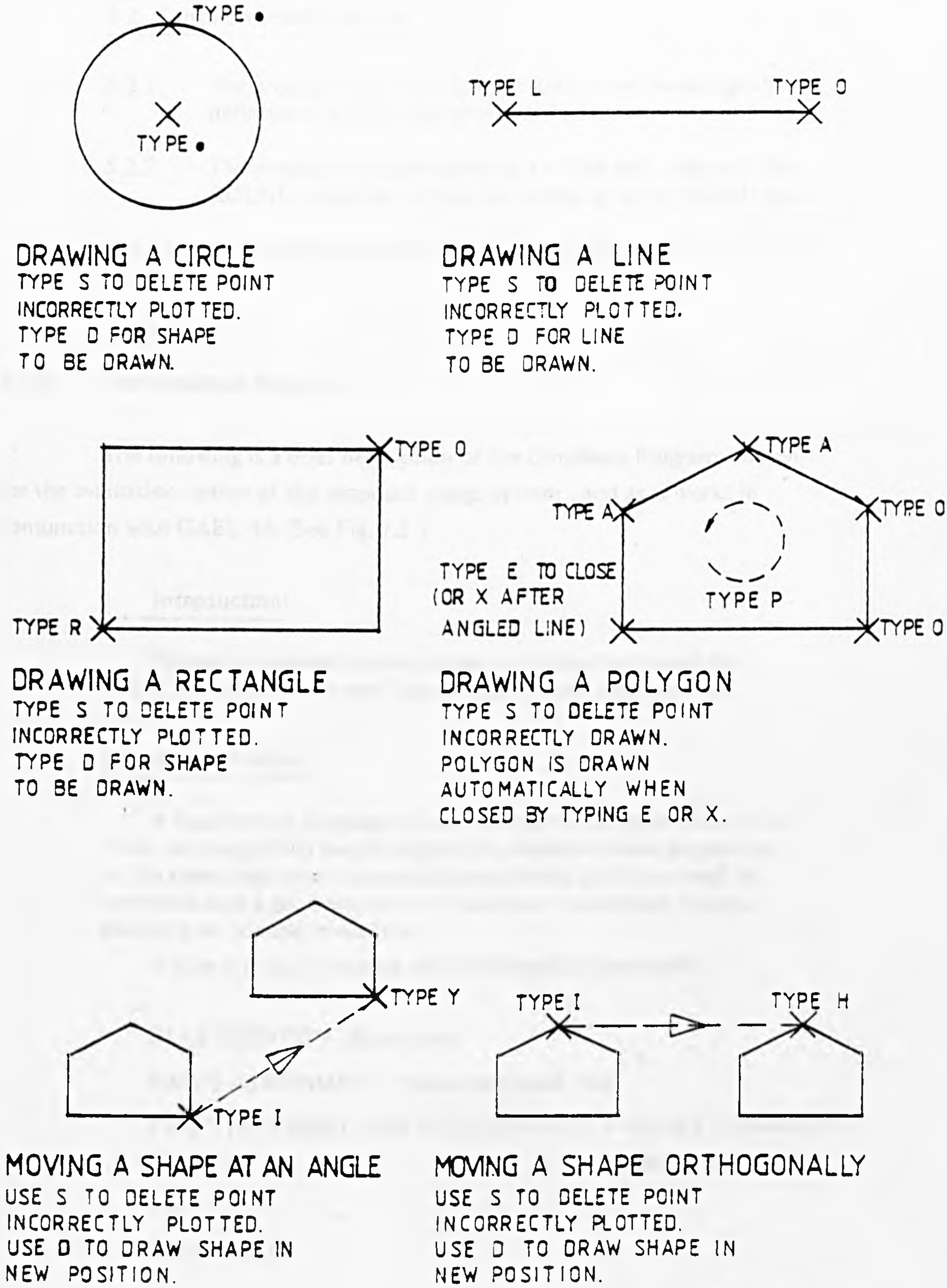

Fig. 7.4. Common Cursor Procedures of the GAEL4A Program.
After Compeda (7.36).

5.2. Synthesis Insufficiencies:

5.2.1. The program does not allow the creation of named group definitions within other group definitions.

5.2.2. The program does not generate a visible grid, although the ROUND command allows the setting up of an invisible grid.

The necessary program changes are discussed in Sub-section 7.4 below.

7.3.3. The Dimcheck Program.

The following is a brief description of the Dimcheck Program, chosen for the evaluation option of the proposed design system , and as it works in conjunction with GAEL 4A (See Fig. 7.5).

1. Introduction:

Checks of dimensional accuracies of a layout produced by GAEL 4A can be performed according to a three stage process:

1.1. Rule definition:

A flexible rule language enables the user to define his own rules. These can range from simple separation checks between geometries on the same mask layer to sophisticated checks such as a check to determine that a geometry on one mask layer completely bisects a geometry on another mask layer.

A rule definition consists of the following components:

RULE IDENTITY (Rule name)

SHAPE ASSIGNMENT (Shapes and mask list)

FAIL STATEMENT AND DEFINITION OF FAILURE CONDITION (tests against a value)

END

ENDOFFILE.

The precise method of writing a rule check is set out in the Dimcheck Manual (7.38).

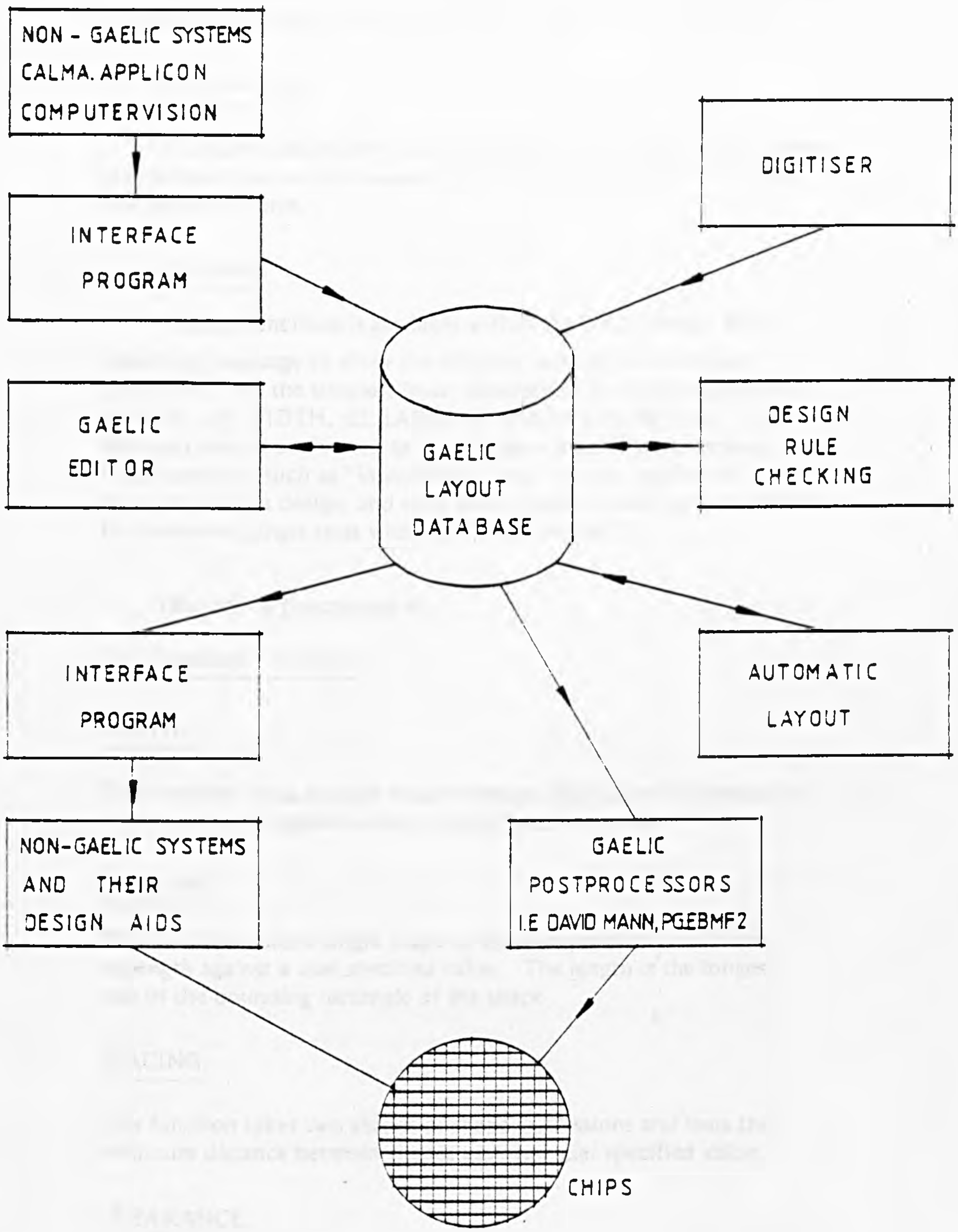

Fig. 7.5. Design Rule Checking within the GAELIC System.
After Owen, J.W. (7.37).

1.2. Rule compilation:

The source file holding the design rules is run through a compiler program to generate a compiled rule file. See below for details.

1.3. Rule checking:

The main rule-checking program checks a GAELIC layout against the defined rule and produces a rule violation output in both listing and graphical form.

2. Functions:

A set of functions is available within the DRC (Design Rule Checking) language to allow the efficient writing of rule failure conditions. At the simplest level, dimensional and shape operators are used, e.g. WIDTH, CLEARANCE and OVERLAP tests. However, tests can also be performed on new shapes or part shapes created from operators such as "intersection" and "union" performed on the basic shapes of a design, and even more complex tests may be performed by combining single tests with AND, OR and NOT.

The various functions are:

2.1. Standard Functions:

WIDTH:

This function takes a single shape or shape expression and checks its minimum width against some constant specified value.

LENGTH:

This function takes a single shape or shape expression and checks its length against a user specified value. The length is the longest side of the bounding rectangle of the shape.

SPACING:

This function takes two shapes or shape expressions and tests the minimum distance between shapes against a user specified value.

CLEARANCE:

This function tests the minimum clearance between an enclosed shape and an enclosing shape against a user specified value.

INTERLIMB:

This function takes a single shape and tests the distance between limbs of the shape against a user specified value.

XDIM YDIM:

These functions take a single shape and check the X and Y dimensions of the shape bounding rectangle against a user specified value.

AREA:

This function takes a single shape expression and checks its area against a user specified value. This is an important facility for many of the area calculations in the present evaluation method.

BRAREA:

This function checks the area of the bounding rectangle of a shape expression against a user specified value. This is also a useful function for the evaluation method.

2.2. Topological Checks:

The following functions perform checks on pairs of shapes:

ENCLOSED:

This function takes the inside shape and outside shape in that order and checks for enclosure.

OVERLAP:

This function takes a pair of shapes and checks any overlap. An essential routine for the evaluation method.

ABUT:

This function takes a pair of shapes or shape expressions and tests for any wholly or partly abutting edges or sides.

SEPARATE:

This function checks that two shapes or shape expressions do not overlap.

DISTINCT:

Two shapes are distinct if there is no part or edge common to both shapes, and this function checks for distinction.

PARTED:

This function checks whether one shape divides another shape into a number of separate parts.

2.3. Orientation Checks:

There are two orientation checking functions,HORIZONTAL and VERTICAL. They check whether the longer dimension of the bounding rectangle of a single shape is horisontal or vertical.

2.4. Shape Operators:

A set of operators is available which enables new shapes to be created by writing expressions involving two shape variables. The operators provided are union, intersection, difference and exclusive union, as per standard definitions.

Fig. 7.6 shows the design rule structure in relation to the various functions.

3. Design Rule Compilation:

The design rules on completion are entered into a source or input file, which is compiled by a sub-program (See Fig. 7.7).

4. Rule Checking:

The DRC program takes as input the compiled rule file and a GAELIC layout file (See Fig. 7.8). After initialisation of the DRC program, the following commands are available:

ALL	–	APPLY RULES TO EACH DEFINITION IN TURN
APPLY	–	APPLY THE RULES TO SPECIFIED PART OF LAYOUT
DEPTH	–	MODIFY DEPTH OF GROUPING CHECKED
END	–	END PROGRAM
ERRORS	–	CHANGE MAXIMUM ERROR LIMIT
FORMAT	–	CHANGE VIOLATION MARKER FORMAT
GROUP	–	CHECK SPECIFIC GROUP DEFINITION
HELP	–	PRINT OUT THIS LIST
INCLUDE	–	INCLUDE CHECKS FOR SPECIFIC RULES
LIST	–	LIST GROUPS IN DATA STRUCTURE
MULTIPLE	–	SET PARAMETERS FOR MULTIPLE SHAPES
OMIT	–	OMIT CHECKS FOR SPECIFIC RULES
OPT	–	ENABLE OPTIMISING CHECK MODE
RULES	–	LIST ENABLE STATUS OF RULES
START	–	RESTART PROGRAM
WINDOW	–	CHANGE WINDOW OF APPLICATION.

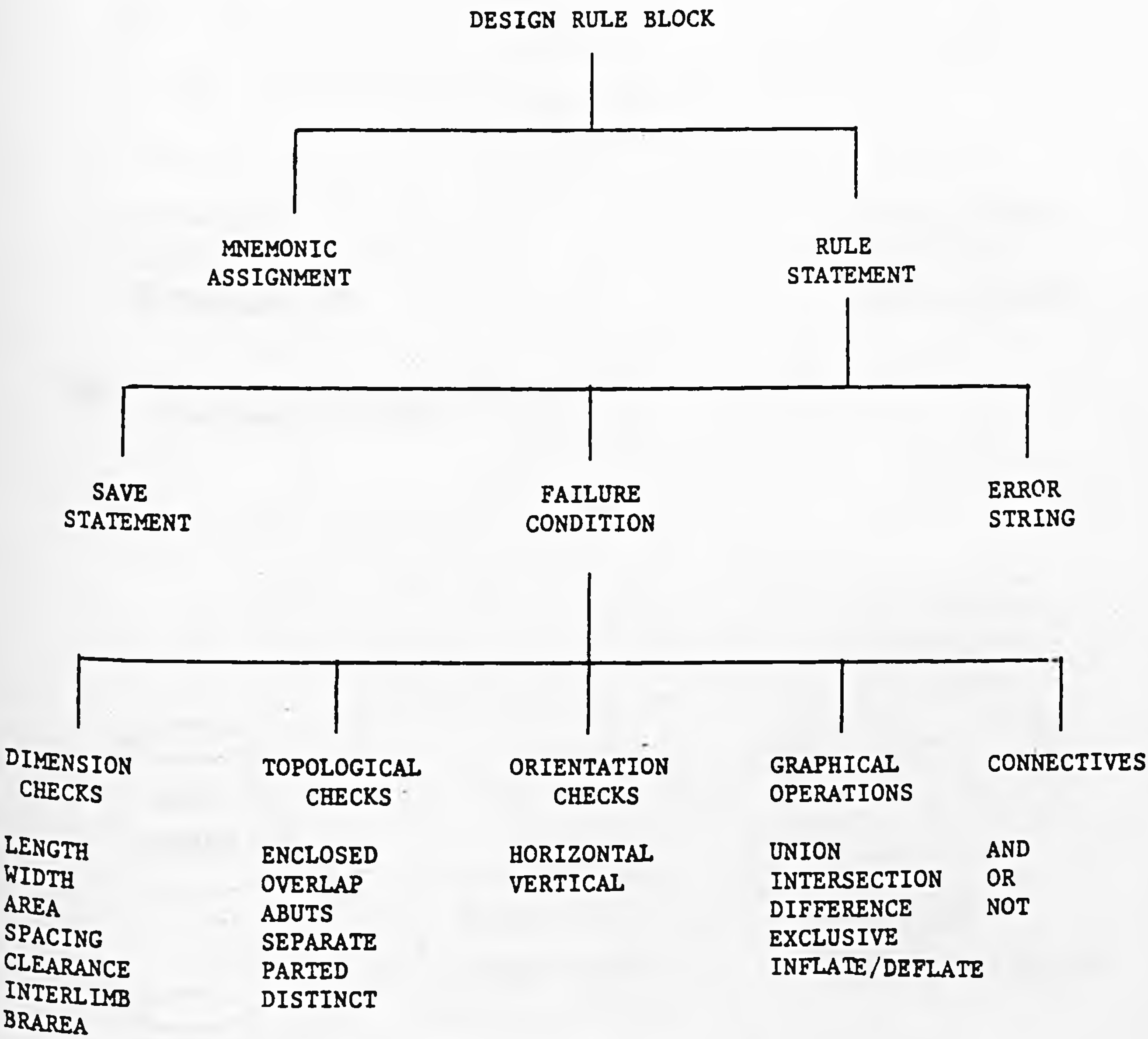

Fig. 7.6. The Dimcheck Design Rule Structure. From Owen, J.W. (7.39).

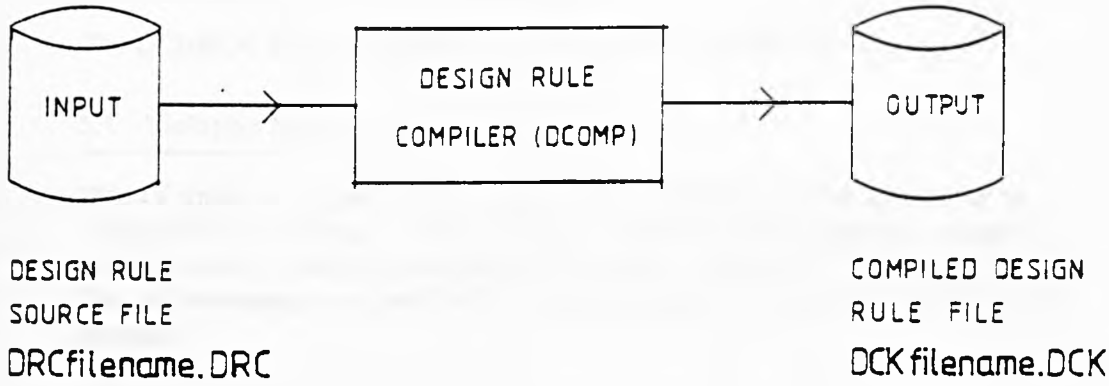

Fig. 7.7. The Dimcheck Rule Compilation Process.
From Owen, J.W. (7.41).

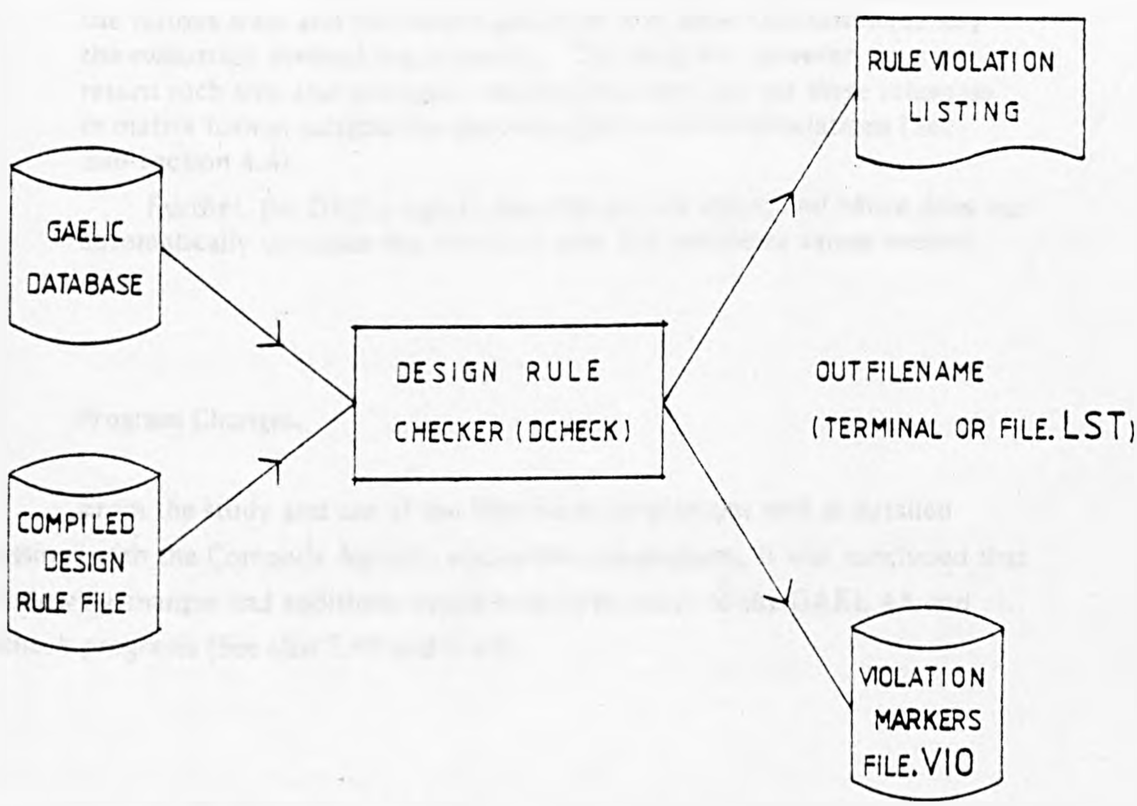

Fig. 7.8. The Process of Running the Main DRC Program.
From Owen, J.W. (7.42).

These options are further described in the program manual (7.40).

5. DRC Output and Interpretation:

The DCHECK program produces 2 forms of rule violation results:

5.1. Violation Markers:

When a shape or shapes fail a Design Rule, violation markers are placed on a separate mask overlay. The markers are circles and they identify violating shapes as well as isolating the position of certain violations. The violation file can be entered into the GAELIC data structure file by using the GAEL 23 program.

5.2. Listing File:

Listing of violations are either done directly to the terminal or to a listing file. Violating shapes are identified by type and co-ordinates.

6. Applicability of the Program:

In order to check rule fail statements the DRC program calculates the various areas and perimeters specified, and these calculations satisfy the evaluation method requirements. The program, however, does not return such area and perimeter values to the user, nor set these values up in matrix format suitable for the evaluation method calculations (See Sub-section 4.4).

Further, the DRC program depends on rule input, and hence does not automatically calculate the necessary area and perimeter values needed.

7.4. Program Changes.

From the study and use of the Dimcheck programs as well as detailed discussions with the Compeda Agency, who wrote the programs, it was concluded that the following changes and additions would have to be made to the GAEL 4A and Dimcheck programs (See also 7.43 and 7.44).

7.4.1. Changes for the Analysis Option.

An extendable data-file should be attached to the GAEL 4A program, and the addition of a main program command option INFO should be implemented.

When the user enters INFO he should have 2 options:

1. To read the data file (Program or design information).

2. To extend the file with his own information.

The addition of the INFO option to the GAEL 4A program is routine programming and does not require further specifications. The INFO option may be external to the program (See Sub-sub-section 7.4.4 below).

7.4.2. Changes for the Synthesis Option.

The insufficiencies of the GAEL 4A program mentioned in Sub-sub-section 7.3.2 were considered as follows:

1. The facility to create group definitions within group definitions would require major amendments to the GAEL 4A program, hence it was decided not to implement this facility for the present project. However, it could be implemented at a later date.

2. Visible grids were not essential for the research project, but would have to be implemented for use of the synthesis program in practice.

7.4.3. Changes for the Evaluation Option.

The following changes and additions to the Dimcheck programs should be effected:

1. The various area and perimeter parameters (See Table 5.1) need to be calculated automatically by the program and set up in matrix form ready for output to the user and for use by the subsequent evaluation program. This could be done by writing internal rules within the program. Input to the program would be an activity space group definition.

2. A numerical program should be appended to the Dimcheck program, which should carry out the necessary evaluation method calculations and allow alphanumerical evaluation output, possibly supplemented by another program which would present the numerical data in graphical form.

3. The dialogue of the DCHECK program must be changed to conform to the input of an activity space group definition and numerical data output options.

7.4.4. General.

The various software specifications are dealt with in Section 9. However, it is worth considering the total design concept again in the light of the acquired programs. At present GAEL 4A and the Dimcheck programs run as separate programs, but this would not be acceptable for use within the proposed design system. The two amended and enlarged programs should be merged using one of the following three approaches, of which the first one is preferable:

1. A control program should be set up giving the user the following options (See Fig. 7.9):

   1.1. The facility to enter the ANALYSIS option, or INFO option, as described.

   1.2. The facility to enter the SYNTHESIS option, which would be the GAEL 4A program.

   1.3. The facility to enter the EVALUATION option, which would consist of the amended and enhanced Dimcheck programs and the evaluation programs, with a choice of either numerical or graphical evaluation output.

2. The ANALYSIS and EVALUATION options could be added as options to the GAEL 4A main program command level (See Fig. 7.10).

3. The programs could be separate as shown in Fig. 7.11, but this approach is by far the least efficient because of all the program entries and exits. It is not anticipated that this approach would be acceptable for an architect in a design situation, as the program switching would disrupt the fluency of the design sequence.

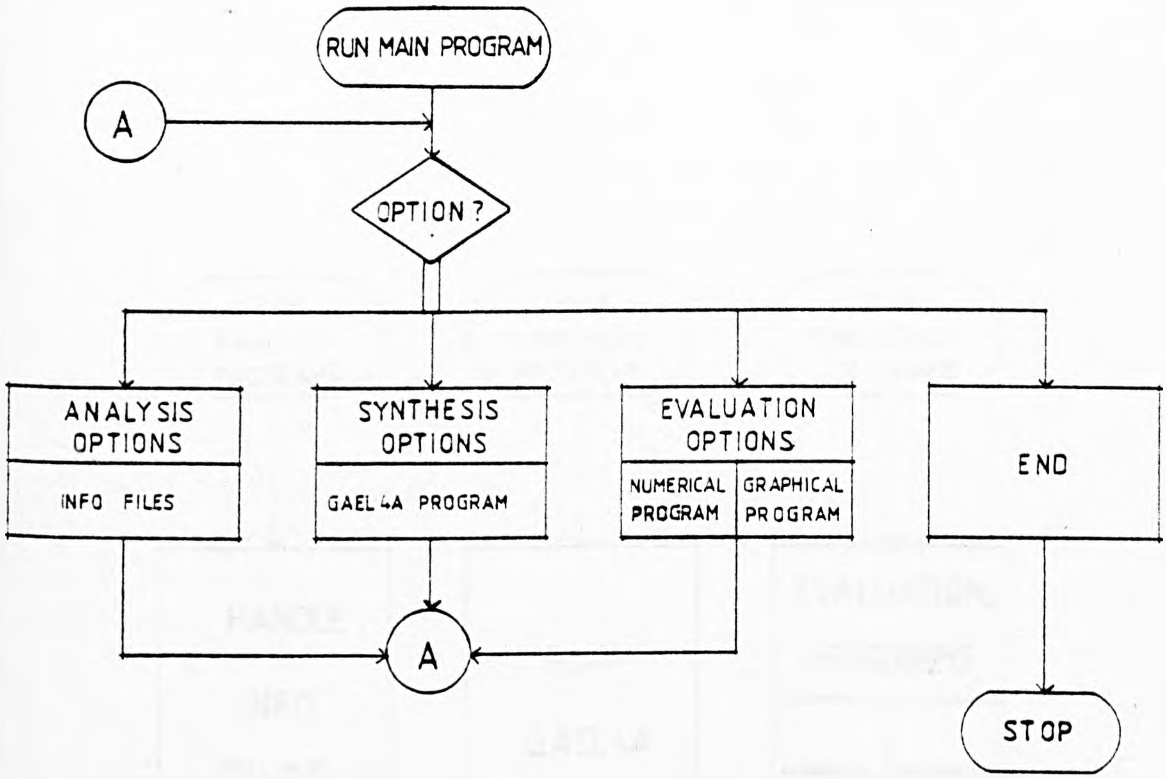

Fig. 7.9. Implementation of the Design System: Option 1.

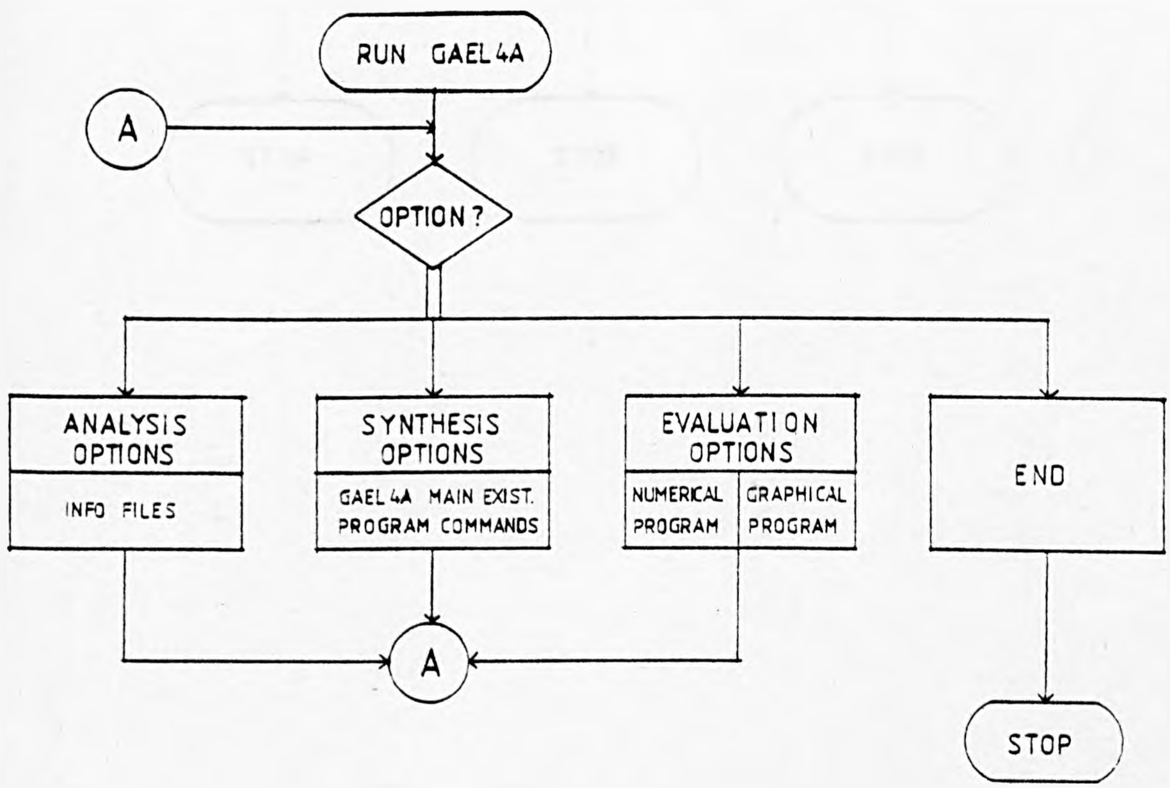

Fig. 7.10. Implementation of the Design System: Option 2.

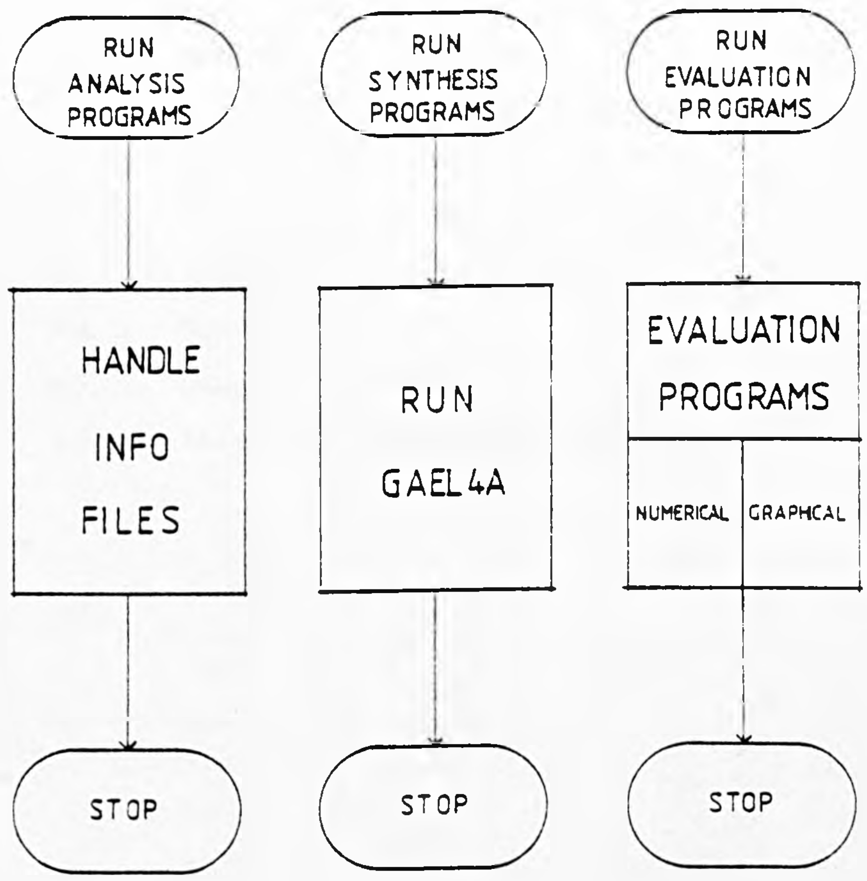

Fig. 7.11. Implementation of the Design System: Option 3.

SECTION 8: THE TOTAL CAAD SYSTEMS MODEL AND HARDWARE REQUIREMENTS

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THE TOTAL CAAD SYSTEMS MODEL AND HARDWARE REQUIREMENTS.

8.1. Introduction.

This section describes the conceptual and physical framework necessary for the implementation of the proposed design system. The software and systems information given is purely conceptual, as details on these matters can be found in Sections 4, 7 and 9. The hardware aspect is given more attention, however.

There are five distinct aspects of the overall design system, and these are:

1. The design sequence or model of the system.
2. The hardware configuration required to implement the systems model.
3. The software components required to implement the systems model.
4. The design components required to implement the systems model.
5. The resultant work station design sequence.

These aspects will now be dealt with in turn.

8.2. The Design Sequence of the System.

The actual conceptual model of the system has been dealt with in Sections 4 and 7, and reference in particular is given to Figs. 4.3 and 7.9. This issue will therefore not be further dealt with in this section (See also 8.1-8.3).

8.3. Hardware Configuration.

Ideally, hardware would have been obtained which would have enabled full implementation of the many facilities in the design system concerning flexibility. However, a second and inevitable alternative was to use the existing hardware facilities available. These two alternative hardware set-ups will now be described.

8.3.1. Optimum Hardware Set-Up for the System.

Fig. 8.1 shows a systems flowchart of what is considered to be an ideal hardware set-up for the present and other similar CAAD systems. The components of the hardware configuration can be described as follows:

1. Input Devices.

1.1. The Terminal:

This should be a large colour refresher graphics terminal. The size of the screen is restricted by current production range, but should ideally correspond to the larger sheets of drawing paper used by architects.

Such a terminal would offer the following advantages:

1.1.1. The screen size would eliminate unnecessary windowing in order to view the whole drawing, and would allow the architect to work to familiar architectural scales. The size would also enable the use of a number of menu, command and text areas on the screen containing libraries of elements, program options and text output (See Sub-section 8.6 below).

1.1.2. The colour faciltity would allow different space categories as well as overlap areas, and lines, to be displayed using different colours and line thicknesses for each type, and would provide a better definition of layouts and a more stimulating working environment than usually available.

1.1.3. The refresher graphics facility and the use of a light pen or cursor and /or joystick would provide the synthesis flexibility necessary for the system. Planning elements from various design level libraries, may for example visually be moved or 'slid' from the appropriate menu area into the right position in the planning area of the screen. This sliding effect would be more useful than the storage tube facility where old images remain until the screen is erased. The refresher facility would also enable use of variable graphs as evaluation output.

1.1.4. Many commands would of course be effected by the terminal keyboard, which could have 'function' keys related to the various program commands, and this would speed up the design mechanics.
Alternatively the keyboard could be replaced by a tablet key-pad and a pen which would increase speed and make commands easier ergonomically.

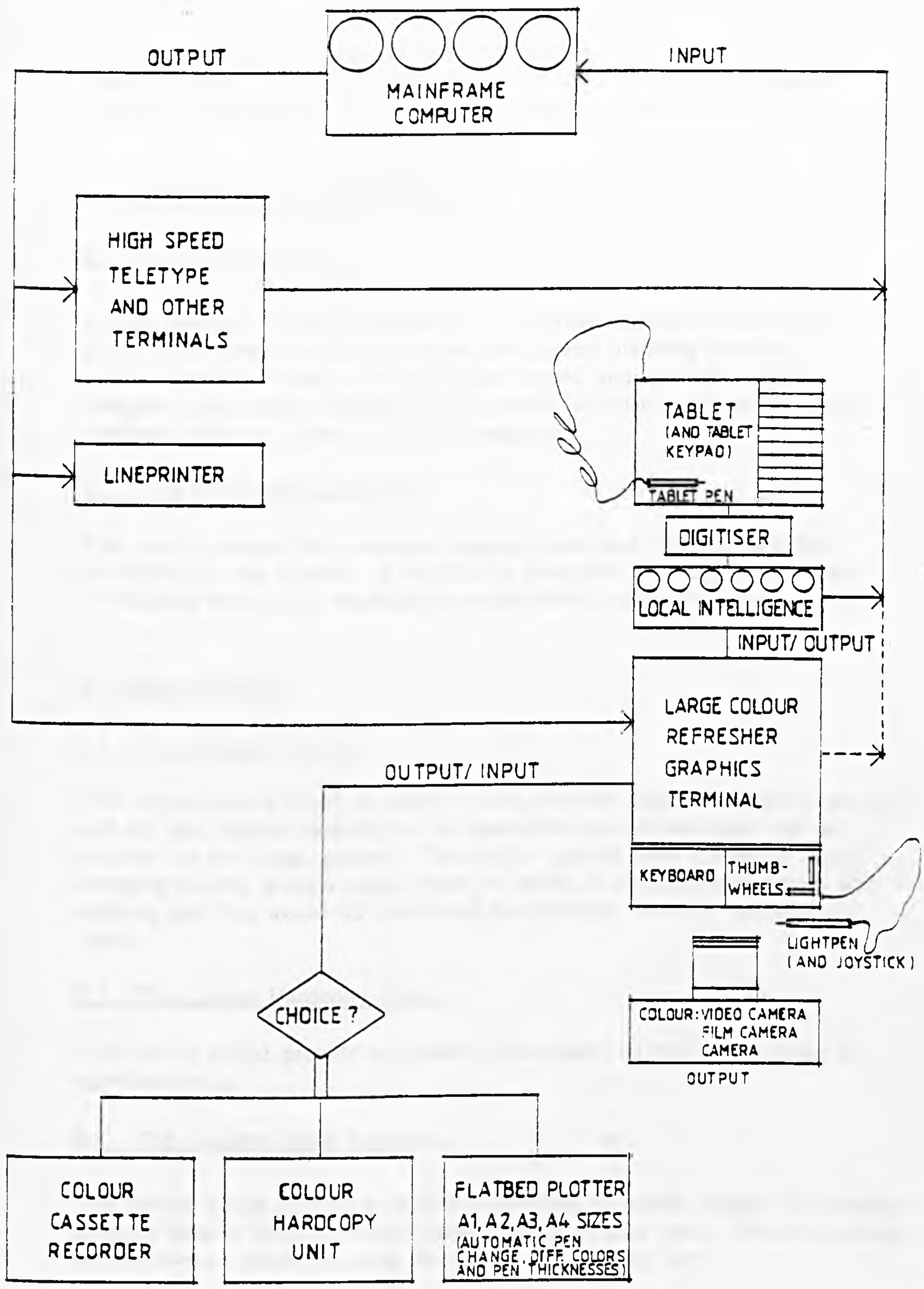


Fig. 8.1. Ideal Systems Hardware Configuration.

1.2. The Tablet:

The tablet should be large (at least A1 size) and have a pen or cursor and a digitiser. This would allow rapid input of drawings. Standard elements and commands could be input from a tablet menu area.

2. Computing and Storage Devices:

2.1. Local Intelligence:

A large amount of local intelligence and storage should be available, as the most frequently used routines and stored planning libraries could be handled locally. Many offices would undoubtedly prefer complete stand-alone systems, as this would eliminate the complications involved in being linked to a main computer.

2.2. The Mainframe Computer:

This would provide the necessary back-up store and computing power to implement the system. A mainframe computer provides a multitude of facilities that would be hard to match with a stand-alone system only.

3. Output Devices:

3.1. The Flatbed Plotter:

This device should be of at least A1 size, possibly supplemented by A4, A3 and A2 size flatbed plotters, or the possibility to set the sheet size as required on the larger plotter. The plotter should have automatic pen changing facility using a large library of pens of different thicknesses and colours, and this would be controlled by software from the terminal or store.

3.2. The Colour Hardcopy Unit:

This device would provide an instant colour copy of the screen image at a reduced scale..

3.3. The Cassette Tape Recorder:

This device would provide a (colour) recording of screen images, of complete program session runs, or of particular layouts or part runs. These recordings can be re-run repeatedly using the screen as a display unit.

3.4. The Colour Video or Film Camera:

These devices would allow recordings of program sessions and can be shown to audiences repeatedly. They are ideal for session demonstration packs, particularly for educational courses.

3.5. The Camera:

The camera allows colour photos or slides to be taken of complete sessions or particular program or layout segments.

3.6. The High-speed Teletype:

This device would allow a rapid input/output device of alphanumeric evaluation data, program listings etc.

3.7. The Terminal and Other VDUs:

As described earlier.

8.3.2. Available Hardware Set-up at the SSSA.

Fig. 8.2 shows the available hardware configuration which is presently being used for the implementation of the proposed design system. Further description of this set-up should be unnecessary and reference is made to the various manuals (8.4 -8.14). The following comments can be made:

1. The Calcomp plotter is not set up to be used with the amended GAELIC programs at present, but this is readily implemented.

2. The video recorder camera available is a black and white camera,

3. The joystick has not been found as ergonomically satisfying to use as the cross-hair thumb-wheels on the terminal.

4. The tablet has been enhanced by a key-pad menu system which is described under software in Sub-section 8.4.

5. The Tektronix flatbed plotter has only recently been acquired and therefore not been used for the present project, except for output from the graphical evaluation program (See Sub-section 10.5.2).

8.4. Software Components.

The software consists of the analysis, synthesis and evaluation programs described in Sections 7, 9 and 10.

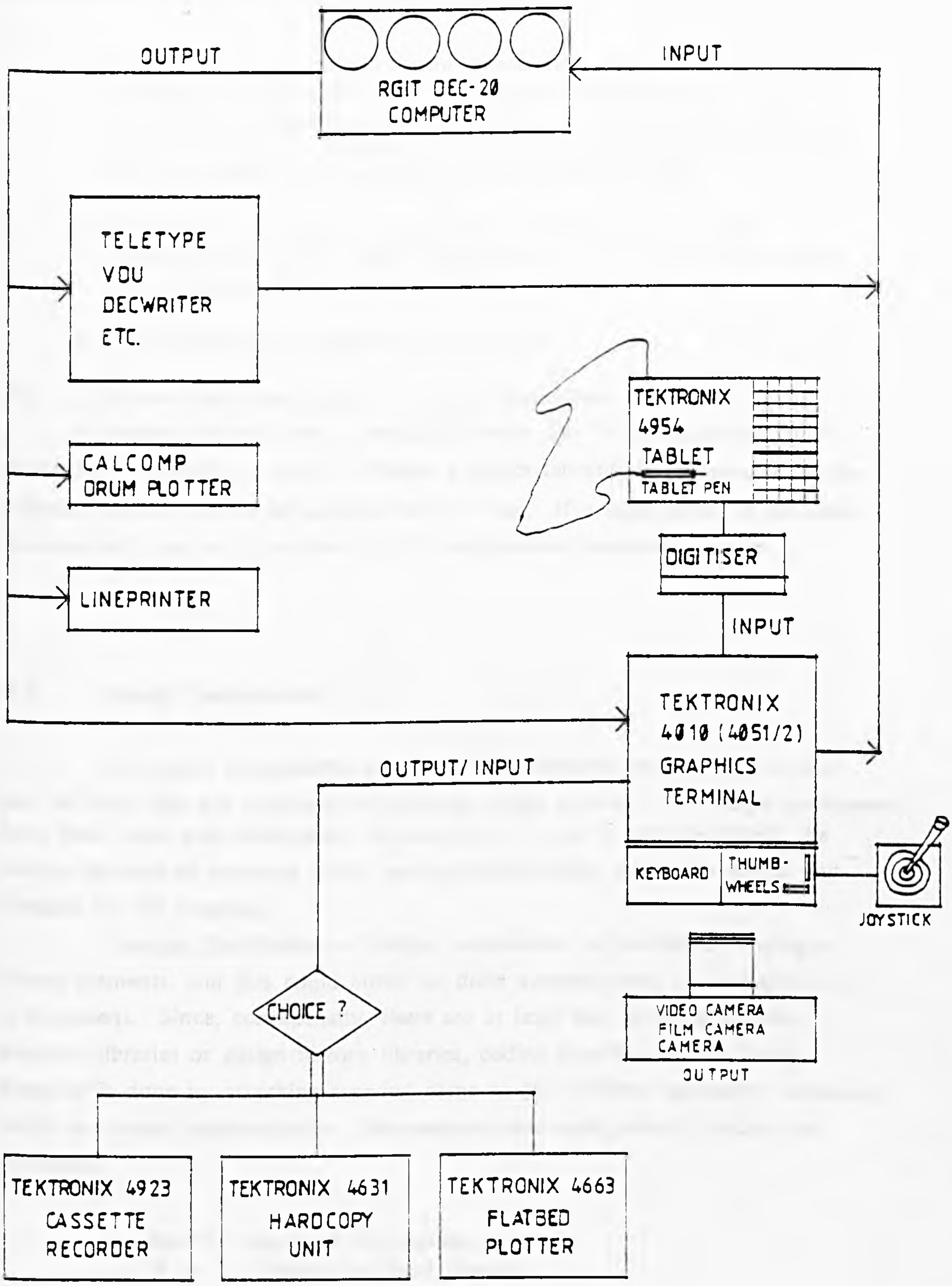


Fig. 8.2. Present Systems Hardware Configuration.

The programs each contain three common facilities:

1. The facility to automatically or interactively process the analysis synthesis and evaluation input and design components as described in Sub-section 8.5 , by using the various manipulation and other program routines. These routines include the interaction of data between the synthesis and evaluation programs.

2. The facility to enable storage of the analysis, synthesis and evaluation input and design components in a data structure which can be re-accessed.

3. The facility for design input and output.

Fig. 8.3 shows asimplified diagram of the software data flow.

At present the software is compatible with the Tektronix storage tube terminals. If, ideally, a colour refresher graphics terminal is obtained, then the software would have to be adapted for such use. If a large screen is obtained, routines will have to be written for the menu-system mentioned earlier.

8.5. Design Components.

By design components are meant the elements, graphic shapes, text and so forth that are necessary for creating design layouts. The design components have been dealt with particularly in Sections 2, 3 and 4, and are mainly the various libraries of elements at the various design levels, which are stored and handled by the program.

Storage classification of design components is possible by coding of library elements, and this could either be done automatically, or manually as it is at present. Since, conceptually, there are at least two types of libraries, standard libraries or design history libraries, coding classification of library elements is done by attaching a coded name to the elements' geometric attributes, which are stored automatically. The element code-name should contain the following:

1. NAME - Name of the element.
2. M or F - Movable or fixed element.
3. LEVEL No. - Design Level Number.
4. S or H - Standard or Design History Library.
5. SIZE - Indication of size of element.
6. VERSION No. - Each basic element has a number of versions.
7. SCHEME - Name of building design or scheme.
8. DATE - Date of creation.

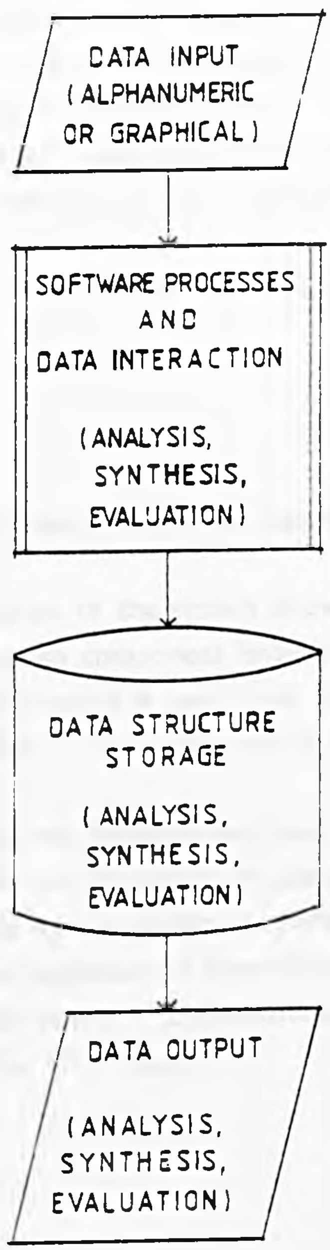


Fig. 8.3. Simplified Diagram of the Data Flow in the Design Systems Software.

Unfortunately, groupname length in GAEL4A is restricted to 6 characters, which rules out content of all the information required; However, for reasonably small designs it is possible to simplify the code names used. Development of a more complex coding system, which would form a tree structure, was not found necessary within the present research project, but will require future development if a completely comprehensive and methodical system is required. It is anticipated that one method of dealing with the coding problem is to keep a small code-name 'visible' to the user and a 'hidden' code-name in the Analysis INFO files which would contain complete coding information, in which case name size or complexity is no longer a program problem.

Design components are data, handled by the design systems model, i.e. by the hardware and software.

8.6. The Complete CAAD Work Station Sequence.

The CAAD work station of the system allows the user, in terms of the hardware, software and design component implementations, to follow the intended design sequence (See Sections 4 and 7 and Figs. 4.3 and 7.9). Fig. 8.2 is an illustration of the presently used work station, and Fig. 8.4 shows a typical design procedure.

If a large refresher screen becomes available, the use of flexible menu, planning and text areas directly on the screen in conjunction with a light pen should be implemented, as this would provide an extremely flexible and powerful design tool. Fig. 8.5 shows a suggestion of how the screen area could be subdivided for the proposed design system. Implementation of a tablet menu area is shown in Section 9 (The GAEL 4T Program).

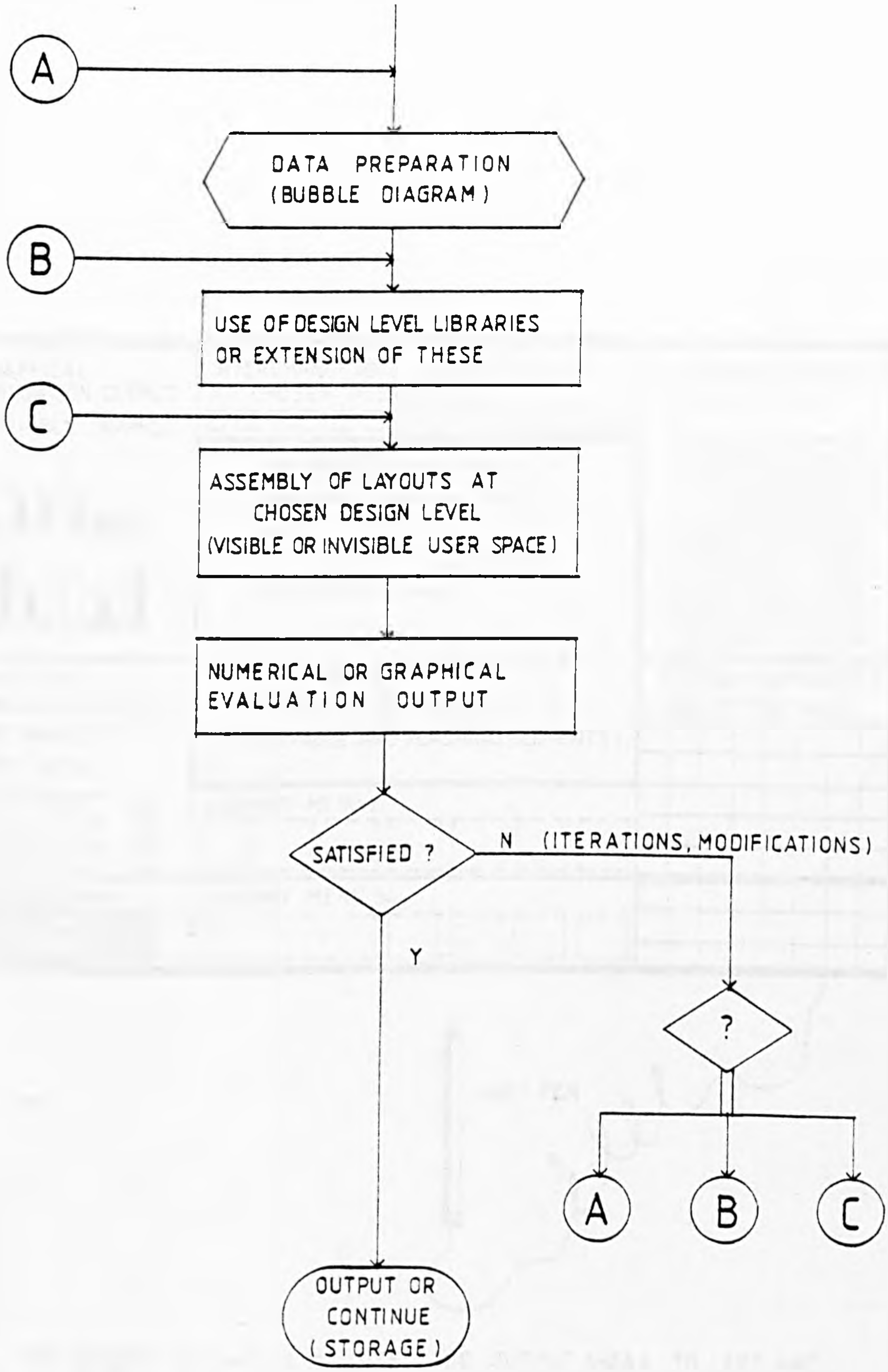
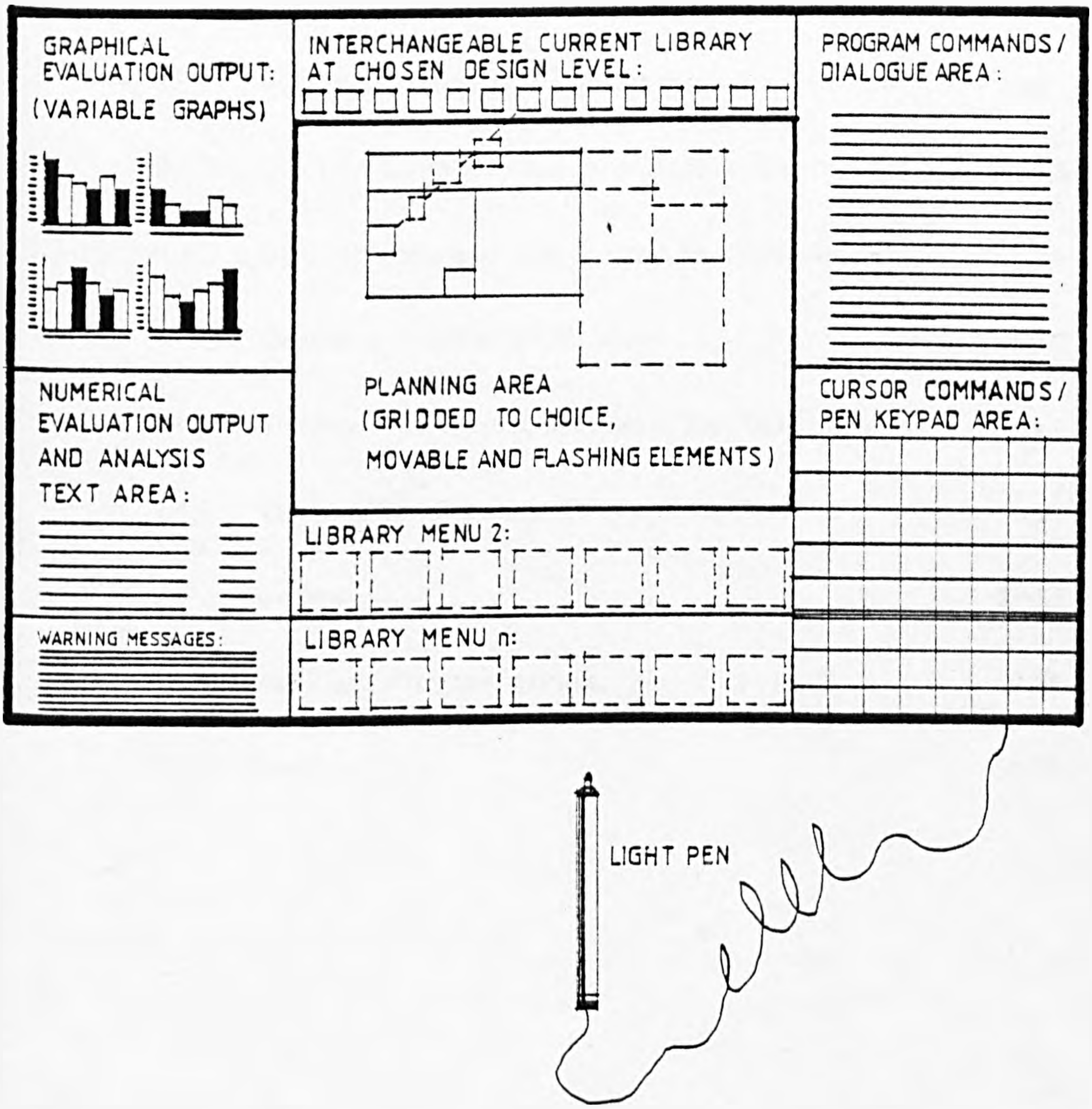


Fig. 8.4. Typical Design Procedure.



NOTE: THE SCREEN RESEMBLES A1 SIZE. THE OUTPUT AREAS TO LEFT AND RIGHT ARE TO A4 SIZE AND THE PLANNING AREA TO A2 WIDTH, HEIGHT DEPENDING ON NO. AND SIZES OF LIBRARY MENUS CHOSEN.

Fig. 8.5. Proposed Screen Area Sub-division.

SECTION 9: NEW SOFTWARE SPECIFICATIONS

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NEW SOFTWARE SPECIFICATIONS.

9.1. Background and Overall Software Logic.

The overall software model and sequence adheres to the design systems model as described above (See Sections 4 and 7, and Figs. 4.3 and 7.9). A control program should be set up, in which the user has the option to enter the analysis, synthesis or evaluation programs as shown in Fig. 9.1. These sub-programs are partly specified for this project only and partly making use of the GAELIC programs as indicated in Fig. 9.1 , and will in the following be treated as separate programs.

The actual program specifications were made in varying detail for the various programs (9.1). This was because the programming was undertaken by others, and, because certain specifications required only fairly routine programming for implementation, whereas others required more complex programming. Most of the programming work was carried out by Martin McLachlan of the RGIT Computer Services Unit, except implementation of the GAEL4T Graphics Tablet Program, which was carried out by W. McCombie under the direction of Dr. John Eades of the Department of Electrical and Electronic Engineering, RGIT.

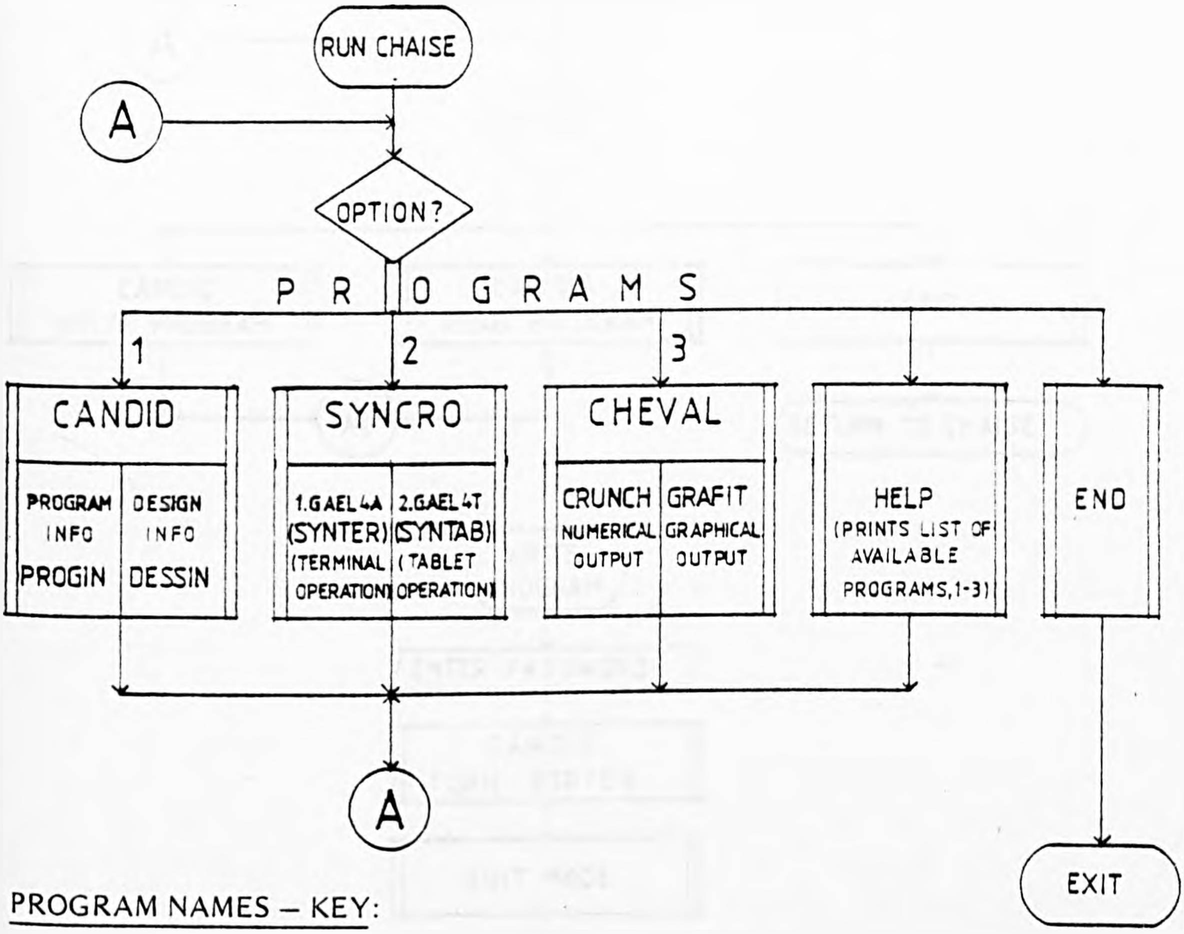
9.2. Analysis Program Specifications.

The Analysis Program should be one or a series of data-files, arranged as shown in Fig. 9.2, to enable the user to read or add information on the following:

1. Program Information.
2. House Design Information.

The information should be classified into a number of sub-options for the two main options, as indicated in Fig. 9.2. It was not found necessary to actually compile such information to assist the present research project, so that the specification is only in "skeletal" form at present. However, any required information on any house design topic can be entered by users of the program from relevant sources (See Sections 2, 3 and 4) at any time. Program information should include essentials from Section 10 below, as an "on-the-system" program user manual.

Readout from the information files is unrestricted, but editing is restricted to privileged or experienced users only, who are only allowed access to the WRITE Program



PROGRAM NAMES – KEY:

1. MAIN PROGRAM	= CHAISE –	Computer House Analysis Information, Synthesis and Evaluation package.
2. ANALYSIS PROGRAM	= CANDID –	Computer ANalysis Design Information Device.
2.1. PROGRAM INFORMATION	= PROGIN.	
2.2. DESIGN INFORMATION	= DESSIN.	
3. SYNTHESIS PROGRAMS	= SYNCRO –	SYNthesis Computer Routines Operations.
3.1. TERMINAL PROGRAM	= GAEL 4A (SYNTER).	
3.2. TABLET PROGRAM	= GAEL 4T (SYNTAB).	
4. EVALUATION PROGRAMS	= CHEVAL –	Computer House EVALuations.
4.1. NUMERICAL PROGRAM	= CRUNCH –	Calculation RUNs of Computer Houses layouts (includes Dimcheck).
4.2. GRAPHICAL PROGRAM	= GRAFIT –	GRA(PH)ical house evaluation Interpretation Trials.

Fig. 9.1. Overall Software Logic.

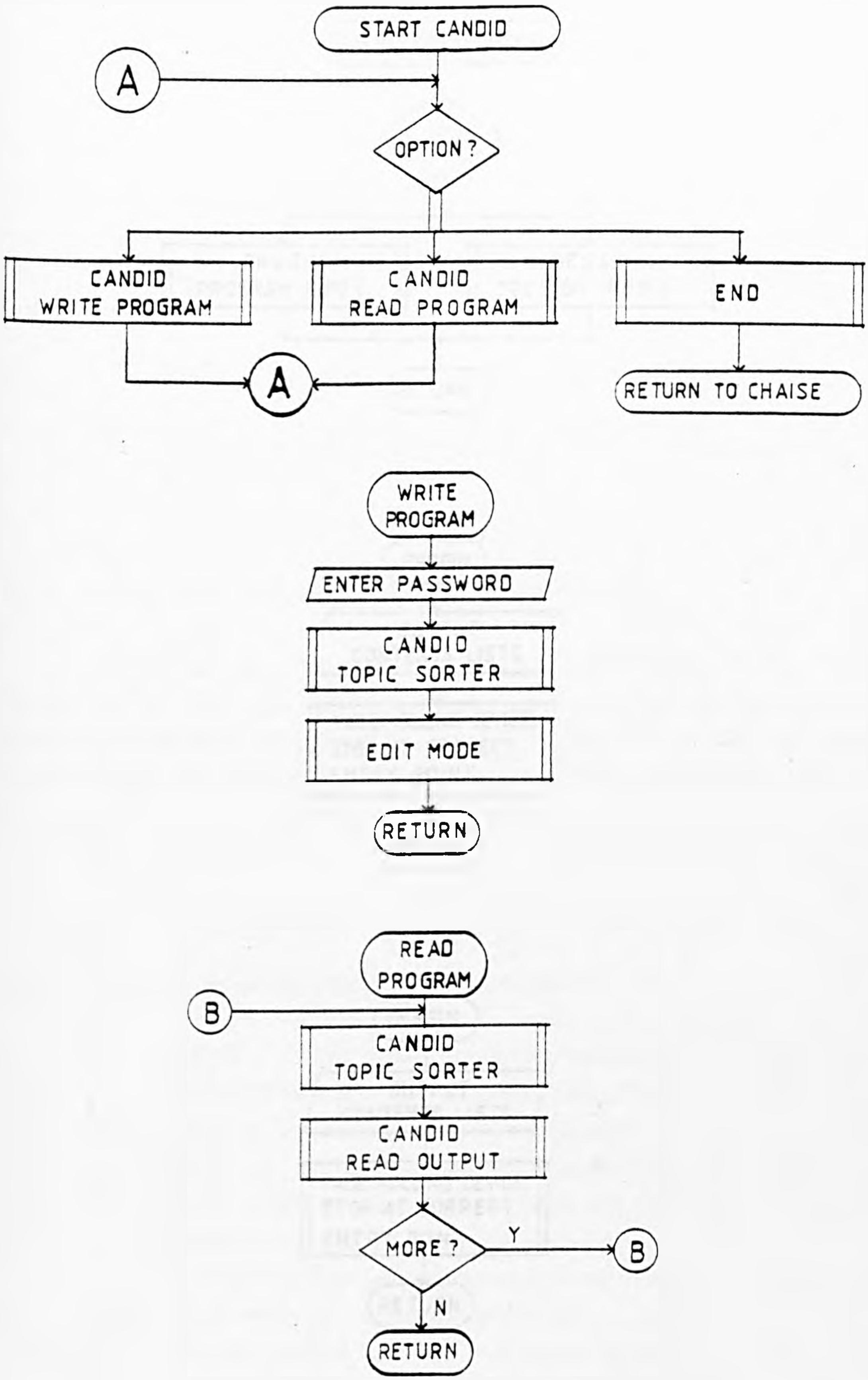
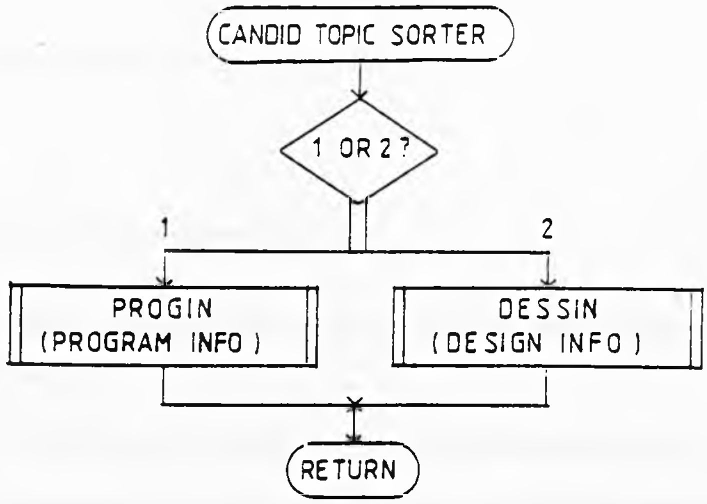
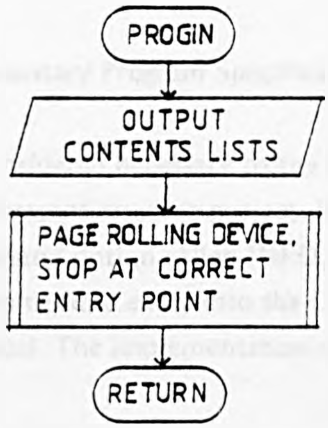


Fig. 9.2. Simplified Flowchart of the CANDID Programs.





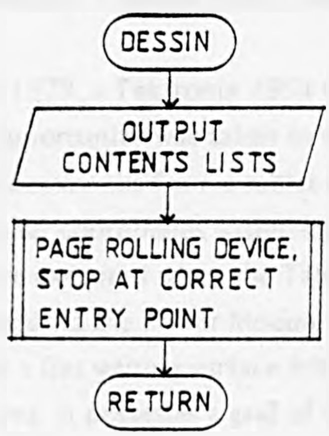


Fig. 9.2. (Continued).

by entering a legitimate password (See again Fig. 9.2).

9.3. Synthesis Program Specifications.

The present Synthesis Option of the proposed design system is implemented by two optional programs:

1. The GAEL4A program as described in Sub-subsection 7.3.2.
2. An enhanced version of GAEL4A which enables program control and data input by means of the Tektronix Graphics Tablet, as described below.

9.3.1. GAEL 4A Complementary Program Specifications.

No changes were considered necessary to the GAEL4A program (See Sub-subsection 7.4.1) for the present research project. However, it is desirable that an additional main program command option called INFO, should be implemented, which would allow the user to gain immediate entry into the CANDID PROGIN file, for perusion of the GAEL4A Manual. The implementation of this INFO option is routine programming.

9.3.2. GAEL4T Complementary Program Specifications.

At the beginning of 1979, a Tektronix 4954 Graphics Tablet was purchased by the SSSA (9.2, 9.3), and the opportunity was taken to amend GAEL4A to allow the user to input data as well as cursor commands from a tablet menu (9.4, 9.5). Commands were executed by associating particular coordinates within squares on the tablet with the relevant commands, which were executed when the Tablet Pen was pressed in the squares and the coordinates were digitised via the Power Module digitiser.

The 4954 Tablet has a flat writing surface with approximately 40 x 30 inches (1014 x 760 mm) of useable area. It possesses a grid of 4096 x 3120 points, which corresponds exactly to the viewable, addressable screen coordinates on the 4014 Terminal, and is also compatible with the viewable addressable screen coordinates (1024 x 780) on the 4010 Terminal.

The tablet area was sub-divided into a planning area, a GAEL4A cursor command area, and a planning element library area as shown in Figs. 9.3 and 9.4.

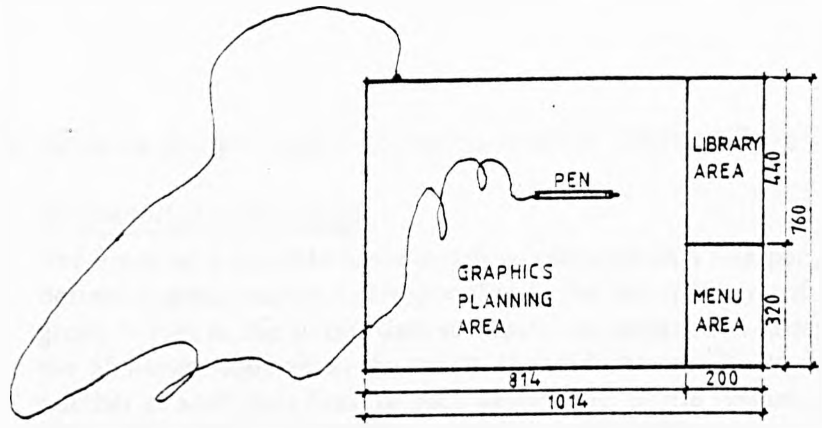


Fig. 9.3. GAEL4T Tablet Area Sub-division.

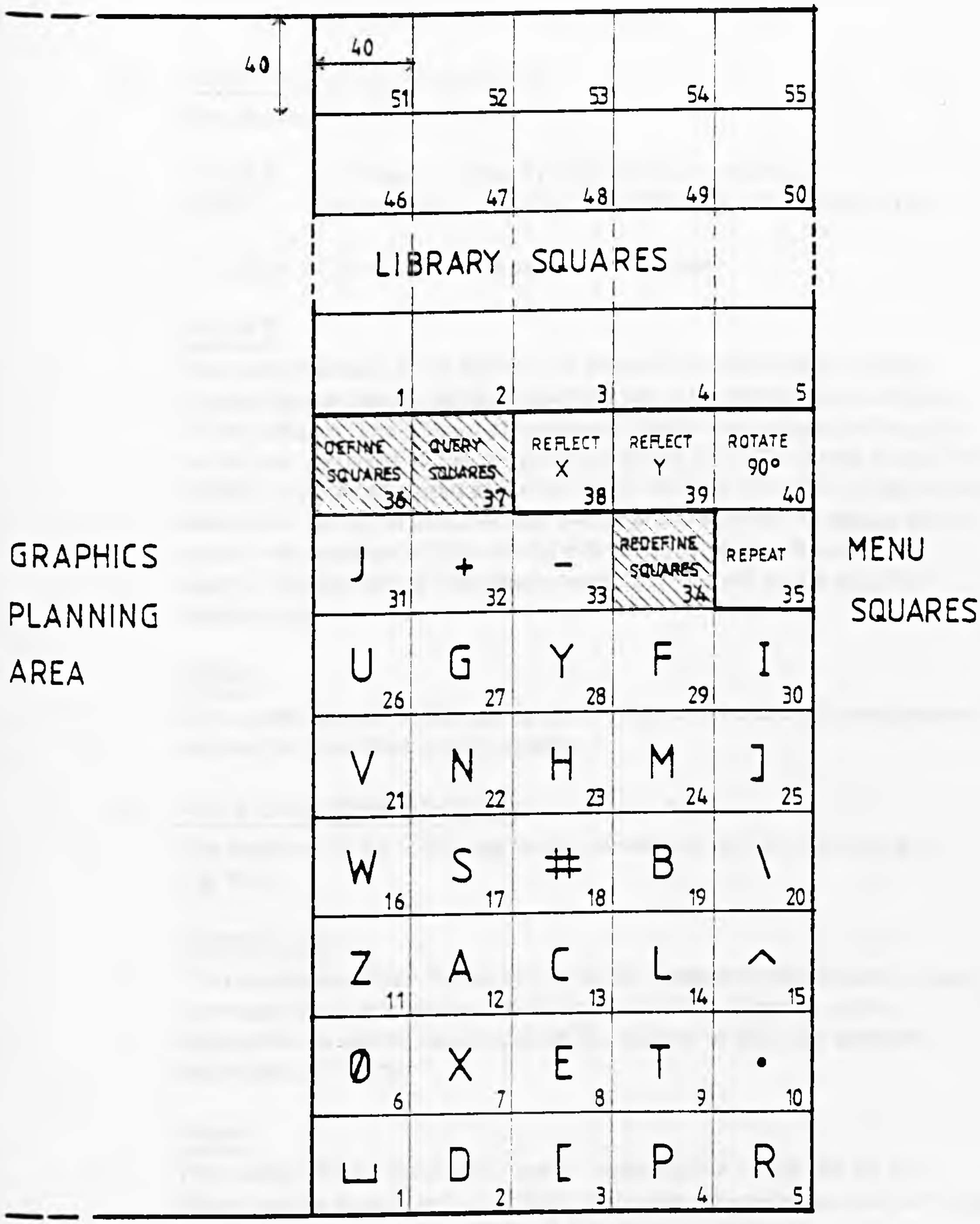


Fig. 9.4. GAEL4T Menu and Library Area Sub-divisions.

The following changes required to be made to the GAEL4A Program:

1. <u>At the Initialisation Stage:</u>

   The entry of a data file name which would contain a number of user-definable group-names, corresponding to the list of library of element group names in the layout data structure and assigned in order of entry to the 55 library squares on the tablet. It should be possible to define any number of such data files for each design level of the system, and to change the name of the library data file at any point in the program, which would re-assign group-names to be associated with the tablet library squares. The restriction of group names to 55 was because of the allowance of pen position tolerance and digitising errors.

2. <u>At the Program Command Level:</u>

   The addition of two options:

   INSERT – DEFINES A NEW SET OF GROUP NAMES
   SHOW – SHOWS WHAT EACH DEFINED SQUARE CONTAINS.

   The effect of these options should be as follows:

   <u>INSERT:</u>

   This option should allow the user to re-name the data file of library element group names, thereby assigning new groupnames to the tablet library squares. The various group name library files should be creatable by the user external to the program, using the DEC-20 editing mode. The INSERT command would allow use of the overlay principle to the library area of the tablet, in that the user could have a number of tracing paper sheets with symbols of the various elements for each defined library square. The content of the sheets should correspond to the data file groupnames.

   <u>SHOW:</u>

   This option should enable a printout of the current data-file groupnames assigned to the tablet library squares.

3. <u>At the Cursor Command Level:</u>

   The addition of the following cursor commands (shown shadowed in Fig. 9.4):

   <u>Define Square:</u>

   If no groupname data file is entered at the program initialisation or main command level, this option should enable individual group name designation to library squares, since the squares in this case are non-designated or "empty".

   <u>Query:</u>

   This option should enable the user by pressing the tablet pen on any library square area to get a printout of the groupname associated with that square, or, alternatively, tell him if the square is "empty".

Redefine Squares:

This option allows the user to press the pen on any library square and re-assign a new individual groupname to be associated with that square.

Other Cursor Commands:

Certain cursor commands should be added which should allow reorientating a shape (See menusquares 38—40) or repeating a shape (square 35). These options exist as subsequent commands when creating shapes in GAEL4A, where shapes are orientated according to a movement code (9.6). Their automatic pen implementation does however make this facility easier to carry out.
The cursor command O for closing a rectangle or ending a line is a default command in GAEL4T, i.e., once L or R is pressed the program only expects a new set of co-ordinates to complete the shape. Pressing a library menu square, following a G command, will enable plotting of the associated element. The INFO command should be added to GAEL4T as for GAEL 4A.

The GAEL4T Program operation is described in Sub-subsection 10.4.2.

9.4. Evaluation Program Specifications.

The Evaluation Option of the proposed design system was implemented according to specifications for a numerical evaluation program and an associated graphics output program, as follows (9.7):

9.4.1. The Numerical Evaluation Program Specifications.

The numerical evaluation program specifications, as detailed in Sub-subsection 7.4.3, were effected in the following sequence:

1. Initial Dimcheck Calculations:

   Calculations of the Evaluation Method for the efficiency of design level 3 activity spaces requires registration and tabulation of the following:

   1.1. A list of the design level 1 single elements contained in a room or activity space, i.e. a list of the groupnames.

   1.2. For each dimensioned single element or group definition, automatic calculation of the various component areas in square meters:

A.E. (Sum of all masks)
A.S (Mask 1)
A.U1 (Mask 2)
A.U2 (Mask 3)
A.U1 +U2 (Mask 2 + mask 3)

1.3. A list of pairs of overlapping elements within the evaluated activity space.

1.4. For each pair of overlapping elements, the calculation of a list of overlap instances and areas of these in square meters, as well as their sum (Σa.O1). The 9 possible 1st. order overlaps are:

a.o1	(E1.S :	E2.S)	–	1:1
a.o1	(E1.S :	E2.U1	–	1:2
a.o1	(E1.S :	E2.U2)	–	1:3
a.o1	(E1.U1 :	E2.S)	–	2:1
a.o1	(E1.U1 :	E2.U1)	–	2:2
a.o1	(E1.U1 :	E2.U2)	–	2:3
a.o1	(E1.U2 :	E2.S)	–	3:1
a.o1	(E1.U2 :	E2.U1)	–	3:2
a.o1	(E1.U2 :	E2.U2)	–	3:3
Σ a.o1				

1.5. For all the overlapping pairs of elements, a summing up of the overlapping areas for all the 9 possible overlap instances (See Table A2.3, extended to 9 overlap instances).

1.6. If a 1:1 overlap instance occurs, the output of a bell signal from the terminal and a warning message, listing names of the offending elements.

1.7. The calculation of the total of 2nd order overlapping element areas for the evaluated activity space (A.02) in square meters.

1.8. Calculation of the area within the bounding rectangle (mask 6) of the activity space (A.R) and the square root of this area ($+\sqrt{A.R}$), in square meters.

1.9. A calculation of the perimeter length, P.R of the bounding rectangle of the activity space in meters.

2. Initial Numerical Program Parameter Calculations:

The following parameters, previously defined in Section 4 and in Table 5.1, should be calculated in square meters and meters as appropriate:

A.R.(as above)
A.BR
A.F
A.O1
A.O2
A.OU
A.O3
A.S
A.U.(TOT)
A.FMO
A.U.(UNION)
A.E.(UNION)
A.NSR
A.NSF
A.NO

P.R
P.F.

All Dimcheck (DCHECK) area calculations are calculated in microns^2 (=mm^2) and should therefore be converted to m^2 (1m^2 = 1.000.000 mm^2).

3. Standard or User Definable Overlap Penalty Libraries:

The user should have two main options:

3.1. The W.01 Penalty Libraries:

There should be two of these:

3.1.1. The W.01 Standard or Default Penalty Library:

This library should be as shown in Table 4.1, with the additions of the following instance weighting factors:

2:1 = 4
3:1 = 3
3:2 = 2.

3.2.2. The W.01 User Definable Penalty Library:

This library would allow the user to change the weighting factors in the W.01 Standard Penalty Library, for all the 9 overlap instances. Values entered here will only be stored for the current program run, or until the user changes the weighting factors again in the current run.

3.2. The Probability of Usage Library:

This library is based on the probability of usage of each space category of any element. The penalties incurred when space categories of two elements overlap are shown in Table 4.2. In this case, the penalty weighting factor for an overlap instance becomes the product of the two associated probabilities of usage. At present, no sufficient data exist to assign probabilities of usage to element space categories. However, it is possible to set up and use this type of overlap penalty mechanism to experiment with different probability of usage input, or await proper data availability.

Since it is not estimated that the user would be able to enter probabilities of usage himself, no user definable library of this type is proposed. An "empty" or experimental matrix data-file should be set up external to the CRUNCH program for entry of probabilities of usage by experienced program users only, by means of normal DEC-2Ø editing facilities. The name of this data file is PROBL.DAT, and should be constructed as follows:

3.2.1. For each element, probabilities should be enterable as shown in Table 9.1. Probabilities may vary for one element, according to which type of activity space it is to be used in.

3.2.2. The interrelationships between the various types of probabilities to be entered into the probability of usage file can be expressed by means of the formulas shown in Table 9.2. Symbol notations are defined in Table 9.1. The important probabilities are P(1), P(2), and P(3), since these are used in the calculation of probability penalty products when two elements overlap (See again Table 4.2).

3.2.3. It can be seen from the above formulas that it is only necessary to know P(1,2)occ. and P(1,2,3) occ. for example, and the remainder of the parameters may be calculated by a small computer program or subroutine which could work in conjunction with PROBL.DAT. However, for the present research project, no use was made of the probability file as such, and so this automatic probability parameter calculation routine was not implemented. Instead, for the current activity space, the user can enter all relevant probabilities in PROBL.DAT in normal editing mode, and if this type of overlap penalty option is chosen, the CRUNCH program will retrieve the appropriate probability values from the file for subsequent calculations.

The CRUNCH program should provide the facility to inspect the three penalty libraries whilst running the program.

4. Efficiency Component Calculations:

E.R and its component values O.P, P.P and A.P, as well as the sub-ratios of these components, should be calculated as follows:

4.1. O.P:

$$O.P = \frac{\Sigma(A.01 \times (W.01 \text{ or } pxp'))}{A.01}.$$

The numerator in this expression may be calculated by multiplying the sums of instance overlap areas for the whole activity space by the appropriate penalty weighting factors and adding these together (See Table A2.3). This calculation may be done in the following two ways, depending on the user's choice of penalty libraries (See CRUNCH flowchart below):

4.1.1. If the standard or user defined W.01 library is chosen, then (ΣA.01 x W.01) is calculated as shown in Table A2.3.

Table 9.1. Probability of Usage File Content and Notation.*

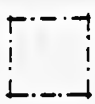
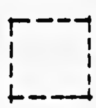
ELEMENT NAME	ACTIVITY SPACE TYPE 1	----------→	ACTIVITY SPACE TYPE N
NAME 1	P(1) UNOCC.		
	P(1,2) OCC.		
	P(1,2,3) OCC.		
	P(1) = 1.0 (ALWAYS)		
	P(2)		
	P(3)		
↓			
NAME N			

NOTATION:

P(1) UNOCC. = Probability of the Solid being unoccupied.
P(1,2) OCC. = Probability of the Solid and User Space 1 only being occupied.
P(1,2,3) OCC. = Probability of Solid, User Spaces 1 and 2 being occupied.
P(1) = 1.0 = Probability of Solid being present.
P(2) = Total probability of User Space 1 being occupied.
P(3) = Total probability of User Space 2 being occupied.

*NOTE: See Table 9.2 for probability relationship formulas.

Table 9.2. Probability of Usage Relationship Formulas.*

STATE OF OCCUPANCY	SPACE CATEGORY PRESENT (1 / 2 / 3)	ASSOCIATED PROBABILITIES AND RELATIONSHIPS
UNOCCUPIED		P(1) UNOCC.=P(1)-P(1)OCC.=P(1)–P(1,2)OCC.-P(1,2,3)OCC.
OCCUPIED		P(1,2)OCC.=P(1)-P(1)UNOCC.-P(1,2,3)OCC.
		P(1,2,3)OCC.=P(1)–P(1)UNOCC.–P(1,2)OCC.
TOTALS OCCUPIED		P(1)OCC.=P(1)–P(1)UNOCC.= P(1,2)OCC.+P(1,2,3)OCC.=P(2)
		P(3)=P(1,2,3)OCC.
		P(2)=P(1,2)OCC.+P(1,2,3)OCC.=P(1)OCC.
		P(1)=1.0=P(1)UNOCC.+P(1,2)OCC.+ P(1,2,3) OCC.

*NOTE: See Table 9.1 for notation of symbols.

4.1.2. If the probability of usage library is used, then (Σ A.01 x p x p′) must be calculated as follows:

1. The probability product for overlap instances should be calculated for each overlapping pair of elements as shown in Table 4.2.

2. For each pair of overlapping elements, the probability products should be multiplied by the appropriate instance overlap areas.

3. The (a.01 x p x p′) products for each pair of overlapping elements should be summed up.

4. The sums of (a.01 x p x p′) for each pair of overlapping elements should be summed up for all the overlapping pairs of elements within the activity space to form the total (Σ A.01 x p x p′).

4.1.3. Calculate O.P as per formula expression.

4.2. P.P:

Calculate: $$\text{P.P} = \frac{\text{P.R}}{+\sqrt{\text{A.R}} \times 4}.$$

4.3. A.P:

4.3.1. The ratios of A.P should be calculated as per the two alternative formula expressions for A.P:

$$\text{(1) A.P} = \left\{ \frac{\text{A.S}}{\text{A.FMO}} + \frac{\text{A.U.(TOT)}}{\text{A.FMO}} - \frac{\text{A.01}}{\text{A.FMO}} + \frac{\text{A.02}}{\text{A.FMO}} + \frac{\text{A.BR}}{\text{A.FMO}} \right\}$$

$$\text{(2) A.P} = \left\{ \frac{\text{A.01}}{\text{A.FMO}} - \frac{\text{2 A.02}}{\text{A.FMO}} + \frac{\text{A.NO}}{\text{A.FMO}} + \frac{\text{A.BR}}{\text{A.FMO}} \right\}.$$

The various ratios should be output in the following order:

(1) $\frac{\text{A.S}}{\text{A.FMO}}$

(2) $\frac{\text{A.NSR}}{\text{A.FMO}}$

(3) $\frac{\text{A.U.(UNION)}}{\text{A.FMO}}$

(4) $\frac{\text{A.E.(UNION)}}{\text{A.FMO}}$

(5) $\frac{\text{A.BR}}{\text{A.FMO}}$

(6) $\dfrac{A.U.(TOT}{A.FMO}$

(7) $\dfrac{A.01}{A.FMO}$

(8) $\dfrac{A.02}{A.FMO}$

(9) $\dfrac{A.OU}{A.FMO}$

(10) $\dfrac{A.NO}{A.FMO}$

(11) $\dfrac{2 \times A.02}{A.FMO}$.

4.3.2. Calculate A.P as per formula expression, and check by calculating:

$$A.P = \frac{A.R}{A.FMO} .$$

4.4. E.R:

Calculate the efficiency of the activity space as per the simplified formula:

$$E.R = O.P \times P.P \times A.P .$$

Check by calculating E.R as per the two full formula expressions shown in Sub-subsection 4.4.2.

5. Storage of Data:

Analysis information is stored, as described above, in the appropriate INFO files, and the synthesis layouts and single element libraries are stored in the ring data structure file generated by the GAEL4A or GAEL4T programs.

The GAEL4A program is used in such a way that an activity space layout is a group definition in GAELIC terminology. Ideally, the programs should store data as indicated in Table 9.3. The nature of storage for activity spaces would then be as follows:

5.1. GAEL4A stores an activity space type with an appropriate name.

5.2. The ring data structure files for the various types of domestic activity spaces contain group definitions corresponding to:

5.2.1. Single elements.

Table 9.3. Data Storage System.

GAELIC RING DATA STRUCTURE FOR ACTIVITY SPACE TYPE	ORIGINAL VERSION OF ACTIVITY SPACE	SUBSEQUENT ACTIVITY SPACE VERSIONS	ASSOCIATED EVALUATION DATA FILES
FILE 1. RNG	GROUP 1.1		FILE 1.1. DAT
		GROUP 1.1.1	FILE 1.1.1. DAT
		¦	¦
		GROUP 1.1.n	FILE.1.1.n.DAT
¦	¦	¦	¦
FILE n.RNG	GROUP n.1		FILE n.1.DAT
		GROUP n.1.1	FILE n.1.1.DAT
		¦	¦
		GROUP n.1.n	FILE n.1.n.DAT

5.2.2. Different designs of the particular type of activity space stored in the data structure. These designs may be named as original versions of design layouts.

5.2.3. Each time the user amends the original version of an activity space layout, the original should be retained and a new version automatically generated. In this way a number of successive versions will result. This system could of course be extremely elaborate, and the proposal is only general in so far as users may have different storage requirements. It is advisable that layout version layouts should be restricted by giving the user the option to delete unwanted layouts.

5.3. When a data structure group definition is evaluated by the CRUNCH numerical evaluation program, the calculations should be saveable by the user into a data file bearing the same name as the group definition (i.e. the activity space name). The SAVE routine could be automatic, or interactive to reduce the number of evaluation data files, and thereby saving computing time.

5.4. Since design level 3 standard, as well as design history layouts are stored as group definitions, evaluation data files can be generated for these layouts as well.

It is anticipated that the evaluation method itself will be extended to include efficiency evaluation of complete floor plans. In this case, a floor plan will simply be a higher design level group definition, coded accordingly for recognition. A full specification of storage facilities for complete floor plans will have to be made at the appropriate future implementation stage. For the present research project it is sufficient to give the user the facility to save data evaluation files and give these files names. Once saved, the data files can be used for future evaluation program runs of the associated activity space, and this would save computing time as calculations would not have to be repeated.

Storage will be further dealt with in Section 10.

6. Program Logic:

The internal program working of CRUNCH is shown in Fig. 9.5, of which further clarification of three points follows:

6.1. Evaluation Data Files:

These files contain the tabulated value results for activity spaces for previous evaluation program runs. If such a file exists, bearing the same name as the activity space entered, the program will retrieve these values rather than re-performing evaluation calculations. Since the calculations take a while for the computer to perform, use of the existing data file values will result in quicker progression for the user.

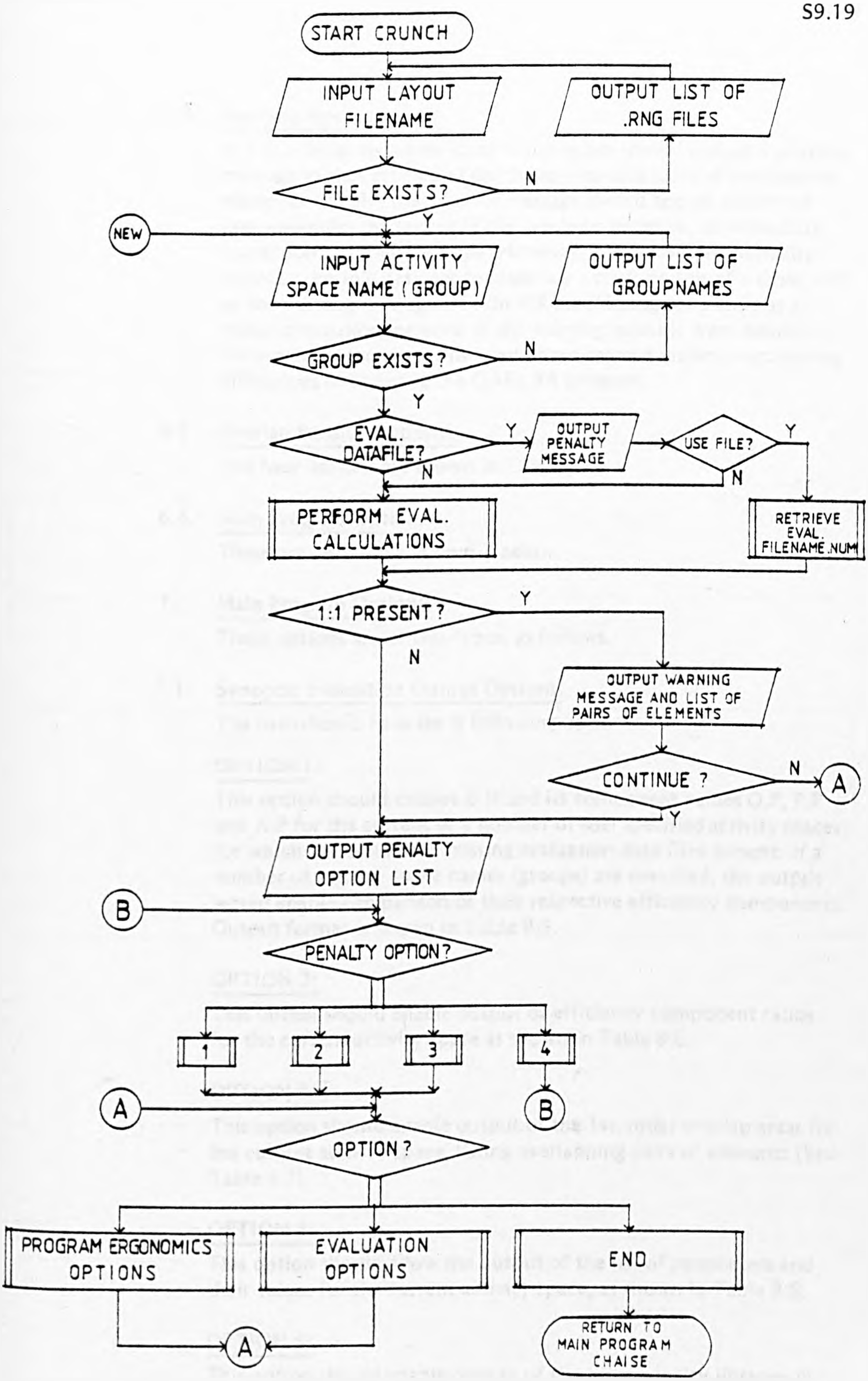


Fig. 9.5. Simplified Flowchart of the CRUNCH Program.

6.2. Warning Messages:

If 1:1 overlap instances occur the program should output a warning message to that effect and list the appropriate pairs of overlapping elements. Ideally, the warning message should appear whilst the user assembles the layout in the synthesis program, as immediate correction can then be made. However, one would not normally expect a sensible designer to place say a chair on top of a table, and so the warning message is in the CRUNCH program purely as a minor precaution measure. If the warning message were desired in the synthesis program, this would have created major programming difficulties in changing the GAEL4A program.

6.3. Overlap Penalty Options:

The four options are shown in Table 9.4.

6.4. Main Program Options:

These are dealt with in item 7 below.

7. Main Program Options:

These options are of two types, as follows.

7.1. Synoptic Evaluation Output Options:

The user should have the 9 following options:

OPTION 1:

This option should output E.R and its component values O.P, P.P and A.P for the current or a number of user specified activity spaces, for which there must be existing evaluation data files present. If a number of activity space names (groups) are specified, the output would enable comparison of their respective efficiency components. Output format is shown in Table 9.5.

OPTION 2:

This option should enable output of efficiency component ratios for the current activity space as shown in Table 9.6.

OPTION 3:

This option should enable output of the 1st. order overlap areas for the current activity space, listing overlapping pairs of elements (See Table 9.7).

OPTION 4:

This option should allow the output of the list of parameters and their values for the current activity space, as shown in Table 9.8.

OPTION 5:

This option should enable display of the three penalty libraries in turn, as shown in Tables 9.9 – 9.11. At present, it was decided to restrict the probability of usage library to values for one type of

Table 9.4. Overlap Penalty Options.

OPTION NO.		OPTION DESCRIPTION
1		Uses standard (default) library of W.01 penalty weighting factors to calculate Σ(A.01 x W.01).
2		Uses the probability of usage library to calculate Σ (A.01 x p x p′).
3		Uses the user defined library of W.01 weighting factors to calculate Σ(A.01 x W.01).
4		Displays the penalty libraries in turn:
	4.1	Displays the library of standard weighting factors.
	4.2	Displays the user defined library of weighting factors.
	4.3	Displays the probability of usage library.

Table 9.5. CRUNCH Option 1: Synoptic Layout Efficiency Component Evaluation Output.

ACTIVITY SPACE	UNITS OF E.R AND COMPONENTS			
	E.R	O.P	P.P	A.P
CURRENT OR LIST OF NAMES ⋮				

Table 9.6. CRUNCH Option 2: Synoptic Layout Efficiency Component Ratios for the Current Activity Space.

RATIOS	COMPONENTS		
	O.P	P.P	A.P
Σ(A.01 x W.01 or P1 x P2)	X		
A.01	X		
P.R		X	
$\sqrt{A.R}$ x 4		X	
A.S/A.FMO			X
A.NSR/A.FMO			X
A.U.(UNION)/A.FMO			X
A.E.(UNION)/A.FMO			X
A.BR/A.FMO			X
A.U.(TOT)/A.FMO			X
A.01/A.FMO			X
A.02/A.FMO			X
A.OU/A.FMO			X
A.NO/A.FMO			X
2A.02/A.FMO			X

Table 9.7. CRUNCH Option 3: Synoptic 1st Order Overlap Area Values for the Current Activity Space.

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES)								
	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
PAIR 1									
↓									
PAIR N									
TOTALS (a.01)									

Table 9.8. CRUNCH Option 4: Synoptic Parameter Value Output for the Current Activity Space.

PARAMETER	VALUE	UNITS
A.R		SQ. METRES
A.BR		"
A.F		"
A.01		"
A.02		"
A.OU		"
A.03		"
A.S		"
A.U.(TOT)		"
A.FMO		"
A.U.(UNION)		"
A.E.(UNION)		"
A.NSR		"
A.NSF		"
A.NO		"
P.R		METRES
P.F		"

Table 9.9. CRUNCH Option 5.1: Standard Library of Penalty Weighting Factors.

OVERLAP INSTANCE	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
WEIGHTING FACTORS	5.0	4.0	3.0	4.0	3.0	2.0	3.0	2.0	1.0

Table 9.10. CRUNCH Option 5.2: User Defined Overlap Penalty Weighting Factors for the Current Activity Space.

OVERLAP INSTANCE	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
WEIGHTING FACTORS									

Table 9.11. CRUNCH Option 5.3: Probability of Usage Library.

ELEMENTS	PROBABILITY VALUE					
	P(1)UNOCC.	P(1,2)OCC.	P(1,2,3)OCC.	P(1)	P(2)	P(3)
ELEMENT 1 ¦ ELEMENT N						

Table 9.12. CRUNCH Option 6: Probability of Penalty Products for the Current Activity Space.

OVERLAPPING PAIR	PENALTY PRODUCTS (P1xP2)								
	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
PAIR 1									
¦									
PAIR N									
TOTALS									

Table 9.13. CRUNCH Option 7: Synoptic Overlap Penalty Values for the Current Activity Space.

OVERLAPPING PAIR	PENALTY VALUES (a.01 x W.01 or PlxP2)								
	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
PAIR 1									
¦									
PAIR N									
TOTALS									

activity space only, but the option would exist to change the probability values by normal editing of the PROBL.DAT file.

OPTION 6:

This option should enable output of probability of usage products of overlapping pairs of elements for the current activity space as shown in Table 9.12.

OPTION 7:

This option should enable output of the overlap penalty product of overlap areas and penalty weighting factors or probability of usage products as appropriate, according to the penalty option chosen, for the current activity space (See Table 9.13).

OPTION 8:

This option should enable output of a list of the elements contained in the current activity space and their various component areas, as shown in Table 9.14. Since an element may occur more than once, an indication should be given of the number of times of occurence, shown in brackets after each element name.

OPTION 9:

This option should enable output of the two complete formula expressions of the efficiency measure of an activity space as shown in Table 9.15.

7.2. Program Ergonomics Options:

The following commands were specified to assist the user when running the program:

ALL:

This option should effect execution of the nine specified evaluation options, in turn in the order specified. After each option output, carriage return command should clear the screen and display the next option output.

END:

This option should cause exit from the CRUNCH program and return to the main program, CHAISE (See Fig. 9.1).

HELP:

This option should clear the screen and print out the list of CRUNCH Main options to the user.

INFO:

This option should enable a printout of the information on program running and design information.

Table 9.14. CRUNCH Option 8: Synoptic Output of Single Element Areas for the Current Activity Space.

ELEMENT	NO. OF OCCURRENCES	AREAS (SQ. METRES)				
		A.E	A.S	A.U1	A.U2	AU=U1+U2
NAME 1	(no.)					
¦	¦					
NAME N	(no.)					

Table 9.15. CRUNCH Option 9: Output of the Efficiency Formula.

$$E.R = O.P \times P.P \times A.P$$

$$E.R(1) = \left\{ \frac{\Sigma k \left[\sum_{y=1}^{n} \left(\sum_{i=1}^{j} a^{y}.01.\Sigma i \right) \times W.01.k \left(\text{or } P.01.k \right) \right]}{\Sigma k \left[\sum_{y=1}^{n} \left(\sum_{i=1}^{j} a^{y}.01.\Sigma i \right) \right]} \right\} \times \left\{ \frac{2l.R + 2b.R}{+\sqrt{A.R} \times 4} \right\} \times \left\{ \frac{A.S}{A.FMO} + \frac{A.U(TOT)}{A.FMO} - \frac{A.01}{A.FMO} + \frac{A.02}{A.FMO} + \frac{A.BR}{A.FMO} \right\}.$$

or:

$$E.R(2) = \left\{ \frac{\Sigma k \left[\left[\sum_{y=i}^{j} \left(\sum_{i=1}^{j} a^{y}.01.\Sigma i \right) \right] \times W.01k \left(\text{or } P.01.k \right) \right]}{\Sigma k \left[\sum_{y=i}^{n} \left(\sum_{i=1}^{j} a^{y}.01.\Sigma i \right) \right]} \right\} \times \left\{ \frac{2lR + 2b.R}{+\sqrt{A.R} \times 4} \right\} \times \left\{ \frac{A.01}{A.FMO} - \frac{2A.02}{A.FMO} + \frac{A.NO}{A.FMO} + \frac{A.BR}{A.FMO} \right\},$$

LIST:

This options should enable a listing of groupnames in the GAELIC layout data structure input to the program.

NEW:

This option should enable input and evaluation of another activity space (group definition).

SAVE:

This option should enable the current evaluation run to be named and stored as a data file (NAME.NUM).

The various calculations concerning initial area and perimeter calculations of the Dimcheck programs are to be done using rulewriting within the program, i.e. the calculations will be done automatically.

9.4.2. The Graphical Evaluation Program Specifications.

Numerical evaluation data for activity spaces, saved from runs using the CRUNCH program, should be presented graphically by means of histograms, graphs and pie-charts, as appropriate (9.8). For this purpose, use was made of the GINOGRAF routines (9.9), which interface with the GINO-F software package (9.10), available on the RGIT DEC-20 system.

Numerical data input for an activity space should ideally be taken by GRAFIT from two possible sources:

1. If no evaluation of the activity space has been made, using the CRUNCH program, the latter program should be automatically entered, calculations performed and a data file saved, from which GRAFIT will take its data.

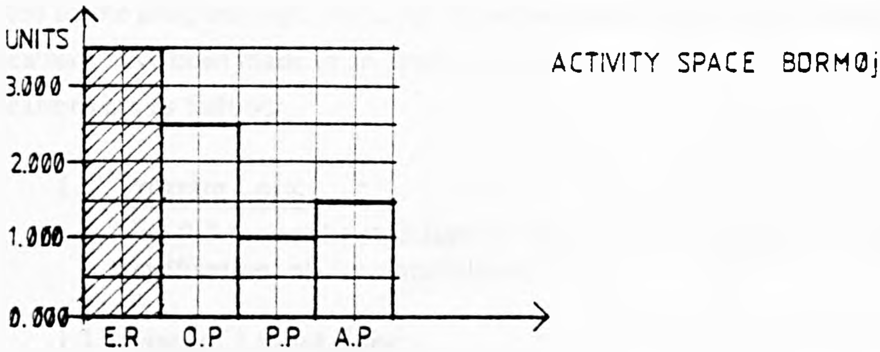
2. If an evaluation data file for the activity space already exists, GRAFIT will take its input directly from this file.

Output from GRAFIT should make use of the following three types of display (See Fig. 9.6):

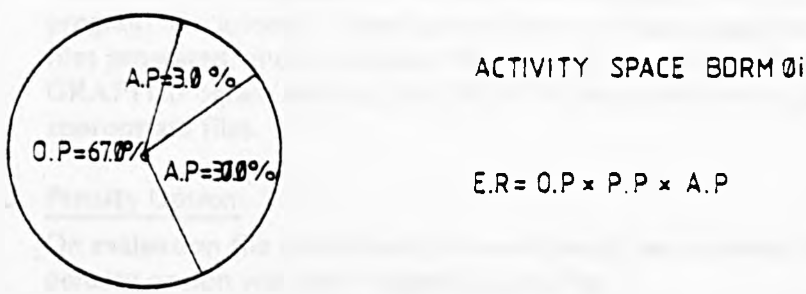
1. Bar-charts.
2. Pie-charts.
3. Multiple Graphs.

Headings should appear above or below the graphs.

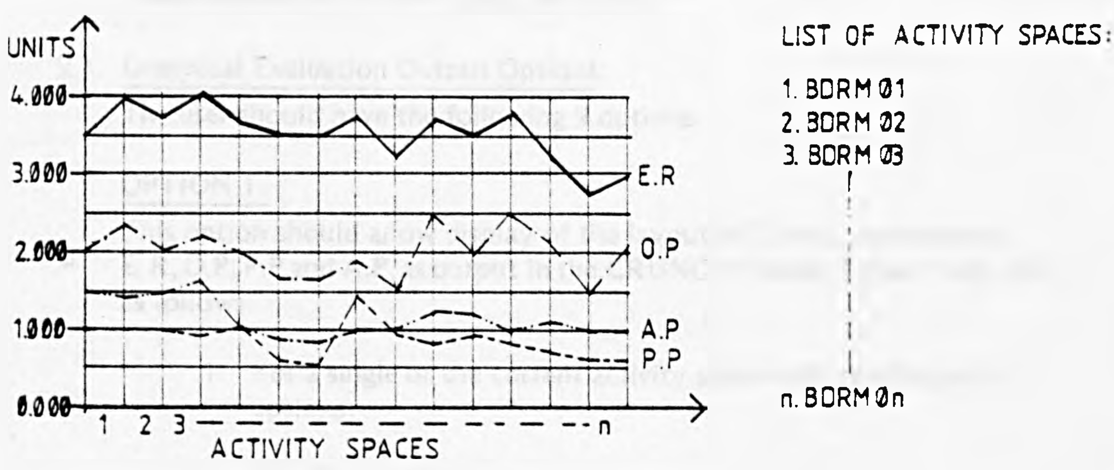
Since the Grafit program is purely an additional output device of the numerical evaluation results from the CRUNCH program, program specifications can be



1. BAR CHARTS.



2. PIECHARTS.



3. MULTIPLE GRAPHS.

NOTE: GRAPH VALUES USED ARE FICTITIONAL.

Fig. 9.6. Types of Graphical Output from the GRAFIT Program.

restricted to the program logic and a list of output requirements. More lucid specifications have been made in an appropriate report (9.11). The GRAFIT program specifications are as follows:

1. <u>Program Logic:</u>

   Fig. 9.7 shows the structure of the GRAFIT program, of which clarification of 4 points follows:

1.1. <u>Input of Layout Files:</u>

   These are the files generated by the SYNCRO Programs GAEL4A (SYNTER) or GAEL4T (SYNTAB).

1.2. <u>Input of Evaluation Files:</u>

   These are the files saved by the user when running the CRUNCH program. Occasionally room layouts may not have associated evaluation files generated, and in this case the user may wish to exit from the GRAFIT program and run the CRUNCH program in order to generate the appropriate files.

1.3. <u>Penalty Option:</u>

   On evaluation file acceptance, the user should be reminded of which penalty option was used to generate the file.

1.4. <u>Main Program Commands:</u>

   These are dealt with in item 2 below.

2. <u>Main Program Options:</u>

   These options are of two types, as follows:

2.1. <u>Graphical Evaluation Output Options:</u>

   The user should have the following 9 options:

   <u>OPTION 1:</u>

   This option should allow display of the layout efficiency components, E.R, O.P, P.P and A.P, as output in the CRUNCH Option 1 (See Table 9.5), as follows:

   1. For a single or the current activity space with the following options:

      1.1. Bar-chart display.
      1.2. Pie-chart display.

   2. For several specified activity spaces, display of a multiple graph with lines clearly identified and a list of the specified activity spaces in the order they appear in the graph.

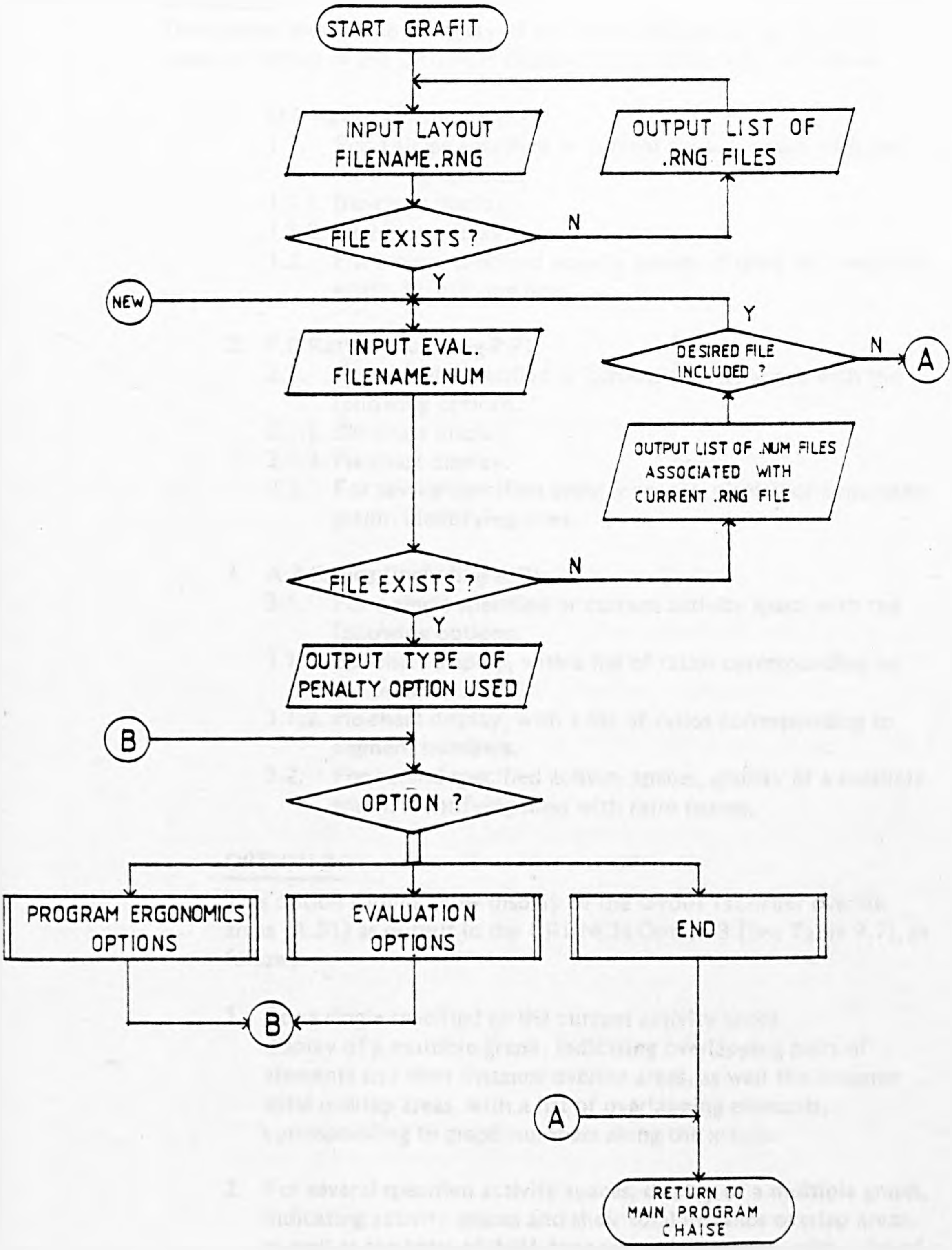


Fig. 9.7. Simplified Flowchart of the GRAFIT Program.

OPTION 2:

This option should allow display of the layout efficiency component ratios as output in the CRUNCH Option 2 (See Table 9.6), as follows:

1. O.P Ratios (including O.P):
   - 1.1. For a single specified or current activity space with the following options:
   - 1.1.1. Bar-chart display.
   - 1.1.2. Pie-chart display.
   - 1.2. For several specified activity spaces, display of a multiple graph, identifying lines.

2. P.P Ratios (including P.P):
   - 2.1. For a single specified or current activity space with the following options:
   - 2.1.1. Bar-chart display.
   - 2.1.2. Pie-chart display.
   - 2.2. For several specified activity spaces, display of a multiple graph, identifying lines.

3. A.P Ratios (including A.P):
   - 3.1. For a single specified or current activity space with the following options:
   - 3.1.1. Bar-chart display, with a list of ratios corresponding to bar numbers.
   - 3.1.2. Pie-chart display, with a list of ratios corresponding to segment numbers.
   - 3.2. For several specified activity spaces, display of a multiple graph, identifying lines with ratio names.

OPTION 3:

This option should allow display of the layout 1st order overlap areas (A.01) as output in the CRUNCH Option 3 (See Table 9.7), as follows:

1. For a single specified or the current activity space, display of a multiple graph, indicating overlapping pairs of elements and their instance overlap areas, as well the instance total overlap areas, with a list of overlapping elements, corresponding to graph numbers along the x-axis.

2. For several specified activity spaces, display of a multiple graph, indicating activity spaces and their total instance overlap areas, as well as the total of A.01 for each activity space, with a list of activity spaces, corresponding to graph numbers along the x-axis.

OPTION 4:

This option should allow display of the layout graphic overlap penalty values as output in the CRUNCH Option 7 (See Table 9.13), as follows:

1. For overlapping pairs of elements in a single specified or the current activity space, display of a multiple graph, indicating overlapping pairs of elements, as well as the a.01 x w.01 or p x p' products for each pair or overlapping elements, for each overlap instance. The total of a .01 x w.01 or p x p' should also be shown for each pair of overlapping elements, and a list of overlapping pairs printed out to correspond to pair numbers along the graph x-axis.

2. For several specified activity spaces, display of a multiple graph, indicating overlap instance totals of a.01 x w.01 or p x p' for each activity space, as well the total of A.01 x W.01 or p x p' for each activity space, and output of a list of activity spaces corresponding to the activity space numbers along the graph x-axis.

OPTION 5:

This option should allow display of the layout parameters as output in the CRUNCH Option 4 (See Table 9.8), as follows:

1. For one specified or the current activity space, bar-chart displays for the following two types of parameters:
   1.1. Display of parameters with square metre (area) units, and a list of parameters corresponding to the parameter numbers for each bar along the graph x-axis.
   1.2. Display of parameters with metre (length) units, including the two sides of the bounding rectangle of the activity space.

2. For several specified activity spaces, multiple graph displays for the following two types of parameters:
   2.1. Display of parameters with area units for each of the activity spaces and a list of activity spaces, corresponding to the activity space numbers along the graph x-axis.
   2.2. Display of parameters with length units for each of the activity spaces, and a list of activity spaces, corresponding to the activity space numbers along the graph x-axis.

OPTION 6:

This option should allow display of the various proportional activity space areas, as follows:

A.R
A.S
A.NS
A.U.(UNION)
A.E.(UNION)
A.OU
A.NO
A.01
A.02
A.BR.

1. For one specified or the current activity space, display of a a bar-chart of the above area parameters, with a list of the parameters corresponding to parameter numbers along the graph x-axis.

2. For several specified activity spaces, display of a multiple graph, showing the parameter values for each activity space, indicating for each line the appropriate parameter name, and a list of activity spaces, corresponding to the activity space numbers along the x-axis.

OPTION 7:

This option should allow output of the W.01 standard or user defined penalty libraries as output in the CRUNCH options 5.1 and 5.2 (See Tables 9.9 and 9.10), as follows:

1. Display of a bar-chart showing values of penalty factors for each overlap instance.

2. Display of a pie-chart showing display of the various penalty factors as proportions of the sum of these factors.

   Note that if the user defined library is to be displayed, then this library would have had to be stored when running the CRUNCH program.

OPTION 8:

This option should allow output of the penalty probability products as output by the CRUNCH Option 6 (See Table 9.12), as follows:

1. For one specified or the current activity space, display of a multiple graph showing the penalty probability product p x p' for each pair of overlapping elements, indicating each overlap instance product as well as the total for each pair, and a list of pairs of overlapping elements corresponding to the pair numbers along the graph x-axis.

2. For several specified activity spaces, display of a multiple graph showing the totals of probability products for each overlap instance, for each activity space, as well as the totals of p x p' for each activity space, and a list of activity spaces corresponding to the activity space numbers along the graph x-axis.

OPTION 9:

This option should allow output of the single element areas as output by the CRUNCH Option 8 (See Table 9.14), as follows:

1. For one specified single element only, displays as follows:

1.1. Bar-chart display of A.E, A.S, A.U1, A.U2 and A.(U1 + U2).

1.2. Pie-chart display of the areas showing A.S, A.U1 and A.U2 as proportions of the total area A.E.

2. For several or all specified single elements within the current layout, display of a multiple graph, showing the above areas for each single element, and a list of single elements corresponding to the element numbers along the graph x-axis.

2.2. <u>Graphical Program Ergonomics Options:</u>

The following commands were specified to assist the user when running the program:

<u>ALL:</u>

The option should effect the execution of the nine specified graphical evaluation options, in turn in the order specified. After each option output, carriage return command should clear the screen and display the next option output.

<u>END:</u>

This option should cause exit from the GRAFIT program and return to the main program CHAISE (See Fig. 9.1).

<u>HELP:</u>

This option should clear the screen and print out the list of GRAFIT main options to the user.

<u>INFO:</u>

This option should enable printout of the information on program running and design information.

<u>LIST:</u>

This option should enable a listing of the evaluation files (.NUM files) saved by running the CRUNCH program for the current data structure (.RNG file).

<u>NEW:</u>

This option should enable input of another evaluation file associated with the current data structure.

3. <u>Storage:</u>

Since the numerical backup data for activity space evaluation already exist by running the CRUNCH program, it is not necessary to store the GRAFIT output. Displays will be generated using the CRUNCH data files, every time the program is run.

9.5. General.

The following is an outline of possible additional program features, as well as a summary of the present program implementation status.

9.5.1. Additional Program Features.

Future program refinements should include the following:

1. Use of the GAEL4D Program:

   The GAEL4D program was written by Dr. John Eades of the Electrical and Electronic Engineering Department of the RGIT (9.12). The program operates essentially as the GAEL4T program, except that the planning area of the tablet can be defined by the tablet pen to any required size, anywhere within the planning area. Since the defined planning area corresponds to the screen area, it is useful to set it smaller when a small screen is used. The GAEL4D program could become a Synthesis program option along with GAEL4A and GAEL4T.

2. Amendment of the GAEL4A/4T LIST Commands:

   If the user has a unique coding system for single elements and activity spaces, he may only wish to inspect certain categories of these library names at a time. It would therefore be helpful to be able to get a list of names printed out for the name categories he is interested in. This amended LIST facility should work in a similar fashion to the DIRECTORY facility on the DEC-2Ø. For example, if the user wishes to view only the files beginning with B, he would type DIR B*, and so forth.

3. Warning Messages:

   At present the warning message for a 1:1 overlap is printed out when the CRUNCH program is run, if such an overlap has occurred. Immediate warning of such an occurrence could be given when the Synthesis programs are run, giving the user the possibility of immediate design correction (See Sub-subsection 9.4.1).

4. Coding Systems:

   At present the user has to keep track of the names of evaluation files generated by the CRUNCH SAVE Option. It is quite convenient to name these files by the names of the associated layouts, i.e. the groupnames. If an activity space is called BED 1, its saved evaluation file would then be called BED1 .NUM. However, the user would still have to remember which penalty option was chosen for that particular file generation. Therefore the message of penalty option used which appears following evaluation file entry in GRAFIT, should also be repeated when the appropriate GRAFIT options 4, 7 and 8 are entered, as these options are all dealing with penalty values. The penalty option is an attribute to the evaluation file.

The user may also wish to clarify the penalty issue by coding the evaluation file name so that the associated penalty option can be identified by reading the name. For example, in the file name example above, the file may be called BED11 .NUM, where the last figure in front of .NUM indicates that penalty option 1 was chosen for that particular file generation.

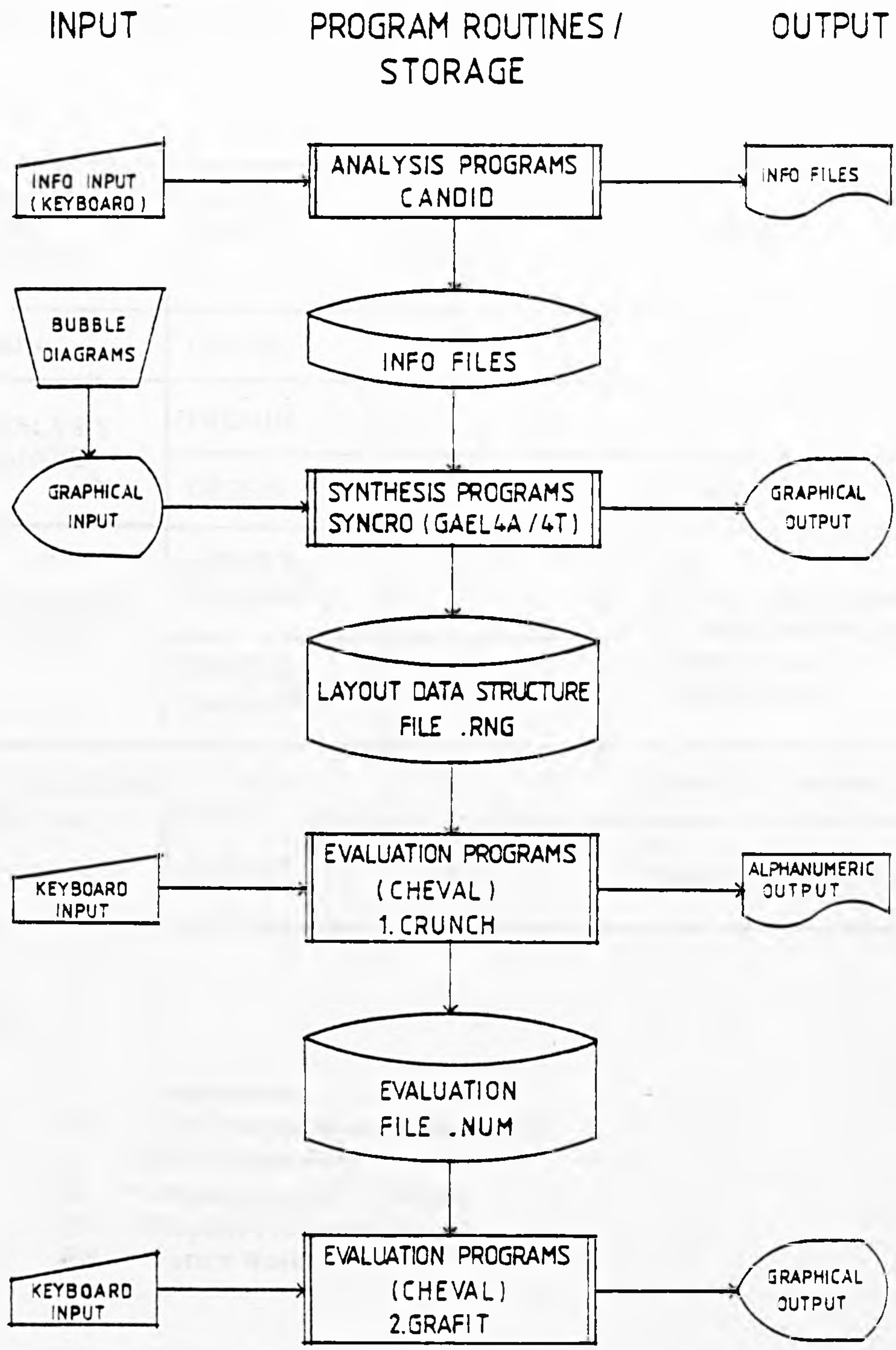
5. Screen Menus and Variable Graphs:

These facilities could be implemented as discussed in Sub-section 8.6 (See Fig. 8.5). Eventually, an instantaneous evaluation feedback is envisaged. For example, the GRAFIT and CRUNCH options should be enterable at the layout assembly stage in the synthesis programs. As the layout is changed, the GRAFIT graphs and the CRUNCH figures should change instantaneously, giving the user a powerful evaluation tool. These facilities, however, require the use of a large refresher graphics screen.

9.5.2. Summary.

As the design model and program specifications show, the designer who uses the programs will normally proceed as the systems data flow diagram shows (See Fig. 9.8; cf. Fig. 8.4). Entry of the main program CHAISE (See Fig. 9.1) enables a tree structure branching route to lower program levels and program commands (See Figs. 9.5 and 9.7), where return to higher level choice is possible at any time. Implementation of the program specifications should therefore produce a program suite which will offer the degree of flexibility required by the proposed design system (See Section 4), accepting the drawbacks inflicted by insufficient hardware (See Section 8).

The current program implementation status is shown in Table 9.16. The object of the present research project was to produce a CAAD system which would allow numerical evaluations of activity spaces (See Sub-section 12.2 for further work).



NOTE: DESIGN ITERATIONS AS PER. FIGS 9.1, 9.2, 9.5 AND 9.7.

Fig. 9.8. Simplified Systems Data Flow Diagram.

Table 9.16. Current Program Implementation Status.

PROGRAM TYPE/ OPTION	PROGRAM NAME	IMPLEMEN-TION STATUS	REMARKS
MAIN	CHAISE	X	II, RP
ANALYSIS (CANDID)	PROGIN	X	FW, RP
	DESSIN	X	FW, RP
SYNTHESIS (SYNCRO)	SYNTER (GAEL4A)	IX	FW, LIST Command amendment, 1:1 Warning Messages, Screen Menus, Variable Graphs.
	SYNTAB (GAEL4T)	IX	
EVALUATION (CHEVAL)	CRUNCH	IX	Minor List Options, II, RP.
	GRAFIT	IX	II, Multiple Graph Options.

KEY:

I = Implemented.
IX = Implemented except <Remarks>.
X = Not implemented.
II = Implementation Imminent.
RP = Routine Programming.
FW = Future Work.

SECTION 10: PROGRAM DESCRIPTION; A MINI USER MANUAL

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PROGRAM DESCRIPTION; A MINI USER MANUAL.

10.1. Introduction.

This section contains a brief description of the running of the currently implemented CHAISE programs which resulted from the research project (See Table 9.16). For programs that were not part of the present work, reference is made to the appropriate user manuals. For programs that have been specified, but not implemented, only brief descriptions are made (marked *). A complete and separate manual is intended for inclusion in the CANDID program files, but this section forms an integral part of the thesis and use of cross-referencing to other sections will therefore be made as appropriate. Use of the programs presupposes that the user is familiar with the Tektronix 4010 type terminals as well as the other Tektronix hardware described in Sub-subsection 8.3.2, and the manuals referred to in that section (See also Fig. 8.2).

10.1.1. General Program Description.

The CHAISE Package is a compilation of programs written in ANSI Fortran IV and currently running on the RGIT DEC-20 Computer System. They are designed to suit the analysis, synthesis and appraisal processes in the design of domestic layouts at Stages C and D of the RIBA Plan of Work. In particular, the programs are intended to assist in the assembly of domestic activity space layouts from a library of house planning elements which are stored in the computer, and to evaluate the efficiency of activity spaces, according to the theoretical design model proposed in Section 4.

10.1.2. Use of the Package.

The typical design procedure involved when making use of the programs has been discussed previously (See Figs. 8.4 and 9.8). If the user starts from scratch he will usually have a bubble diagram of his intended room layout. If necessary he can look at design or program information using the CANDID Analysis programs before proceeding to the SYNCRO Synthesis programs where he can assemble his layout using the SYNTER (GAEL4A) or SYNTAB (GAEL4T) program. The option is available to expand the standard library of house planning elements before commencing the layouts. Having designed an initial layout on the graphics screen, the user can now enter the CHEVAL

Evaluation programs CRUNCH and GRAFIT in order to obtain synoptic efficiency evaluation output for his layout, either in numerical or graphical form. If he feels satisfied with the layout evaluations he may return to the main program and exit, or start a new layout, otherwise he may return to the SYNCRO programs and repeat the synthesis/evaluation procedure until he is satisfied with the layout, which is then saved.

A user who has already designed and evaluated layouts using the SYNCRO and CHEVAL programs and simply wishes to modify his plans, may enter the SYNCRO programs, retrieve his "saved" layout, modify it as desired and proceed in the synthesis/evaluation iterations as described above.

A hardcopy of SYNCRO layouts or GRAFIT evaluation graphs can be made using the Tektronix 4Ø31 Hardcopy Unit, the Tektronix 4663 Flatbed Plotter, or alternatively by running the GAEL5A or GAEL 9 programs for plotter output. If the SYNCRO or GRAFIT programs are run, the 4Ø1Ø or another, compatible, Tektronix graphics terminal is required, since in these programs layout assembly and manipulation or graph output makes it necessary to use a graphics screen. If the CANDID or CRUNCH programs are run only, it is sufficient to use any ordinary terminal, since input/output is purely alphanumerical.

10.2. Running the Main Program CHAISE (*).

The CHAISE control program allows entry into the CANDID, SYNCRO or CHEVAL programs (See Fig. 9.1).

10.2.1. Initialisation of CHAISE.

CHAISE is entered by typing RUN CHAISE.

After loading a prompt says:

CHAISE – COMPUTER HOUSE ANALYSIS INFORMATION, SYNTHESIS AND EVALUATION PACKAGE.

WHICH OPTION DO YOU REQUIRE? – TYPE HELP FOR OPTIONS.

10.2.2. CHAISE Options.

The user enters the name of the program he wants to run or types HELP to get a list of available programs and options at the main command level:

AVAILABLE OPTIONS ARE:–

CANDID – COMPUTER ANALYSIS DESIGN INFORMATION DEVICE PROGRAMS
SYNCRO – SYNTHESIS COMPUTER ROUTINES OPERATIONS PROGRAMS
CHEVAL – COMPUTER HOUSE EVALUATIONS PROGRAMS
HELP – CLEAR SCREEN AND PRINT THIS LIST
END – EXIT FROM MAIN PROGRAM

WHICH OPTION?

The various programs can be run as described in the following.

10.3. Running the Analysis Programs CANDID (*).

These programs enable reading or editing of the PROGIN and DESSIN files, which will contain information on the programs or house design respectively. The programs will operate as described in Sub-section 9.2 (See Fig. 9.2).

10.4. Running the Synthesis Programs SYNCRO.

10.4.1. Running the SYNTER (GAEL4A) Program.

Complete reference to the running of this program can be found in the appropriate GAELIC user manuals (10.1, 10.2). The only change to the original program is the addition of the following main program command (*):

INFO – PRINT INFORMATION ON THE PROGRAM.

The INFO option will provide a brief guidance file on the running of SYNTER.

The LIST command provides the user with a list of available design libraries, at the various design levels as described in Sub-section 4.3. The user may add to these standard libraries by the input of graphical groupname shapes on the appropriate overlays (masks). Coding of library (group) names are at present left to the user. Layouts of activity spaces are also created as group definitions, using the library of single elements at design level 1 for their assembly. The SYNTER program sets up a data structure for the storage of layouts as a FILE NAME. RNG file.

A standard .RNG file may be used for all design projects, but copied into NEWFILENAME.RNG for each new project, which will then receive entry of the associated new layouts for each new project.

Appendix A4.1 (Fig. A4.1) shows some typical hardcopy output from the SYNCRO programs. The degree of graphical detail is entirely up to the user, and must be included in the standard library of single elements. For the current research project, the following mask allocation was used:

MASK 1: Solids (solid lines).
MASK 2: User Space 1 (dashed lines).
MASK 3: User Space 2 (dashed lines).
MASK 4: Symbols within Solids or User Spaces (solid lines).
MASK 5: Symbols within Solids or User Spaces (dashed lines).
MASK 6: Bounding Rectangle of the Activity Space (dashed lines).

There are some 17 masks available in the SYNTER program.

10.4.2. Running the SYNTAB (GAEL4T) Program.

The SYNTAB program operates identically to the SYNTER program, except that certain new commands are added at the initialisation and program command levels, and that cursor command input is via a menu on the Tektronix 4954 Graphics Tablet (10.3). Operation of the program is exactly as described in the program specifications in Sub-subsection 9.3.2 (See also Figs. 9.3 and 9.4). The most important input changes are (See also Appendix A4.2):

1. At the Program Initialisation Stage:
   The program prompts:

   ENTER NAME OF DATA FILE CONTAINING GROUP INSTANCES.

   The user enters a FILENAME.DAT which contains a list of groupnames, 1 per line, which corresponds to the symbols shown on the current tablet library area overlay. The limit is 55 names, which must exist as groupnames in the data structure. Linenumbers must be removed from the file, otherwise these will be read as groupnames. Carriage return will cause the program to proceed to the WHAT NEXT level.

2. At the Program Command Level:
   The list of options include two additions:

   INSERT – DEFINES A NEW SET OF GROUP NAMES
   SHOW – SHOWS WHAT EACH SQUARE CONTAINS.

   These options effect the following:

INSERT:

This option prompts:

ENTER NAME OF DATA FILE CONTAINING GROUP INSTANCES.

The user responds as at the program initialisation stage. This option allows the user to change the library data file, and he should now overlay new library symbols for the tablet library area. If the user enters a non existent library file, the program prompts:

FILE DOES NOT EXIST. TRY AGAIN!

If the names contained in the data file do not match groupnames in the data structure, the program prompts the following for each error:

GROUP CALLED <NAME> IS UNDEFINED

and returns to WHAT NEXT.

SHOW:

This option enables a printout of the current definition of a library square. For each defined square the program prompts:

SQUARE NUMBER X IS DEFINED WITH GROUP <NAME>

and returns to WHAT NEXT.

3. At the Cursor Command Level:

When the cursor command level is entered the program writes in the menu area of the screen:

CURSOR COMMAND □

and the cursor stands by, and is displayed as for alphanumeric input, i.e. no crosshair lines are shown. Cursor commands are given by pressing the tablet menu squares with the tablet pen, and on receipt of the command a characheristic bell signal is sounded. The following cursor commands are added to the GAEL4A commands (shown shadowed in Fig. 9.4):

Define Squares:

This option enables "empty" library menu squares to be individually assigned groupnames from the library of single elements. When this menu square is pressed, the following prompt is written in the screen menu area:

WHICH SQUARE TO BE DEFINED?

The user presses the tablet pen on the desired library square, and the program prompts:

GROUP NAME?

The user enters by the keyboard a name contained in the library of single elements. If a non-existing groupname is entered the program prompts:

UNDEFINED GROUP

and returns to the cursor command level. If the groupname is accepted, the program prompts:

SQUARE DEFINED

and returns to the cursor command level.

Query:

This option enables a printout of the groupname associated with a library square. If the pen is pressed in the Query menu square, the program prompts in the screen menu area:

WHICH GROUP SQUARE?

The user should respond by pressing the pen in a library square. If this square is defined, the program prompts:

GROUPNAME IS <NAME>

and returns to the cursor command level. If the square is not defined, the program prompts:

SQUARE NOT DEFINED

and returns to the cursor command level.

Redefine Squares:

This option allows the user to insert a new library data file into the program. If the Redefine menu square is pressed by the pen, the program prompts:

ENTER NAME OF DATA FILE CONTAINING GROUP INSTANCES.

Upon entry of a legitimate filename, the program prompts:

WAITING FOR A <RETURN>,

Giving the user the option to change the filename. When carriage return is hit the program returns to cursor command level.

Other Cursor Commands:

Group shapes (single elements) can be positioned on the screen when assembling activity spaces by using the tablet pen in the following manner:

1. Press G to insert a group into the current layout. The program prompts:

GROUP NAME?
and returns to the cursor command level.

2. Press the desired library square to indicate which group (single element) is to be positioned on the screen.

3. Unless the original orientation of the group shape is wanted, press one of the orientation coding menu squares. These options are:

   3.1. Reflect shape about the X-axis.
   3.2. Reflect shape about the Y-axis.
   3.3. Rotate the shape 90°.
   3.4. Combine any reflect or rotate option.

4. Press a point on the planning area of the tablet to specify where the group origin is to be positioned (cursor is visible on the graphics screen).

5. Press appropriate cursor commands to reposition the group origin or to specify co-ordinates for the group origin position from the keyboard.
6. Press the menu D-square to draw the shape in the correct position on the screen.

7. On completion of the shape drawing, the program returns to the cursor command level.

If a modification of the screen layout is wanted, the user must exercise the following procedure:

1. Press I to identify a shape.

2. Move the pen across the planning area just above the surface (presence mode). This will cause the screen cursor to track along the screen following the pen, since the tablet area corresponds to the screen area. When the cursor is above the origin of the group shape to be moved or reorientated, the pen should be pressed on the tablet area.

3. The desired cursor command menu square should now be pressed to allow the shape to be moved or reorientated as desired.

The cursor command O for closing a rectangle or ending a line is a default option in SYNTAB, i.e., once L or R are pressed, the program only expects a new set of co-ordinates to complete the shape.

There is a little knack involved in getting familiar with the screen/tablet interaction. Since the tablet planning area is so much larger than, yet corresponds to, the screen area, it is difficult to move the arm for tablet pen positioning. However, the GAEL4D program may be used (10.4), which allows activation of only part of the planning area of the tablet.

The GAEL4A and GAEL 4T programs differ at the cursor command level as follows:

1. In GAEL4A the cross-hair cursor is moved by the thumbwheels to a desired position and an appropriate key pressed to execute a command which will be related to that position.

2. In GAEL4T, the desired menu square command is pressed first, followed by pressing the pen in a desired position on the tablet planning area to relate the position to the previous cursor command.

Copies of screen layouts can be made, using the previously mentioned Tektronix Hardcopy Unit, or flatbed plotter, or using the GAEL5A or GAEL9 programs for plotter output on various plotter types.

10.4.3. Advanced Use of Other GAELIC Programs.

Once the GAELIC ring data structure has been created and stored by the SYNCRO programs it may be worked upon using some of the other programs in the GAELIC Suite (10.5), or conversely a ring data structure could be created by alpha-numeric input only. The latter, however, would not be practicable for an architect designing layouts.

The FILENAME.RNG file may be handled using other GAELIC programs as follows:

The GAEL7A Program:

This program will take the ring data structure and convert it into a GAELIC Language data file, FILENAME.DAT, which can be edited provided the GAELIC Language is known (10.6). A numerate user may in this way insert groups, shapes and layouts, or modify existing layouts using normal DEC-2Ø editing mode on the .DAT file (See Appendix A4.3 for an example of a GAEL7A File).

The GAEL23 Program:

To display or modify the new layout on the screen, the user loads the GAEL7A .DAT file, which has been edited, into the GAEL 23 Program which converts it into a .RNG ring data structure which can be entered into the GAEL4A/4T programs.

If many repetitive shapes are to be done, then it may well be worth employing the GAEL23 and GAEL7A programs (See Sub-section 7.3 for a description of the GAELIC Program Suite).

10.5. Running the Evaluation Programs CHEVAL.

The current implementations of the CHEVAL programs are run as described below, but the program prompt wording will still be under review pending user feedback.

10.5.1. Running the Numerical Evaluation Program CRUNCH.

CRUNCH is a numerical program, attached to the DimCheck programs, which evaluates the efficiency of activity spaces created by the SYNCRO programs according to the evaluation method detailed in Sub-section 4.4 and as demonstrated manually in Section 5(10.7). The program takes as input a ring data structure saved by the SYNCRO programs. After calculations the CRUNCH program enables the user to save an evaluation file .NUM, which may be used in subsequent CRUNCH or GRAFIT runs, or, a number of evaluation output options may be chosen. The CRUNCH program use and operation is as follows (See also Appendix A4.4 for a typical CRUNCH run):

1. <u>CRUNCH Initial Input:</u>
   The program is entered from the CHAISE main command level by typing:

   CRUNCH

   or, the program may be run as a separate program by typing:

   RUN CRUNCH.

   The program writes the following heading:

   CRUNCH – NUMERICAL PROGRAM TO EVALUATE THE
   EFFICIENCY OF ACTIVITY SPACES

   and then prompts:

   ENTER NAME OF LAYOUT FILE.

   The user can enter an existing ring data structure layout file .RNG which contains the activity spaces he wishes to evaluate. If a non-existing or erroneous filename is entered the program will prompt:

   FILE NAMED <ERROR NAME> .RNG NOT AVAILABLE –
   TRY AGAIN

   and then repeats the original file entry prompt. On acceptance of an existing filename followed by carriage return (CR), the program prompts:

   ENTER NAME OF GROUP TO BE CHECKED OR PRESS RETURN
   FOR WHOLE LAYOUT.

The user can now enter a groupname which is part of the previously entered .RNG file, and which will correspond to the activity space the user wishes to evaluate. If a non-existing groupname is entered, CR will cause the program to prompt:

GROUP <ERROR NAME> NOT FOUND – TRY AGAIN

and repeats the original question to allow correct input. If an evaluation file .NUM exists with the same name as the group (activity-space), CR causes the following prompt:

DO YOU WISH TO USE THE EXISTING EVALUATION FILE CALLED <NAME> .NUM GENERATED WITH PENALTY OPTION <1, 2 or 3> ? TYPE YES OR NO.

YES followed by CR causes the program to skip calculations and use the data in the existing evaluation file, then proceed to the next question.

NO followed by CR effects calculations of the necessary evaluation parameters for the entered activity space. One reason for not using an existing evaluation file may be that the layout has been amended since the file was saved, another that the wrong penalty option might have been used for its generation.

Otherwise, an evaluation file input will save computing time and cause the program to proceed quicker to the next question.

If a CR is pressed in response to the original question, the program will base its calculations on the layouts present in the SYNCRO main layout, rather than group layouts, and proceed to do calculations as for group-name entries. Occasionally, a user may wish to use the main layout, although it is preferable to use group definitions only for layouts, since layouts then can be used to assemble higher design level layouts, an option lost if the main layout is used.

If the main layout is used, however, it will appear in subsequent CRUNCH output with no associated name label. An option exists in the GAEL4A program called CHANGE which allows the user to assign a name to the main layouts, as for groups, and it is recommended to use this option if the main layout is entered in CRUNCH, to avoid confusion.

If a CR, a correct groupname followed by CR or, a NO response to the evaluation file question has been given, the program prompts:

PLEASE WAIT WHILE CALCULATIONS ARE PERFORMED:

and a pause follows, the length of which depends on the DEC-20 computing load. Obviously the less load, the less time will be taken for the pause.

If a 1:1 overlay has taken place in the currently evaluated layout, the program causes a bell signal and the prompt:

YOU HAVE INFLICTED A NON-PERMISSIBLE 1:1 INSTANCE OVERLAP BETWEEN THE FOLLOWING PAIRS OF ELEMENTS:

Followed by the relevant list of pairs of elements, and then prompts:

DO YOU WISH TO CONTINUE THE EVALUATION RUN?
TYPE YES OR NO.

If a NO response, a CR, or illegal characters are typed the program will cause immediate exit to the monitor level if CRUNCH is run as a separate program, otherwise it will return to the main CHAISE program control level and design changes for the layout may be made by entering the SYNCRO programs. If a YES followed by a CR response is given, the program proceeds to the next program input question. It does not make much sense to get evaluation output if a 1:1 overlap instance is present in the current layout, but if the 1:1 overlap area is very small, it may not influence the overall results too much.

If no 1:1 overlaps are present, the program immediately upon completion of calculations proceeds to the next question, which is:

WHICH PENALTY OPTION DO YOU WISH TO USE?
1 –WØ1 STANDARD LIBRARY OF WEIGHTING FACTORS
2 –PROBABILITY OF USAGE LIBRARY
3 –USER DEFINED WEIGHTING FACTORS
4 –INSPECT PENALTY LIBRARIES
TYPE 1, 2, 3 or 4.

Penalty options 1 to 3 are as specified in Sub-subsection 9.4.1, according to the proposed evaluation method.

If anything else than 1–4 is typed the following prompt is printed:

WRONG CHARACTER

and then repeats the complete penalty option question, allowing the user to try again.

If a 4 is pressed followed by CR, the program will print out the various penalty libraries as shown for the main program option PENALTY in Appendix A4.4, and repeats the complete penalty option question.

If a 3 is pressed followed by CR, the program prompts:

TYPE IN THE NEW WEIGHTING FACTORS YOU WISH TO USE – THE STANDARD VALUES ARE GIVEN IN BRACKETS.

The user can now specify his own penalty weighting factors for each instance for the user defined penalty library. A question is printed for each of the nine overlap instances (See PENALTY output in Appendix A4.4), e.g.:

1:1 (5.Ø):–

and the user enters his own values. It is not necessary to type in decimals for whole integers as the program will convert the value into real number form. Otherwise, real numbers may be entered. Procession to the next instance input, or to the next program question after input of the 3:3 instance value is achieved by CR.

If non-digital characters are entered, CR will effect the following prompt:

ILLEGAL CHARACTER – REENTER THE LAST VALUE

and then repeats the previous input prompt, allowing the user to enter a digit. CR only will not affect the program, since it is waiting for a digit input.

After input for the 3:3 instance and CR, the program prompts:

DO YOU WISH TO CHANGE ANY OF THE NEW VALUES?

The user can now type YES or NO, followed by CR.

If a YES response is given the original question is prompted and the user can reenter penalty values for the various instances. Upon completion of penalty values, the user is again asked if he wishes to change any values.

If a NO response, a CR or illegal characters are given, the program will proceed to the main program command options.

If a 1 or 2 is specified in response to the original penalty option question, the program will pick the correct penalty library to use for subsequent calculations and proceed, in each case, when a CR is pressed, to the main program options.

2. CRUNCH Main Program Options:

When the program enters this level after the user has chosen the desired penalty option, the following prompt is given:

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE? – TYPE HELP FOR OPTIONS.

The user now has a number of options available. Some options merely assist in the smooth running of the program, and these are called Program Ergonomics Options (Marked PE in brackets after option names below).

The remainder of the options are the 9 Synoptic evaluation outputs availabe, as described in the program specifications, Sub-subsection 9.4.1 (Marked 1-9 in brackets after option names below).

Each option requires only input of the first two characters of its name, followed by CR. The screen will then be cleared and the output written out, followed by the original question.

If the user types HELP, the program makes a printout of the list of options and a brief description of their functions as shown below:

OPTIONS ARE:–

ALL (PE)	– PERFORMS ALL OPTIONS IN TURN
AREAS (8)	– SYNOPTIC OUTPUT OF SINGLE ELEMENT AREAS

COMPONENT (1)	– SYNOPTIC LAYOUT EFFICIENCY COMPONENT EVALUATION
END (PE)	– END PROGRAM
FORMULA (9)	– DISPLAY EFFICIENCY FORMULA
HELP (PE)	– PRINT THIS LIST
INFO (PE)	– TYPE OUT INFORMATION ON PROGRAM
LIST (PE)	– LIST OUT GROUP NAMES
NEW (PE)	– EVALUATE ANOTHER GROUP FROM THE LAYOUT
OVERLAP (3)	– SYNOPTIC 1ST. LEVEL OVERLAP AREA VALUES
PARAMETER (4)	– SYNOPTIC PARAMETER VALUE OUTPUT
PENALTY (5)	– SYNOPTIC PENALTY LIBRARIES OUTPUT
PRODUCT (6)	– SYNOPTIC PROBABILITY PENALTY PRODUCT
RATIO (2)	– SYNOPTIC LAYOUT EFFICIENCY COMPONENT RATIOS
SAVE (PE)	– STORE RESULTS ON FILE
VALUES (7)	– SYNOPTIC OVERLAP PENALTY VALUES

and then repeats the original question:

WHICH OPTION?

If any other response is given the program treats it as a HELP command.

The various options will now be dealt with in detail, for both types.

2.1. Synoptic Evaluation Options Output:

These options will now be briefly described. Any output referred to can be found in Appendix A4.4, following the appropriate command. The 9 available evaluation options are:

COMPONENT (1):

This option enables the user to get output of the current activity space efficiency factor E.R and its component values O.P, P.P and A.P. On CR the program prompts:

OUTPUT OF LAYOUT EFFICIENCY COMPONENTS

ENTER NAMES OF RESULT FILES TO BE INCLUDED.

The user now has five choices. He can either do CR twice and the program will output the results for the current activity space, or he can include other activity spaces to make a comparison between their efficiency measures. If he chooses the latter option he should type in names of existing evaluation .NUM files (excluding .NUM) followed by CR for each name, and end the list with CR twice. Output will then appear as shown in Appendix A5.2.1. If a non existing file is entered, the program prompts:

FILE <ERROR NAME> .NUM WAS NOT FOUND
REPEAT THE LAST FILE ENTRY

and this will allow the user to input the correct filename and then continue the file list or end by CR pressed twice.

RATIO (2):

This option will print out the various ratios of O.P, P.P and A.P as shown by the appropriate output in Appendix A4.4.

OVERLAP (3):

This option will print out a list of the pairs of overlapping elements in the current activity space and their 1st. order overlap areas for each affected overlap instance, and the total for each instance, as shown by the sample seen in Appendix A4.4 (Bedroom II of the bedroom sample referred to in Section 5).

PARAMETER (4):

This option will print out the various area and perimeter parametres for the current activity space as shown by the appropriate output example in Appendix A4.4.

PENALTY (5):

This option prints out the current weighting factors in the various penalty libraries in turn as shown by the appropriate output in Appendix A4.4.

PRODUCT (6):

This option prints out a list of the overlapping pairs of elements in the current activity space and the probability of usage product and totals for each of the overlap instances affected, as shown by the output in Appendix A4.4.

VALUES (7):

This option again prints out a list of the overlapping pairs of elements in the current activity space and the appropriate product of penalty weighting factors or probability product times the associated 1st. order overlap areas for each effected overlap instance, as well as the total product for each instance, as shown by the appropriate output in Appendix A4.4. The type of penalty product output will depend upon the penalty option chosen earlier in the program.

AREAS (8):

This option will print out a list of the types of elements contained in the current activity space, their number of occurrences and their various component areas, A.E, A.S, A.U1, A.U2 andA.U(1+2), as shown by the appropriate output in Appendix A4.4.

FORMULA (9):

This option prints out the two alternative complete formula expressions for E.R, the efficiency measure for an activity space, as shown by this output in Appendix A4.4.

2.2. Program Ergonomics Options:

The following commands are currently implemented to assist the user when running the program:

ALL:

This option effects the execution of all the 9 evaluation output options in the sequence listed and numbered above. After each option output, the program pauses, and CR causes the screen to be cleared and printout of the subsequent option output. Following the last option output the original question as to which option is required is repeated, and the user again has a choice of entering the desired main program option.

END:

This option causes exit from the CRUNCH program. If the user has run CRUNCH as a separate program, he is returned to the DEC-2Ø monitor level. If CRUNCH was run within the Main program CHAISE, the user is returned to the CHAISE program control level where he may choose another program to run, or exit altogether to the monitor level.

HELP:

This option prints out the list of CRUNCH main program command options as shown above and repeats the WHICH OPTION? question, allowing the user to enter the desired option.

INFO:

This option enables a printout on CRUNCH program operation, parameter definitions and brief design information. For each page of text, the program pauses and a CR causes the screen to be cleared and a new page to be written. At present such information has not been compiled, and the program merely prompts:

MORE INFORMATION ON THE PROGRAM WILL BE AVAILABLE LATER.

The information is simply typed into a data file called NUMINF.TXT from the keyboard at the editing mode of the DEC-2Ø system.

More comprehensive information input and output is available from the CANDID Analysis programs.

LIST:

This option prints out the list of groupnames (design library names) which exist in the ring data structure layout file .RNG. These include the library of single elements as well as the library of activity space layouts, as shown by the output in Appendix A4.4.

NEW:

This option allows the user to enter another group name (activity space) into the program for evaluation. The program prints:

ENTER NAME OF GROUP TO BE CHECKED OR PRESS RETURN FOR WHOLE LAYOUT

and the user proceeds as outlined at the same stage above (item 1).

SAVE:

This option enables the user to save an evaluation file for the evaluation results of the current activity space to be stored in. The program prompts:

ENTER NAME OF FILE TO STORE RESULTS.

The user may now enter the groupname of the current activity space and the program saves a data file named <GROUP NAME> .NUM, which is retrievable by the CRUNCH program as well as the GRAFIT program.

3. Storage of Related Files:

There are four types of stored files that are used for the CRUNCH program, and which are of interest to the user. These are:

3.1 Layout Files:

These are the GAELIC Ring Data Structure files saved by running the SYNCRO programs, and these are used as input for the SYNCRO and CHEVAL programs. It is recommended that after a major design session, copies should be taken of the .RNG file. If the original file becomes corrupted or accidentally deleted, then the back-up file ensures that no work is lost. The .RNG files may be edited by the GAEL7A and GAEL23 programs as described in Sub-subsection 10.4.3 above.

3.2. Evaluation Files:

These are the .NUM files saved by running the CRUNCH program. They become updated if stored by the same name in a subsequent evaluation run of the modified activity space, and are used as input for the CRUNCH and GRAFIT programs. The .NUM files should be given the same name as the associated activity space (groupname). The .NUM files contain all the initial area recordings from the amended Dimcheck programs plus the various calculated parameters needed for the CRUNCH output options.

Area and lengths parameters are stored in mm^2 or mm respectively in the .NUM file, but these values are converted into m^2 or m in the CRUNCH output. The .NUM files also contain information on which penalty option was used in the calculation of the parameters in the files, and this is subsequently displayed when the file is to be input in the CRUNCH or GRAFIT programs. Future use of the program will require automatic penalty option labelling of the CRUNCH files, e.g. NAME.CR1, NAME.CR2 or NAME.CR3, the numerals indicating overlap penalty option used.

3.3. Probability of Usage File:

This file contains the values of the probability values of P(1 , 2) occ. and P(1, 2, 3) occ. for each of the single elements used in the data structure. These probabilities are used to calculate values for and display the probability of usage library in the CRUNCH program. The filename is PROBL.DAT.

3.4 Information Files:

A file called NUMINF.TXT exists which is output when the CRUNCH INFO option is chosen. A similar file called GRAFIN.TXT is available for the GRAFIT INFO option.

3.5. File Handling:

The four file types described above can be handled as follows:

3.5.1. The .RNG layout file can be edited by the GAELIC programs as described.
3.5.2. The evaluation .NUM file must be kept in the form it was saved.
3.5.3. The probability of usage file can be edited if the user has data on probability values, which then can be inserted into the PROBL.DAT file.
3.5.4. Information can be added to the NUMINF.TXT or GRAFIN.TXT files if the user wishes to add his own data on design or the programs, by use of normal editing facilities.

4. Interpretation of Program Output:

It is suggested that the user proceeds in the following sequence when interpreting data from the CRUNCH program:

4.1. Efficiency components of the current activity space may be compared to efficiency components of other activity spaces by using the COMPONENT option. The user will be able to build up a "norm" for values of these components.

4.2. From the efficiency component comparison the user should decide which measures of O.P, P.P and A.P are inefficient.

4.3. Next, the user may look at other evaluation output to pinpoint the cause of innefficiency. For example if the value of O.P is considered high, the user can look at the OVERLAP option output to pinpoint the 1st. order overlap areas, and then look at the VALUES option output to identify the highest overlap penalties inflicted.

4.4. Based on the numerical output interpretation, the user can, if appropriate, return to the synthesis design programs and make suitable design changes of the layout and iterate the synthesis – evaluation sequence.

10.5.2. Running the Graphical Evaluation Output Program GRAFIT.

The GRAFITprogram takes the numerical layout evaluation data for activity spaces generated by the CRUNCH program and gives the user the option to see the data presented graphically as pie-charts, bar-charts and multiple graphs using the GINO graphics facilities described earlier (10.9, 10.10), resulting in a graphical performance profile for the efficiency of space utilisation of plan layouts according to the evaluation method detailed in Sub-section 4.4. The program takes as input the numerical evaluation files <NAME> .NUM saved by the CRUNCH program. The GRAFIT program does not enable a save of files, as the various graphs are easily and quickly regenerated by re-running the program.

There are at present two non-implemented capabilities of the program: One is that there are no default characters for the program, i.e. the program accepts only the correct input to the various prompts or questions, otherwise the user will normally be exited from the program; and the second is that the multiple graph options specified in Sub-subsection 9.4.2 are not yet available, hence comparison of evaluation data from several activity-spaces is not possible using one graph only. These capabilities, however, will be implemented shortly.

The GRAFIT program use and operation is as follows (10.8):

1. GRAFIT Initial Input:

   The program is entered from the CHAISE main command level by typing:

   GRAFIT

   or, the program may be run as a separate program by typing:

   RUN GRAFIT.

   The program writes the following heading:

   GRAFIT – PROGRAM TO DISPLAY GRAPHICALLY THE RESULTS OF A ROOM LAYOUT EVALUATION (CRUNCH)

   and then:

   GINO MK 2.5C 16/MAY/ 79,

   which simply identifies the version of the GINO graphics program which was used to display the evaluation data in graphs.

   The program then prompts:

   ENTER NAME OF FILE OF RESULTS TO BE USED.

   The user can enter an existing .NUM file for the layout he wishes to see graphical evaluation output for. On acceptance of an existing filename followed by carriage return (CR), the program prompts:

THE PENALTY OPTION USED IN THIS EVALUATION
IS <1, 2 or 3, as listed in the CRUNCH penalty options list>.

This reminds the user of whether the .NUM file was generated using the overlap penalty option he desires. If the penalty option is not suitable, the user may on receipt of the next program prompt use the NEW command to enter another, suitable, .NUM file, or alternatively use the END command to exit from the program, and run the CRUNCH program to generate a suitable .NUM file for entry into the GRAFIT program.

After the penalty option reminder prompt, the program proceeds to the main program options.

2. GRAFIT Main Program Options:

When the program enters this level, the following prompt is given:

WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
–TYPE HELP FOR OPTIONS.

The user now has a number of options available. Some options merely assist in the smooth running of the program, and these are called Program Ergonomics Options (Marked PE in brackets after option names below). The remainder of the options are the 9 synoptic graphical evaluation outputs available, as described in the program specifications, Sub-subsection 9.4.2 (Marked 1–9 in brackets after option names below; for programming reasons this order differs slightly from the one given in the specifications).

Each option requires only input of the first two characters of its name, followed by CR. The screen will then normally be cleared and the program drops to a lower level and asks for detailed input of output requirements and what type of graph the output should be presented in. At present there are two graph options: The first draws a pie-chart with relevant parameters or values displayed as percentages of the total value of such parameters; and the second draws a bar-chart where the bars represent actual values of the various parameters asked for. The user types in the desired graph specifications in response to the graph options given, followed by CR, and the graph output is displayed. Following each graphical output, the main program option question is repeated, and the user may choose another option.

If the user types HELP, the program makes a printout of the list of options and a brief description of their functions, as shown below:

OPTIONS ARE:

ACT (9)	– GRAPHICAL PROPORTIONAL ACTIVITY – SPACE AREA OUTPUT
ALL (PE)	– PERFORMS ALL OPTIONS IN TURN
AREAS (8)	– GRAPHICAL OUTPUT OF SINGLE ELEMENT AREAS
COMPONENT (1)	– GRAPHICAL LAYOUT EFFICIENCY COMPONENT OUTPUT

END (PE)	– END PROGRAM
HELP (PE)	– PRINT THIS LIST
INFO (PE)	– TYPE OUT INFORMATION ON PROGRAM
LIST (PE)	– TYPE OUT LIST OF RESULTS FILE NAMES
NEW (PE)	– SELECT A NEW RESULTS FILE
OVERLAP (3)	– GRAPHICAL 1ST. LEVEL OVERLAP AREA VALUES OUTPUT
PARAMETER (4)	– GRAPHICAL PARAMETER VALUE OUTPUT
PENALTY (5)	– GRAPHICAL PENALTY LIBRARIES OUTPUT
PRODUCT (6)	– GRAPHICAL PROBABILITY PENALTY PRODUCT OUTPUT
RATIO (2)	– GRAPHICAL LAYOUT EFFICIENCY COMPONENT RATIOS OUTPUT
VALUES (7)	– GRAPHICAL OVERLAP PENALTY VALUES OUTPUT

and then repeats the original question:

WHICH OPTION?

The various options will now be dealt with in detail, for both types.

2.1. Synoptic Graphical Evaluation Output Options:

These options will now be briefly described. Any output referred to can can be found in the associated illustrations within this section. The 9 available graphical evaluation options are:

COMPONENT (1):

This option enables the user to get graphical output of the current activity space factor E.R. and its component values O.P, P.P and A.P. On CR the program prompts:

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

PIE-CHART (1) OR BAR-CHART (2).

The user can type 1 or 2 and the graphical output will be displayed in each case as shown in Fig. 10.1 (A test run of Bedroom II of the bedroom sample mentioned in Section 5 was used to produce the various graphical output graphs).

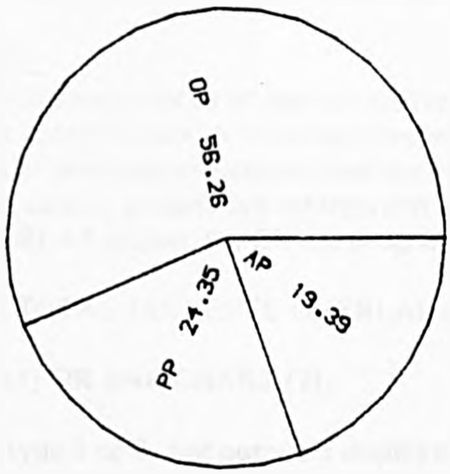
RATIO (2):

This option will graphically display the various ratios of O.P, P.P and A.P. On CR the program prompts:

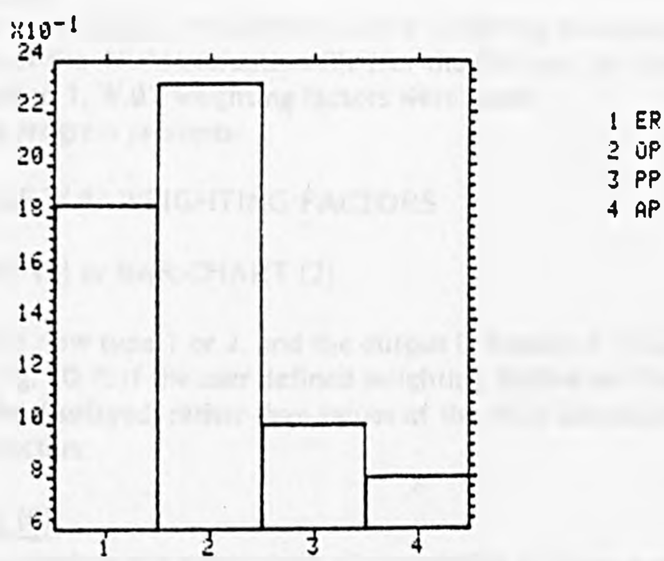
OUTPUT OF LAYOUT EFFICIENCY COMPONENT RATIOS
O.P (1) P.P (2) OR A.P (3).

The user can type 1, 2 or 3, and the program prompts:

PIE-CHART (1) or BAR-CHART (2).




```
WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
                    - TYPE HELP FOR OPTIONS
COMPONENT
```




```
WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
                    - TYPE HELP FOR OPTIONS
RATIO
```

Fig. 10.1. GRAFIT Output Option 1: Efficiency COMPONENT Values.

The user can type 1 or 2. Examples of the various combinations of graphical output are shown in Figs. 10.2 – 10.4.

OVERLAP (3):

This option will display totals of the various types of overlap areas present in the current activity space. A non-implemented part of this option is to identify pairs of overlapping elements and the various overlap instance areas for each case; at present this information is given by the CRUNCH program OVERLAP option. On CR the program prompts:

OUTPUT OF TOTAL 1ST. LEVEL OVERLAP AREAS

PIE-CHART (1) OR BAR-CHART (2).

The user can type 1 or 2, and output is displayed in each case as shown in Fig. 10.5.

PARAMETER (4):

This option will display the various area and perimeter parameters for the current activity space. On CR the program directly displays a bar chart only, of the various parameter values and an associated list of the parameter names, as shown in Fig. 10.6 (See Sections 4 and 5 for definitions of these parameters, and others).

PENALTY (5):

This option will display the current overlap weighting factors used in the generation of the .NUM evaluation file (for the file used for the test run, penalty option 1, W.Ø1 weighting factors were used).
On CR the program prompts:

OUTPUT OF W.Ø1 WEIGHTING FACTORS

PIE-CHART (1) or BAR-CHART (2).

The user can now type 1 or 2, and the output is displayed in each case as shown in Fig. 10.7. If the user defined weighting factors were used, then these will be displayed, rather than values of the W.Ø1 standard library of weighting factors.

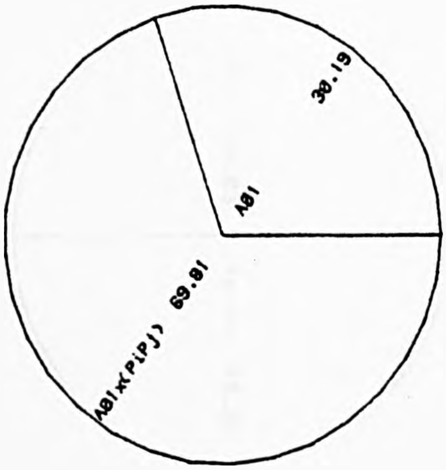
PRODUCT (6):

This option displays the total values of probability of usage products for the current activity space for the overlap instances present. On CR the program prompts:

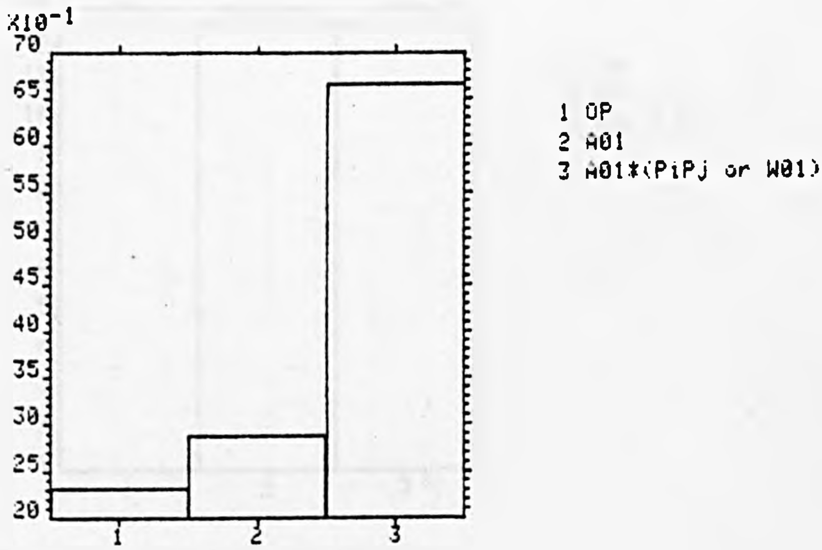
OUTPUT OF TOTAL PROBABILITY PENALTY PRODUCTS

PIE-CHART (1) OR BAR-CHART (2).

The user can enter 1 or 2, and output is displayed in each case as shown in Fig. 10.8.

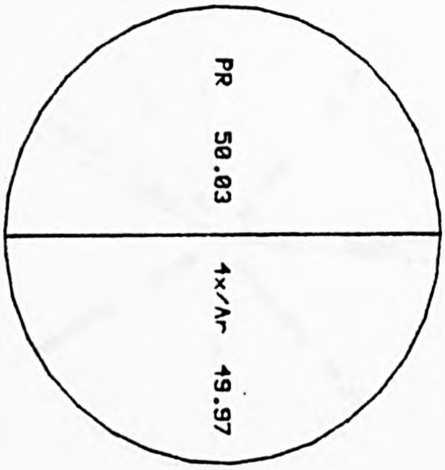


WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS
RATIO

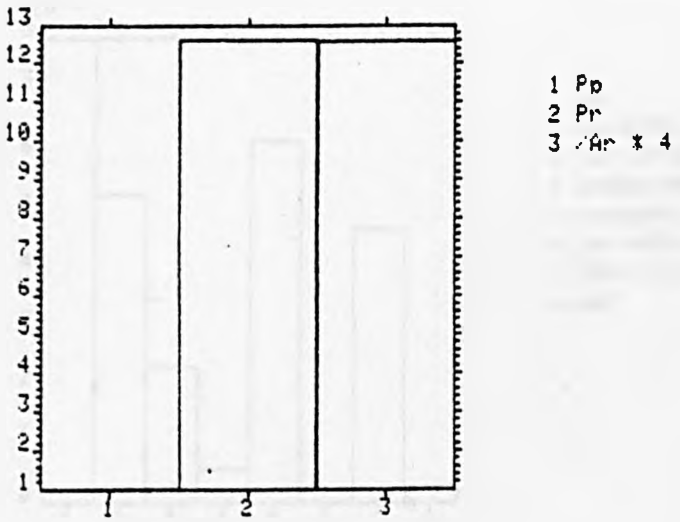


WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS
RATIO

Fig. 10.2. GRAFIT Output Option 2: O.P RATIOS.

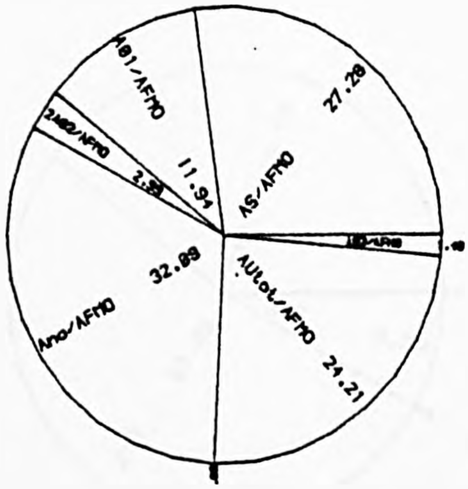


WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS
RATIO

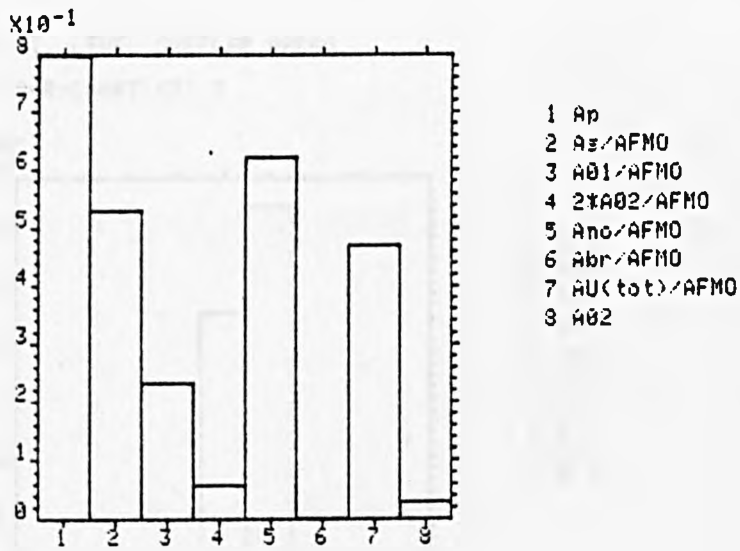


WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS
RATIO

Fig. 10.3. GRAFIT Output Option 2: P.P RATIOS.



WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS
RATIO

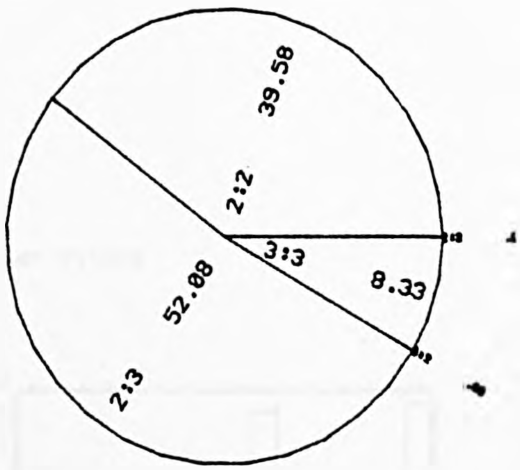


WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS
OVERLAP

Fig. 10.4. GRAFIT Output Option 2: A.P RATIOS.

OUTPUT OF TOTAL 1ST. LEVEL OVERLAP AREAS

PIE-CHART (1) OR BAR-CHART (2) 1

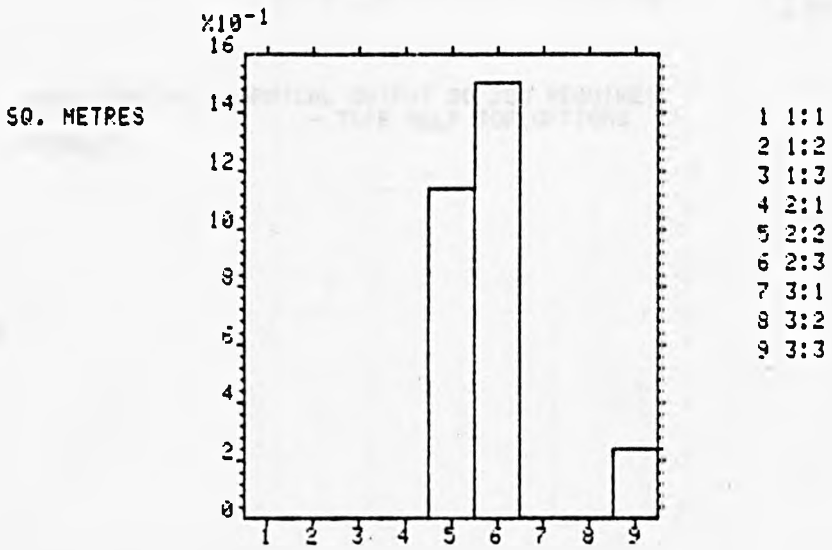


WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

OVERLAP

OUTPUT OF TOTAL 1ST. LEVEL OVERLAP AREAS

PIE-CHART (1) OR BAR-CHART (2) 2

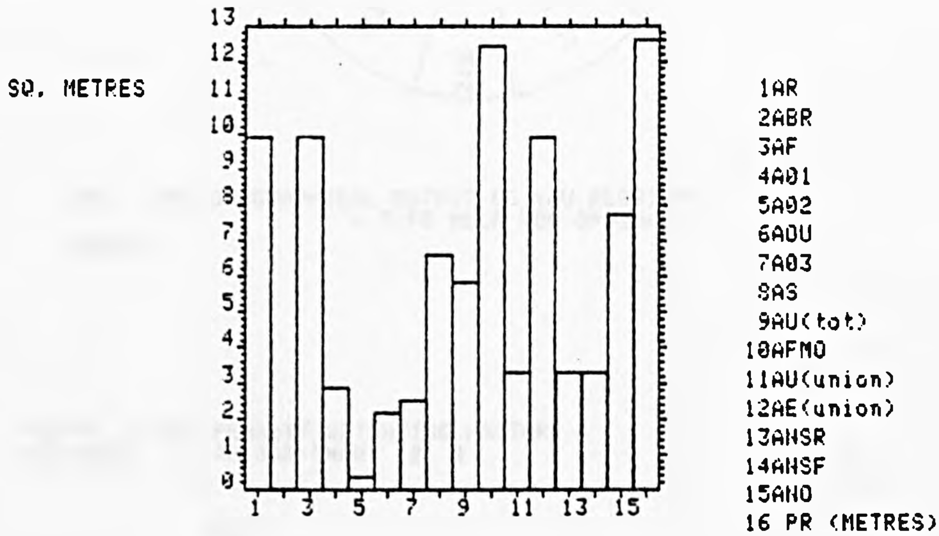


WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PARAMETER

Fig. 10.5. GRAFIT Output Option 3: 1st. Order OVERLAP Areas.

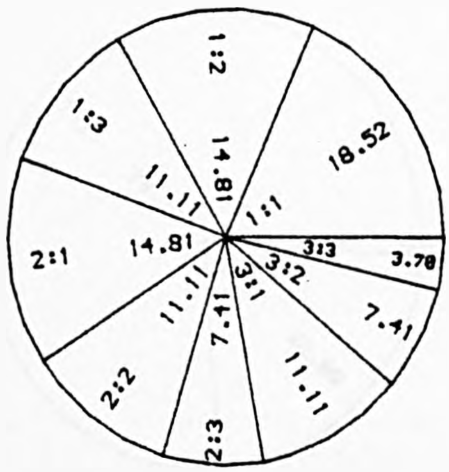
output of parameter values



WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS
PENALTY

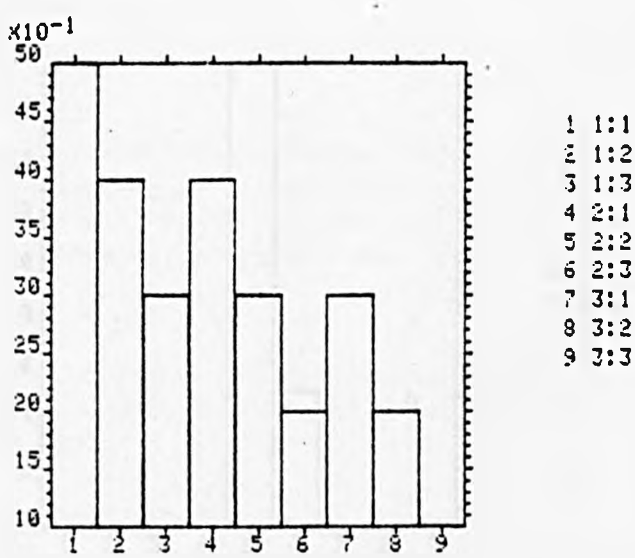
Fig. 10.6. GRAFIT Output Option 4: PARAMETER Values.

```
OUTPUT OF W01 PENALTY WEIGHTING FACTORS
PIE-CHART (1) OR BAR-CHART (2) 1
```




```
WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
                        - TYPE HELP FOR OPTIONS
PENALTY
```

```
OUTPUT OF W01 PENALTY WEIGHTING FACTORS
PIE-CHART (1) OR BAR-CHART (2) 2
```

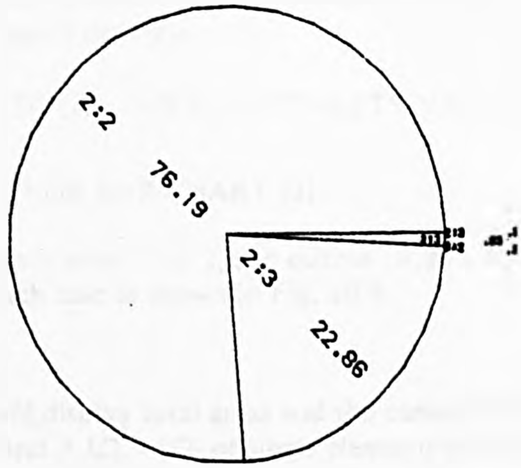



```
WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
                        - TYPE HELP FOR OPTIONS
PRODUCT
```

Fig. 10.7. GRAFIT Output Option 5: Overlap PENALTY Weighting Factors.

OUTPUT OF TOTAL PROBABILITY PENALTY PRODUCTS

PIE-CHART (1) OR BAR-CHART (2) 1

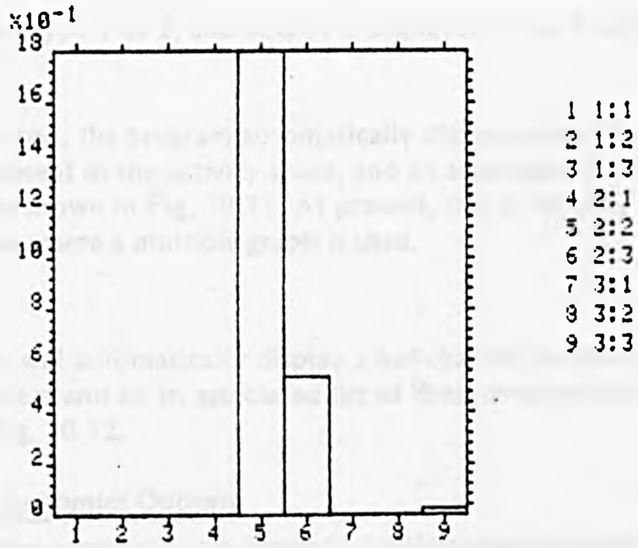


WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PRODUCT

OUTPUT OF TOTAL PROBABILITY PENALTY PRODUCTS

PIE-CHART (1) OR BAR-CHART (2) 2



WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VALUES

Fig. 10.8. GRAFIT Output Option 6: Probability Overlap Penalty PRODUCT.

VALUES (7):

This option displays the total values of the product of overlap penalty values, whichever penalty option is used, and the corresponding overlap areas of 1st order between pairs of elements, for the current activity space. On CR the program prompts:

OUTPUT OF TOTAL OVERLAP PENALTY VALUES

PIE-CHART (1) OR BAR-CHART (2).

The user can then enter 1 or 2, and output (A.Ø1 x W.01 or Pi Pj) is displayed in each case as shown in Fig. 10.9.

AREAS (8):

This option will display total areas and the component areas, A.E, A.S, A.U 1, A.U2 and A.U1 + U2, of single elements present in the current activity space. On CR the program prompts:

OUTPUT OF SINGLE ELEMENTS AREAS

ENTER NAME OF ELEMENT OR "ALL" FOR ALL ELEMENTS IN LAYOUT.

If the user types the name of an element present in the activity space, the program prompts:

PIE-CHART (1) OR BAR-CHART (2).

The user can type 1 or 2, and output is displayed in each case as shown in Fig. 10.10.

If ALL is typed, the program automatically displays area values for all the elements present in the activity space, and an associated list of these elements, as shown in Fig. 10.11. At present, this is the only occasion in the program where a multiple graph is used.

ACT (9):

This option will automatically display a bar-chart of proportional activity space sub-areas and an an associated list of these area parameters, as shown in Fig. 10.12.

2.2. Program Ergonomics Options:

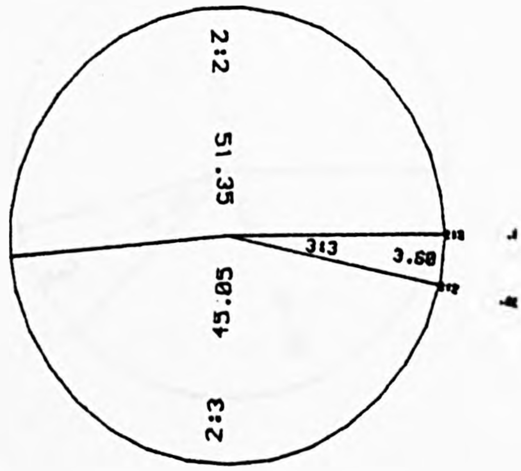
The following commands are currently implemented to assist the user when running the program:

ALL:

This option effects the execution of all the 9 graphical evaluation output options in the sequence listed and numbered above. The program occasionally pauses at required input points to allow user input, and then displays the relevant output graphs, after which it again pauses, waiting

OUTPUT OF TOTAL OVERLAP PENALTY VALUES

PIE-CHART (1) OR BAR-CHART (2) 1

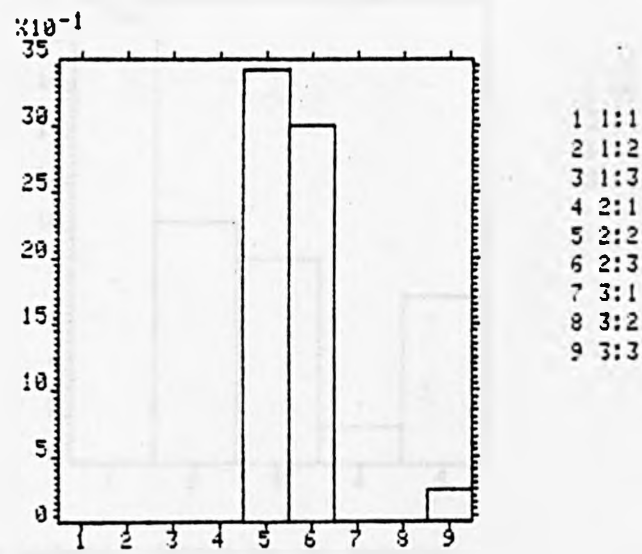


WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VALUES

OUTPUT OF TOTAL OVERLAP PENALTY VALUES

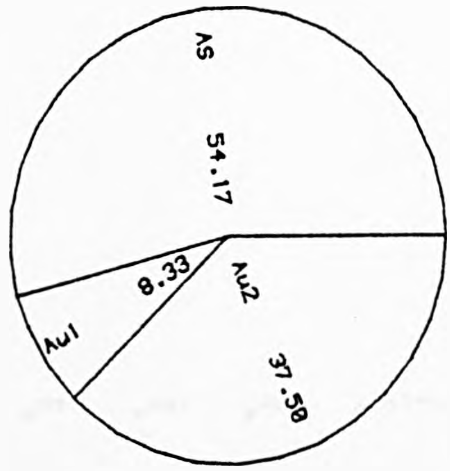
PIE-CHART (1) OR BAR-CHART (2) 2



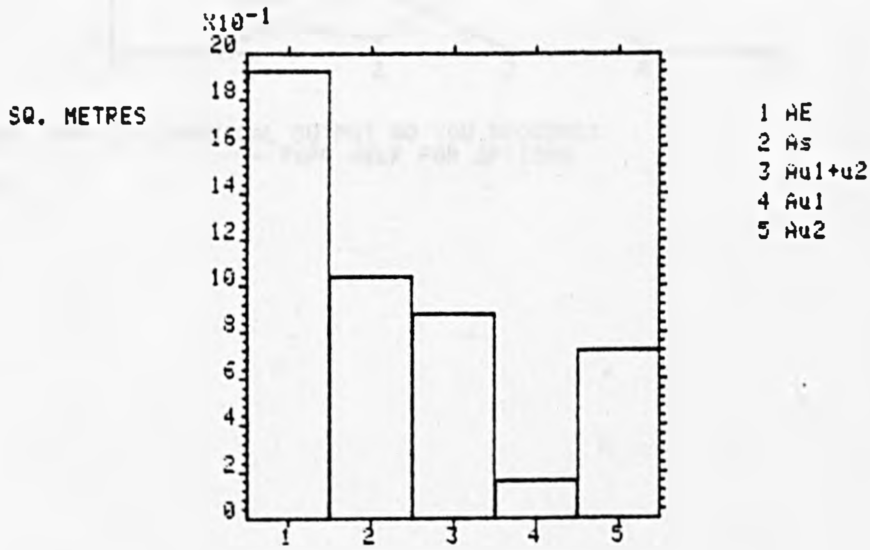
WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

AREAS

Fig. 10.9. GRAFIT Output Option 7: Overlap Penalty VALUES Output.

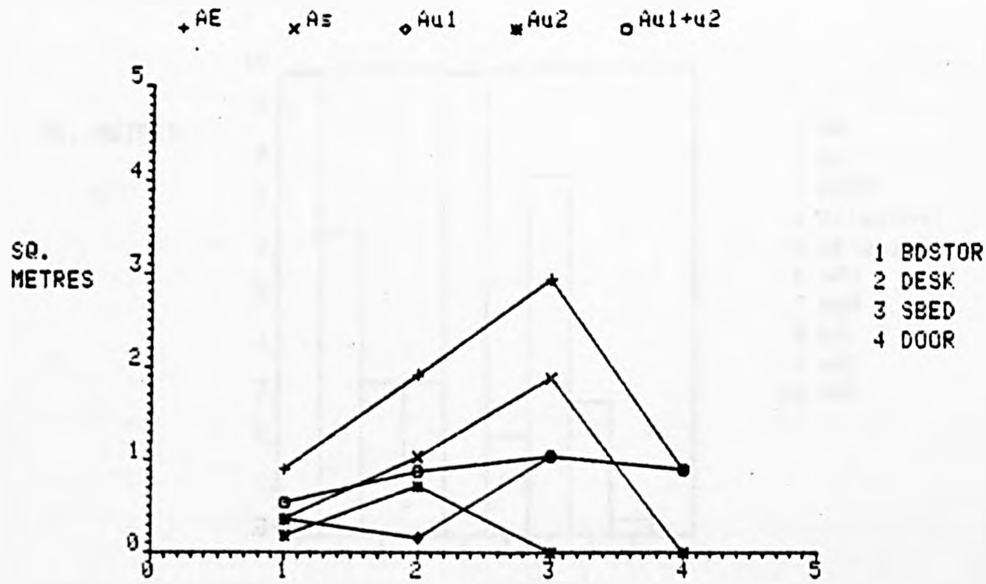



```
WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
                     - TYPE HELP FOR OPTIONS
AREAS
```




```
WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
                     - TYPE HELP FOR OPTIONS
AREAS
```

Fig. 10.10. GRAFIT Output Option 8: AREAS of One Single Element.

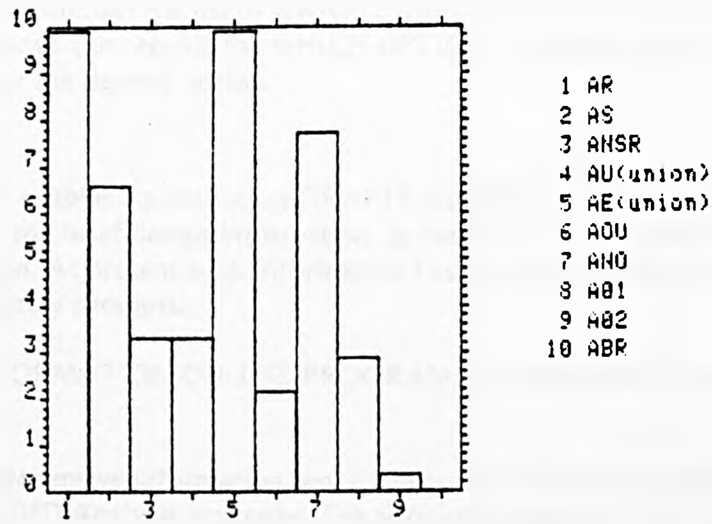


WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS
ACT

Fig. 10.11. GRAFIT Output Option 8: AREAS of All Activity Space Elements.

OUTPUT OF PROPORTIONAL ACTIVITY SPACE AREAS

SQ. METRES



WHAT TYPE OF GRAPHICAL OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

HELP

Fig. 10.12. GRAFIT Output Option 9: Proportional ACTivity Space Areas.

for a CR which will effect execution of the next output option. Following CR after the final output option, the program returns to the main program command level, where the user again has the choice of all main options.

END:

This option causes exit from the GRAFIT program. If the user has run GRAFIT as a separate program, he is returned to the DEC-2Ø monitor level. If GRAFIT was run within the main program CHAISE, the user is returned to the CHAISE program control level where he may choose another program to run or exit altogether to the monitor level.

HELP:

This option prints out the list of GRAFIT main program command options as shown above and repeats the WHICH OPTION? question, allowing the user to enter the desired option.

INFO:

This option enables a printout on GRAFIT program operation, parameter definitions and brief design information, as described for the CRUNCH INFO option. At present such information has not been compiled, and the program merely prompts:

MORE INFORMATION ON THE PROGRAM WILL BE AVAILABLE LATER.

More comprehensive information input and output will be possible by use of the CANDID Analysis programs (See also Sub-subsection 10.5.1, item 3.4).

LIST:

This option prints out a list of the .NUM evaluation files generated by the CRUNCH program, which are present in the user's directory area on the computer.

NEW:

This option allows the user to enter another .NUM file into the GRAFIT program for graphical evaluation of the associated activity space.
The program prints (See above):

ENTER NAME OF FILE OF RESULTS TO BE USED

and the user proceeds as outlined for that stage in the program (item 1 above).

3. Interpretation of Program Output:

Since the GRAFIT options are essentially graphical versions of the CRUNCH numerical options, the user may proceed to interpret evaluation results as per corresponding suggestions for the CRUNCH program (See Sub-subsection 10.5.1, item 4).

SECTION 11: PROGRAM PERFORMANCE VALIDATION

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PROGRAM PERFORMANCE VALIDATION.

Two types of program performance were considered. Firstly, the numerical calculation accuracy of the CRUNCH evaluation program was validated and its computing efficiency observed, and secondly, the user ergonomics of the CHAISE Package was considered. The result of the tests follow.

11.1. Numerical Performance of the CRUNCH Program.

The manual evaluation results for the sample of 21 bedrooms, as obtained by the objective manual evaluation experiment described in Section 5, were compared to the associated CRUNCH program output as follows (See Appendix A2.3 for manual result figures).

11.1.1. Bedroom Layout Input.

The 21 bedroom layouts were input to the GAEL4A synthesis program as follows:

1. A data structure file called BEDRUM.RNG was opened.
2. The single elements used for the 21 bedrooms as shown in Fig. A2.2 were input as groups and given groupnames as shown in Appendix A5.1.1 , Fig. A5.1. The exact dimensions of the elements were input on masks 1, 2 and 3, as appropriate.
3. Using the single elements, the 21 bedroom layouts were accurately assembled by means of group origin co-ordinate input, and in addition a bounding rectangle was input for each layout on mask 6. Use of the correct mask numbers is of course essential since the CRUNCH program only expects shapes for evaluation on masks 1, 2, 3 and 6. This does not prevent the user to insert additional shapes, text or symbols on other masks, as these will not affect the CRUNCH calculations. The 21 bedroom layouts were output on the Tektronix Hardcopy Unit as shown in Appendix A5.1.2, Fig. A5.2, showing their groupnames and dimensions. Dashed lines were effected by the GAEL4A DASH command.

11.1.2. CRUNCH Output.

The CRUNCH program was run inputting the BEDRUM.RNG layout file and by using the NEW and SAVE commands to evaluate each bedroom layout in turn and to SAVE their associated evaluation files. The following options were output:

1. Option 1: COMPONENT
2. Option 2: RATIOS
3. Option 3: OVERLAP
4. Option 4: PARAMETER
5. Option 7: VALUES.

The output values are shown in Appendix A5.2.2. Other, common data for the bedroom layouts are shown in Appendix A5.2.1, and these were mainly the following:

1. Option 1: COMPONENT (showing comparative values for all the 21 bedrooms).
2. Option 5: PENALTY (showing the various penalty libraries).
3. Option 8: AREAS (showing single element areas).

The overlap penalty option 1 was used for all the outputs, since this option also was the basis of the manual calculations.

11.1.3. Numerical Performance Conclusions.

There was a near perfect match between the manual figures and the CRUNCH output figures, the minute differences being caused by the slightly different rounding techniques used in the program from the manual calculations. These differences were only noticable in the fourth decimal of the E.R components and are therefore negligible or un-interesting. It can therefore be concluded that the CRUNCH program calculations are done accurately. It is anticipated that the computing time would be shortened by stripping the Dimcheck program of irrelevant routines, and this is a future task. There was a slight pause in the beginning of the program while calculations were being performed, which time would be shortened by such program streamlining as mentioned.

11.2. User Ergonomics Performance.

It was not considered that a user ergonomics study of the program should be part of the present research project, and the timetable involved would indeed have excluded the possibility of its inclusion. Since the various computer programs of the resultant CAAD system were chosen and designed to suit the proposed design model, it is considered that ergonomic drawbacks only occur where the available hardware or software are insufficient, or, where the limitations of the present research project, in terms of finance and time, did not permit the development of a fully practical design aid.

However, the following brief subjective comments on the current program implementation are intended to draw attention mainly to some present systems drawbacks, or point to areas outside the present work, which, when completed will increase the usefulness of the CAAD System, and to indicate where appropriate, advantages of certain systems features. The various programs will now be dealt with in turn.

11.2.1. Ergonomics of the CHAISE Main Program.

The CHAISE Program, when implemented, will provide the user with design and program information at the analysis design activity, and allow subsequent iterations between the synthesis and evaluation activities until a satisfactory layout has been chosen. At present the analysis information on house design, products and so forth has not been compiled, and the synthesis and evaluation programs are run separately. However, iterations between the synthesis and evaluation activities can take place as intended, except that the bother of entering, exiting and re-entering the programs will obviously be eliminated once the CHAISE control program is implemented.

11.2.2. Ergonomics of the CANDID Analysis Programs.

The compilation of design information to be made available in the CANDID programs is not part of the present work, but such data can readily be fed into the CANDID data files, using any desired classification system future users might prefer. Having all the design information available at the terminal will obviously save time in the information retrieval process, and provide the user with an invaluable design aid.

11.2.3. Ergonomics of the SYNCRO Synthesis Programs.

The main drawback involved in using the SYNTER (GAEL4A) program is the amount of time that has to be spent by a novice in order to become a proficient user of the program. Once the skill has been mastered however, the program provides an extremely flexible design tool for assembling layouts using the library of single elements. The SYNTAB tablet menu program was designed and implemented in order to eliminate the familiarisation problem, as well as displaying single element libraries. Therefore, the user does not need to worry so much about remembering cursor commands or element names, since these are constantly displayed visually to him on the tablet menu area.

However, the ideal hardware set up described in Sub-section 8.3.1 is preferable to the current use of the Tektronix 4Ø1Ø storage tube terminal. To provide a large colour refresher graphics terminal with a light pen and the use of screen menus would satisfy the requirements of the proposed Synthesis Model as intended. The interactivity of the SYNCRO programs would also be enhanced by making their terminology more architectural.

11.2.4. Ergonomics of the CHEVAL Evaluation Programs.

The CRUNCH program gives a comprehensive rundown on an activity space layout, in terms of its constituent areas and the various efficiency components required by the Evaluation Model. The design of the program makes it possible for the user to choose among the main program commands, including the evaluation outputs, so that these can be executed in any order or repeated as required by him. It is considered that this interactive or lateral approach is preferable to one in which the program proceeds in a set sequence from start to finish, giving the user no choice of output options. Using the CRUNCH program, the user has full flexibility of option choice, and needs only investigate the efficiency of a layout to the level of detail required, and can thereby save time.

The GRAFIT program is designed almost identically to the CRUNCH program in terms of interactivity and flexibility, but in the GRAFIT program the evaluation output is displayed graphically as bar-charts, piecharts or multiple graphs (the latter is presently not implemented). The GRAFIT program was designed as an optional extra for quick rundown on activity space efficiency, and is perhaps more interesting to use for a designer than the CRUNCH numerical output program.

There are two further ergonomics points to be considered concerning the CHEVAL programs. One is the suitability of the evaluation terminology, and this can only be validated by user feedback on the programs. Secondly, there is the question of whether the CHEVAL programs provide the instantaneous feedback of evaluation data required. Again, the current hardware set up inhibits the possibility of complete instantaneousness of evaluation feedback. It is necessary to make use of a larger screen in order to have sufficient screen area for the designation of an evaluation output area as well as menu, text and planning areas (See Fig. 8.5). If a larger screen area were available, it would be possible to have constant updating of optional evaluation output as the layout assembly proceeds. A back-up file of the layout data structure would have to be taken every time a design change in the layout occurs, and this file should be automatically input to the CHEVAL programs so that optional output may appear immediately on the screen, subsequently returning the user to the synthesis program.

The current implementation and set up of the CHEVAL programs allows a near instantaneous feedback of evaluation data, the drawback being mainly that the user has to exit, enter and re-enter the Synthesis and Evaluation programs manually.

11.2.5. Program Ergonomics Conclusions.

In the absence of ideal hardware, which because of its current limited availability and prohibitive cost puts it beyond reach for use in the present research project, it is considered that the currently implemented programs provide a viably ergonomic design aid, competitive with similar CAAD systems.

SECTION 12: DISCUSSIONS AND FURTHER WORK

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DISCUSSIONS AND FURTHER WORK.

This final section contains a brief discussion on whether the proposed design system for domestic layouts in terms of its Analysis, Synthesis and Evaluation Models was appropriate, and whether the resultant CAAD System was suitable for the proposed design models. Subsequently, proposals are made for possible future work relating to the CAAD system.

12.1. Discussions of the Models and the CAAD System.

The following is a review of many of the critical decisions that were made in the course of designing the final CAAD system.

12.1.1. Appropriateness of the Proposed Design Models.

One starting point for the current research project was the generally accepted model of the design activity by Markus and others, shown in Fig. 2.1. The approach was that by investigating this model further, solutions could be found to many of the problems related to the design of domestic layouts, such as design flexibility for the designer in the 'assembly' of layouts and a measure of the efficiency (or cost effectiveness) of layouts.

Analysis of the design model led to the further investigations of functional aspects of domestic layouts, as discussed in Section 2, and a study of related design models and theories, as discussed in Section 3. Based on these studies, detailed proposals for the Analysis, Synthesis and Evaluation Models were made as contained in Section 4. The functional studies led to the conception of the Synthesis Model, which principal novel features are those of floor space classification and the assembly approach to the design of layouts at various design levels of escalating layout sizes based on the lowest design level which comprised a library of single house planning elements.

The floor space classification led to the identification of a number of floor area parameters, including overlap areas of various overlap instance types, and perimeter parameters. Based on the various parameters and their interaction, the proposed Evaluation Model was conceived, which allowed evaluation of activity space floor area efficiency, and therefore could be used to promote cost effective layouts, as one objective evaluation aid for the architect.

Subsequently a sample of 21 bedrooms were chosen and their layouts evaluated manually (See Section 5 and Appendix A2) according to the Evaluation method. A subsequent subjective test (See Section 6 and Appendix A3), involving subjects evaluating a selection of the bedroom layouts, showed that there was an extremely low statistical sample agreement among the test subjects, and further, that no positive statistical correlation could be found between the objective and subjective room layout evaluations.

Four extremely strong reasons in favour of the implementation of a CAAD system to satisfy the proposed design model requirements had consequently been clearly established:

1. The obvious need for a single design information source at the Analysis and other design activities could only efficiently be satisfied by means of a computer information retrieval system.

2. The kind of flexibility required by the proposed Synthesis Design Model could only be realised by the use of computer graphics.

3. The complexity of the numerical Evaluation Method excluded its manual use, and consequently it could only practicably be implemented by use of computer calculations.

4. The failure of test subjects to make any consistent layout evaluations and their deviation from the objective evaluations, led to the conclusion that layout evaluations related to floor area efficiency at least, would best be done by objective means, hence by computer implementation.

12.1.2. Suitability of the Resultant CAAD System.

An early decision was to exclude programs that would automatically design layouts at the Synthesis design activity, and there were several reasons for this decision:

1. This approach did not agree with the requirements of the Synthesis Model, since the view was taken that architects would prefer to do the designing themselves.

2. Architects are not going to be responsive to a computer program that might threaten to make them redundant.

3. Design is an interactive process in which the designer should be able to stop and move backwards and forwards in the scheme of events, but an automatic generation technique would design layouts according to a set method every time, not allowing for oddities or the need for diversions.

4. Even if this approach had been chosen, the chance of either obtaining or successfully writing the required program would not be guaranteed. An automatic design technique operating on the most naive levels would still require a tremendously complex element attribute constraint system, and no acceptable such program has yet been found.

It is therefore considered that the choice of the interactive Synthesis programs was a valid one which would still leave the architect in charge of the design, and provide him with a degree of flexibility required as shown by the early design investigations. As with any CAAD system, an added bonus is of course the facility to store layouts in the computer, producing drawings only when required. The use of a coding system for layouts will ensure that all versions of layouts can be retrieved at any time. Such a manual storage system will rapidly become unmanageable because of the bulk of drawings involved.

The Evaluation programs have been found to perform excellently according to the Evaluation Model proposed, and give the user access to evaluation data previously unavailable. As with any novel evaluation technique it is inevitable that program use by the profession may point to changes and developments, but this is highly desirable. It is considered, however, that all crucial parameters of a floor plan layout have been taken into consideration in the evaluation method. No doubt a first addition to the program will be cost measures, but since cost in this 2-D case can mainly be based on floor area and since cost per square metre fluctuates very rapidly anyway, it was not felt necessary to include this measure to demonstrate the validity of the evaluation program or for the present research project.

12.1.3. Conclusions.

It is considered that, subject to hardware refinements, the objectives of the proposed design models, which have been shown to be appropriate, have been met by the implemented CHAISE package of programs. The main requirements of the design models, which as CAAD program implementations are also advantages over manual design theories, are as follows:

1. A central design analysis information system.

2. Design flexibility and speed at the synthesis design activity.

3. Accuracy and speed of the novel evaluation method offering near instantaneous layout evaluation feedback of objective data which would complement the architect's subjective assessment of layouts.

4. The facility to operate using iterations between the design activities of analysis, synthesis and evaluation, and between options in each of the programs.

The appropriateness of the design models has been ensured by the systematic progression of the early design investigations, and the adherence to the flexible model of the design process. Similar systems for comparison were not found, as most of the domestic or other CAAD systems available rely heavily on an association matrix for connectivity between rooms, based on travel distance. Many CAAD systems provide some form of graphics interaction at the synthesis design activity, but a detailed evaluation of activity spaces has not been successfully implemented prior to the proposed system.

A final aspect concerning the programs is their portability. At present the programs can run on any timesharing mainframe computer system, which would allow most architectural offices to make use of the programs by telephone link-up. However, there is no reason why the programs could not operate on a stand alone mini-computer system. At present, the trend in CAAD appears to favour refresher graphics and mini-computers, and the cost of such equipment is decreasing, in contrast to the early view that large national computer systems was the answer. There is reason to believe that stand alone systems may become common in architects' offices in the future.

Discussions with and interest shown by the Compeda software agency, who already have a vested interest in the GAELIC programs, has led to the possibility of an imminent commercial marketing of the CHAISE package of programs.

12.2. Further Work.

This Sub-section contains two types of proposals for possible future work relating to the proposed CAAD system; firstly work concerned with its intended use, and secondly, work related to other architectural and non-architectural applications of the system. Further work may arise from two equally desirable circumstances; one, from commercial use and marketing of the package, which would enhance its practicability, and two, from further academic research in the field, particularly in the form of research student - or fellowships, which would promote other novel or original changes and additions to the programs.

12.2.1. Sophistication of the CAAD System for its Intended Use.

The following suggestions for further work have all been mentioned previously in the thesis:

1. Work on the Analysis Programs:

   Firstly the Analysis CANDID programs as detailed in Sub-section 9.2 should be implemented, and secondly, and this would probably form a research project in its own right, domestic design information (and program information) must be compiled, classified and input to the CANDID files. Although this work at first glance may appear routine, its complexity should not be underestimated since the classification of information must be tailored for the requirements of this particular design system. Information would include not only standard design information such as is found in the New Metric Handbook (12.1), Neufert's Architects' Data (12.2) and so forth, but would also comprise Building Regulations and product information.
   It is hoped that the eventual outcome of such a project would lead to some sort of design brief production aid, possibly taking into account the CISfB classification system.

2. Work on the Synthesis Programs:

   Firstly, the hardware set up should be upgraded to include a large refresher graphics colour terminal with a light pen, and this would enable the software to be enhanced to include the various types of screen areas as detailed in Sub-section 8.6 (See Fig. 8.5). Recently, the SSSA has purchased an APPLE minicomputer which works in conjunction with a colour TV screen, and it is hoped that the present CAAD programs may be implemented on this hardware. Definition of floor space categories would be vastly improved by colour rather than dashed line outlines.

   Other refinements of the Synthesis programs could include:

   2.1. The facility to create group definitions within other group definitions as discussed in Sub-sub-section 4.3.6 and in Section 7, which would increase the design flexibility at the synthesis design activity stage.

2.2. The coding system for the storage of layouts at all design levels as detailed in Sub-section 8.5 needs to be reviewed and refined to create a practicable coding system for architects in practice. It is, however, anticipated that each office would have unique coding systems for their drawings, and that this development therefore would take place by use of the programs in offices.

2.3. Use of the programs might create layout data structures containing a large number of layout names, i.e. groupnames. At present use of the LIST command will cause all these names to be listed. It may prove advantageous to complement the LIST command to allow listing of only particular groupnames, for example display of only bedroom layouts at design level 3. Such an option would obviously need to tie in with the coding system employed.

2.4. It is possible to use the synthesis programs as a basis for a program to generate layouts automatically. However, this is not seen as desirable from the author's point of view for reasons given in Sub-sub-section 12.1.1 above. Automatic generation may be seen as desirable if used only to present the designer with a range of layouts to choose from for further re-design. The current state of artificial intelligence would not seem to warrant the success of such a program.

3. Work on the Evaluation Programs:

An important improvement is the facility to obtain evaluation data whilst designing using the synthesis programs, but this kind of instantaneous feedback, as discussed in Section 8 and Sub-sub-section 11.24, would require a larger screen area than presently available. There seems to be little doubt that when implemented, instantaneous evaluation of layouts might revolutionise layout design and create a truly dynamic design situation.

Other work, which would enhance the evaluation programs would be as follows:

3.1. The Dimcheck programs need to be rationalised to include routines necessary only for the proposed evaluation method. Although simple in principle, this is an extremely time consuming piece of work, since all interactions between subroutines must be checked.

3.2. Storage of evaluation files should preferably be labelled according to the overlap penalty option used for the evaluation calculations within the CRUNCH programs, as discussed in Sub-sub-section 9.5.1, and at present this is done manually by the user and in addition the user is reminded of the penalty option used when retrieving an evaluation file for the CRUNCH or GRAFIT programs. Automatic penalty option labelling would be preferable, and the penalty option should appear in the evaluation file name, e.g. as NAME. CR 1 for penalty option 1, NAME. CR 2 for penalty option 2 and so forth.

3.3. Insertion of probability of usage data for house planning elements is essential for correct use of the evaluation method. Such data, however can only be obtained by controlled observation of element usage by researchers in the field. If fragmented data was made available, this could of course be used to anticipate other element probability of usage values.

3.4. A layout adaptability evaluation measure could be included (See Appendix A1.1) which would check a layout's dimensions and window and door positions with those of other layouts of the same type in the design libraries, and so determine which other layouts could be fitted within the current layout perimeter. Another similar measure could check a complete floor plan for the possibility of extensions in all directions, based on wall constraints.

3.5. The evaluation method should be extended to take into account circulation areas and the efficiency of a complete floor plan, including wall elements. At present this can simply be done by taking an average of the constituent activity space efficiency values.

3.6. Further research work should enable the inclusion of other layout efficiency measures, such as cost discussed above, and others (See Appendix A1.1).

4. User Program Validation Work:

A pilot study of the proposed CAAD system, including user feedback on terminology suitability of all the programs and the general ergonomics of them, would be an ideal follow up research studentship project. In addition a larger and more comprehensive sample of activity-spaces of all categories should be chosen for test runs in such a study.

12.2.2. Other Architectural Applications of the CAAD System.

Subject to appropriate changes, particularly of the evaluation method, the proposed CAAD system may be used for the design and evaluation of plans of other building types and for other purposes, as follows:

1. Design and Evaluation of Non-residential Building Plans:

Since single planning elements in principle all are of the same type, there is no reason why the Synthesis programs could not be used to design floor plans of any building, which could be evaluated by the Evaluation programs. House plans were chosen for this research project because of the author's predilictions and because this type of application would have more impact than other building types, such as schools, restaurants, office buildings, agricultural buildings, and so forth.

2. Applications for Area Planning:

If a land area is delimited as a polygon, then it is possible to design an area plan within it, using component areas of housing, industry etc. as "planning elements". These planning elements may be defined in a similar way to that of house planning elements, and an assembly of elements would therefore result in a land use plan. The analogy with floor plan layouts does obviously not hold true, but differences can be accommodated by the definition of "elements". Evaluations of land use efficiency should be possible by using an amended version of the CRUNCH program, and by altering its terminology. Housing layout planning and urban planning fall into the same category.

3. Educational Use of CHAISE:

The CHAISE package, when fully implemented, may be used as an educational teaching device for architectural and design students. By using the Synthesis programs layouts may be designed, and subsequent evaluations by the CRUNCH program would help students pinpoint violations of spatial standards and inefficient design. The synthesis and evaluation programs would be most useful as a teaching aid to beginning students, whereby they would learn the importance of design elements and spatial standards of layouts, but could also be used as a design aid for students of later years. The information provided by the Analysis programs should also prove useful to architectural students.

4. CHAISE as a Design Participation Device:

Architects may employ the CHAISE programs as a participation device between various members of the design and building team in a variety of ways. The Synthesis program in particular may be used as a guide sketch pad device for communicating layouts between the architect and the client, the builder and other members of the design team such as engineers and quantity surveyors. Evaluation output for the various layouts may then be obtained by use of the CHEVAL programs, in particular the GRAFIT program since its output is in an easy to grasp format for quick discussions, and the architect can explain pros and cons of the various layouts, taking the evaluation output into consideration as part of his total assessment of the layouts. Similarly, the programs can be used for design participation by naive designers, i.e. non-professionals.

5. Design of Prefabricated Houses:

Once suitable activity spaces and a house floor plan has been designed, using the synthesis programs, other elements can be inserted such as walls, windows, doors and so forth. The library system provides the ideal medium for creating standard components used in prefabricated housing or other building types. The program would be suitable for any degree of prefabrication used, e.g. if whole room units are factory built, then these will appear as group definitions in the program. The Evaluation programs would be used as normal, and would be particularly appropriate to such designs which often rely heavily on competitive cost effectiveness.

6. 3—D Implementation:

If the programs could be enhanced to allow the assembly of layouts with 3-dimensional elements, this would obviously be desirable. Since the system has been demonstrated to work 2-dimensionally it should also work 3-dimensionally. The third dimension would inevitably give rise to the addition of further evaluation measures which will not be discussed here. Additionally, the synthesis program would allow perspective views of room interiors, which would enhance its design value considerably.

12.2.3. Non-Architectural Applications of the CAAD System.

In principle, the synthesis and evaluation programs should be applicable to any layout design where layouts are assembled using some sort of elements or modules to create a layout where area restriction or utilisation may be of importance, for example in ship floor and oil platform layout design to mention only a few.

SECTION R: REFERENCE SECTION

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R2.	References	R.4
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R3.1.	Essential Bibliography	R.18
R3.2.	General Bibliography	R.28

R1. ABBREVIATIONS.

The following abbreviations have been used in the text, but mainly in the references and the bibliography.

AA -	Architectural Association.
AAQ -	Architectural Association Quarterly.
ABACUS -	Architecture and Building Aids Computer Unit Strathclyde, Department of Architecture and Building Science, University of Strathclyde, Glasgow.
AD -	Architectural Design (Journal).
AHO -	Arkitekthögskolen i Oslo (The School of Architecture in Oslo).
AJ -	Architects' Journal.
AP -	Architectural Press.
BCS -	British Computer Society.
BOCAAD -	Bulletin of Computer-Aided Architectural Design, published by ABACUS.
BSD -	Building Systems Development, U.K. Head Office: Ezra Ehrenkrantz, San Fransisco.
BSI -	British Standards Institution.
CAAD -	Computer-Aided Architectural Design.
CAD -	Computer-Aided Design.
CADC -	Computer-Aided Design Centre, Cambridge.
CDEHCD -	Commonwealth Department of Environment, Housing and Community Development, Canberra.
CSU -	Computer-Services Unit, RGIT.
DEC Inc. -	Digital Equipment Corportion Incorporated, Marlboro, Massachusetts.
DEC-2Ø -	The Mainframe Computer System of DEC Inc., used by CSU, RGIT.
DES -	Department of Education and Science (West Germany).
DOE -	Department of the Environment (UK).

EARU -	Edinburgh Architectural Research Unit, University of Edinburgh.
EDCAAD -	Edinburgh Computer Aided Architectural Design, University of Edinburgh, Department of Architecture.
EDRA(4) -	Environmental Design Research (2 vols), edited by Preiser, W. Virginia Polytechnic University, Blacksburg, Virginia, 1973.
GLC -	Greater London Council.
HB -	HB-Blad (Data Sheets of the DNSH).
HMSO -	Her Majesty's Stationery Office.
DNSH -	Den Norske Stats Husbank (The Norwegian State House Bank).
IFB -	Institut für Bauforschung (Institute of Building Research, West Germany).
LUBFS -	Land Use and Built Form Studies, University of Cambridge, School of Architecture.
M -	Unit of International Modular Co-ordination, M = 100 mm = 1o cm = 1d m = 0.1 m.
MHLG -	Ministry of Housing and Local Government (UK).
MHPP; DIEA -	Institute of Housing and Physical Planning, Department of Information and External Affairs (Holland).
MIT -	Massachusetts Institute of Technology.
NBA -	National Building Agency (UK).
NBI -	Norges byggforskningsinstitutt (Norwegian Building Research Institute).
NBS -	Norges byggstandardiseringsråd (Norwegian Building Standards Association).
NRDC -	National Research and Development Corporation (UK).
PA -	Progressive Architecture (Journal).
RCA -	Royal College of Art, London.
RGIT -	Robert Gordon's Institute of Technology, Aberdeen.
RIBA -	Royal Institute of British Architects.
SAR -	Stichting Architecten Research (Architectural Research Society, Eindhoven, Holland).
SBI -	Statens Byggeforskningsinstitut (Danish Building Research Institute).

SDD - Scottish Development Department.

SIB - Statens institut för byggnadsforskning (Swedish Building Research Institute).

SSHA - Scottish Special Housing Association.

SSSA - Scott Sutherland School of Architecture, RGIT.

2-D - Two Dimensional.

R2. REFERENCES.

NOTE: References below which appear in a foreign language have been translated in their entries in Sub-section R3, Bibliography. Sections absent in the following sectionalized reference list have no bibliographical entries. Sub-section R1 contains definitions of abbreviations used.

SECTION 2:

2.1. Broadbent, G. and Ward, A. Design Methods in Architecture. 1969.

2.2. Broadbent, G. "Notes on Design Method". In Design Methods in Architecture, edited by Broadbent, G. and Ward, A. 1969. pp. 198-204.

2.3. Broadbent, G. Design in Architecture; Architecture and the Human Sciences. 1975.

2.4. Archer, L.B. The Structure of Design Processes. 1969.

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R3. BIBLIOGRAPHY.

This bibliography is arranged in two parts. The first of these parts contains the essential reference sources which were used specifically for the work, and as references for the thesis; the second part comprises a general bibliography on the topic of house design and CAAD, which sources were only briefly consulted, but which may be of interest to those readers who wish to pursue the study of peripheral topics to this work. Reference should be made to Sub-section R1 for any abbreviations used.

Bibliographical entries followed by (*) were those used for the course of advanced reading, which was part of the research work preparations.

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APPENDIX 1: HYPOTHETICALLY PROPOSED EVALUATION MEASURES

A1.1.	Outline of Early Proposals for Evaluation Measures	A1.2
A1.2.	Note on Overlaps of More than Three Elements	A1.7

HYPOTHETICALLY PROPOSED EVALUATION MEASURES.

A1.1. Outline of Early Proposals for Evaluation Measures.

The following list of evlauation measures for house plan layouts were those proposed at an early stage of the research project. Realising the programming task needed to implement these measures, most of them were abandoned in favour of the evaluation method proposed in Sub-subsection 4.4. It was, however, felt that a broad description of such evaluation measures should be included as a record, and for future reference. The evaluation measures, which are concerned with spatio-functional aspects (See Section 2), and which presume the existence of a synthesis graphics program, are as follows:

1. <u>DISTANCE CHECKING</u>:

   This routine has two aspects:

1.1. <u>AUTODIST</u>:

   This routine uses the previously described rules for combination ofelements (Sub-section 2.5). When a rule has been violated, i.e. a distance between two elements is too small, a bell signal should sound, and a warning text be written in the text area of the screen to indicate that the distance is too small as well as specifying the required distance.

1.2. <u>INTERDIST</u>:

   This routine should allow the user to query a distance between specified points of two elements, which he then may compare to the minimum required distance which should be output also (cf. GAEL 4A cursor command Q - Q; Section 7).

2. <u>DIM. BOUNDARY</u>:

   This option has two aspects:

2.1. <u>DIM. BOUND</u>:

   This routine should allow the user to query the overall dimensions of a space, which are the sides of the bounding rectangle of a layout. The processor will take the corner co-ordinates of the bounding rectangle, (x. min, y. min) and (x. max, y. max), to compute the correct dimensions (cf. GAEL 4A cursor command D; Section 7).

2.2. DIM. BREAKS:

This routine should allow the user to query node co-ordinates and side length of the bounding orthogonal polygon of a lay-out.

3. AREA:

This option should enable output of the area of a specified shape or layout at any design level (cf. EDCAAD Polygon Package;Section 7). Three options should be possible:

3.1. TOTAL AREA:

This routine should calculate the total area within the lay-out space perimeter (cf. A.R and A.F of the proposed evaluation method; Sub-subsection 4.4).

3.2. SOLID AREA:

This routine should select the solid areas within a layout and calculate their total area (cf. A.S; Sub-section 4.4).

3.3. USER AREA:

This routine should select the user areas within a layout and calculate their total area (cf. A.U.(TOT); Sub-section 4.4).

Area calculations should cope with orthogonal polygons as well as circles. Based on these area figures, it will be possible to calculate ratios, such as SOLID/USER, SOLID/TOTAL AREA, or USER/TOTAL AREA within layouts, and these will indicate a measure of the "compactness" of the layout.

4. COST:

This option is related to the TOTAL AREA. Option 3.1 above, and should be available in two options, as follows:

4.1. AREA COST:

This routine should take the total area within a layout, including interior walls, if any, and multiply this figure (m^2) with an up to date price (£/m^2) for the type of house used. The price should be up-datable by the user.

4.2. ELEMENTAL COST:

This routine should make an item list of constructional elements used for a design and multiply with elemental cost figures to give a total construction cost figure. Additional costing procedures must be included for floors and roofs, since these are not immediately defined by the 2 - D plan layout.

5. <u>AREA EFFICIENCY 1</u>:

This routine will be applicable to design level 3, activity space layouts. The routine should select layouts from a standard library of layouts of comparable size to the layout being evaluated, for example by reference to items of furniture present, or number of persons accommodated, and proceed to compare their total areas with the area of the layout being evaluated. Output of area figures in m^2 and proportional percentage figures could be followed by the output of a mean distribution curve, describing area variations of standard layouts and indicating the position of the evaluating space on this curve. If refresher graphics is used, the position of the present layout on the mean distribution curve may alter as its design is changed, i.e. a variable or fluctuating graph.

6. <u>AREA EFFICIENCY 2</u>:

This routine should operate exactly as option 5: AREA EFFICIENCY 1, except that in this case, the present space is compared to a library of user - designed activity spaces, i.e. a user design history file.

This particular routine can be developed to take into account the design "idio - syncracies" of a user. This would be done by having the processor record frequently used element positions and interrelationships by a user. If, at any layout design, the user deviates from his "pattern", an output may inform him of this and query whether he wants to persue this line of design. Such a measure, which could be applied to other evaluation options than area efficiency, would constitute some form of dialogue between the designer and the computer, in which the designer is involved in a design learning process.

7. <u>AREA EFFICIENCY 3</u>:

This routine should consider adjacent pairs of elements and check which types of area overlaps have taken place in a layout, and the area of wasted space. Area figures can be used to calculate area ratios of the layout, such as WASTED/TOTAL AREA, OVERLAPPING AREA/TOTAL AREA and so forth (cf. The proposed evaluation method; Sub-section 4.4).

8. <u>LAYOUT ADAPTABILITY</u>:

This routine, which may be interactive or automatic, would have two sub-options, as follows:

8.1. <u>ADAPT. STAND. LIB</u>:

This routine should select spaces of comparable size to the evaluated layout, from the appropriate design level library of standard layouts, and make a check as to which spaces will "fit" inside the boundary of the present layout, taking into

account door and window positions. A useful output ratio would be the number of "fits" among the total stock of library layouts and this would express some form of adaptability measure for the layout. A high ratio would indicate a high degree of adaptability of the layout, since it would be possible to change the use of the space in many different ways.
Next, each "fit" may be graphically overlayed onto the present layout to show alternative spatial usage of that space. This type of adaptability check may be used to generate variants of room layouts and house plans (cf. The Habraken design system; Sub-section 3.4), and would provide a novel and extremely useful design aid.

8.2. <u>ADAPT. HIST. LIB</u>:

This routine would operate exactly as the previous routine, except comparisons would be made using the designer's history file of designs rather than the standard library of designs.

9. <u>OVERALL CIRCULATION</u>:

This routine should have two options, one interactive, and one automatic, as follows:

9.1. <u>INTER. CIRC</u>:

This routine should allow the user to "track" or indicate a circulation route on a plan layout, using a cursor or a light pen on the graphics screen, at any design levels, and to check the width of this route at desired points against a specified value.
If the track width is satisfied against the required width, the test is successful, if not it is unsuccessful, in which case the track routine may cause the obstructing elements to move aside and "pave" way for the required circulation route. The movements "of obstructing elements may cause distance rule violations between pairs of elements, which in turn, by the methodology, could rearrange and reposition themselves in a chain reaction, so as to satisfy distance requirements between elements. Appropriate text should be output, identifying obstructing elements and rule breaks. If refresher graphics is used, obstructing or violating elements may "flicker" or "flash" to identify themselves.

Using a method as outlined, the user can thus perform simulations of circulation patterns within the dwelling (cf. TRACK option in GAEL 4A, Section 7).

9.2. <u>AUTO. CIRC</u>:

This routine is similar to the previous routine, except that in this case circulation patterns are pre-programmed; i.e. movement patterns of all habitants of the dwelling are time-tabled. Each individual may be represented by a suitable symbol on the plan, possibly flashing for clarity,

and his circulation route indicated by lines at required distances from one another, trailing the symbol.
In a 24 hour speeded - up circulation simulation, areas of congestion would be indicated with suggestions of corrective design alterations of the plan to be taken.

Travel distance is another mechanism which could be built into the program, and this presumes a preprogrammed or specified association matrix for the connectivity between elements, firstly within spaces, and secondly between elements in different activity spaces. Actual travel distances between elements on the plan could be tested against the association matrix, to determine if the matrix has been satisfied. If distances are not satisfied, movements of elements should take place, and these may cause other inter-elemental violations as discussed for option 9.1.

10. <u>COMPACT</u>:

This is a routine which could be closely linked to routine 7: AREA EFFICIENCY 3 (Overlap Area Checks). By taking into consideration the wasted space within a plan layout, elements could be automatically moved closer together so that their inter-distances are reduced to their minimum permissible values and so as to cause a compactness of the layout with a resultant possibility of reducing the overall dimensions of its bounding rectangle or polygon. A ratio of the areas of the compacted and non-compacted layouts would give an indication of area (and cost) saving resulting from the layout compactness routine.

11. <u>SUGGEST</u>:

If an association matrix is specified for element connectivity (See option 9.2) and element side adjacency permissibility, it is possible to specify a method for automatic generation of element layouts, or if the designer has assembled a layout manually, such a methodology could be used to generate "variants" of his layout, by reference to element associations and side adjacency permissibilities.

It is anticipated that design techniques such as those outlined above will become increasignly common among architectural designers of the future. At present the introduction of CAAD to architectural practices is inhibited by the lack of sophistication of computer graphics offered at an acceptable price. The use of storage tube graphics has probably done more to inhibit rather than to promote CAAD for the purpose of layout plan design and evaluation. The reason for this is that the synthesis and evaluation design process, as demonstrated by the work of this research project (Sections 2 - 4), require an extremely high degree of flexibility and instantaneousness of evaluation feedback which can, in the author's opinion, only be realised through the use of refresher graphics as discussed in Section 8. If sophisticated, small stand - alone refresher graphics hardware systems, preferably making use of large colour screens, can become available at an acceptable cost, unlimited possibilities will be created for using novel design techniques. Additionally, the sophistication of such hardware would reduce the need for the tremendously bulky and comprehensive software evidenced in many early and current CAAD systems.

A1.2. Note on Overlaps of More than Three Elements.

If practical use of the evaluation method for evaluating the efficiency of activity - spaces or other types of layouts in other application areas, by use of the CRUNCH or GRAFIT computer programs, or if future research work on the evaluation method should show occurrence of overlaps of more than three elements, then the union (cf. A.E.(UNION)) area of all elements within the bounding polygon of the layout must be considered by use of Boolean algebra as in the following deduction:

1. Consider the n set of polygons (planning elements), shown as rectangles in Fig. A1.1(1), each representing the bounding polygon of single elements; i.e. the polygons include the various 1, 2 and 3 space categories within them, but do not detail these sub - areas of solids and user spaces.

2. For calculated areas, the following notation is used initially:

   - (1, 2, 3 -----,(n-1), n) is the set of n polygons.

   - A(1) = the area of the polygon 1.

   - (1 ∩ 2) = the intersection (overlap) between elements 1 and 2.

   - (1 ∪ 2) = the union of elements 1 and 2.
   - (1 ∪ (or ∩) 2') = the set 1 AND NOT 2 (See Fig. A1.1(2)).

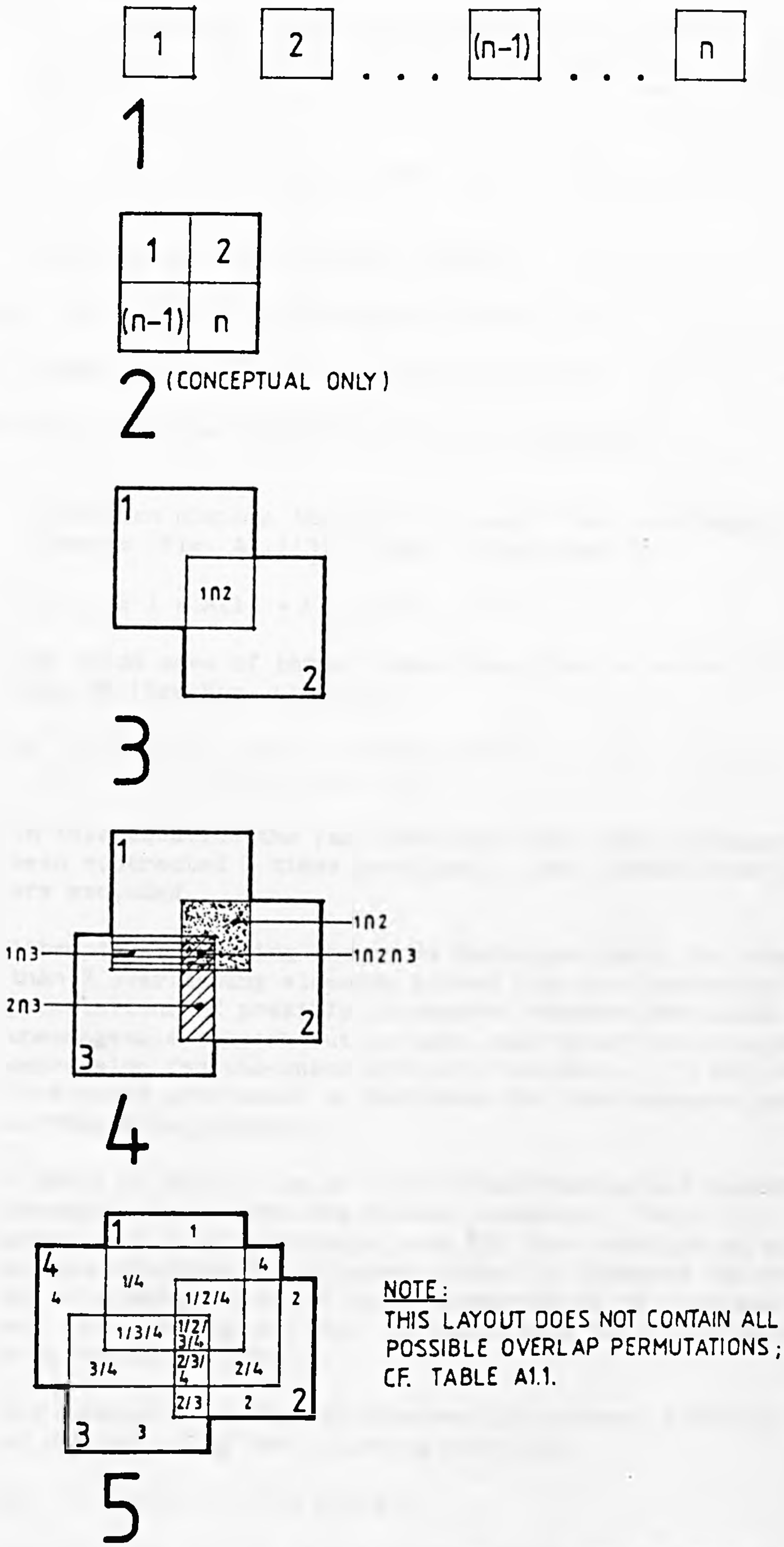


Fig. A1.1. Elemental Overlap Cases.

3. If n elements are stacked or assembled together in a layout so that no overlaps (intersections) occur (Fig. A1.1(2)), then it is obvious that the union area of the n elements (cf. A.FMO) is:

$$A(1 \cup 2 \cup 3 \cup \text{-----} \cup (n-1) \cup n) = A(1) + A(2) + A(3) + \text{-----} \text{-----} + A((n-1)) + A(n),$$

excluding any wasted areas present.

However, if overlaps occur between elements, calculation of the union area becomes progressively more complex the more elements are involved in the overlaps, as can be demonstrated in the following:

4. It is also obvious that in the case of two overlapping elements (Fig. A1.1(3)), their union area is:

$$A(\ 1 \cup 2\ ) = A(1) + A(2) - A(\ 1 \cap 2\ ).$$

5. The union area of three element may also be worked out by hand as (See Fig. A1.1(4)):

$$A(\ 1 \cup 2 \cup 3\ ) = A(1) + A(2) + A(3) - A(\ 1 \cap 2\ ) - A(\ 1 \cap 3\ ) - A(\ 2 \cap 3\ ) + 2A(\ 1 \cap 2 \cap 3\ ).$$

In this equation the last area was added twice because it had been subtracted 3 times previously. Any wasted areas present are excluded.

6. Attempts at pursuing the above deduction logic for more than 3 overlapping elements proved that the complexity of permutations of possible intersects rendered the union area unmanageable to work out by hand, and to arrive at a general expression for the union area of n elements. It was therefore found profitable to introduce two new concepts and corresponding notation:

6.1. A table or matrix can be constructed showing all possible permutations of overlaps between elements. Table A1.1 shows such overlap permutations for four overlapping elements, and permutations for a larger number of elements can be worked out similarly. Some of these permutations of overlaps may not occur in a given case, in which case their corresponding area values are zero.

6.2. The concept of exclusive intersection between elements can be defined using the following notation:

$$A(\ 1 \cap 4 \cap (2,\ 3)'\ ) = A(1/4),$$

meaning that A(1/4) is the intersecting area between elements 1 and 4 exclusively, disregarding intersects involving elements 2 and 3, in the set (1, 2, 3, 4).

Table A1.1. Permutations of Overlaps Between Four Elements.

NUMBER OF ELEMENTS INVOLVED		
TWO	THREE	FOUR
1,2	1,2,3	1,2,3,4
1,3	1,2,4	
1,4	1,3,4	
2,3	2,3,4	
2,4		
3,4		

7. Based on the concepts introduced in (6) above the union area of four elements (Fig. A1.1(5)) can now be written as:

$$A(1 \cup 2 \cup 3 \cup 4) = A(1) + A(2) + A(3) + A(4) - A(1/2) - A(1/3) - A(1/4) - A(2/3) - A(2/4) - A(3/4) - 2A(1/2/3) - 2A(1/2/4) - 2A(1/3/4) - 2A(2/3/4) - 3A(1/2/3/4),$$

excluding any wasted areas present.

It will be noted that intersecting areas are subtracted by a number which is 1 less than the number of intersecting elements involved.
It is now theoretically possible to produce a general expression for the union area of n elements, but this becomes a pointless excercise since it is clear that a computing methodology is required to cope effectively with such a calculation.

The computing methodology for the calculation of the union area of n polygons by reference to their identifying numbers and various exclusive intersects can be evolved as follows:

1. The computer identifies the bounding polygon of the n overlapping elements. If the area within this polygon is all that is required, then such a calculation is trivial.

2. The computer identifies the polygons (1, 2, 3, -----,(n-1),n).

3. The computer identifies the various sub - polygons that occur as a result of intersections, and there may also be some polygons within the bounding polygon which are wasted areas.

4. For each intersection sub - polygon, the computer checks for how many and which elements it is part of. This is done by reference to co-ordinates, and subsequently a matrix can be produced showing the sub - polygons, which elements they belong to, and the number of these elements.

5. The union area of the n elements within the bounding polygon can now be written as:

$$A(1 \cup 2 \cup 3 \cup \text{-----} \cup (n-1) \cup n)\ (+A.BR) = A(1) + A(2) + A(3) + \text{-----} + A(n-1) + A(n) - (\text{intersecting areas})(+A.BR).$$

If A.BR, the sum of wasted areas, is required, then such areas are added to the union area proper of the n elements, if not, it is left out.

The various intersecting areas are subtracted by reference to their nature (taken from the matrix referred to in 4 above) as follows:

5.1. Sub - areas exclusively involving intersections between 2 elements are subtracted once.

5.2. Sub - areas exclusively involving intersections between 3 elements are subtracted twice.

5.3. Sub - areas exclusively involving intersections between 4 elements are subtracted 3 times.

5.4. Sub - areas exclusively involving intersections between (n-1) elements are subtracted (n-2) times.

5.5. Sub - areas exclusively involving intersections between n elements are subtracted (n-1) times.

6. Alternatively, instead of the subtracting method shown above, a purely additive method can be used to find the union area of the n elements, as follows:

$$A(1 \cup 2 \cup 3 \cup \text{-----} \cup (n-1) \cup n) = AO(1) + AO(2) + AO(3) + \text{-----} + AO(n-1) + AO(n),$$

where: AO(1) = the sum of areas belonging exclusively to 1 element only, i.e. non - intersecting areas.

AO(n) = the sum of intersecting areas involving the n elements exclusively.

A.BR may also be added if required.

It is envisaged that it is feasible to include the above computing methodology in the Dimcheck/CRUNCH programs at present, and this could be a suitable future research project. If implemented, this methodology would form the ultimate extension of the work, since based on the identification of each of the multitude of exclusive intersecting sub - polygons possible, an associated penalty system can be worked out where penalties are weighted according to the exact severity of these exclusive intersections. If a penalty system is implemented, however, each elemental polygon must again be sub - divided into space categories 1, 2 and 3, and hence the number of exclusive intersections between elemental space categories would be increased dramatically from the number of exclusive intersections mentioned between bounding polygons of elements.

APPENDIX 2: OBJECTIVE MANUAL EVALUATION EXPERIMENT DATA

A2.1.	Common Data for the 21 Two-Person Bedrooms	A2.2
A2.2.	A Typical Manual Evaluation Run	A2.6
A2.3.	Numerical Evaluation Results for the 21 Bedrooms	A2.10

OBJECTIVE MANUAL EVALUATION EXPERIMENT DATA.

A2.1. Common Data for the 21 Two - Person Bedrooms.

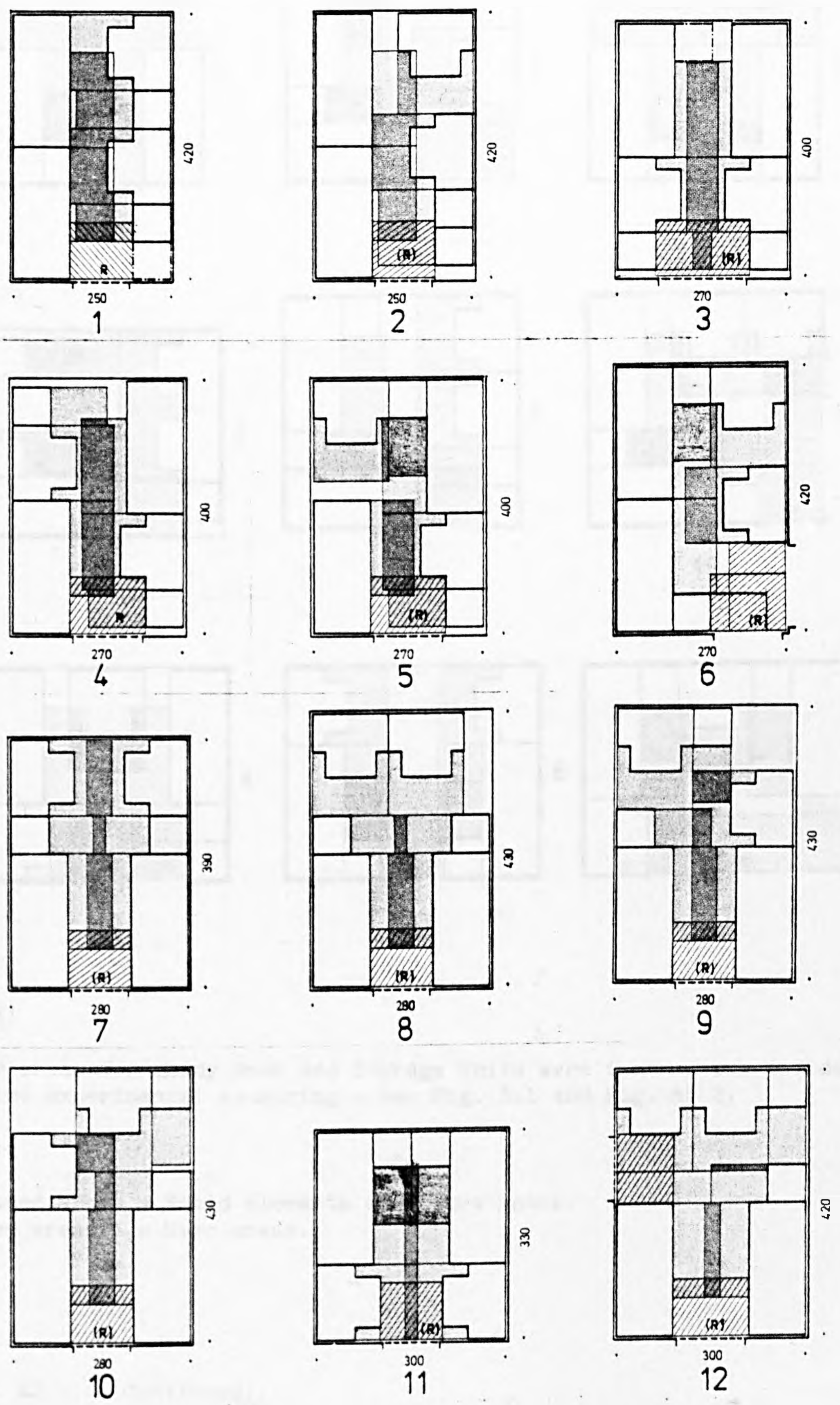
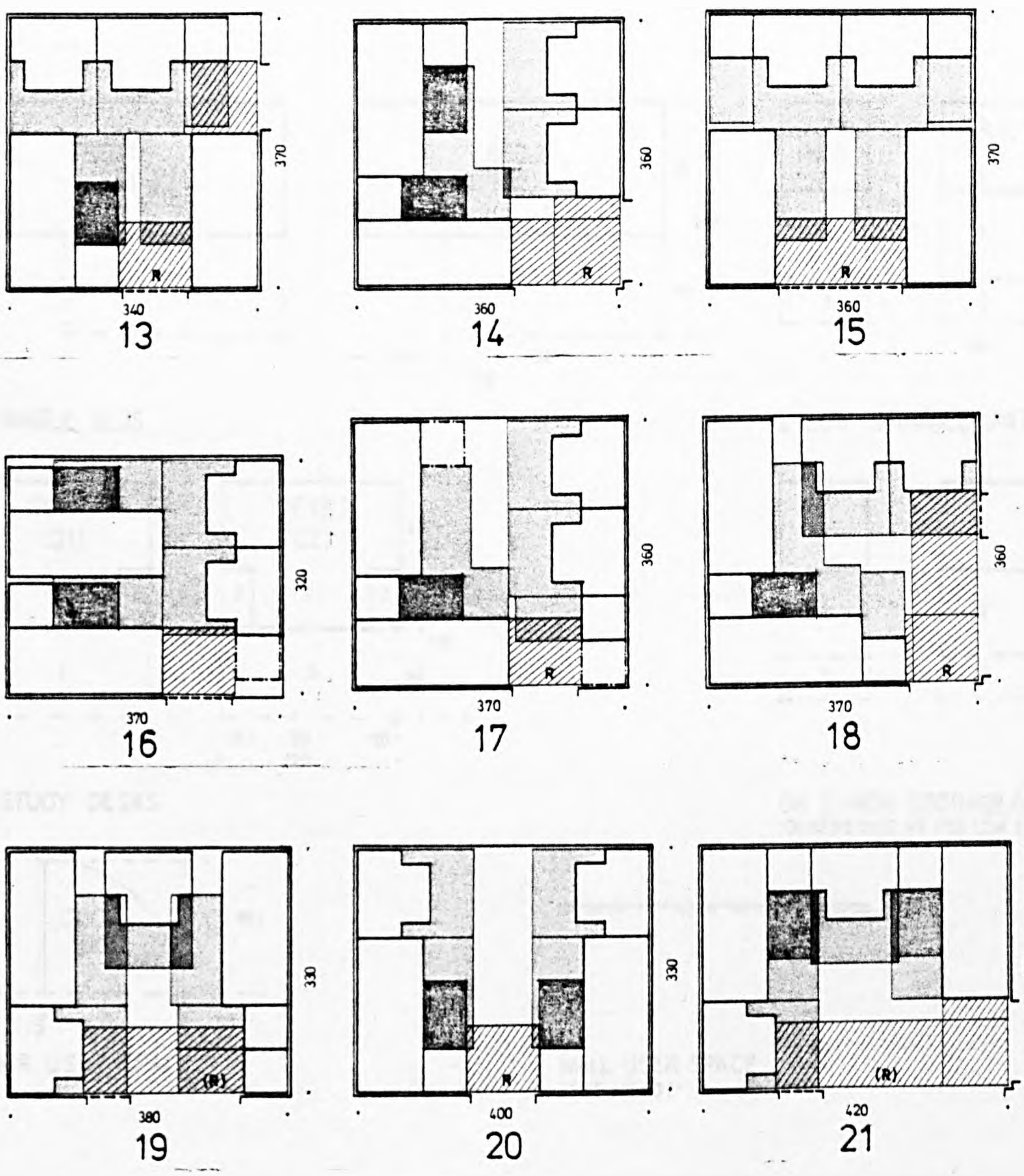


Fig. A2.1. The 21 Bedroom Layout Sample. From Thiberg, A.(A2.1).



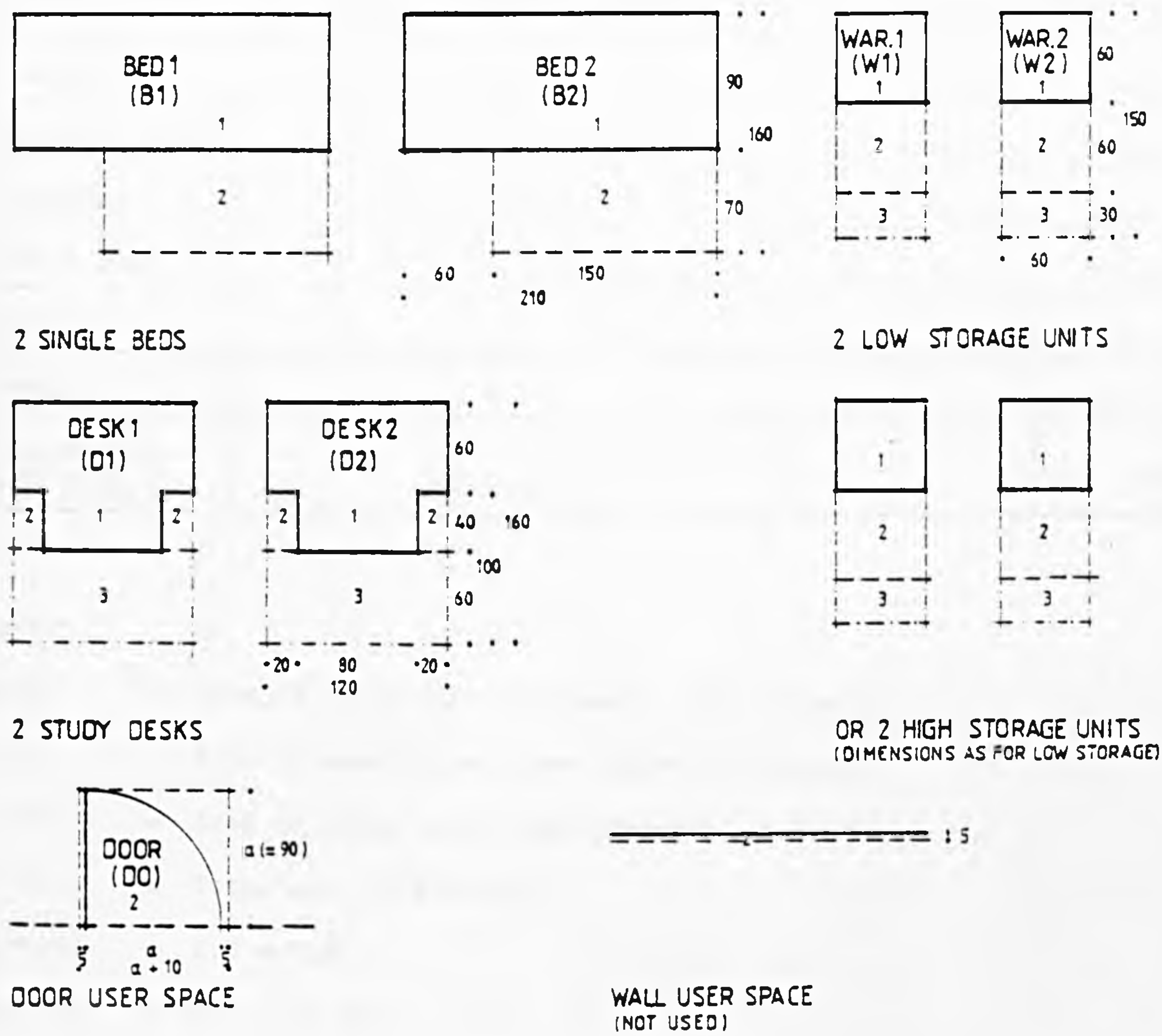
NOTE:

User areas for Study Desk and Storage Units were further sub-divided in the experimental measuring - See Fig. 5.1 and Fig. A5.2.

KEY:

Untoned areas = Solid elements or wasted space.
Toned areas = User areas.

Fig. A2.1. (Continued).



NOTE: SMALL NUMERALS REFER TO SPACE CATEGORIES.
ELEMENT CODES ARE AS USED IN SUBSEQUENT TABLES/FIGURES.
SCALE 1:50.
DIMENSIONS IN CM.

Fig. A2.2. Standard Element Content of the 21 Bedroom Sample.

Table A2.1. Element Areas of the 21 Bedroom Sample.

SINGLE ELEMENT NAMES	No. OF OCCURRENCES	AREAS (m^2)					
		A.S	A.U1	A.U2	A.E	A.S+U1	A.U1+U2
SINGLE BED	2	1.89	1.05	-	2.94	2.94	1.05
BEDSIDE TABLES	1	0.36	0.36	0.18	0.90	0.72	0.54
WARDROBE	1	0.36	0.36	0.18	0.90	0.72	0.54
STUDY DESK	2	1.04	0.16	0.72	1.92	1.20	0.88
DOOR	1	-	0.90	-	0.90	0.90	0.90
TOTALS		6.58					5.84
PARAMETERS FOR TOTALS		A.S					A.U.(TOT)

KEY:

A.S = Area of solid part of element (space type 1).

A.U1 = Area of space type 2 user space of element.

A.U2 = Area of space type 3 user space of element.

A.E = Total area of element.

A.S+U1 = A.S + A.U1.

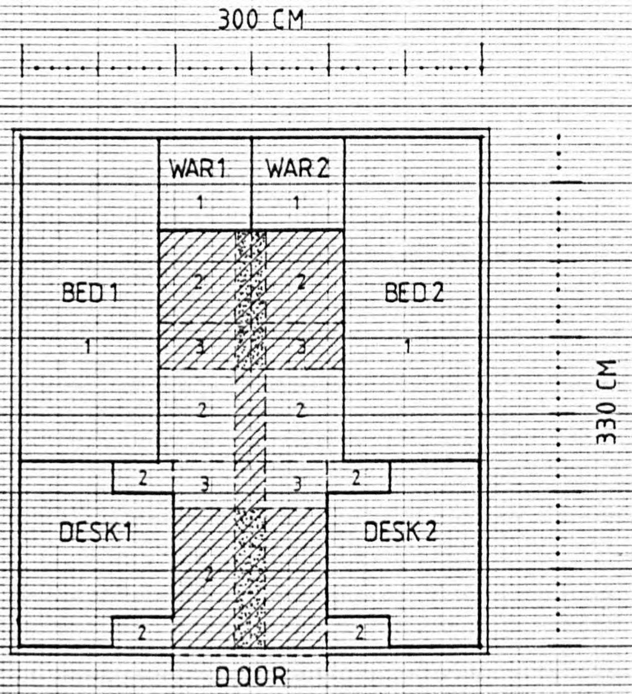
A.U1+U2 = A.U1 + A.U2.

A.S = A.S(TOT) = Solid areas of all elements.

A.U.(TOT) = Total area of all user spaces of all elements.

A.FMO = A.S + A.U(TOT) = 12.42.

A2.2. A Typical Manual Evaluation Run.



PLAN (SCALE 1:50)

Fig. A2.3. Evaluation Step 1 (Room Layout 11).

Table A2.2. Evaluation Step 2 (Room 11: Overlapping Pairs of Elements).

ROOM 11 CONTENT	BED1	BED2	DESK 1	DESK2	WAR 1	WAR 2	DOOR
BED1		● ○			● ○	● ○	
BED2					● ○	● ○	
DESK1				● ○			● ○
DESK 2							● ○
WAR 1							
WAR 2							
DOOR							

KEY:

● 1ST. ORDER OVERLAPS.
○ 2ND. ORDER OVERLAPS.

Table A2.3. Evaluation Step 3(Room 11: Overlap Areas).

OVERLAPPING ELEMENTS	OVERLAP INSTANCE	CALCULATION	OVERLAP INSTANCE AREAS(m^2) 1:1	1:2	1:3	2:2	2:3	3:3	TOTAL
BED 1/BED 2	1:1								
	1:2								
	1:3								
	(2) 2:2	0.2 x 1.5				0.3			
	2:3								
	3:3								0.3
BED 1/WAR 1	1:1								
	1:2								
	1:3								
	(2) 2:2	0.6 x 0.6				0.36			
	(2) 2:3	0.6 x 0.3					0.18		
	3:3								0.54
BED 1/WAR 2	1:1								
	1:2								
	1:3								
	(2) 2:2	0.1 x 0.6				0.06			
	(2) 2:3	0.1 x 0.3					0.03		
	3:3								0.09
BED 2/WAR 1	1:1								
	1:2								
	1:3								
	(2) 2:2	0.1 x 0.6				0.06			
	(2) 2:3	0.1 x 0.3					0.03		
	3:3								0.09
BED 2/WAR 2	1:1								
	1:2								
	1:3								
	(2) 2:2	0.6 x 0.6				0.36			
	(2) 2:3	0.6 x 0.3					0.18		
	3:3								0.54
DESK 1/DESK 2	1:1								
	1:2								
	1:3								
	2:2								
	2:3								
	(2) 3:3	0.2 x 1.2						0.24	0.24
DESK 1/DOOR	1:1								
	1:2								
	1:3								
	2:2								
	(2) 2:3	0.6 x 0.9					0.54		
	3:3								0.54
DESK 2/DOOR	1:1								
	1:2								
	1:3								
	2:2								
	(2) 2:3	0.6 x 0.9					0.54		
	3:3								0.54
A.01						1.14	1.50	0.24	2.88
WEIGHTING FACTORS (W.Ø1)			5	4	3	3	2	1	
O.P = A.Ø1 x W.Ø1						3.42	3.00	0.24	6.66
A.02 (2nd. order Overlaps total)			(manual calculations)						0.36

Table A2.4. Evaluation Step 4 (Room 11: Parameter Data Sheet).

AREAS: (m^2)	A.R	=	3.3 x 3 = 9.90
	$\sqrt{A.R}$	=	3.1464
	A.R+5	=	
	A.BR	=	0.00
	A.F	=	9.90
	A.G	=	
	A.O1	=	2.88
	A.O2	=	0.36
	2A.O2	=	0.72
	A.OU	=	A.O1 - 2A.O2 = 2.88 - 0.72 = 2.16
	A.O3	=	A.O1 - A.O2 = 2.88 - 0.36 = 2.52
	A.S	=	6.58 (CONSTANT)
	A.U.(TOT)	=	5.84 (CONSTANT)
	A.FMO	=	A.S + A.U.(TOT) = 6.58 + 5.84 = 12.42 (CONSTANT)
	A.U.(UNION)	=	A.U.(TOT) - A.O3 = 5.84 - 2.52 = 3.32
	A.E.(UNION)	=	A.R - A.BR = A.FMO - A.O3 = 9.90
	A.BR + 5	=	
	A.BG	=	
	A.NSR	=	A.R - A.S = 9.90 - 6.50 = 3.32
	A.NSR + 5	=	
	A.NSG	=	
	A.NSF	=	
	A.NO	=	A.E.(UNION) - A.OU = 9.90 - 2.16 = 7.74
PERIPHERIES: (m)	P.R	=	6.6 + 6.0 = 12.6
	P.F	=	
	P.R+5	=	
	P.G	=	

Table A2.5. Evaluation Step 5 (Room 11: Efficiency Components).

Σ(A.01 x w.01)/A.01 = 6.66/2.88 = <u>2.3125</u> (O.P)

P.R/$\sqrt{\text{A.R}}$ x 4 = 12.6/3.1464 x 4 = <u>1.0011</u> (P.P)

A.R/A.FMO = 9.9/12.42 = <u>0.7971</u> (A.P)

A.S/A.FMO = 6.58/12.42 = <u>0.5298</u> (CONSTANT)

A.NSR/A.FMO = 3.32/12.42 = <u>0.2673</u>

A.U.(UNION)/A.FMO = 3.32/12.42 = <u>0.2673</u>

A.BR/A.FMO = 0.00/12.42 = <u>0.0000</u>

A.U.(TOT)/A.FMO = 5.84/12.42 = <u>0.4702</u> (CONSTANT)

A.01/A.FMO = 2.88/12.42 = <u>0.2319</u>

A.02/A.FMO = 0.36/12.42 = <u>0.0290</u>

A.E.(UNION)/A.FMO = 9.90/12.42 = <u>0.7971</u>

A.OU/A.FMO = 2.16/12.42 = <u>0.1739</u>

A.NO/A.FMO = 7.74/12.42 = <u>0.6232</u>

2A.02/A.FMO = 0.72/12.42 = <u>0.058</u>

$$\text{E.R.11} = \left(\frac{\Sigma(\text{A.01 x w.01})}{\text{A.01}}\right) \times \left(\frac{\text{P.R}}{+\sqrt{\text{A.R}} \times 4}\right) \times \left(\frac{\text{A.R}}{\text{A.FMO}}\right)$$

E.R.11 = 2.3125 x 1.0011 x 0.7971 = <u>1.8453</u>

Table A2.6. Overlapping Pairs of Elements, Overlap Areas and Penalties for the 21 Bedrooms.

BN[1]	O.I.[2]	OVERLAPPING PAIRS OF ELEMENTS AND SUB-AREA OVERLAP INSTANCES (1ST ORDER; m2)																					TOTALS		
		B1/B2	B1/D1	B1/D2	B1/W1	B1/W2	B1/DO	B2/D1	B2/D2	B2/W1	B2/W2	B2/DO	D1/D2	D1/W1	D1/W2	D1/DO	D2/W1	D2/W2	D2/DO	W1/W2	W1/DO	W2/DO	A.01	w.01	P3
01	1:1																							5	
	1:2		0.04*	0.01*					0.07*														0.12	4	0.48
	1:3																							3	
	2:2		0.02	0.02	0.18				0.02	0.18		0.21										0.18	0.18	3	2.43
	2:3		0.36	0.24	0.18				0.48	0.18												0.09*	1.53	2	3.06
	3:3																							1	
	TOTAL		0.42	0.27	0.36				0.57	0.36		0.21										0.27	2.46		5.97
02	1:1																							5	
	1:2		0.04*	0.03					0.05*														0.12	4	0.48
	1:3																							3	
	2:2		0.08*	0.02					0.02	0.18	0.06	0.21									0.06	0.36	0.99	3	2.97
	2:3		0.18	0.30					0.42	0.18	0.06										0.03*	0.18*	1.35	2	2.70
	3:3																							1	
	TOTAL		0.30	0.35					0.49	0.36	0.12	0.21									0.90	0.54	2.46		6.15
03	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2	0.75														0.03		0.03					1.23	3	3.69
	2:3															0.12*		0.12*			0.21	0.21	0.60	2	1.20
	3:3																			0.18	0.18*	0.18	0.78	1	0.78
	TOTAL	0.75														0.15		0.15		0.18	0.39	0.39	2.61		5.67
04	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2	0.10				0.01	0.18			0.01									0.06			0.30	0.66	3	1.98
	2:3			0.60		0.03		0.60		0.03									0.12*			0.18*	1.56	2	3.12
	3:3																							1	
	TOTAL	0.10		0.60		0.04	0.18	0.60		0.04									0.18			0.48	2.22		5.10

NOTE: * ⟶ OVERLAP IN OTHER ORDER (I.E. B1/B2* INSTANCE 1:2 MEANS B1.2:B2.1).
(1) BN. = BEDROOM NUMBER. (2) O.I. = OVERLAP INSTANCE. (3) P = A.01 x w.01 (see Table 4.1 for penalties.

Table A2.6. (Continued).

B.N[1]	OI[2]	OVERLAPPING PAIRS OF ELEMENTS AND SUB-AREA OVERLAP INSTANCES (1 ST. ORDER; m2)																					TOTALS		
		B1/B2	B1/D1	B1/D2	B1/W1	B1/W2	B1/D0	B2/D1	B2/D2	B2/W1	B2/W2	B2/D0	D1/D2	D1/W1	D1/W2	D1/D0	D2/W1	D2/W2	D2/D0	W1/W2	W1/D0	W2/D0	A.01	w.01	P[3]
05	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2	0.10	0.04		0.36						0.01	0.18							0.06			0.30	1.05	3	3.15
	2:3		0.06		0.18				0.60		0.03								0.12			0.18	1.17	2	2.34
	3:3																							1	
	TOTAL	0.10	0.10		0.54				0.60		0.04	0.18							0.18			0.48	2.22		5.49
06	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2		0.04		0.36						0.36												0.76	3	2.28
	2:3		0.06	0.25	0.18				0.35		0.18												1.02	2	2.04
	3:3																	0.04					0.04	1	0.04
	TOTAL		0.10	0.25	0.54				0.35		0.54							0.04					1.82		4.36
07	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2	0.60					0.21					0.21											1.02	3	3.06
	2:3																							2	
	3:3												0.48							0.12			0.60	1	0.60
	TOTAL	0.06					0.21					0.21	0.48							0.12			1.62		3.66
08	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2	0.60					0.21					0.21											1.02	3	3.06
	2:3																							2	
	3:3																			0.12			0.12	1	0.12
	TOTAL	0.60					0.21					0.21								0.12			0.14		3.18

Table A2.6. (Continued).

BN[1]	OI[2]	OVERLAPPING PAIRS OF ELEMENTS AND SUB-AREA OVERLAP INSTANCES (1 ST. ORDER; m^2)																					TOTALS		
		B1/B2	B1/D1	B1/D2	B1/W1	B1/W2	B1/D0	B2/D1	B2/D2	B2/W1	B2/W2	B2/D0	D1/D2	D1/W1	D1/W2	D1/D0	D2/W1	D2/W2	D2/D0	W1/W2	W1/D0	W2/D0	A.01	w.01	P[3]
09	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2	0.60					0.21					0.21											1.02	3	3.06
	2:3																0.12*						0.12	2	0.24
	3:3																0.18	0.18					0.36	1	0.36
	TOTAL	0.60					0.21					0.21					0.30	0.18					1.50		3.66
10	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2	0.60					0.21					0.21											1.02	3	3.06
	2:3																							2	
	3:3												0.36		0.18								0.54	1	0.54
	TOTAL	0.60					0.21					0.21	0.36		0.18								1.56		3.60
11	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2	0.30			0.36	0.06				0.06	0.36												1.14	3	3.42
	2:3				0.18	0.03				0.03	0.18					0.54			0.54				1.50	2	3.00
	3:3												0.24										0.24	1	0.24
	TOTAL	0.30			0.54	0.09				0.09	0.54		0.24			0.54			0.54				2.88		6.66
12	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2	0.30					0.18					0.18											0.66	3	1.98
	2:3																	0.06*					0.06	2	0.12
	3:3																	0.03					0.03	1	0.03
	TOTAL	0.30					0.18					0.18						0.09					0.75		2.13

Table A2.6. (Continued).

BN[1]	OI[2]	OVERLAPPING PAIRS OF ELEMENTS AND SUB-AREA OVERLAP INSTANCES (1.ST. ORDER; m^2)																					TOTALS		
		B1/B2	B1/D1	B1/D2	B1/W1	B1/W2	B1/D0	B2/D1	B2/D2	B2/W1	B2/W2	B2/D0	D1/D2	D1/W1	D1/W2	D1/D0	D2/W1	D2/W2	D2/D0	W1/W2	W1/D0	W2/D0	A OI	w OI	P[3]
13	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2					0.36	0.03					0.21											0.60	3	1.80
	2:3					0.18																	0.18	2	0.36
	3:3																							1	
	TOTAL					0.54	0.03					0.21											0.78		2.16
14	1:1																							5	
	1:2	0.03																					0.03	4	0.12
	1:3																							3	
	2:2	0.07			0.36						0.36												0.79	3	2.37
	2:3				0.18				0.04		0.18												0.40	2	0.80
	3:3																							1	
	TOTAL	0.10			0.54				0.04		0.54												1.22		3.29
15	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2						0.09					0.09											0.18	3	0.54
	2:3																							2	
	3:3																							1	
	TOTAL						0.09					0.09											0.18		0.54
16	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2				0.36						0.36								0.04				0.76	3	2.28
	2:3				0.18						0.18								0.06*				0.42	2	0.84
	3:3																		0.04					1	
	TOTAL				0.54						0.54								0.10				1.18		3.12

Table A2.6. (Continued).

BN[1]	OL[2]	OVERLAPPING PAIRS OF ELEMENTS AND SUB-AREA OVERLAP INSTANCES (1ST ORDER; m2)																					TOTALS		
		B1/B2	B1/D1	B1/D2	B1/W1	B1/W2	B1/D0	B2/D1	B2/D2	B2/W1	B2/W2	B2/D0	D1/D2	D1/W1	D1/W2	D1/D0	D2/W1	D2/W2	D2/D0	W1/W2	W1/D0	W2/D0	A.01	W.01	P[3]
17	1:1																							5	
	1:2	0.03																					0.03	4	0.12
	1:3																							3	
	2:2	0.07								0.36												0.18	0.61	3	1.83
	2:3									0.18												0.09*	0.27	2	0.54
	3:3																							1	
	TOTAL	0.10								0.54												0.27	0.91		2.49
18	1:1																							5	
	1:2	0.03	0.04*																				0.07	4	0.28
	1:3																							3	
	2:2	0.07	0.08							0.36													0.51	3	1.53
	2:3		0.18							0.18													0.36	2	0.72
	3:3																							1	
	TOTAL	0.10	0.30							0.54													0.94		2.53
19	1:1																							5	
	1:2		0.04					0.04*															0.08	4	0.32
	1:3																							3	
	2:2		0.08					0.08															0.16	3	0.48
	2:3		0.18					0.18													0.09*	0.18*	0.63	2	1.26
	3:3																							1	
	TOTAL		0.30					0.30													0.09	0.18	0.87		2.06
20	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2				0.36		0.03				0.36	0.03											0.78	3	2.34
	2:3				0.18						0.18												0.36	2	0.72
	3:3																							1	
	TOTAL				0.54		0.03				0.54	0.03											1.14		3.06

Table A2.6. (Continued).

BN[1]	OI[2]	B1/B2	B1/D1	B1/D2	B1/W1	B1/W2	B1/D0	B2/D1	B2/D2	B2/W1	B2/W2	B2/D0	D1/D2	D1/W1	D1/W2	D1/D0	D2/W1	D2/W2	D2/D0	W1/W2	W1/D0	W2/D0	A.01	w.01	P[3]
		OVERLAPPING PAIRS OF ELEMENTS AND SUB-AREA OVERLAP INSTANCES (1ST ORDER; m^2)																					TOTALS		
21	1:1																							5	
	1:2																							4	
	1:3																							3	
	2:2		0.04		0.36			0.04			0.36												0.80	3	2.40
	2:3		0.06		0.18			0.06			0.18												0.48	2	0.96
	3:3																							1	
	TOTAL		0.10		0.54			0.10			0.54												1.28		3.36
	1:1																								
	1:2																								
	1:3																								
	2:2																								
	2:3																								
	3:3																								
	TOTAL																								
	1:1																								
	1:2																								
	1:3																								
	2:2																								
	2:3																								
	3:3																								
	TOTAL																								
	1:1																								
	1:2																								
	1:3																								
	2:2																								
	2:3																								
	3:3																								
	TOTAL																								

Table A2.7. Area and Perimeter Parameter Values for the 21 Bedrooms.

B.N.	EVALUATION PARAMETERS (m^2)															(m)
	A.R	$\sqrt{A.R}$	A.BR	A.S	A.U(TOT)	A.FMO	A.01	A.02	A.03	2A.02	A.U(UNION)	A.F = A.E(UNION)	A.NSR	A.OU	A.NO	PR
01	10.50	3.2404	0.36	6.58	5.84	12.42	2.46	0.18	2.28	0.36	5.84	10.14	3.92	2.10	8.04	13.40
02	10.50	3.2404	0.36	"	"	"	2.46	0.18	2.28	0.36	3.56	10.14	3.92	2.10	8.04	13.40
03	10.80	3.2863	0.71	"	"	"	2.61	0.28	2.33	0.56	3.51	10.09	4.22	2.05	8.04	13.40
04	10.80	3.2863	0.46	"	"	"	2.22	0.14	2.08	0.28	3.76	10.34	4.22	1.94	8.40	13.40
05	10.80	3.2863	0.46	"	"	"	2.22	0.14	2.08	0.28	3.76	10.34	4.22	1.94	8.40	13.40
06	11.34	3.3675	0.70	"	"	"	1.82	0.04	1.78	0.08	4.06	10.64	4.76	1.74	8.90	13.80
07	10.92	3.3045	0.00	"	"	"	1.62	0.12	1.50	0.24	4.34	10.92	4.34	1.38	9.54	13.40
08	12.04	3.4699	0.64	"	"	"	1.14	0.12	1.02	0.24	4.82	11.40	5.46	0.90	10.50	14.20
09	12.04	3.4699	1.00	"	"	"	1.50	0.12	1.38	0.24	4.46	11.04	5.46	1.26	9.78	14.20
10	12.04	3.4699	1.06	"	"	"	1.56	0.12	1.44	0.24	4.40	10.98	5.46	1.32	9.66	14.20
11	9.90	3.1462	0.00	"	"	"	2.88	0.36	2.52	0.72	3.32	9.90	3.32	2.16	7.74	12.60
12	12.60	3.5496	0.87	"	"	"	0.75	0.06	0.69	0.12	5.15	11.73	6.02	0.63	11.10	14.40
13	12.58	3.5468	0.94	"	"	"	0.78	0.00	0.78	0.00	5.06	11.64	6.00	0.78	10.86	14.20
14	12.96	3.6000	1.76	"	"	"	1.22	0.00	1.22	0.00	4.62	11.20	6.38	1.22	9.98	14.40
15	13.32	3.6497	1.08	"	"	"	0.18	0.00	0.18	0.00	5.66	12.24	6.74	0.18	12.06	14.60
16	11.84	3.4409	0.60	"	"	"	1.18	0.00	1.18	0.00	4.66	11.24	5.26	1.18	10.06	13.80
17	13.32	3.6497	1.81	"	"	"	0.91	0.00	0.91	0.00	4.93	11.51	6.74	0.91	10.60	14.60
18	13.32	3.6497	1.84	"	"	"	0.94	0.00	0.94	0.00	4.90	11.48	6.74	0.94	10.54	14.60
19	12.54	3.5412	0.99	"	"	"	0.87	0.00	0.87	0.00	4.97	11.55	5.96	0.87	10.68	14.20
20	13.20	3.6332	1.92	"	"	"	1.14	0.00	1.14	0.00	4.70	11.28	6.62	1.14	10.14	14.60
21	13.86	3.7229	2.72	"	"	"	1.28	0.00	1,28	0.00	4.56	11.14	7.28	1.28	9.86	15.00

Table A2.8. Evaluation Efficiency Components and Component Ratios for the 21 Bedrooms.

B.N.	E.R	E.R COMPONENTS																	
		O.P	O.P RATIOS		P.P	P.P RATIOS		A.P	A.P RATIOS										
			Σ A.01~01	A.01		P.R	$\sqrt{AR} \times 4$		A.S / A.FMO	A.NSR / A.FMO	AE(UNION) / A.FMO	A.BR / A.FMO	A.U(TOT) / A.FMO	A.01 / A.FMO	A.02 / A.FMO	A.0U / A.FMO	A.NO / A.FMO	2A.02 / A.FMO
01	2.1211	2.4268	5.97	2.46	1.0338	13.40	12.9616	0.8454	0.5298	0.3156	0.8164	0.0290	0.4702	0.1981	0.0145	0.1691	0.6473	0.0290
02	2.1850	2.5000	6.15	2.46	1.0338	13.40	12.9616	0.8454	"	0.3156	0.8164	0.0290	"	0.1981	0.0145	0.1691	0.6473	0.0290
03	1.9457	2.1724	5.67	2.61	1.0194	13.40	13.1425	0.8696	"	0.3398	0.8124	0.0572	"	0.2101	0.0225	0.1651	0.6473	0.0450
04	2.0364	2.2973	5.10	2.22	1.0194	13.40	13.1452	0.8696	"	0.3398	0.8325	0.0370	"	0.1787	0.0113	0.1562	0.6473	0.0226
05	2.1921	2.4730	5.49	2.22	1.0194	13.40	13.1452	0.8696	"	0.3398	0.8325	0.0370	"	0.1787	0.0113	0.1562	0.6473	0.0226
06	2.2408	2.3966	4.36	1.82	1.0245	13.80	13.4700	0.9130	"	0.3833	0.8567	0.0564	"	0.1465	0.0032	0.1401	0.7166	0.0064
07	2.0139	2.2593	3.66	1.62	1.0138	13.40	13.2180	0.8792	"	0.3494	0.8792	0.0000	"	0.1304	0.0097	0.1111	0.7681	0.0194
08	2.7666	2.7895	3.18	1.14	1.0231	14.20	13.8796	0.9694	"	0.4396	0.9179	0.0515	"	0.0918	0.0097	0.0725	0.8454	0.0194
09	2.4200	2.4400	3.66	1.50	1.0231	14.20	13.8796	0.9694	"	0.4396	0.8889	0.0805	"	0.1208	0.0097	0.1014	0.7874	0.0194
10	2.2888	2.3077	3.60	1.56	1.0231	14.20	13.8796	0.9694	"	0.4396	0.8841	0.0853	"	0.1256	0.0096	0.1063	0.7729	0.0192
11	1.8453	2.3125	6.66	2.88	1.0011	12.60	12.5856	0.7971	"	0.2673	0.7971	0.0000	"	0.2319	0.0290	0.1739	0.6232	0.0580
12	2.9221	2.8400	2.13	0.75	1.0142	14.40	14.1984	1.0145	"	0.4847	0.9444	0.0700	"	0.0604	0.0048	0.0507	0.8937	0.0096
13	2.8740	2.7692	2.16	0.78	1.0009	14.20	14.1872	1.0129	"	0.4831	0.9372	0.0757	"	0.0628	0.0000	0.0628	0.8744	0.0000
14	2.8140	2.6967	3.29	1.22	1.0000	14.40	14.4000	1.0435	"	0.5137	0.9018	0.1417	"	0.0982	0.0000	0.0982	0.8035	0.0000
15	3.2178	3.0000	0.54	0.18	1.0001	14.60	14.5988	1.0725	"	0.5427	0.9855	0.0870	"	0.0145	0.0000	0.0145	0.9710	0.0000
16	2.5272	2.6441	3.12	1.18	1.0026	13.80	13.7636	0.9533	"	0.4235	0.9050	0.0483	"	0.0950	0.0000	0.0950	0.8100	0.0000
17	2.9350	2.7363	2.49	0.91	1.0001	14.60	14.5988	1.0725	"	0.5427	0.9267	0.1457	"	0.0733	0.0000	0.0733	0.8535	0.0000
18	2.8869	2.6915	2.53	0.94	1.0001	14.60	14.5988	1.0725	"	0.5427	0.9179	0.1481	"	0.0757	0.0000	0.0757	0.8486	0.0000
19	2.3967	2.3678	2.06	0.87	1.0025	14.20	14.1648	1.0097	"	0.4799	0.9300	0.0797	"	0.0700	0.0000	0.0700	0.8600	0.0000
20	2.8659	2.6842	3.06	1.14	1.0046	14.60	14.5328	1.0628	"	0.5330	0.9082	0.1546	"	0.0918	0.0000	0.0918	0.8164	0.0000
21	2.9506	2.6250	3.36	1.28	1.0073	15.00	14.8316	1.1159	"	0.5862	0.8969	0.2190	"	0.1031	0.0000	0.1031	0.7939	0.0000

APPENDIX 3: RESULTS AND STATISTICAL CORRELATION DATA FROM THE OBJECTIVE AND SUBJECTIVE TESTS

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RESULTS AND STATISTICAL CORRELATION DATA FROM THE OBJECTIVE AND SUBJECTIVE TESTS.

A3.1. Subjective Questionnaire, Room Layouts and Data.

Table A3.1. Questionnaire for the Subjective Evaluation Test.

SCOTT SUTHERLAND SCHOOL OF ARCHITECTURE
ROBERT GORDON'S INSTITUTE OF TECHNOLOGY

A METHOD OF EVALUATING EFFICIENCIES OF RECTANGULAR DOMESTIC ACTIVITY-SPACES CONTAINING ORTHOGONALLY ARRANGED RECTANGULAR FURNITURE AND USER SPACES - A SUBJECTIVE TEST BY DESIGNERS.

K LANGSKOG - RESEARCH - 07.02.80.

Please enter answers, or tick as appropriate, in the boxes provided.

When you have completed the test, which should take about 20-30 minutes, please submit the form to the organisers.

1. What is your year of study (answer 3-6): [ ]

   Refer to the appended room layouts for the following questions:

2. For each pair of room-layouts, identify the room layout that to you seems to contain the least amount of conflict, bearing in mind that each element or furniture, including the door, in actual fact has a user space adjacent to it in order to enable a person to use the element and to allow the element to function, and that elements may be used simultaneously (O.P).

	ROOM 1	ROOM 2
PAIR 1	[ ]	[ ]
PAIR 2	[ ]	[ ]
PAIR 3	[ ]	[ ]
PAIR 4	[ ]	[ ]

3. (a) For each pair of elements, identify which layout that to you seems to make the best use of the available space, at the cost of the least amount of conflict and least wasted space (A.P).

	ROOM 1	ROOM 2
PAIR 1	[ ]	[ ]
PAIR 2	[ ]	[ ]
PAIR 3	[ ]	[ ]
PAIR 4	[ ]	[ ]

Table A3.1. (Continued).

(b) Relating to part (a) of this question, please pick, from the total, the four room layouts that you think make the best use of the available space, and rank them from 1 to 4 (A.P).

	ROOM 1	ROOM 2
PAIR 1		
PAIR 2		
PAIR 3		
PAIR 4		

4. From the total number of room layouts, please identify and rank the first four layouts that you think seem the most efficient in terms of a composite of the following criteria (E.R):

(i) Least amount of conflict (O.P).
(ii) Optimal room shape (perimeter in relation to area) for allowing efficient layout of furniture (P.P).
(iii) Best use of available space (A.P).

	ROOM 1	ROOM 2
PAIR 1		
PAIR 2		
PAIR 3		
PAIR 4		

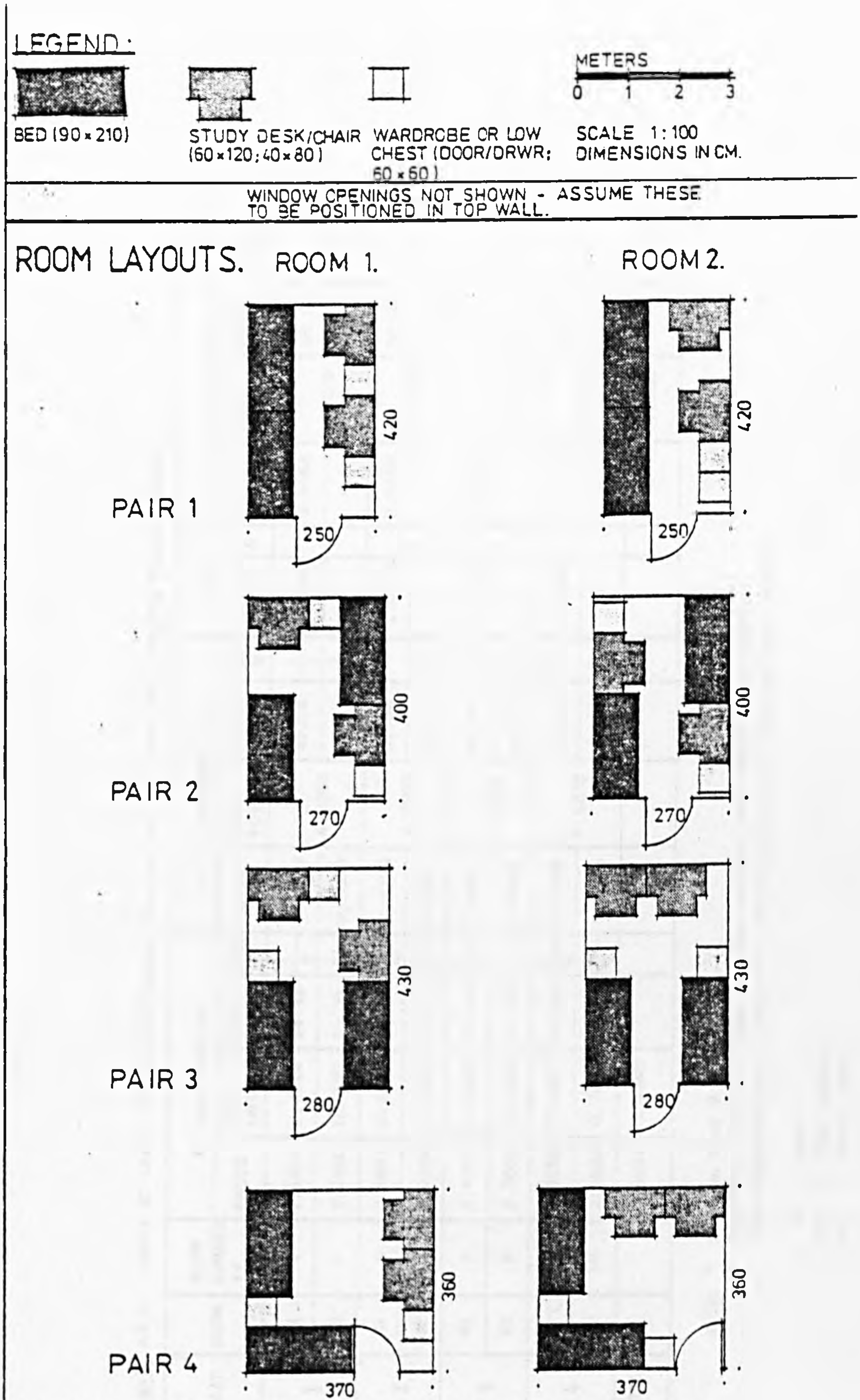


Fig. A3.1. The 8 Room Layouts for the Subjective Evaluation Test.

Table A3.2. Table of the 8 Rooms with Manual Evaluation Run Data and Ranking Calculations.

PAIR	ROOM	ROOM NUMBER **	E (Question 4) UNITS	INV. UNITS	INV. TOT.%	RP/RT	O.P (Question 2) UNITS	PAIR TOTAL	PAIR* %	RP/RT	P.P UNITS	R	A.P (Questions 3(a) and (b)) UNITS	PAIR TOTAL	PAIR %	INV. UNITS	INV. TOT.%	R
1	R1	1	2.1211	0.4715	14.12	1/2	2.4260	4.9268	49.26	1/2	1.0338	4	0.8454	1.6908	50.00	1.1829	27.52	1 $\frac{13.76}{13.76}$
	R2	2	2.1850	0.4577	13.71	2/3	2.5000		50.74	2	"		"		50.00			
2	R1	5	2.1921	0.4562	13.66	2/4	2.4730	4.7703	51.84	2	1.0194	2	0.8696	1.7392	50.00	1.1500	26.76	2 $\frac{13.38}{13.38}$
	R2	4	2.0364	0.4911	14.71	1/1	2.2973		48.16	1	"		"		50.00			
3	R1	9	2.4200	0.4132	12.38	1/5	2.4400	5.2295	46.66	1	1.0231	3	0.9694	1.9388	50.00	1.0316	24.02	3 $\frac{12.01}{12.01}$
	R2	8	2.7666	0.3615	10.83	2/6	2.7895		53.34	2	"		"		50.00			
4	R1	17	2.9350	0.3407	10.21	2/8	2.7363	5.4278	50.41	2	1.0001	1	1.0725	2.1450	50.00	0.9324	21.70	4 $\frac{10.85}{10.85}$
	R2	18	2.8869	0.3464	10.38	1/7	2.6915		49.59	1	"		"		50.00			
TOTALS			19.5031	3.3383									3.7569	7.5138		4.2969		

NOTE: * Same as Pair % for E.
** See Fig. A3.1 for Room Layouts without user spaces indicated.
(See Appendix A2.1, Fig. A2.1 for Room Layouts showing user spaces.

R = Rank
R.P = Pair Rank.
R.T = Total Rank.

A3.2. Subjective Results and Statistical Calculations for Questions 2 and 3(a).

A3.2.1. Subjective Result Figures.

Table A3.3. Subjective Results for Question 2 for the 18 Staff Members.

PAIR	EVAL. RESULTS	SUBJECTIVE RESPONSES						CORRELATION RATING.*
		ROOM 1		EQUAL		ROOM 2		
		NO.	%	NO.	%	NO.	%	
PAIR 1	ROOM 1	12 12.5	66.67 69.44	1	5.56	5 5.5	27.78 30.56	FAIR
PAIR 2	ROOM 2	10 11	55.56 61.11	2	11.11	6 7	33.33 33.89	GOOD
PAIR 3	ROOM 1	4 4.5	22.22 25.00	1	5.56	13 13.5	72.22 75.00	BAD
PAIR 4	ROOM 2	0	0.00	0	0.00	18	100.00	VERY GOOD

Table A3.4. Subjective Results for Question 2 for the 38 Architectural Students.

PAIR	EVAL. RESULTS	SUBJECTIVE RESPONSES						CORRELATION RATING.*
		ROOM 1		EQUAL		ROOM 2		
		NO.	%	NO.	%	NO.	%	
PAIR 1	ROOM 1	30 32	78.94 84.21	4	10.53	4 6	10.53 15.79	BAD
PAIR 2	ROOM 2	14	36.84			24	63.16	GOOD
PAIR 3	ROOM 1	13 13.5	34.21 35.53	1	2.63	24 24.5	63.16 64.47	GOOD
PAIR 4	ROOM 2	5	13.16			33	86.84	VERY GOOD

* NOTE: RATINGS:
VERY GOOD - 70 - 100% CORRELATION.
GOOD - 50 - 70% CORRELATION.
FAIR - 30 - 50% CORRELATION.
BAD - 0 - 30% CORRELATION.

Table A3.5. Subjective Results for Question 3(a) for the 18 Staff Members.

PAIR	EVAL. RESULTS	SUBJECTIVE RESPONSES: ROOM 1 NO.	ROOM 1 %	EQUAL NO.	EQUAL %	ROOM 2 NO.	ROOM 2 %	CORRELATION RATING.*
PAIR 1	EQUAL	13	77.22	2	11.11	3	16.67	FAIR
		14	77.78			4	22.22	
PAIR 2	EQUAL	11	61.11	0		7	38.89	VERY GOOD
PAIR 3	EQUAL	2	11.11	2	11.11	14	77.78	FAIR
		3	16.67			15	83.33	
PAIR 4	EQUAL	1	5.56	2	11.11	15	83.33	BAD
		2	11.11			16	88.89	

Table A3.6. Subjective Results for Question 3(a) for the 38 Architectural Students.

PAIR	EVAL. RESULTS	SUBJECTIVE RESPONSES: ROOM 1 NO.	ROOM 1 %	EQUAL NO.	EQUAL %	ROOM 2 NO.	ROOM 2 %	CORRELATION RATING.*
PAIR 1	EQUAL	31	81.58	2	5.26	5	13.16	BAD
		32	84.21			6	15.79	
PAIR 2	EQUAL	17	44.74			21	55.26	VERY GOOD
PAIR 3	EQUAL	8	21.05	1	2.63	29	76.32	BAD
		8.5	22.37			29.5	77.63	
PAIR 4	EQUAL	13	34.21			25	65.79	FAIR

* NOTE: RATINGS:

VERY GOOD	- 0 - 30% DIFFERENCE.
GOOD	- 30 - 50% DIFFERENCE.
FAIR	- 50 - 70% DIFFERENCE.
BAD	- 70 - 100% DIFFERENCE.

A3.2.2. Normal Distribution Calculations for Questions 2 and 3(a).

1. Calculations for Question 2 for the 18 Staff Members:

Ho:p = ½ that subject chooses 1st room (i.e. that it follows Normal distribution).

Reject Ho if Z > 1.96 (2.5% significance)
or > 1.64 (5% significance)
or > 1.28 (10% significance).

PAIR 1: Obj(E)*, Subj (1)*.

S = 18 Ns = 12.5

Var (Ns) = 18 x ½ x ½ = 4.5

E(Ns) = 18 x ½ = 9.

$$\Rightarrow \quad Z = \frac{Ns - E(Ns)}{\sqrt{Var(Ns)}} = \frac{12.5 - 9}{\sqrt{4.5}} = \frac{2.5}{2.12} = \underline{1.17}$$

⇒ accept Ho:p = ½ ⟶ normal distribution.

* E = Equal
* 1,2 = Room 1 or Room 2 in Pair.

PAIR 2: Obj(2), Subj(2).

S = 18 Ns = 11

Var(Ns) = 4.5 E(Ns) = 9.

$$\Rightarrow \quad Z = \frac{11 - 9}{\sqrt{4.5}} = \frac{2}{2.12} = \underline{0.94}$$

⇒ accept Ho:p = ½.

PAIR 3: S = 18 Ns = 4.5 Obj(1), Subj(2).

Var(Ns) = 4.5 E(Ns) = 9.

$$\Rightarrow \quad Z = \frac{4.5 - 9}{\sqrt{4.5}} = \frac{|-4.5|}{2.12} = \underline{2.12} > 1.96 \text{ (2.5\% sign.)}.$$

⇒ reject Ho:p < ½.

PAIR 4: Obj(2), Subj(2).

S = 18 Ns = 0

Var(Ns) = 4.5 E(Ns) = 9.

$$\Rightarrow \quad Z = \frac{0 - 9}{\sqrt{4.5}} = \frac{|-9|}{2.12} = \underline{4.25} > 1.96 \text{(2.5\% sign.)}.$$

⇒ reject Ho:p < ½.

2. Calculations for Question 2 for the 38 Architectural Students:

PAIR 1: Obj(E), Subj(1).

$S = \underline{38}$ $\quad Ns = \underline{32}$

$Var(Ns) = 38 \times \frac{1}{4} = \underline{9.5}$ $\quad E(Ns) = 38 \times \frac{1}{2} = \underline{19}$.

$\Rightarrow \quad Z = \frac{Ns - E(Ns)}{\sqrt{Var(Ns)}} = \frac{32 - 19}{\sqrt{9.5}} = \frac{13}{3.08} = \underline{4.22} > 1.96(2.5\%)$.

$\Rightarrow$ reject $Ho: \underline{p < \frac{1}{2}}$.

PAIR 2: Obj(2), Subj(2).

$S = \underline{38}$ $\quad Ns = \underline{14}$

$Var(Ns) = \underline{9.5}$ $\quad E(Ns) = \underline{19}$.

$\Rightarrow \quad Z = \frac{24 - 19}{\sqrt{9.5}} = \frac{5}{3.08} = \underline{1.62} > 1.28(10\%)$.

$\Rightarrow$ reject $Ho: \underline{p < \frac{1}{2}}$.

PAIR 3: Obj(2), Subj(2).

$S = \underline{38}$ $\quad Ns = \underline{13.5}$

$Var(Ns) = \underline{9.5}$ $\quad E(Ns) = \underline{19}$.

$\Rightarrow \quad Z = \frac{13.5 - 19}{\sqrt{9.5}} = \frac{|-55|}{3.08} = \underline{1.79} > 1.64(5\%)$.

$\Rightarrow$ reject $Ho: \underline{p < \frac{1}{2}}$.

PAIR 4: Obj(2), Subj(2).

$S = \underline{38}$ $\quad Ns = \underline{5}$

$Var(Ns) = \underline{9.5}$ $\quad E(Ns) = \underline{19}$.

$\Rightarrow \quad Z = \frac{5 - 19}{\sqrt{9.5}} = \frac{|-14|}{3.08} = \underline{4.55} > 1.96(2.5\%)$.

$\Rightarrow$ reject $Ho: \underline{p < \frac{1}{2}}$.

3. Calculations for Question 3(a) for the 18 Staff Members:

Ho:p = ½ that subject chooses 1st room.
(i.e. that it follows Normal Distribution).

Reject Ho if Z > 1.96 (2.5% significance)
or > 1.64 (5% significance)
or > 1.28 (10% significance).

PAIR 1: Obj(E), Subj(1).

$S = \underline{18} \quad Ns = \underline{14}$

$Var(Ns) = \underline{4.5} \qquad E(Ns) = \underline{9}.$

$\Rightarrow \quad Z = \frac{Ns - E(ns)}{\sqrt{Var(Ns)}} = \frac{14 - 9}{\sqrt{4.5}} = \frac{5}{2.12} = \underline{2.35} > 1.96(2.5\%).$

$\Rightarrow$ reject Ho:p < ½.

PAIR 2: Obj(E), Subj(1).

$S = \underline{18} \quad Ns = \underline{11}.$

$Var(Ns) = \underline{4.5} \qquad E(Ns) = \underline{9}.$

$\Rightarrow \quad Z = \frac{11 - 9}{2.12} = \frac{2}{2.12} = \underline{0.94}$

$\Rightarrow$ accept Ho:p ≥ ½.

PAIR 3: Obj(E), Subj(2).

$S = \underline{18} \quad Ns = \underline{3}.$

$Var(Ns) = \underline{4.5} \qquad E(Ns) = \underline{9}.$

$\Rightarrow \quad Z = \frac{3 - 9}{2.12} = \frac{|-6|}{2.12} = \underline{2.83} > 1.96(2.5\%).$

$\Rightarrow$ reject Ho:p < ½.

PAIR 4: Obj(E), Subj(2).

$S = \underline{18} \quad Ns = \underline{2}$

$Var(Ns) = \underline{4.5} \qquad E(Ns) = \underline{9}.$

$\Rightarrow \quad Z = \frac{2 - 9}{2.12} = \frac{|-7|}{2.12} = \underline{3.30} > 1.96(2.5\%).$

$\Rightarrow$ reject Ho:p < ½.

4. <u>Calculations for Question 3(a) for the 38 Architectural Students</u>:

<u>PAIR 1</u>: Obj(E), Subj(1).

$S = \underline{38} \qquad Ns = \underline{32}$

$Var(\ s) = \underline{9.5} \qquad\qquad E(Ns) = \underline{19}.$

$$\Rightarrow \quad Z = \frac{Ns - E(Ns)}{\sqrt{Var(Ns)}} = \frac{32 - 19}{\sqrt{9.5}} = \frac{13}{3.08} = \underline{4.22} > 1.96(2.5\%).$$

$\Rightarrow$ reject Ho:$\underline{p < \tfrac{1}{2}.}$

<u>PAIR 2</u>: Obj(E), Subj(2).

$S = \underline{38} \qquad Ns = \underline{17}$

$Var(Ns) = \underline{9.5} \qquad\qquad E(Ns) = \underline{19}.$

$$\Rightarrow \quad Z = \frac{17 - 19}{3.08} = \frac{|-2|}{3.08} = \underline{0.65}$$

$\Rightarrow$ accept Ho:$\underline{p \geq \tfrac{1}{2}.}$

<u>PAIR 3</u>: Obj(E), Subj(2).

$S = \underline{38} \qquad Ns = \underline{8.5}$

$Var(Ns) = \underline{9.5} \qquad\qquad E(Ns) = \underline{19}.$

$$\Rightarrow \quad Z = \frac{8.5 - 19}{3.08} = \frac{|-10.5|}{3.08} = \underline{3.40} > 1.96(2.5\%).$$

$\Rightarrow$ reject Ho:$\underline{p < \tfrac{1}{2}.}$

<u>PAIR 4</u>: Obj(E), Subj(2).

$S = \underline{38} \qquad Ns = \underline{13}$

$Var(Ns) = \underline{9.5} \qquad\qquad E(Ns) = \underline{19}.$

$$\Rightarrow \quad Z = \frac{13 - 19}{3.08} = \frac{|-6|}{3.08} = \underline{1.95} > 1.64(5\%).$$

$\Rightarrow$ reject Ho:$\underline{p < \tfrac{1}{2}.}$

A3.3. Subjective Results and Calculations for Questions 3(b) and 4.

A3.3.1 Subjective Ranking Figures.

Table A3.7. Subjective Ranking Figures for Question 3(b).

JUDGES (6+9=15)		PAIR 1		PAIR 2		PAIR 3		PAIR 4		TOTAL			
		R1	R2	R1	R2	R1	R2	R1	R2	36	10	26	6.5
STAFF	2*	10.5	1	2	2	3	3	4	10.5	36	15	21	10.5
	3*	1	1	18	2	3	3	4	4	36	18	18	18
	4	6.5	6.5	6.5	2	6.5	4	3	1	36			
	8*	1 3	1 3	2 4	2 4	3 5	4 6	4 6	3 5	36	20	16	2
	9*	1 3	3 5	4 6	4 6	2 4	1 3	3 5	2 4	36	20	16	2
	17*	1 3	1 3	2 4	2 4	3 5	3 5	4 6	4 6	36	20	16	2
STUDENTS	2	2	4	6.5	6.5	6.5	6.5	3	1	36			
	4*	2 4	4 6	1 3	1 3	3 5	3 5	4 6	2 4	36	20	16	2
	5*	6.5	4	6.5	6.5	3	2	1	6.5	36			
	10	2	6.5	3	1	6.5	4	6.5	6.5	36			
	11	6.5	6.5	2	1	6.5	6.5	3	4	36			
	16	3	6.5	1	2	6.5	6.5	6.5	4	36			
	19	1	6.5	2	6.5	6.5	6.5	4	3	36			
	37	6.5	6.5	4	3	6.5	1	2	6.5	36			
	38	1	6.5	2	6.5	4	3	6.5	6.5	36			
Obs. R		59.5	72.5	70.5	56.0	77.5	65.0	66.5	72.5	540			
Exp. R		67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	540			
d		8	-5	-3	11.5	-10	2.5	1	-5				
d^2 = S		64	25	9	132.25	100	6.25	1	25	S = 362.5			
R.O.		2	6	5	1	8	3	4	6				
%		11.0	13.43	13.06	10.37	14.35	12.04	12.31	13.43	100%			
INN. RATIO X 100		1.68	1.38	1.42	1.79	1.29	1.54	1.50	1.38	11.98			
%		14.02	11.52	11.85	14.94	10.77	12.85	12.52	11.52	100%			

Table A3.8. Subjective Ranking Figures for Question 4 for the 18 Staff Members.

JUDGES	P1		P2		P3		P4		TOTAL
	R1	R2	R1	R2	R1	R2	R1	R2	
1	6.5	4	3	6.5	6.5	2	6.5	1	
2	6.5	2	3	1	4	6.5	6.5	6.5	
3	2	6.5	3	1	4	6.5	6.5	6.5	
4	6.5	6.5	6.5	2	6.5	4	3	1	
5	6.5	6.5	3	4	6.5	6.5	2	1	
6	4	6.5	1	6.5	6.5	3	6.5	2	
7	4	6.5	2	6.5	6.5	1	6.5	3	
8	3	6.5	4	6.5	6.5	2	6.5	1	
9	6.5	6.5	6.5	6.5	4	1	3	2	
10	4	6.5	2	3	6.5	6.5	6.5	1	
11	3	6.5	6.5	4	2	6.5	6.5	1	
12	2	6.5	6.5	1	6.5	3	6.5	4	
13	3	6.5	6.5	1	6.5	4	6.5	2	
14	3	6.5	6.5	2	6.5	4	6.5	1	
15	3	6.5	6.5	2	6.5	4	6.5	1	
16	6.5	6.5	2	3	1	6.5	4	6.5	
17	6.5	2	3	1	4	6.5	6.5	6.5	
18	4	6.5	3	6.5	6.5	1	6.5	2	
TOT.R.	80.5	105,5	74.5	64.0	97.0	74.5	103,0	49.0	648,0
R.O.	5	8	3	2	6	3	7	1	
INV. RATIO X 100	1.24	0.95	1.34	1.56	1.03	1.34	0.97	2.04	10.47
%	11.84	9.07	12.80	14.90	9.84	12.80	9.26	19.49	100%

Table A3.9. Subjective Ranking Figures for Question 4 for the 38 Architectural Students.

JUDGES	P1		P2		P3		P4		TOTAL
	R1	R2	R1	R2	R1	R2	R1	R2	
1	3	6.5	2	6.5	6.5	4	6.5	1	
2	6.5	6.5	4	6.5	3	2	6.5	1	
3	6.5	6.5	3	6.5	6.5	2	4	1	
4	4	6.5	6.5	2	6.5	3	6.5	1	
5	6.5	4	6.5	6.5	3	2	6.5	1	
6	4	6.5	6.5	2	1	6.5	3	6.5	
7	4	6.5	6.5	2	1	6.5	3	6.5	
8	3	6.5	1	6.5	6.5	4	6.5	2	
9	2	6.5	6.5	1	6.5	3	4	6.5	
10	6.5	6.5	6.5	1	4	3	2	6.5	
11	6,5	6.5	3	1	6.5	2	6.5	4	
12	6.5	4	6.5	1	2	6.5	6.5	3	
13	6.5	4	6.5	3	6.5	2	6.5	1	
14	6.5	6.5	4	3	6.5	6.5	2	1	
15	3	6.5	6.5	4	6.5	2	6.5	1	
16	3	6.5	1	2	6.5	6.5	6.5	4	
17	4	6.5	6.5	3	6.5	2	6.5	1	
18	3	6.5	6.5	1	4	6.5	6.5	2	
19	3	6.5	6.5	6.5	4	6.5	2	1	
20	4	6.5	6.5	3	6.5	6.5	2	1	
21	3	4	6.5	7.5	6.5	1	2	6.5	
22	2	6.5	6.5	1	6.5	4	6.5	3	
23	4	6.5	2	1	6.5	3	6.5	6.5	
24	4	6.5	6.5	3	6.5	2	6.5	1	
25	2	6.5	6.5	1	6.5	3	6.5	4	

Table A3.9. (Continued).

JUDGES	P1		P2		P3		P4		TOTAL
	R1	R2	R1	R2	R1	R2	R1	R2	
26	1	6.5	6.5	2	6.5	4	6.5	3	
27	1	6.5	6.5	2	6.5	3	6.5	4	
28	2	6.5	1	3	6.5	6.5	6.5	4	
29	2	6.5	6.5	3	6.5	4	6.5	1	
30	3	6.5	4	6.5	6.5	1	6.5	2	
31	6.5	6.5	1	3	4	6.5	6.5	2	
32	4	6.5	6.5	3	6.5	6.5	2	1	
33	2	6.5	6.5	1	4	6.5	6.5	3	
34	2	6.5	3	6.5	4	6.5	6.5	1	
35	6.5	6.5	6.5	4	6.5	3	1	2	
36	1	6.5	4	6.5	6.5	2	3	6.5	
37	3	6.5	1	4	6.5	2	6.5	6.5	
38	1	6.5	3	6.5	4	6.5	6.5	2	
TOT.R.	142,-	237,-	186.5	131.5	207,-	154,-	199,-	111,-	1368,-
R.O.	3	8	5	2	7	4	6	1	
INV.RATIO X 100	0.70	0.42	0.54	0.76	0.48	0.65	0.50	0.90	4.95
%	14.14	8.48	10.90	15.35	9.70	13.13	10.10	18.19	100%

A3.3.2. Rank Correlation Calculations.

1. Step 1: Ranking Calculations:

Table A3.10. Individual Ranking Sheet for Question 3(b).

SAMPLE: SUBJECT NO:

ROOM	OBJ. RANK (i)		SUBJ. RANK (Ti)*	Ti-i	$(Ti-i)^2$
P1/R1	(1)	1.5			
P1/R2	(2)	1.5			
P2/R1	(3)	3.5			
P2/R2	(4)	3.5			
P3/R1	(5)	5.5			
P3/R2	(6)	5.5			
P4/R1	(7)	7.5			
P4/R2	(8)	7.5			
TOTALS					

* NOTE:

See Table for obj. rank allocations.

$$D^{**} = \sum_{1}^{8} (Ti-i)^2$$

Table A3.11. Individual Ranking Sheet for Question 4.

SAMPLE: SUBJECT NO:

ROOM	OBJ. RANK (i)	SUBJ. RANK $(Ti)^2$	Ti-i	$(Ti-i)^2$
P2/R2	1	6.5		
P1/R1	2	1		
P1/R2	3	2		
P2/R1	4	6.5		
P3/R1	5	4		
P3/R2	6	3		
P4/R2	7	6.5		
P4/R1	8	6.5		
TOTALS				

* NOTE:

Ranks from 1 - 4, with a "Tied" rank of 6.5 for remaining 4 rooms.

$$D^{*} = \sum_{1}^{8} (Ti-i)^2$$

2. Step 2: Deviation Calculations:

Table A3.12. Deviation Results for Question 3(b).

15 JUDGES	$D^{**} = \sum_{i}^{3} (Ti-i)^2$
2	57.00
3	57.00
4	122.75
8	57.00
9	69.00
17	57.00
(6)	419.75
2	117.00
4	85.00
5	111.00
10	37.00
11	93.00
16	51.00
19	71.00
37	103.00
38	47.00
(9)	715.00
$\sum D^{**}$	1134.75

Table A3.13. Deviation Results for Question 4 for the 18 Staff Members.

18 JUDGES	$D^{**} = \sum_{1}^{8} (Ti-i)^2$
1	109,00
2	26,00
3	39,00
4	107,00
5	117,00
6	94,00
7	96,00
8	100,00
9	145,00
10	65,00
11	76,00
12	41,00
13	53,00
14	65,00
15	65,00
16	73,00
17	26,00
18	91,00
$\sum D^{**}$	1388,00

Table A3.14. Deviation Results for Question 4 for the 38 Architectural Students.

38 JUDGES	$D^{**} = \sum_{1}^{8} (Ti-i)^2$
1	92.00
2	121.00
3	134.00
4	73.00
5	116.00
6	65.00
7	65.00
8	86.00
9	46.00
10	76.00
11	63.00
12	55.00
13	88.00
14	111.00
15	85.00
16	37.00
17	83.00
18	48.00
19	123.00
20	101.00
21	102.00
22	43.00
23	34.00
24	83.00
25	42.00
26	45.00

Table A3.14. (Continued).

38 JUDGES	$D^{**} = \sum_{1}^{8} (Ti-i)^2$
27	43.00
28	39.00
29	67.00
30	98.00
31	74.00
32	101.00
33	38.00
34	83.00
35	133.00
36	87.00
37	52.00
38	73.00
$\sum D^{**}$	2905.00

3. Step 3: Expexted Deviation Calculations:

3.1. E(D**) for Question 3(b):

$$E(D^{**}) = 1/6(N^3-N) - 1/12\ \Sigma\,(di^3-di) - 1/12\ \Sigma\,(fi^3-fi)$$

$$= 1/6(8^3-8) - 1/12(4^3-4) - 1/12(2^3-2)$$

$$= \underline{78.5}$$

3.2. E(D*) for question 4:

D* has an approximately normal distribution, hence:

$$E(D^*) = 1/6(N^3-N) - 1/12\ \Sigma\,(di^3-di)$$

$$= 1/6(8^3-8) - 1/12(4^3-4)$$

$$= \underline{79}$$

4. Step 4: Variation of Deviation Calculations:

4.1. Var(D**) for question 3(b):

$$Var(D^{**}) = \frac{(N-1)N^2(N+1)^2}{36}\left[1 - \frac{\Sigma\,(di^3-di)}{N^3-N}\right]\left[1 - \frac{\Sigma\,(fi^3\,fi)}{N^3-N}\right]$$

$$= \frac{160 \times 37}{7 \times S}$$

$$= \frac{845.71}{S}$$

where: S = Number of Subjects.

4.2. Var(D*) for Question 4:

$$Var(D^{**}) = \frac{(N-1)N^2(N+1)^2}{36}\left[1 - \frac{\Sigma\,(di^3-di)}{N^3-N}\right]$$

$$= \frac{7 \times 8^2 \times 9^2}{36}\left[1 - \frac{(4^3-4)}{(8^3-8)}\right]$$

$$= \underline{888}$$

5. Step 5: Mean Deviation Calculations:

5.1. $\overline{D}$** for Question 3(b):

S = 15 and Σ D** = 1134.75, hence:

$$\overline{D}^{**} = \frac{\Sigma\,D^*}{S}$$

$$= \frac{1134.75}{15}$$

$$= \underline{75.65}$$

5.2. $\overline{D}^*$ for Question 4:

5.2.1. $\overline{D}^*$ for the 18 Staff Members:

S = 18 and $\Sigma D^* = 1388$, hence:

$$\overline{D}^* = \frac{\Sigma D^*}{S}$$

$$= \frac{1388}{18}$$

$$= \underline{77.11}$$

5.2.2. $\overline{D}^*$ for the 38 Architectural Students:

S = 38 and $D^* = 2905$, hence:

$$\overline{D}^* = \frac{2905}{38}$$

$$= \underline{76.45}$$

6. Step 6: Mean Variation of Deviation Calculations:

6.1. $Var(\overline{D}^{**})$ for Question 3(b):

$$Var(\overline{D}^{**}) = \frac{Var(D^{**})}{S}$$

$$= \frac{845.71}{15}$$

$$= \underline{56.38}$$

6.2. $Var(\overline{D}^*)$ for Question 4:

6.2.1. $Var(\overline{D}^*)$ for the 18 Staff Members:

$$Var(\overline{D}^*) = \frac{888}{18}$$

$$= \underline{49.33}$$

6.2.2. $Var(\overline{D}^*)$ for the 38 Architectural Students:

$$Var(\overline{D}^*) = \frac{888}{38}$$

$$= \underline{23.37}$$

7. Step 7: Z - distribution Value Calculations:

7.1. Z for Question 3(b):

$$Z = \frac{E(D^{**}) - \overline{D}^{**}}{\sqrt{Var(\overline{D}^{**})}}$$

$$= \frac{78.5 - 75.65}{\sqrt{56.38}} = \underline{0.379}$$

7.2. Z for Question 4:

7.2.1. Z for the 18 Staff Members:

$$Z = \frac{79 - 77.11}{\sqrt{49.33}}$$

$$= \underline{0.269}$$

7.2.2. Z for the 38 Architectural Students:

$$Z = \frac{79 - 76.45}{\sqrt{23.37}}$$

$$= \underline{0.528}$$

8. Step 8: T - distribution Table Comparisons:

Ho = No ranking correlation between objective and subjective results (null hypothesis).

Reject Ho if:

1. $z > 1.96$ (2.5% significance level).
2. $z > 1.64$ (5% significance level).
3. $z > 1.28$ (10% significance level).

Otherwise, accept Ho.

8.1. T - distribution Comparison for Question 3(b):

$z = 0.379$, hence: Accept Ho.

8.2. T - distribution Comparison for Question 4:

8.2.1. T - distribution Comparison for the 18 Staff Members:

$z = 0.269$, hence: Accept Ho.

8.2.2. T - distribution Comparison for the 38 Architectural Students:

$z = 0.528$, hence: Accept Ho:

A3.3.3. Subjective Sample Agreement Calculations.

1. Subjective Sample Agreement Calculations for Question 3(b):

1.1 Step 1: Total Rank Checking:

Table A3.7 gives Roi(TOT) = 540; checking gives:

$$R_{TOT} = \frac{mn(n+1}{2}$$

$$= \frac{15 \times 8 \times 9}{2}$$

$$= \underline{540}$$

1.2. Step 2: Expected Ranking:

$$R_{Ei} = \frac{m(n+1)}{2} = \frac{R_{TOT}}{n}$$

$= \underline{67.5}$ (if no agreement).

1.3. Step 3: Difference between Expected and Observed Ranking:

See d, Table A3.7.

1.4. Step 4: Sum of the Squared Differences:

See d^2 and $\underline{S = 362.5}$, Table A3.7.

1.5. Step 5: Maximum Possible Sum of Squares of Differences:

$$S_{max} = \frac{m^2(m^3-n)}{12}$$

$$= \frac{15^2(8^3-8)}{12}$$

$$= \underline{9450}$$

1.6. Step 6: Coefficient of Concordance:

$$W = \frac{S}{S_{max}}$$

$$= \frac{362.5}{9450}$$

$= \underline{0.03836}$; hence: extremely small sample agreement.

1.7. Step 7: Snedecor's Significance Test:

1.7.1. Continuity Correction of W:

$$\overline{W} = \frac{S - 1}{S_{max} + 2}$$

$$= \frac{361.5}{9452}$$

$$= \underline{0.03825}$$

1.7.2. Calculation of F - Value:

$$F = \frac{(m-1)\overline{W}}{1-\overline{W}}$$

$$= \frac{14 \times 0.03825}{1 - 0.03825}$$

$$= \underline{0.5568}$$

<u>1.7.3. Calculation of Degrees of Freedom</u>:

$$fg = (n-1) - \frac{2}{m}$$

$$= 7 - \frac{2}{15}$$

$$= \underline{6.8667}$$

$$fl = (m-1) \times fg$$

$$14 \times 6.8667$$

$$= \underline{96.1338}$$

<u>1.7.4. F - table Checks</u>:

At the 1% level <u>F = 2.10</u>
At the 5% level <u>F = 2.82</u>

Hence: <u>F is not significant at the 1% and 5% levels; a likely reason is the small sample number. Since $\overline{W}$, however is very small, it must be taken that there is no sample agreement</u>.

<u>2. Subjective Sample Agreement Calculations for Question 4 for the 18 Staff Members:</u>

<u>2.1. Step 1: Total Rank Checking</u>:

Table A3.15 gives <u>Roi(TOT) = 648</u>; checking gives:

$$R_{TOT} = \frac{18 \times 8 \times 9}{2} = \underline{648}$$

<u>2.2. Step 2: Expected Ranking:</u>

$$R_{Ei} = \frac{18 \times 9}{2}$$

$$= \underline{81} \text{ (if no agreement).}$$

<u>2.3. Step 3: Difference between Expected and Observed Ranking</u>:

See d, Table A3.15.

<u>2.4. Step 4: Sum of the Squared Differences</u>:

See d^2 and <u>S = 2738</u>,Table A3.15.

2.5. Step 5: Maximum Possible Sum of Squares of Differences:

$$S_{max} = \frac{18^2\,(8^3-8)}{12}$$

$$= \underline{13824}$$

Table A3.15. Calculation of Sums of Squared Differences for Question 4 for the 18 Staff Members.

PAIR	P1		P2		P3		P4		Σ
ROOM	R1	R2	R1	R2	R1	R2	R1	R2	
Obs. R.	80.5	105.5	74.5	64.0	97.0	74.5	103.0	49.0	648.0
Exp. R	81	81	81	81	81	81	81	81	
d	0.5	-6.5	-6.5	17	16	-6.5	22	-32	
$S = d^2$	0.25	42.25	42.25	289	256	42.25	484	1024	S = 2738

Table A3.16. Calculation of Sums of Squared Differences for Question 4 for the 38 Architectural Students.

PAIR	P1		P2		P3		P4		Σ
ROOM	R1	R2	R1	R2	R1	R2	R1	R2	
Obs. R	142.0	237.0	186.5	131.5	207.0	154.0	199.0	111	1368.0
Exp. R	171	171	171	171	171	171	171	171	
d	-29	66	15.5	-39.5	36	-17	28	-60	
$S = D^2$	841	4356	240.25	1560.25	1296	289	784	3600	S=12966.5

2.6. Step 6: Coefficient of Concordance:

$$W = \frac{2738}{13824}$$

$= \underline{0.19806}$; hence: very small sample agreement.

2.7. Step 7: Snedecor's Significance Test:

2.7.1. Continuity Correction of W:

$$\overline{W} = \frac{2737}{13826}$$

$= \underline{0.19796}$

2.7.2. Calculation of F - Value:

$$F = \frac{17 \times 0.19796}{1 - 0.19796}$$

$= \underline{4.19595}$

2.7.3. Calculation of Degrees of Freedom:

$$fg = 7 - \frac{2}{18}$$

$= \underline{6.8888}$

$fl = 17 \times 6.8888$

$= \underline{117.1096}$

2.7.4. F - Table Checks:

At the 1% level $\underline{F = 2.08}$
At the 5% level $\underline{F = 2.79}$

Hence: F is significant at both the 1% and 5% levels; little sample agreement confirmed.

3. Subjective Sample Agreement Calculations for Question 4 for the 38 Architectural Students:

3.1. Step 1: Total Rank Checking:

Table A3.16 gives Roi(TOT) = 1368; checking gives:

$$R_{TOT} = \frac{38 \times 8 \times 9}{2}$$

$= \underline{1368}$

3.2. Step 2: Expected Ranking:

$R_{Ei} = \frac{38 \times 9}{2} = \underline{171}$ (if no agreement).

3.3. Step 3: Difference between Expected and Observed Ranking:

See d, Table A3.16.

3.4. Step 4: Sum of the Squared Differences:

See d^2 and $S = 12966.5$, Table A3.16.

3.5. Step 5: Maximum Possible Sum of Squares of Differences:

$$S_{max} = \frac{38^2 \times (8^3 - 8)}{12}$$

$$= 61610.667$$

3.6. Step 6: Coefficient of Concordance:

$$W = \frac{12966.5}{61610.667}$$

$= 0.21045$; hence: very small sample agreement.

3.7. Step 7: Snedecor's Significance Test:

3.7.1. Continuity Correction of W:

$$\overline{W} = \frac{12965.5}{61612.667}$$

$$= 0.21043$$

3.7.2. Calculation of F - Value:

$$F = \frac{37 \times 0.21043}{1 - 0.21043}$$

$$= 9.86095$$

3.7.3. Calculation of Degrees of Freedom:

$$fg = 7 - \frac{2}{38}$$

$$= 6.94737$$

$$fl = 37 \times 6.94737$$

$$= 257.0527$$

3.7.4. F - Table Checks:

At the 1% level $F = 2.05$
At the 5% level $F = 2.73$

Hence: F is significant at both the 1% and 5% levels; little sample agreement confirmed.

APPENDIX 4: PROGRAM USAGE OF IMPLEMENTED PROGRAMS

A4.1.	Examples of GAEL 4A/4T Graphical Output	A4.2
A4.2.	Typical SYNTAB Input	A4.5
A4.3.	Example of GAEL 7A GAELIC Language File	A4.7
A4.4.	Typical CRUNCH Run	A4.8

PROGRAM USAGE OF IMPLEMENTED PROGRAMS.

A4.1. Examples of GAEL 4A/4T Graphical Output.

LIST COMMAND:

```
GROUP DEFINITIONS PRESENT ARE:

   MSBE11   MDBE11   MCBE11   MACH11   MECH11   MDCH11   MSCH11
   MBTA11   MWAR11   MSDE11   MSDE21   MSDE31   MCHE11   MDRT11
   MDTA11   MDRE11   MDRE21   MDRE31   MOCU11   MOCU21   FWC.11
   FBID11   FBTH11   FSHO11   FBAS11   FOCU31   MSO311   MSO211
   MCTA11   MCTA21   MTV.11   MSTU11   MSTU21   MBCA11   MBCA21
   FWTP11   FSIN11   FCKR11   CIR090   FDRS11   FFCD11   FFRI11
   FPNC11   FWDR11   FDCB11    FCLC1   FCLC11   FAWM11   FTDR11
   FTUB11   FCLK11   SIT011   SLE011   DIN011   GRF011   BTH011
   KIT011   UTI011   FISE11
    THAT'S ALL FOLKS - PRESS RETURN TO CONTINUE
```

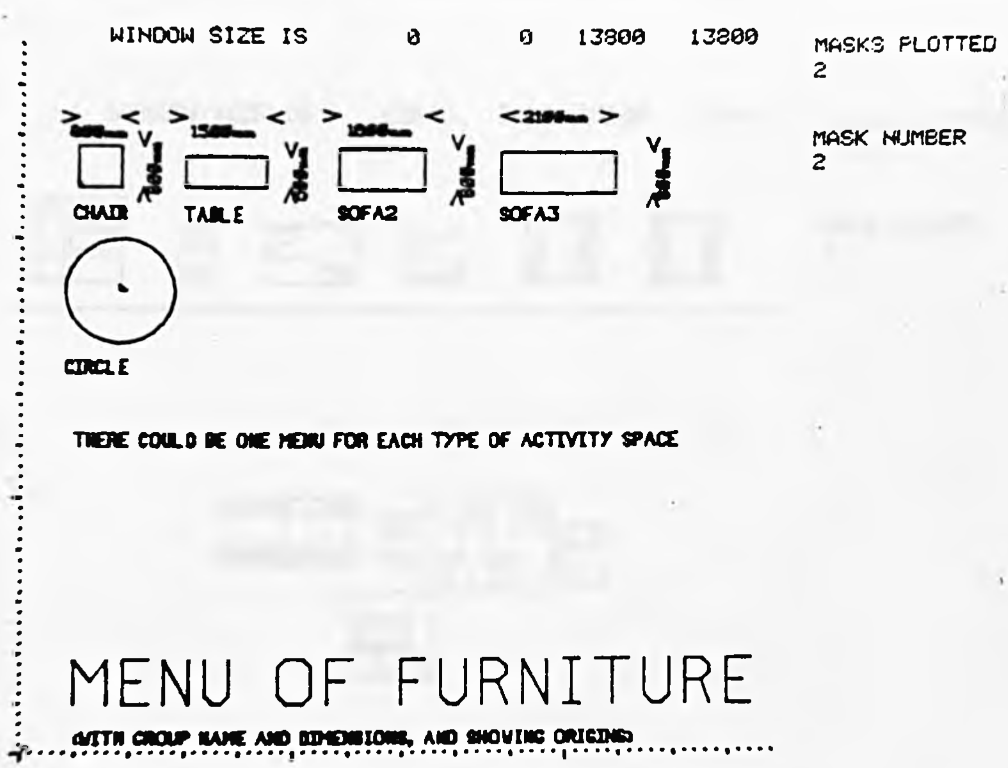
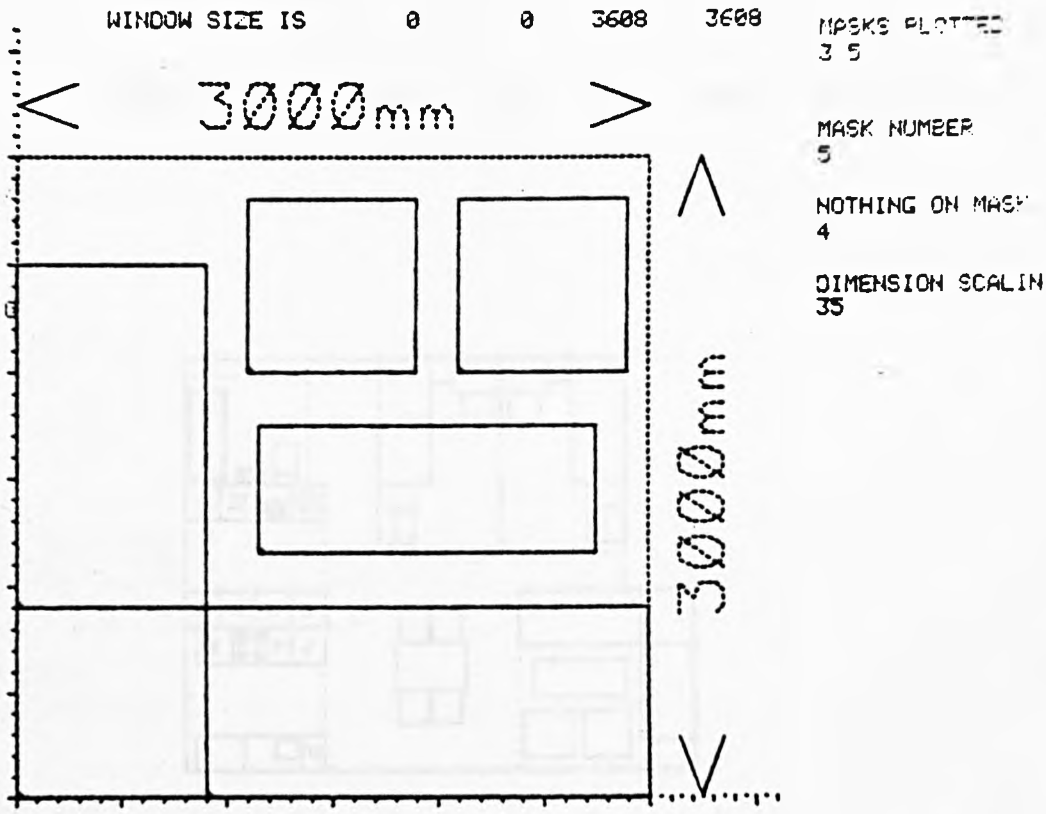


Fig. A4.1. Examples of GAEL 4A/4T Graphical Output.



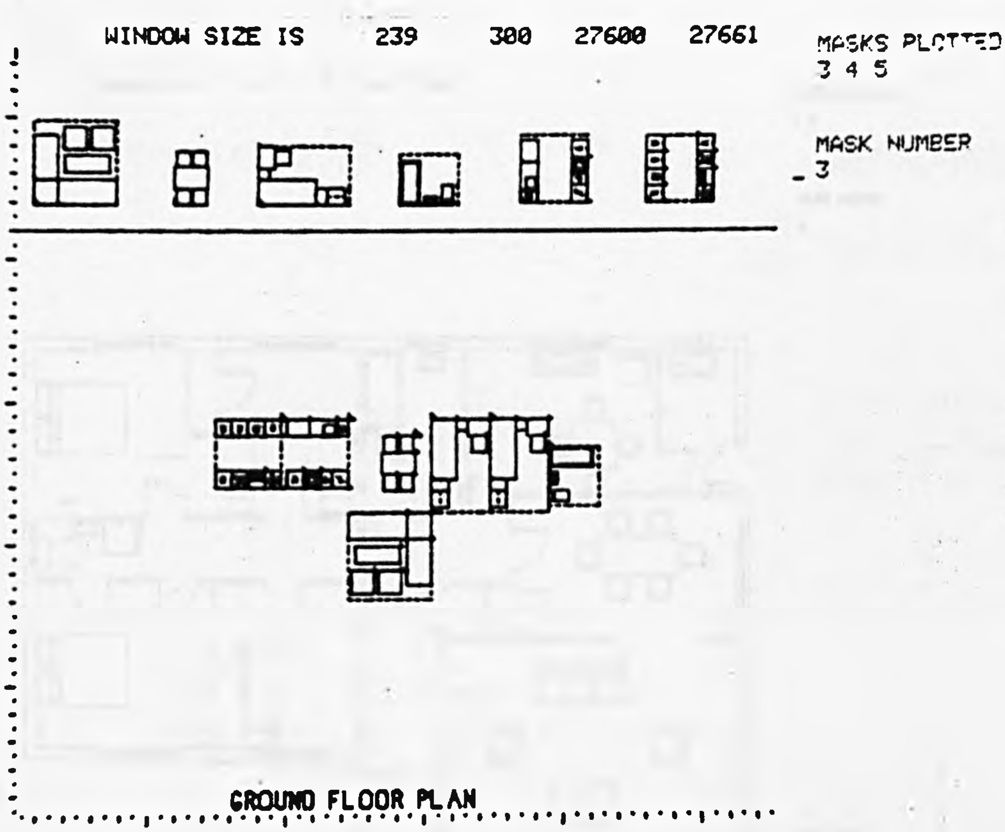
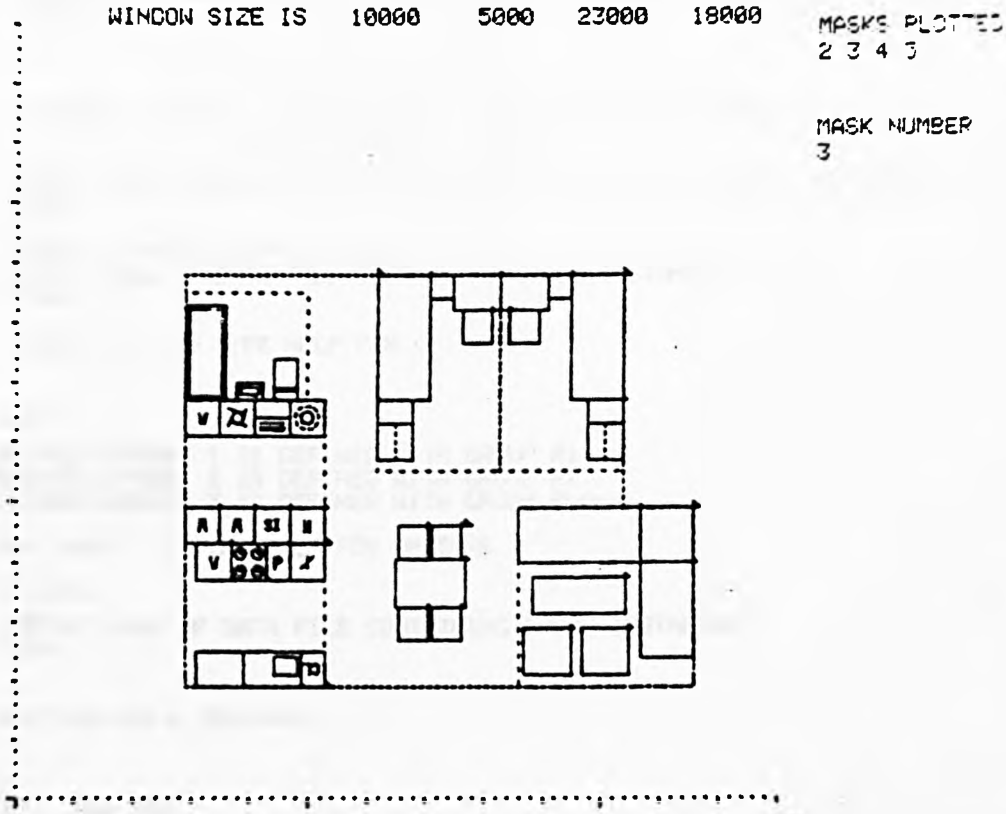
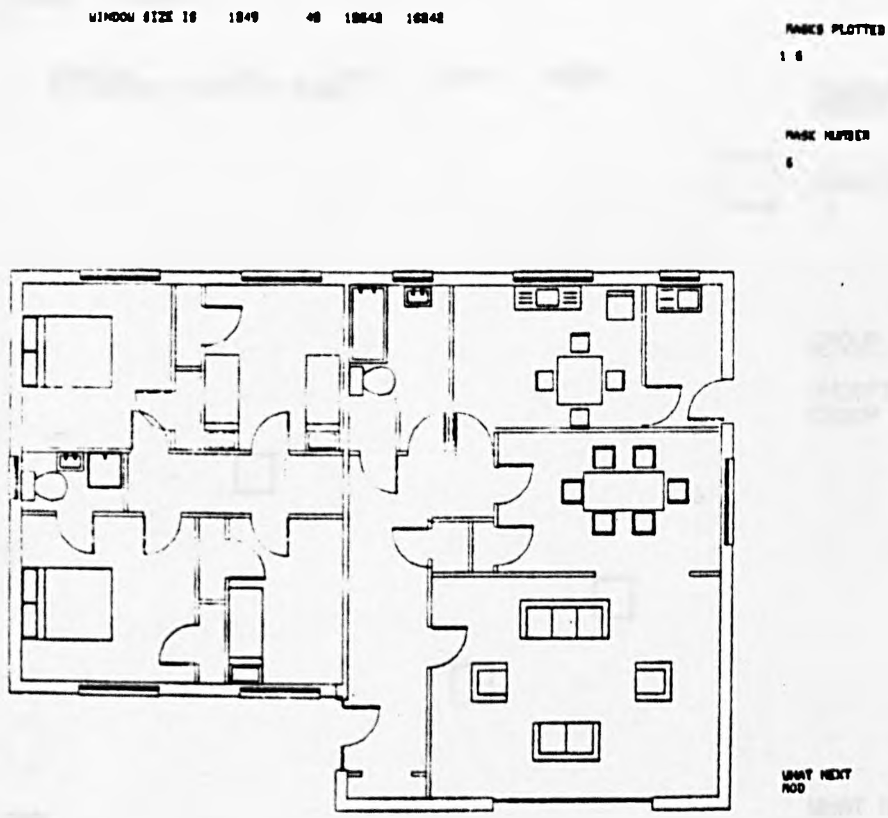


Fig. A4.1. (Continued).



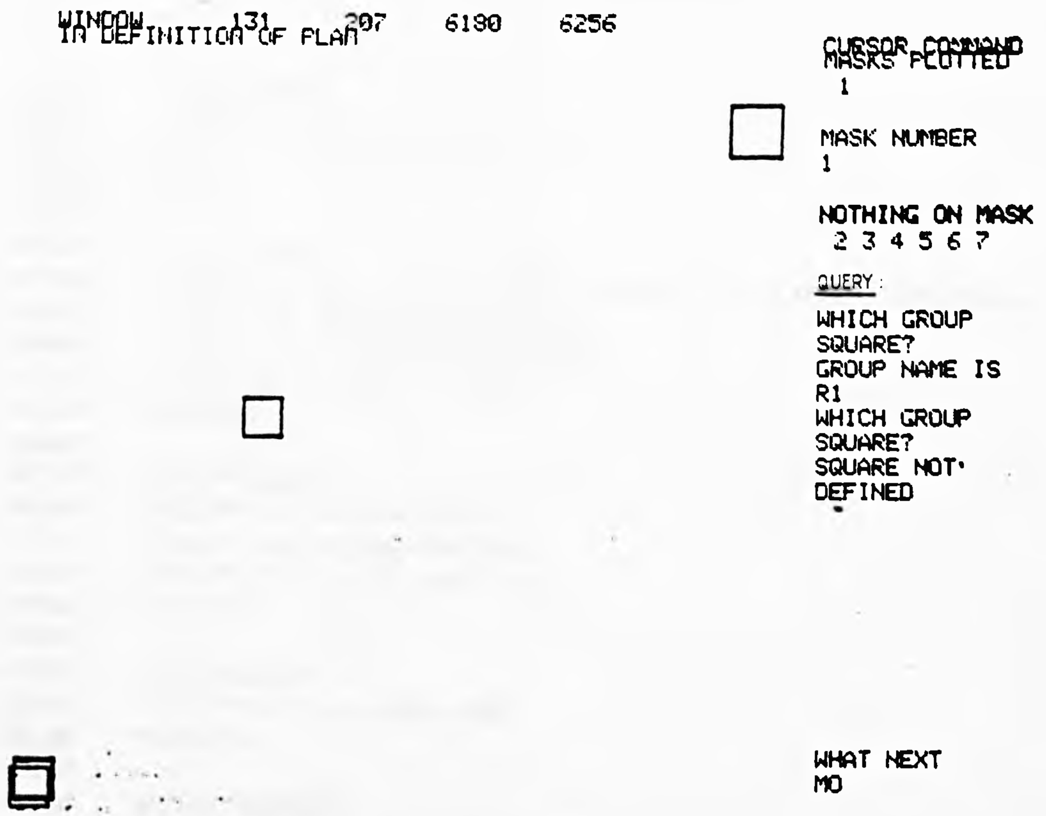


(Courtesy of Dr. J.D. Eades).

Fig. A4.1. (Continued).

```
@RUN GAEL4T

ENTER TEKTRONIX TYPE (E.G. 4010) AND TRANSMISSION RATE (CHARS/SEC)
4010 120

                           'GAEL4T'
PROGRAM TO PLOT, DRAW OR MODIFY A RING DATA STRUCTURE
               USING A GRAPHICS TABLET

ENTER NAME FOR EXISTING DATA STRUCTURE FILE OR RETURN      (AS INSERT)
TEMP

TAKING WORKING COPY OF FILE
ENTER NAME OF DATA FILE CONTAINING GROUP INSTANCES
TEMP

WHAT NEXT ? - TYPE HELP FOR OPTIONS

SHOW:

SQUARE NUMBER  1 IS DEFINED WITH GROUP R1
SQUARE NUMBER  2 IS DEFINED WITH GROUP R2
SQUARE NUMBER  3 IS DEFINED WITH GROUP PLAN

WHAT NEXT ? - TYPE HELP FOR OPTIONS
REDEFINE:

ENTER NAME OF DATA FILE CONTAINING GROUP INSTANCES
TEMP

WAITING FOR A <RETURN>...


@TY TEMP.DAT
00100   R1
00200   R2
00300   PLAN
@

   WINDOW      131      207     6180     6256
   IN DEFINITION OF PLAN
                                                       CURSOR COMMAND
                                                       MASKS PLOTTED
                                                        1
                                                       MASK NUMBER
                                                        1

                                                       GROUP NAME?

                                                       UNDEFINED GROUP
                                                       GROUP NAME?

                                                       WHAT NEXT
                                                       DG
```

Fig. A4.2. Typical SYNTAB Input.



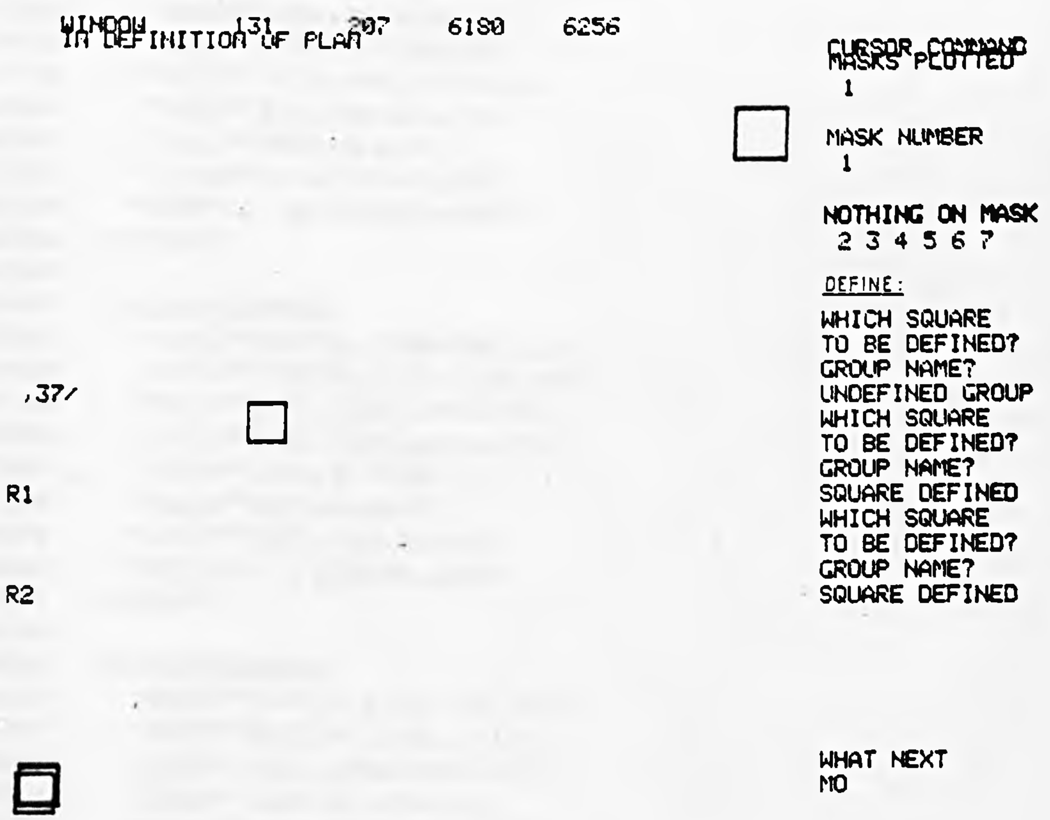


Fig. A4.2. (Continued).

A4.3. Example of GAEL 7A GAELIC Language File.

```
@TY BEDRUM.TXT

"NEWGR"SBED;
 "RECT"(1) 0,0:2100,900;
 "RECT"(2) 600,900:1500,700;
"ENDGR";

"NEWGR"DESK;
 "POLY"(1) S,0,0:1200,600,-200,400,-300,-400,-200,-600;
 "RECT"(3) 0,1000:1200,600;
 "RECT"(2) 1000,600:200,400;
 "RECT"(2) 0,600:200,400;
"ENDGR";

"NEWGR"BDSTOR;
 "RECT"(1) 0,0:600,600;
 "RECT"(2) 0,600:600,600;
 "RECT"(3) 0,1200:600,300;
"ENDGR";

"NEWGR"DOOR;
 "RECT"(2) 0,0:1000,900;
"ENDGR";

"NEWGR"BDRM01;
  "GROUP"BDSTOR,2500,1200,101;
  "GROUP"DESK,2500,2400,101;
  "GROUP"BDSTOR,2500,3000,101;
  "GROUP"DESK,2500,4200,101;
  "GROUP"SBED,0,4200,111;
  "GROUP"SBED,0,0,011;
  "GROUP"DOOR,900,0,000;
 "RECT"(6) 0,0:2500,4200;
"ENDGR";

"NEWGR"BDRM02;
  "GROUP"BDSTOR,2500,800,101;
  "GROUP"BDSTOR,2500,1400,101;
  "GROUP"DESK,2500,2600,101;
  "GROUP"DESK,2500,4200,110;
  "GROUP"SBED,0,4200,111;
  "GROUP"SBED,0,0,011;
  "GROUP"DOOR,900,0,000;
 "RECT"(6) 0,0:2500,4200;
"ENDGR";

"NEWGR"BDRM03;
  "GROUP"BDSTOR,2700,700,101;
  "GROUP"BDSTOR,0,700,111;
  "GROUP"DESK,2700,1900,101;
  "GROUP"DESK,0,1900,111;
  "GROUP"SBED,2700,4000,101;
  "GROUP"SBED,0,4000,111;
  "GROUP"DOOR,850,0,000;
 "RECT"(6) 0,0:2700,4000;
"ENDGR";

"FINISH";
@
```

A4.4. Typical CRUNCH Run.

```
 TOPS20 WELCOME TO RGIT'S DECSYSTEM-20, TOPS-20 MONITOR 4(3247)
@LOG ACR.LANGSKOG 5501
 JOB 8 ON TTY3 11-APR-81 11:17:57
 END OF LOGIN.CMD.42
@ACCESS SY:<CSU.MARTIN.SUB>
PASSWORD:
@RUN CRUNCH

 CRUNCH  -  NUMERICAL PROGRAM TO EVALUATE
            THE EFFICIENCY OF ACTIVITY SPACES

ENTER NAME OF LAYOUT FILE
BEDRUM

ENTER NAME OF GROUP TO BE CHECKED OR PRESS RETURN FOR WHOLE LAYOUT
BDRM11


PLEASE WAIT WHILE CALCULATIONS ARE PERFORMED :


WHICH PENALTY OPTION DO YOU WISH TO USE?
1 - W01 STANDARD LIBRARY OF WEIGHTING FACTORS
2 - PROBABILITY OF USAGE LIBRARY
3 - USER DEFINED WEIGHTING FACTORS
4 - INSPECT PENALTY LIBRARIES
TYPE 1,2,3 OR 4
1

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                    - TYPE HELP FOR OPTIONS
HELP

OPTIONS ARE :-
ALL       - PERFORMS ALL OPTIONS IN TURN
AREAS     - SYNOPTIC OUTPUT OF SINGLE ELEMENT AREAS
COMPONENT - SYNOPTIC LAYOUT EFFICIENCY COMPONENT EVALUATION
END       - END PROGRAM
FORMULA   - DISPLAY EFFICIENCY FORMULA
HELP      - PRINT THIS LIST
INFO      - TYPE OUT INFORMATION ON PROGRAM
LIST      - LIST OUT GROUP NAMES
NEW       - EVALUATE ANOTHER GROUP FROM THE LAYOUT
OVERLAP   - SYNOPTIC 1ST. LEVEL OVERLAP AREA VALUES
PARAMETER - SYNOPTIC PARAMETER VALUE OUTPUT
PENALTY   - SYNOPTIC PENALTY LIBRARIES OUTPUT
PRODUCT   - SYNOPTIC PROBABILITY PENALTY PRODUCT
RATIO     - SYNOPTIC LAYOUT EFFICIENCY COMPONENT RATIOS
SAVE      - STORE RESULTS ON FILE
VALUES    - SYNOPTIC OVERLAP PENALTY VALUES

WHICH OPTION ?
COMPONENT
```

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED
BDRM02
BDRM03

ACTIVITY SPACE	ER	OP	PP	AP
BDRM11	1.8454	2.3125	1.0011	0.7971
BDRM02	2.1850	2.5000	1.0338	0.8454
BDRM03	1.9257	2.1724	1.0194	0.8696

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS
RATIO

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM11

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	6.6600		
A01	2.8800		
PR		12.6000	
SQRT(AR)*4		12.5857	
AS/AFMO			0.5298
ANSR/AFMO			0.2673
AU(UNION)/AFMO			0.2673
AE(UNION)/AFMO			0.7971
ABR/AFMO			0.0000
AU(TOT)/AFMO			0.4702
A01/AFMO			0.2319
A02/AFMO			0.0290
AOU/AFMO			0.1739
ANO/AFMO			0.6232
2*A02/AFMO			0.0580

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS
OVERLAP

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM11

OVERLAPPING PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
	OVERLAPPING AREAS (SQ. METRES)								
SBED /BDSTOR					0.360				
SBED /BDSTOR					0.060				
SBED /SBED					0.300				
BDSTOR/SBED					0.060				
BDSTOR/SBED					0.360				
SBED /BDSTOR						0.180			
SBED /BDSTOR						0.030			
SBED /BDSTOR						0.030			
SBED /BDSTOR						0.130			
DOOR /DESK						0.540			
DOOR /DESK						0.540			
DESK /DESK									0.240
TOTALS	0.000	0.000	0.000	0.000	1.140	1.500	0.000	0.000	0.240

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PARAMETER

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM11

PARAMETER	VALUE	UNITS
AR	9.9000	SQ. METRES
ABR	0.0000	"
AF	9.9000	"
A01	2.8800	"
A02	0.3600	"
AOU	2.1600	"
A03	2.5200	"
AS	6.5800	"
AU(TOT)	5.3400	"
AFMO	12.4200	"
AU(UNION)	3.3200	"
AE(UNION)	9.9000	"
ANSR	3.3200	"
ANSF	3.3200	"
ANO	7.7400	"
PR	12.6000	METRES
PF	12.6000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PENALTY

OVERLAP PENALTIES

STANDARD WEIGHTING FACTORS

DISTANCE	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
FACTOR	5.0	4.0	3.0	4.0	3.0	2.0	3.0	2.0	1.0

USER DEFINED WEIGHTING FACTORS

DISTANCE	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
FACTOR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PROBABILITY OF USAGE LIBRARY

	P(S)	P(U1)ONLY	P(U2)ONLY	P(U1)	P(U2)
BDSTOR	1.00	.45	.15	.60	.15
SBED	1.00	.45	.15	.60	.15
DESK	1.00	.45	.15	.60	.15
DOOROL	1.00	.45	.15	.60	.15
WARDRB	1.00	.45	.15	.60	.15

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PRODUCT

OUTPUT OF PROBABILITY PENALTY PRODUCTS FOR ACTIVITY SPACE BDRM11

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
SBED /BDSTOR					0.360				
SBED /BDSTOR					0.360				
SBED /SBED					0.360				
BDSTOR/SBED					0.360				
BDSTOR/SBED					0.360				
SBED /BDSTOR						0.090			
SBED /BDSTOR						0.090			
SBED /BDSTOR						0.090			
SBED /BDSTOR						0.090			
DOOR /DESK						0.090			
DOOR /DESK						0.090			
DESK /DESK									0.023
TOTALS	0.000	0.000	0.000	0.000	1.300	0.540	0.000	0.000	0.023

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VALUES

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM11

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
SBED /BDSTOR					1.080				
SBED /BDSTOR					0.180				
SBED /SBED					0.900				
BDSTOR/SBED					0.180				
BDSTOR/SBED					1.030				
SBED /BDSTOR						0.360			
SBED /BDSTOR						0.060			
SBED /BDSTOR						0.060			
SBED /BDSTOR						0.360			
DOOR /DESK						1.080			
DOOR /DESK						1.080			
DESK /DESK									0.240
TOTALS	0.000	0.000	0.000	0.000	3.420	3.000	0.000	0.000	0.240

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

AREAS

OUTPUT OF SINGLE ELEMENT AREAS

ELEMENT	NO. IN LAYOUT	AREA (SQ. METRES) AE	AS	AU1	AU2	AU=U1+U2
DESK	2	1.9200	1.0400	0.1600	0.7200	0.8800
SBED	2	2.9400	1.8900	1.0500	0.0000	1.0500
BDSTOR	2	0.9000	0.3600	0.3600	0.1800	0.5400
DOOR	1	0.9000	0.0000	0.9000	0.0000	0.9000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

FORMULA

```
OUTPUT OF EFFICIENCY FORMULA

ER = OP X PP X AP

=>

I

( EA01 X (PIPJ OR W01) )    (     PR    )
< -------------------- > X < ------- > X
(         A01          )    ( /AR X 4 )

                               (  AS     AU(TOT)    A01     A02     ABR )
                               < ---- + ------- - ---- + ---- + ---- >
                               ( AFMO     AFMO     AFMO    AFMO    AFMO )


II

( EA01 X (PIPJ OR W01) )    (     PR    )
< -------------------- > X < ------- > X
(         A01          )    ( /AR X 4 )

                                ( A01    2A02    ANO    ABR  )
                                < ---- - ---- + ---- + ---- >
                                ( AFMO   AFMO   AFMO   AFMO )

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                      - TYPE HELP FOR OPTIONS
INFO

MORE INFORMATION ON THE PROGRAM WILL BE AVAILABLE LATER.


WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                      - TYPE HELP FOR OPTIONS
SAVE

ENTER NAME OF FILE TO STORE RESULTS
EDRM11

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                      - TYPE HELP FOR OPTIONS
LIST
```

```
GROUP DEFINITIONS PRESENT ARE:
SBED
DESK
BDSTOR
DOOR
BDRM11
MENU
BDRM01
BDRM02
BDRM03
BDRM04
BDRM05
BDRM06
BDRM07
BDRM08
BDRM09
BDRM10
BDRM12
BDRM13
BDRM14
BDRM15
BDRM16
BDRM17
BDRM18
BDRM19
BDRM20
BDRM21

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                    - TYPE HELP FOR OPTIONS
NEW

ENTER NAME OF GROUP TO BE CHECKED OR PRESS RETURN FOR WHOLE LAYOUT
BDRM01


PLEASE WAIT WHILE CALCULATIONS ARE PERFORMED :


WHICH PENALTY OPTION DO YOU WISH TO USE?
1 - W01 STANDARD LIBRARY OF WEIGHTING FACTORS
2 - PROBABILITY OF USAGE LIBRARY
3 - USER DEFINED WEIGHTING FACTORS
4 - INSPECT PENALTY LIBRARIES
TYPE 1,2,3 OR 4
2

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                    - TYPE HELP FOR OPTIONS
NEW

ENTER NAME OF GROUP TO BE CHECKED OR PRESS RETURN FOR WHOLE LAYOUT
BDRM02


PLEASE WAIT WHILE CALCULATIONS ARE PERFORMED :
```

```
WHICH PENALTY OPTION DO YOU WISH TO USE?
1 - WØ1 STANDARD LIBRARY OF WEIGHTING FACTORS
2 - PROBABILITY OF USAGE LIBRARY
3 - USER DEFINED WEIGHTING FACTORS
4 - INSPECT PENALTY LIBRARIES
TYPE 1,2,3 OR 4
4

OVERLAP PENALTIES

          STANDARD WEIGHTING FACTORS

INSTANCE   1:1   1:2   1:3   2:1   2:2   2:3   3:1   3:2   3:3

 FACTOR    5.Ø   4.Ø   3.Ø   4.Ø   3.Ø   2.Ø   3.Ø   2.Ø   1.Ø


          USER DEFINED WEIGHTING FACTORS

INSTANCE   1:1   1:2   1:3   2:1   2:2   2:3   3:1   3:2   3:3

 FACTOR   1Ø.Ø   9.Ø   8.Ø   9.Ø   8.Ø   7.Ø   8.Ø   7.Ø   3.Ø


          PROBABILITY OF USAGE LIBRARY
           P(S)  P(U1)ONLY P(U2)ONLY     P(U1)      P(U2)

BDSTOR     1.ØØ        .45       .15       .6Ø        .15
SBED       1.ØØ        .45       .15       .6Ø        .15
DESK       1.ØØ        .45       .15       .6Ø        .15
DOOROL     1.ØØ        .45       .15       .6Ø        .15
WARDRB     1.ØØ        .45       .15       .6Ø        .15

WHICH PENALTY OPTION DO YOU WISH TO USE?
1 - WØ1 STANDARD LIBRARY OF WEIGHTING FACTORS
2 - PROBABILITY OF USAGE LIBRARY
3 - USER DEFINED WEIGHTING FACTORS
4 - INSPECT PENALTY LIBRARIES
TYPE 1,2,3 OR 4
3
```

```
TYPE IN THE NEW WEIGHTING FACTORS YOU WISH TO USE
THE STANDARD VALUES ARE GIVEN IN BRACKETS

1:1 ( 5.Ø) :- 1Ø

1:2 ( 4.Ø) :- 9

1:3 ( 3.Ø) :- 8

2:1 ( 4.Ø) :- 9

2:2 ( 3.Ø) :- 8

2:3 ( 2.Ø) :- 7

3:1 ( 3.Ø) :- 8

3:2 ( 2.Ø) :- 7

3:3 ( 1.Ø) :- 3

DO YOU WISH TO CHANGE ANY OF THE NEW VALUES?
NO

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                    - TYPE HELP FOR OPTIONS
COMPONENT

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES


ENTER NAMES OF RESULTS FILES TO BE INCLUDED


 ACTIVITY
  SPACE           ER        OP        PP        AP

BDRMØ2          5.4999    6.2927    1.Ø338    Ø.8454
BDRMØ2          2.185Ø    2.5ØØØ    1.Ø338    Ø.8454

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                    - TYPE HELP FOR OPTIONS
END

END OF EXECUTION
CPU TIME: 1:23.ØØ        ELAPSED TIME: 1:19:23.Ø4
EXIT
@
@
@NOTE: OPTION OUTPUT ABOVE IS DONE IN ORDER OF THE ALL OPTION OUTPUT.
```

APPENDIX 5: PROGRAM PERFORMANCE DATA

A5.1.	SYNCRO Output	A5.2
A5.1.1.	Single Element Library for the 21 Bedrooms	A5.2
A5.1.2.	Room Layouts for the 21 Bedrooms	A5.3
A5.2.	CRUNCH Evaluation Output for the 21 Bedrooms	A5.9
A5.2.1.	Common Data for the 21 Bedrooms	A5.9
A5.2.2.	Numerical Output for the 21 Bedrooms	A5.13

PROGRAM PERFORMANCE DATA.

A5.1. SYNCRO Output.

A5.1.1. Single Element Library for the 21 Bedrooms.

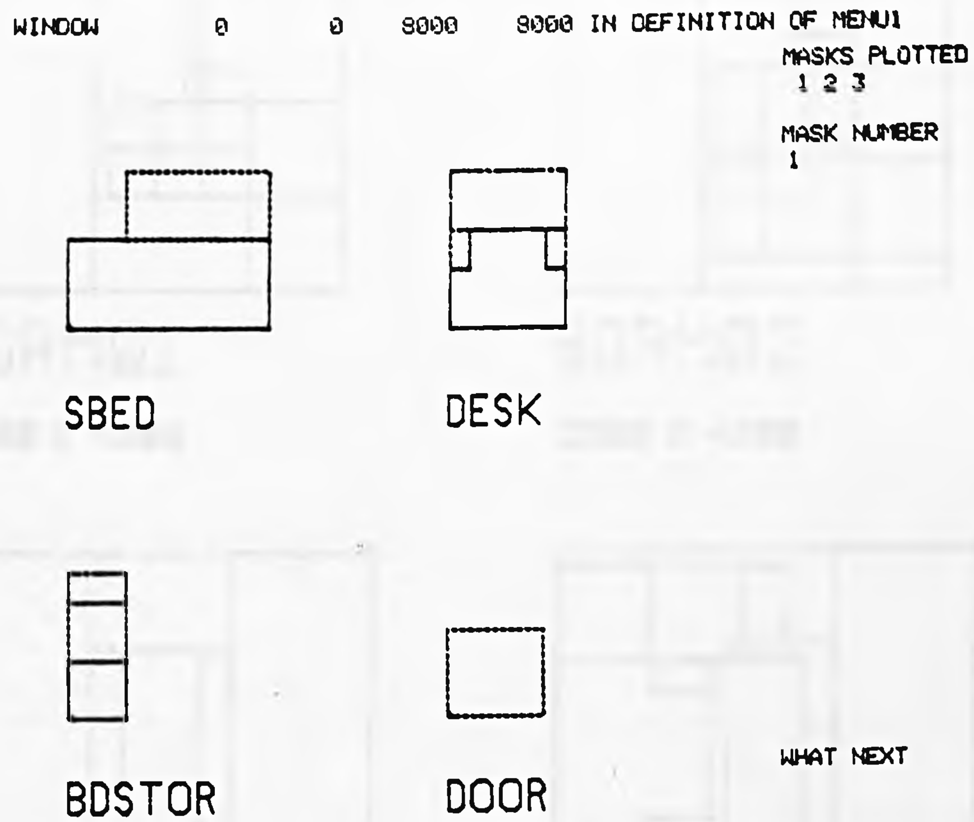
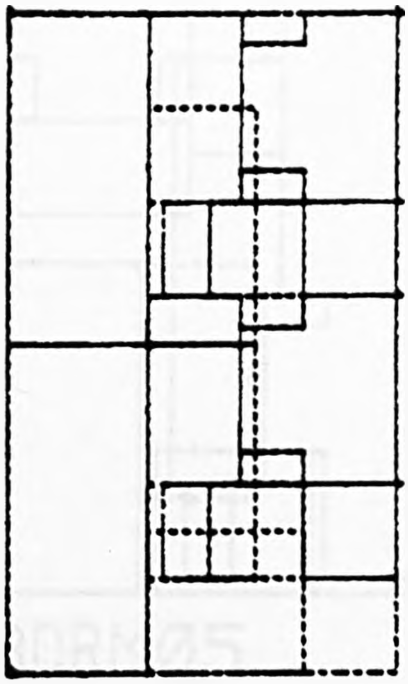


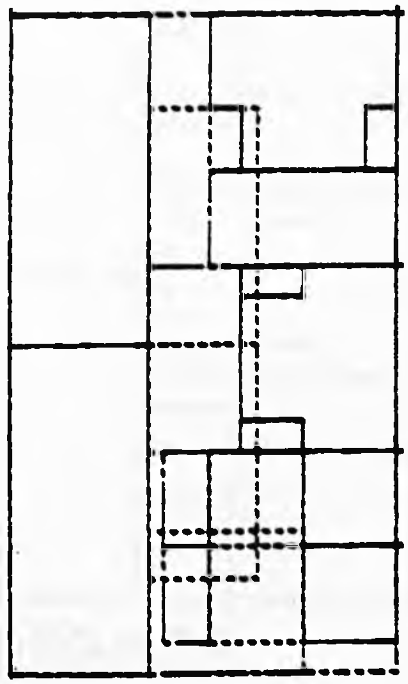
Fig. A5.1. Single Element Library for the 21 Bedrooms.

A5.1.2. Room Layouts for the 21 Bedrooms.



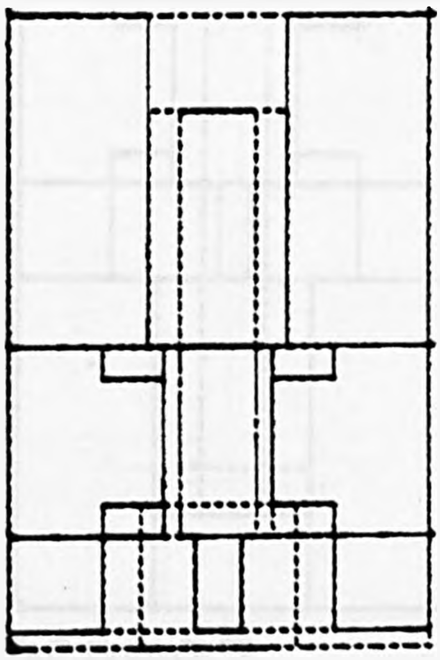
BDRMØ1

2500 X 4200



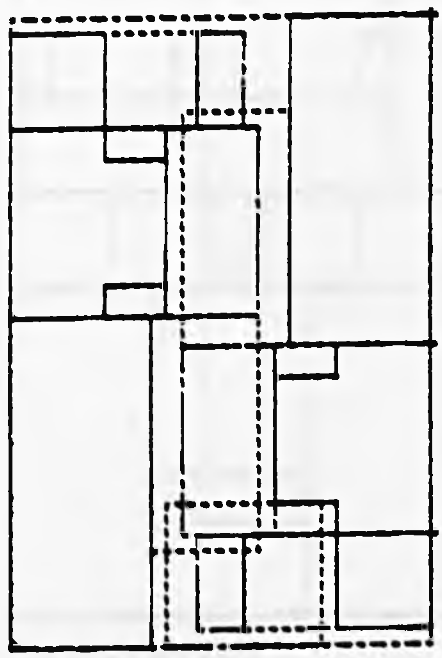
BDRMØ2

2500 X 4200



BDRMØ3

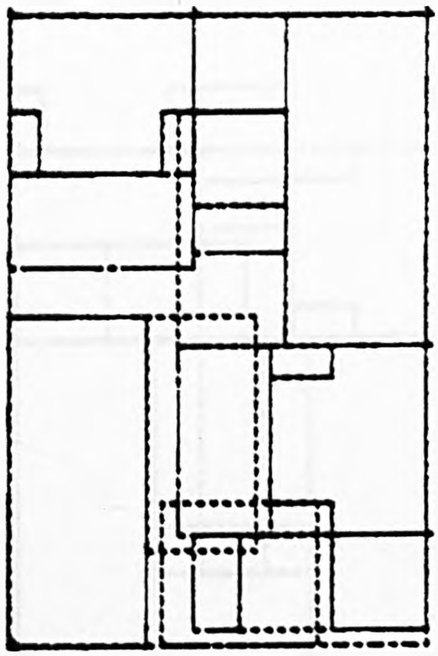
2700 X 4000



BDRMØ4

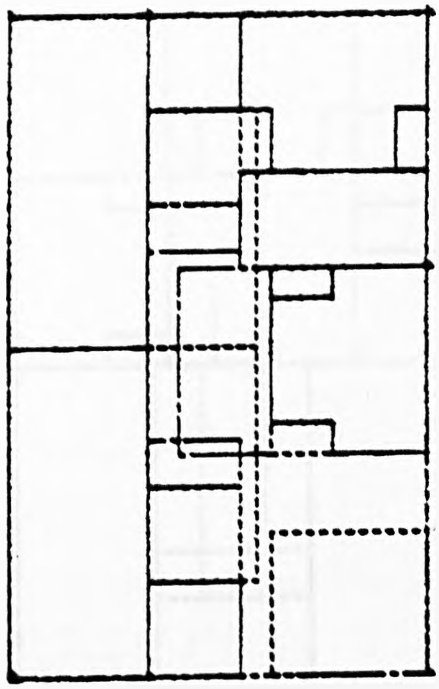
2700 X 4000

Fig. A5.2. Room Layout Output for the 21 Bedrooms.



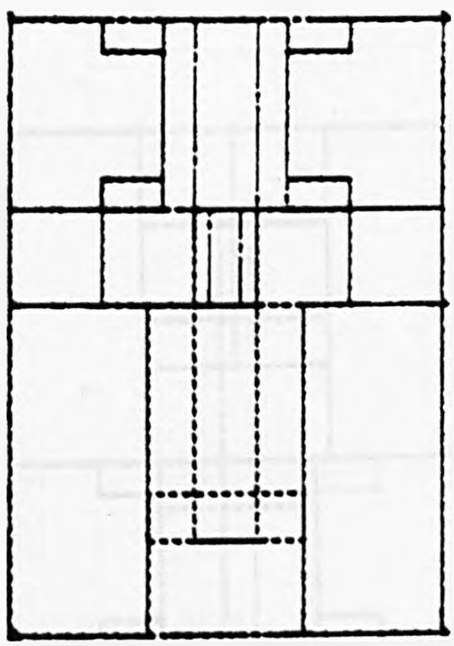
BDRMØ5

2700 X 4000



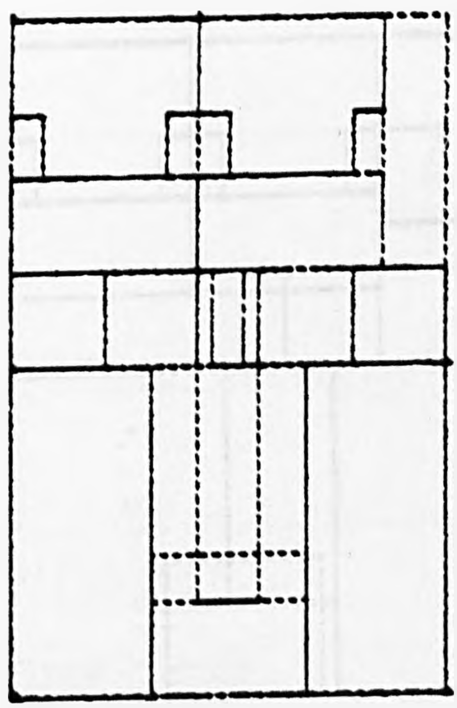
BDRMØ6

2700 X 4200



BDRMØ7

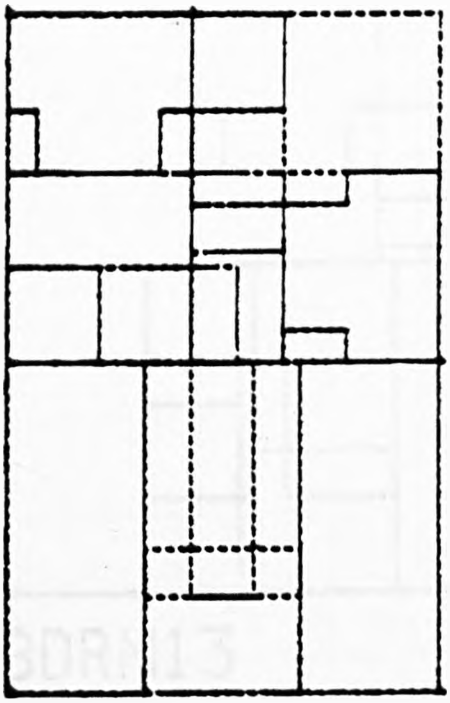
2800 X 3900



BDRMØ8

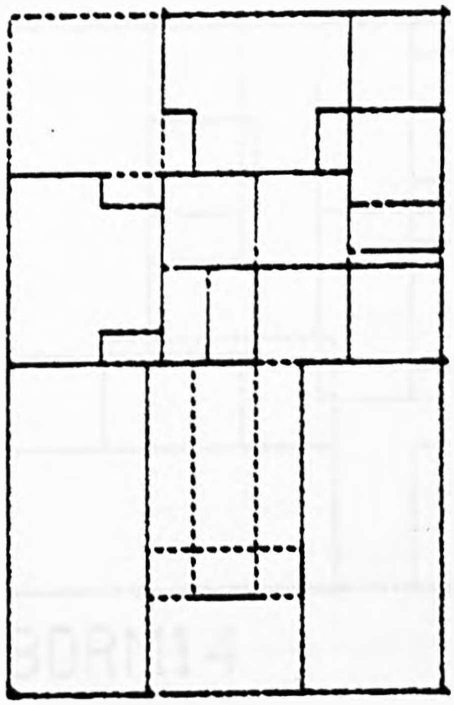
2800 X 4300

Fig. A5.2. (Continued).



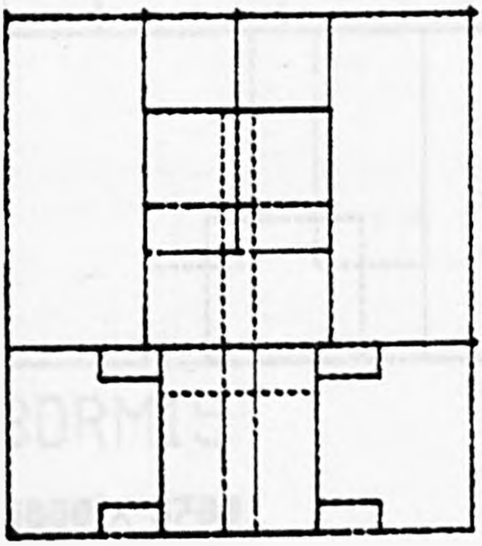
BDRMØ9

2800 X 4300



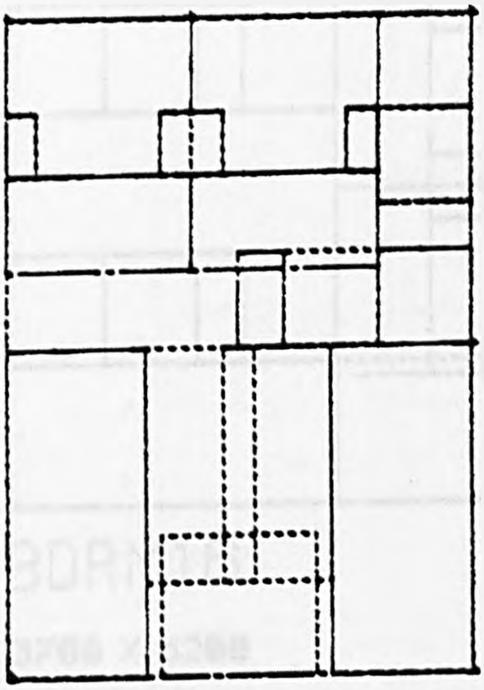
BDRM1Ø

2800 X 4300



BDRM11

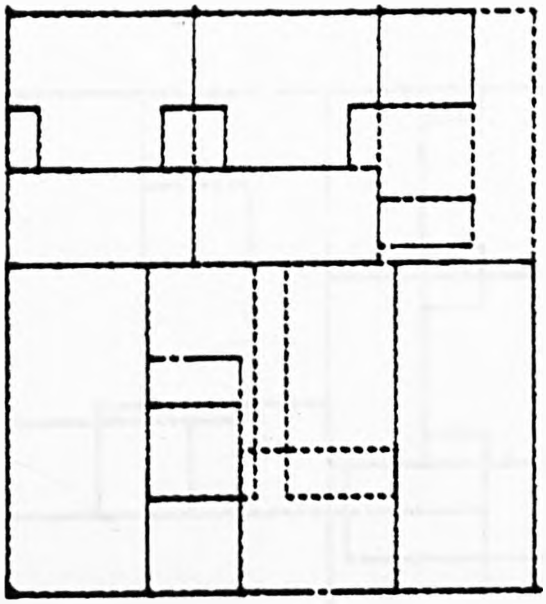
3000 X 3300



BDRM12

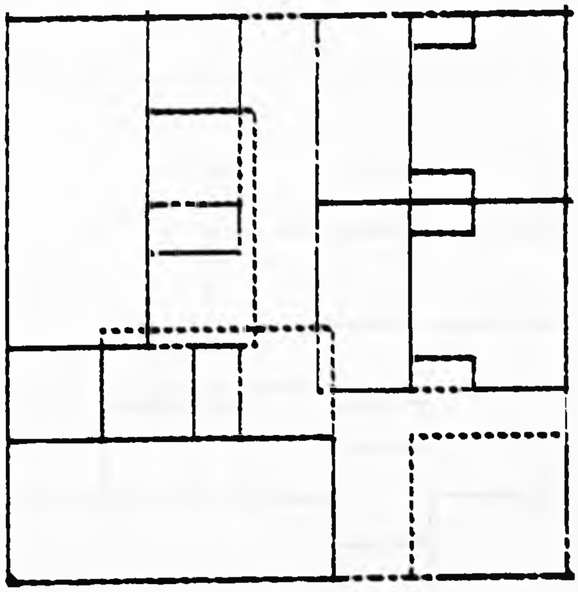
3000 X 4200

Fig. A5.2. (Continued).



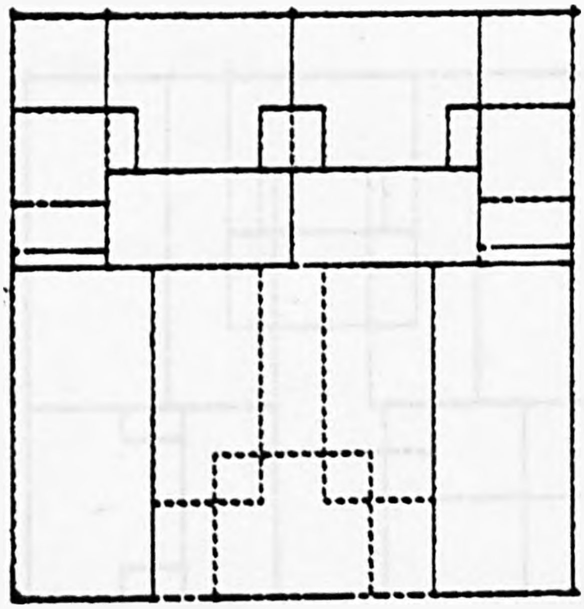
BDRM13

3400 X 3700



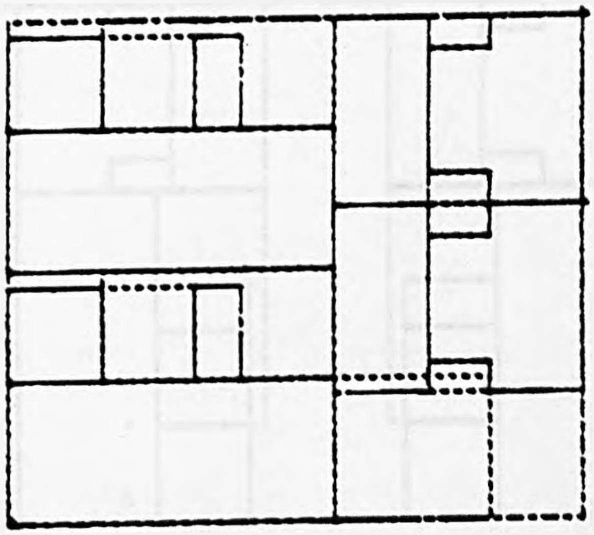
BDRM14

3800 X 3800



BDRM15

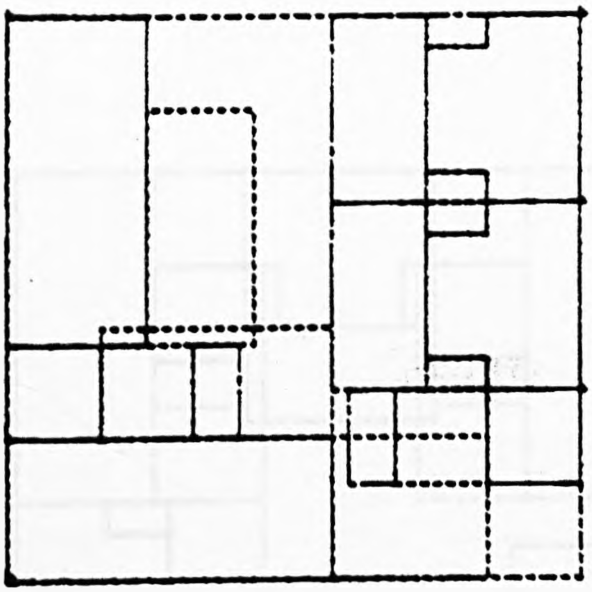
3800 X 3700



BDRM16

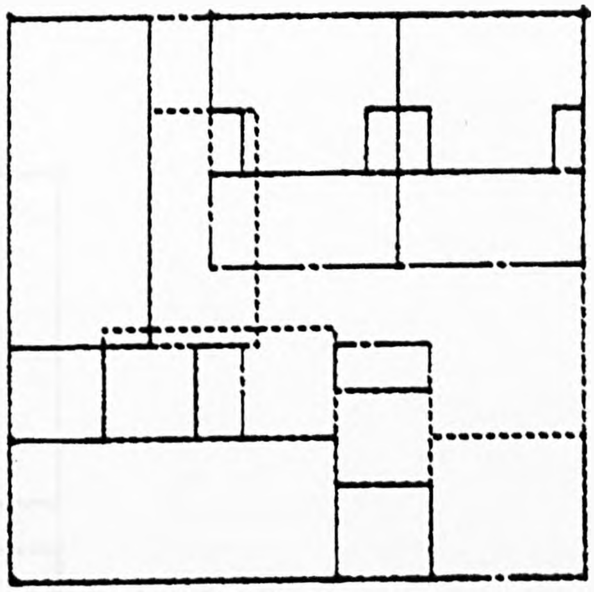
3700 X 3200

Fig. A5.2. (Continued).



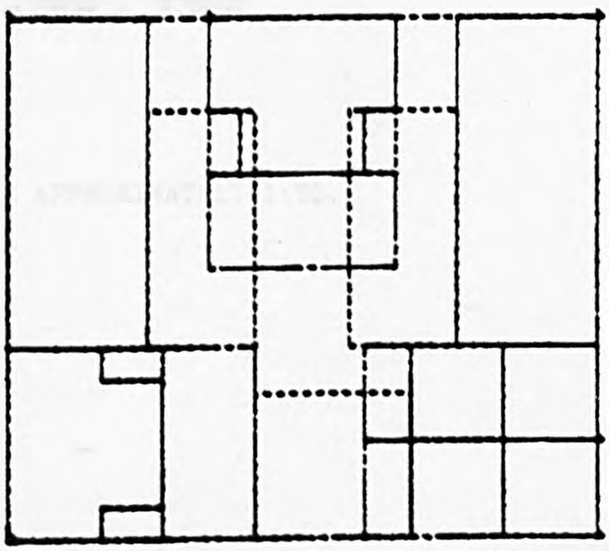
BDRM17

3700 X 3800



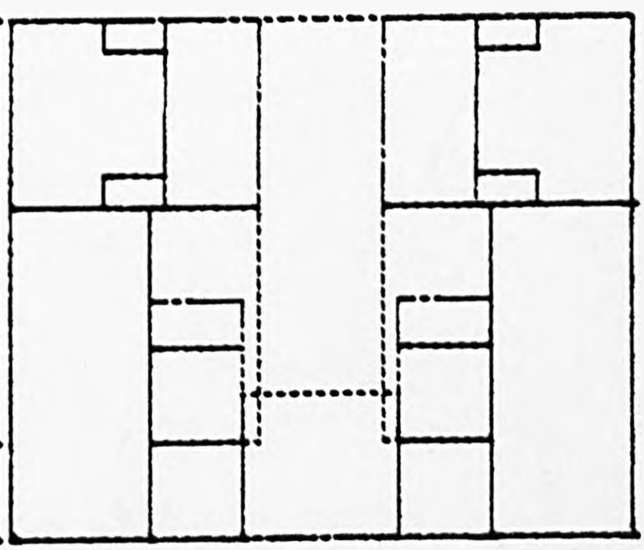
BDRM18

3700 X 3800



BDRM19

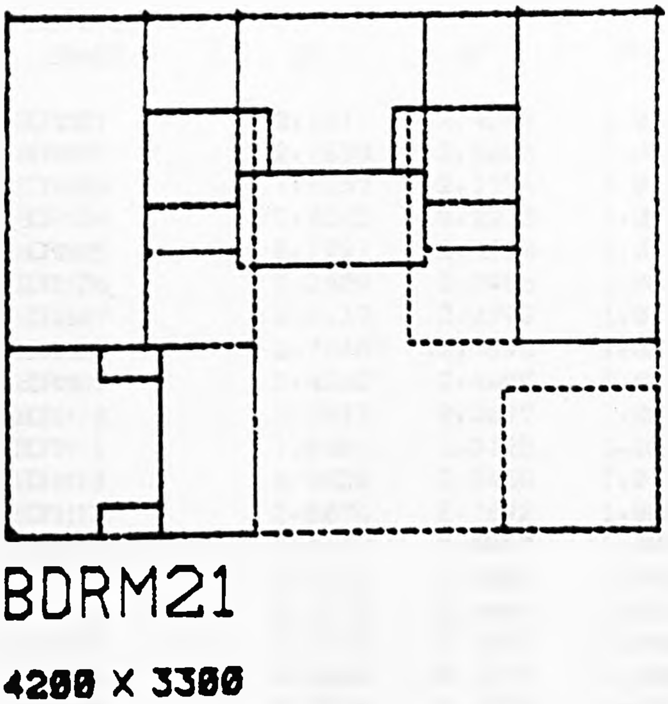
3800 X 3300



BDRM2Ø

4000 X 3300

Fig. A5.2. (Continued).



SCALE APPROXIMATELY 1:50.

Fig. A5.2. (Continued).

A5.2. CRUNCH Evaluation Output for the 21 Bedrooms.

A5.2.1. Common Data for the 21 Bedrooms.

COMPONENT

ACTIVITY SPACE	ER	OP	PP	AP
BDRM01	2.1211	2.4268	1.0338	0.8454
BDRM02	2.1850	2.5000	1.0338	0.8454
BDRM03	1.9257	2.1724	1.0194	0.8696
BDRM04	2.0363	2.2973	1.0194	0.8696
BDRM05	2.1921	2.4730	1.0194	0.3696
BDRM06	2.2409	2.3956	1.0245	0.9130
BDRM07	2.0137	2.2593	1.0138	0.8792
BDRM08	2.7666	2.7895	1.0231	0.9694
BDRM09	2.4200	2.4400	1.0231	0.9694
BDRM10	2.2837	2.3077	1.0231	0.9694
BDRM11	1.8454	2.3125	1.0011	0.7971
BDRM12	2.9220	2.8400	1.0142	1.0145
BDRM13	2.8074	2.7692	1.0009	1.0129
BDRM14	2.8140	2.6967	1.0000	1.0435
BDRM15	3.2177	3.0000	1.0001	1.0725
BDRM16	2.5272	2.6441	1.0026	0.9533
BDRM17	2.9348	2.7363	1.0001	1.0725
BDRM18	2.8868	2.6915	1.0001	1.0725
BDRM19	2.3966	2.3678	1.0025	1.0097
BDRM20	2.8660	2.6842	1.0046	1.0628
BDRM21	2.9507	2.6250	1.0073	0.0157

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

AR

OUTPUT OF SINGLE ELEMENT AREAS

ELEMENT	NO. IN LAYOUT	AREA (SQ. METRES) AE	AS	AU1	AU2	AU=U1+U2
DESK	2	1.9200	1.0400	0.1600	0.7200	0.8800
SBED	2	2.9400	1.8900	1.0500	0.0000	1.0500
BDSTOR	2	0.9000	0.3600	0.3600	0.1800	0.5400
DOOR	1	0.9000	0.0000	0.9000	0.0000	0.9000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PE

OVERLAP PENALTIES

STANDARD WEIGHTING FACTORS

INSTANCE	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
FACTOR	5.0	4.0	3.0	4.0	3.0	2.0	3.0	2.0	1.0

USER DEFINED WEIGHTING FACTORS

INSTANCE	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
FACTOR	10.0	9.0	8.0	9.0	8.0	7.0	8.0	7.0	3.0

PROBABILITY OF USAGE LIBRARY

	P(S)	P(U1)ONLY	P(U2)ONLY	P(U1)	P(U2)
BDSTOR	1.00	.45	.15	.60	.15
SBED	1.00	.45	.15	.60	.15
DESK	1.00	.45	.15	.60	.15
DOOROL	1.00	.45	.15	.60	.15
WARDRB	1.00	.45	.15	.60	.15

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

```
@TY PROBL.DAT
BDSTOR Ø.45 Ø.15
SBED   Ø.45 Ø.15
DESK   Ø.45 Ø.15
DOOROL Ø.45 Ø.15
WARDRB Ø.45 Ø.15
@
```

```
@TY NUMINF.TXT
MORE INFORMATION ON THE PROGRAM WILL BE AVAILABLE LATER.


@
```

```
@TY BDRM11.NUM
    1.3454     2.3125     1.ØØ11     Ø.7971
   99ØØ2ØØ          Ø    99ØØØØØ    238ØØØØ    653ØØØØ     36ØØØØ    584ØØØØ
 332ØØØØ
   99ØØØØØ   1242ØØØØ    332ØØØØ    332ØØØØ    774ØØØØ      126ØØ          Ø
  13    5
BDSTORBDSTORBDSTORBDSTORSBED  DOOR  DOOR  SBED  SBED  SBED  SBED  DESK
SBED  SBED  SBED  SBED  SBED  DESK  DESK  BDSTORBDSTORBDSTORBDSTORDESK
    36ØØØØ      6ØØØØ      6ØØØØ     36ØØØØ     3ØØØØØ     54ØØØØ     54ØØØØ
  18ØØØØ
     3ØØØØ      3ØØØØ     13ØØØØ     24ØØØØ
         2          2          2          2          2          2          2
       2
         2          2          2          3
         2          2          2          2          2          3          3
       3
         3          3          3          3
BDSTORDESK  SBED  DOOR
    36ØØØØ     36ØØØØ     18ØØØØ
   1Ø4ØØØØ     16ØØØØ     72ØØØØ
   189ØØØØ    1Ø5ØØØØ          Ø
         Ø     9ØØØØØ          Ø
1 Ø.Ø Ø.Ø Ø.Ø Ø.Ø Ø.Ø Ø.Ø Ø.Ø Ø.Ø Ø.Ø
@
```

```
@DIR B*

   PS:<ACR.LANGSKOG>
 BDRM00.NUM.1
 BDRM01.DAT.2
   .NUM.3
 BDRM02.DAT.2
   .NUM.1
 BDRM03.DAT.1
   .NUM.1
 BDRM04.DAT.1
   .NUM.1
 BDRM05.DAT.1
   .NUM.1
 BDRM06.DAT.1
   .NUM.1
 BDRM07.DAT.1
   .NUM.1
 BDRM08.DAT.1
   .NUM.1
 BDRM09.DAT.2
   .NUM.1
 BDRM10.DAT.2
   .NUM.1
 BDRM11.DAT.2
   .NUM.4
 BDRM12.DAT.3
 BDRM13.DAT.2
   .NUM.1
 BDRM14.DAT.2
   .NUM.1
 BDRM15.DAT.2
   .NUM.1
 BDRM16.DAT.2
   .NUM.1
 BDRM17.DAT.2
   .NUM.1
 BDRM18.DAT.2
   .NUM.1
 BDRM19.DAT.2
   .NUM.1
 BDRM20.DAT.2
   .NUM.1
 BDRM21.DAT.2
   .NUM.1
 BEDCOP.RNG.6
 BEDROM.RNG.1
 BEDRUM.RNG.8
 BSRM05.NUM.1

 TOTAL OF 46 FILES
@
```

A5.2.2. Numerical Output for the 21 Bedrooms.

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRMØ1	2.1211	2.4268	1.Ø338	Ø.8454
	Ø.ØØØØ	Ø.ØØØØ	Ø.ØØØØ	Ø.ØØØØ

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRMØ1

RATIOS	COMPONENTS OP	PP	AP
EAØ1*WØ1 OR (P1*P2)	5.97ØØ		
AØ1	2.46ØØ		
PR		13.4ØØØ	
SQRT(AR)*4		12.9615	
AS/AFMO			Ø.5298
ANSR/AFMO			Ø.3156
AU(UNION)/AFMO			Ø.2866
AE(UNION)/AFMO			Ø.8164
ABR/AFMO			Ø.Ø29Ø
AU(TOT)/AFMO			Ø.47Ø2
AØ1/AFMO			Ø.1981
AØ2/AFMO			Ø.Ø145
AOU/AFMO			Ø.1691
ANO/AFMO			Ø.6473
2*AØ2/AFMO			Ø.Ø29Ø

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRMØ1

OVERLAPPING PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
					OVERLAPPING AREAS (SQ. METRES)				
DESK /SBED		Ø.Ø1Ø							
DESK /SBED		Ø.Ø7Ø							
DESK /SBED		Ø.Ø4Ø							
DOOR /BDSTOR					Ø.18Ø				
DOOR /SBED					Ø.21Ø				
BDSTOR/SBED					Ø.18Ø				
DESK /SBED					Ø.Ø2Ø				
DESK /SBED					Ø.Ø2Ø				
BDSTOR/SBED					Ø.18Ø				
DESK /SBED					Ø.Ø2Ø				
DOOR /BDSTOR						Ø.Ø9Ø			
SBED /DESK						Ø.18Ø			
SBED /BDSTOR						Ø.18Ø			
SBED /DESK						Ø.36Ø			
SBED /BDSTOR						Ø.18Ø			
SBED /DESK						Ø.54Ø			
TOTALS	Ø.ØØØ	Ø.12Ø	Ø.ØØØ	Ø.ØØØ	Ø.81Ø	1.53Ø	Ø.ØØØ	Ø.ØØØ	Ø.ØØØ

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM01

PARAMETER	VALUE	UNITS
AR	10.5000	SQ. METRES
ABR	0.3600	"
AF	10.1400	"
A01	2.4600	"
A02	0.1800	"
AOU	2.1000	"
A03	2.2800	"
AS	6.5800	"
AU(TOT)	5.3400	"
AFMO	12.4200	"
AU(UNION)	3.5600	"
AE(UNION)	10.1400	"
ANSR	3.9200	"
ANSF.	3.5600	"
ANO	8.0400	"
PR	13.4000	METRES
PF	13.4000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM01

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DESK /SBED		0.040							
DESK /SBED		0.280							
DESK /SBED		0.160							
DOOR /BDSTOR					0.540				
DOOR /SBED					0.630				
BDSTOR/SBED					0.540				
DESK /SBED					0.060				
DESK /SBED					0.060				
BDSTOR/SBED					0.540				
DESK /SBED					0.060				
DOOR /BDSTOR						0.180			
SBED /DESK						0.360			
SBED /BDSTOR						0.360			
SBED /DESK						0.720			
SBED /BDSTOR						0.360			
SBED /DESK						1.080			
TOTALS	0.000	0.480	0.000	0.000	2.430	3.060	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM02	2.1850	2.5000	1.0338	0.8454
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM02

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	6.1500		
A01	2.4600		
PR		13.4000	
SQRT(AR)*4		12.9615	
AS/AFMO			0.5298
ANSR/AFMO			0.3156
AU(UNION)/AFMO			0.2866
AE(UNION)/AFMO			0.8164
ABR/AFMO			0.0290
AU(TOT)/AFMO			0.4702
A01/AFMO			0.1981
A02/AFMO			0.0145
AOU/AFMO			0.1691
ANO/AFMO			0.6473
2*A02/AFMO			0.0290

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM02

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DESK /SBED		0.030							
DESK /SBED		0.050							
DESK /SBED		0.040							
DOOR /BDSTOR					0.360				
DOOR /BDSTOR					0.060				
DOOR /SBED					0.210				
BDSTOR/SBED					0.060				
BDSTOR/SBED					0.180				
DESK /SBED					0.020				
DESK /SBED					0.020				
DESK /SBED					0.030				
DOOR /BDSTOR						0.180			
DOOR /BDSTOR						0.030			
SBED /DESK						0.300			
SBED /DESK						0.130			
SBED /BDSTOR						0.060			
SBED /BDSTOR						0.180			
SBED /DESK						0.420			
TOTALS	0.000	0.120	0.000	0.000	0.990	1.350	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM02

PARAMETER	VALUE	UNITS
AR	10.5000	SQ. METRES
ABR	0.3600	"
AF	10.1400	"
A01	2.4600	"
A02	0.1800	"
AOU	2.1000	"
A03	2.2800	"
AS	6.5300	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	3.5600	"
AE(UNION)	10.1400	"
ANSR	3.9200	"
ANSF	3.5600	"
ANO	8.0400	"
PR	13.4000	METRES
PF	13.4000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM02

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DESK /SBED		0.120							
DESK /SBED		0.200							
DESK /SBED		0.160							
DOOR /BDSTOR					1.030				
DOOR /BDSTOR					0.180				
DOOR /SBED					0.630				
BDSTOR/SBED					0.180				
BDSTOR/SBED					0.540				
DESK /SBED					0.060				
DESK /SBED					0.060				
DESK /SBED					0.240				
DOOR /BDSTOR						0.360			
DOOR /BDSTOR						0.060			
SBED /DESK						0.600			
SBED /DESK						0.360			
SBED /BDSTOR						0.120			
SBED /BDSTOR						0.360			
SBED /DESK						0.840			
TOTALS	0.000	0.480	0.000	0.000	2.970	2.700	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM03	1.9257	2.1724	1.0194	0.8696
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM03

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	5.6700		
A01	2.6100		
PR		13.4000	
SQRT(AR)*4		13.1453	
AS/AFMO			0.5298
ANSR/AFMO			0.3398
AU(UNION)/AFMO			0.2826
AE(UNION)/AFMO			0.8124
ABR/AFMO			0.0572
AU(TOT)/AFMO			0.4702
A01/AFMO			0.2101
A02/AFMO			0.0225
AOU/AFMO			0.1651
ANO/AFMO			0.6473
2*A02/AFMO			0.0451

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM03

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /BDSTOR					0.210				
DOOR /BDSTOR					0.210				
DOOR /DESK					0.030				
DOOR /DESK					0.030				
SBED /SBED					0.750				
DOOR /BDSTOR						0.180			
DOOR /BDSTOR						0.180			
DOOR /DESK						0.120			
DOOR /DESK						0.120			
BDSTOR/BDSTOR									0.180
DESK /DESK									0.600
TOTALS	0.000	0.000	0.000	0.000	1.230	0.600	0.000	0.000	0.780

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM03

PARAMETER	VALUE	UNITS
AR	10.8000	SQ. METRES
ABR	0.7100	"
AF	10.0900	"
A01	2.6100	"
A02	0.2800	"
AOU	2.0500	"
A03	2.3300	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	3.5100	"
AE(UNION)	10.0900	"
ANSR	4.2200	"
ANSF	3.5100	"
ANO	8.0400	"
PR	13.4000	METRES
PF	13.4000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

UA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM03

OVERLAPPING				PENALTIES					
PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /BDSTOR					0.630				
DOOR /BDSTOR					0.630				
DOOR /DESK					0.090				
DOOR /DESK					0.090				
SBED /SBED					2.250				
DOOR /BDSTOR						0.360			
DOOR /BDSTOR						0.360			
DOOR /DESK						0.240			
DOOR /DESK						0.240			
BDSTOR/BDSTOR									0.130
DESK /DESK									0.600
TOTALS	0.000	0.000	0.000	0.000	3.690	1.200	0.000	0.000	0.730

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM04	2.0363	2.2973	1.0194	0.8696
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM04

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	5.1000		
A01	2.2200		
PR		13.4000	
SQRT(AR)*4		13.1453	
AS/AFMO			0.5298
ANSR/AFMO			0.3398
AU(UNION)/AFMO			0.3027
AE(UNION)/AFMO			0.8325
ABR/AFMO			0.0370
AU(TOT)/AFMO			0.4702
A01/AFMO			0.1787
A02/AFMO			0.0113
AOU/AFMO			0.1562
ANO/AFMO			0.6763
2*A02/AFMO			0.0225

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM04

OVERLAPPING PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
				OVERLAPPING AREAS (SQ. METRES)					
DOOR /BDSTOR					0.300				
DOOR /DESK					0.060				
DOOR /SBED					0.180				
BDSTOR/SBED					0.010				
BDSTOR/SBED					0.010				
SBED /SBED					0.100				
DOOR /BDSTOR						0.180			
DOOR /DESK						0.120			
SBED /BDSTOR						0.030			
SBED /DESK						0.600			
SBED /BDSTOR						0.030			
SBED /DESK						0.600			
TOTALS	0.000	0.000	0.000	0.000	0.660	1.560	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM04

PARAMETER	VALUE	UNITS
AR	10.8000	SQ. METRES
ABR	0.4600	"
AF	10.3400	"
A01	2.2200	"
A02	0.1400	"
AOU	1.9400	"
A03	2.0800	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	3.7600	"
AE(UNION)	10.3400	"
ANSR	4.2200	"
ANSF	3.7600	"
ANO	8.4000	"
PR	13.4000	METRES
PF	13.4000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM04

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /BDSTOR					0.900				
DOOR /DESK					0.180				
DOOR /SBED					0.540				
BDSTOR/SBED					0.030				
BDSTOR/SBED					0.030				
SBED /SBED					0.300				
DOOR /BDSTOR						0.360			
DOOR /DESK						0.240			
SBED /BDSTOR						0.060			
SBED /DESK						1.200			
SBED /BDSTOR						0.060			
SBED /DESK						1.200			
TOTALS	0.000	0.000	0.000	0.000	1.930	3.120	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM05	2.1921	2.4730	1.0194	0.8696
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM05

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	5.4900		
A01	2.2200		
PR		13.4000	
SQRT(AR)*4		13.1453	
AS/AFMO			0.5298
ANSR/AFMO			0.3398
AU(UNION)/AFMO			0.3027
AE(UNION)/AFMO			0.8325
ABR/AFMO			0.0370
AU(TOT)/AFMO			0.4702
A01/AFMO			0.1787
A02/AFMO			0.0113
AOU/AFMO			0.1562
ANO/AFMO			0.6763
2*A02/AFMO			0.0225

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM05

OVERLAPPING PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /BDSTOR					0.300				
DOOR /DESK					0.060				
DOOR /SBED					0.180				
BDSTOR/SBED					0.010				
BDSTOR/SBED					0.360				
DESK /SBED					0.040				
SBED /SBED					0.100				
DOOR /BDSTOR						0.180			
DOOR /DESK						0.120			
SBED /BDSTOR						0.180			
SBED /DESK						0.060			
SBED /BDSTOR						0.030			
SBED /DESK						0.600			
TOTALS	0.000	0.000	0.000	0.000	1.050	1.170	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM05

PARAMETER	VALUE	UNITS
AR	10.8000	SQ. METRES
ABR	0.4600	"
AF	10.3400	"
A01	2.2200	"
A02	0.1400	"
AOU	1.9400	"
A03	2.0800	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	3.7600	"
AE(UNION)	10.3400	"
ANSR	4.2200	"
ANSF	3.7600	"
ANO	8.4000	"
PR	13.4000	METRES
PF	13.4000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM05

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /BDSTOR					0.900				
DOOR /DESK					0.180				
DOOR /SBED					0.540				
BDSTOR/SBED					0.030				
BDSTOR/SBED					1.080				
DESK /SBED					0.120				
SBED /SBED					0.300				
DOOR /BDSTOR						0.360			
DOOR /DESK						0.240			
SBED /BDSTOR						0.360			
SBED /DESK						0.120			
SBED /BDSTOR						0.060			
SBED /DESK						1.200			
TOTALS	0.000	0.000	0.000	0.000	3.150	2.340	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM06	2.2409	2.3956	1.0245	0.9130
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM06

RATIOS	COMPONENTS		
	OP	PP	AP
EA01*W01 OR (P1*P2)	4.3600		
A01	1.8200		
PR		13.8000	
SQRT(AR)*4		13.4700	
AS/AFMO			0.5298
ANSR/AFMO			0.3833
AU(UNION)/AFMO			0.3269
AE(UNION)/AFMO			0.8567
ABR/AFMO			0.0564
AU(TOT)/AFMO			0.4702
A01/AFMO			0.1465
A02/AFMO			0.0032
AOU/AFMO			0.1401
ANO/AFMO			0.7166
2*A02/AFMO			0.0064

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM06

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES)								
	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
BDSTOR/SBED					0.360				
BDSTOR/SBED					0.360				
DESK /SBED					0.040				
SBED /BDSTOR						0.180			
SBED /DESK						0.250			
SBED /DESK						0.060			
SBED /BDSTOR						0.180			
SBED /DESK						0.350			
BDSTOR/DESK									0.040
TOTALS	0.000	0.000	0.000	0.000	0.760	1.020	0.000	0.000	0.040

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM06

PARAMETER	VALUE	UNITS
AR	11.3400	SQ. METRES
ABR	0.7000	"
AF	10.6400	"
A01	1.8200	"
A02	0.0400	"
AOU	1.7400	"
A03	1.7800	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	4.0600	"
AE(UNION)	10.6400	"
ANSR	4.7600	"
ANSF	4.0600	"
ANO	8.9000	"
PR	13.3000	METRES
PF	13.3000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM06

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
BDSTOR/SBED					1.080				
BDSTOR/SBED					1.080				
DESK /SBED					0.120				
SBED /BDSTOR						0.360			
SBED /DESK						0.500			
SBED /DESK						0.120			
SBED /BDSTOR						0.360			
SBED /DESK						0.700			
BDSTOR/DESK									0.040
TOTALS	0.000	0.000	0.000	0.000	2.280	2.040	0.000	0.000	0.040

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM07	2.0137	2.2593	1.0138	0.8792
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM07

RATIOS	COMPONENTS		
	OP	PP	AP
EA01*W01 OR (P1*P2)	3.6600		
A01	1.6200		
PR		13.4000	
SQRT(AR)*4		13.2182	
AS/AFMO			0.5298
ANSR/AFMO			0.3494
AU(UNION)/AFMO			0.3494
AE(UNION)/AFMO			0.8792
ABR/AFMO			0.0000
AU(TOT)/AFMO			0.4702
A01/AFMO			0.1304
A02/AFMO			0.0097
AOU/AFMO			0.1111
ANO/AFMO			0.7681
2*A02/AFMO			0.0193

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM07

OVERLAPPING	OVERLAPPING AREAS (SQ. METRES)								
PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.210				
DOOR /SBED					0.210				
SBED /SBED					0.600				
BDSTOR/BDSTOR									0.120
DESK /DESK									0.480
TOTALS	0.000	0.000	0.000	0.000	1.020	0.000	0.000	0.000	0.600

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WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                       - TYPE HELP FOR OPTIONS
PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM07


PARAMETER      VALUE     UNITS

AR            10.9200    SQ. METRES
ABR            0.0000        "
AF            10.9200        "
A01            1.6200        "
A02            0.1200        "
AOU            1.3800        "
A03            1.5000        "
AS             6.5800        "
AU(TOT)        5.8400        "
AFMO          12.4200        "
AU(UNION)      4.3400        "
AE(UNION)     10.9200        "
ANSR           4.3400        "
ANSF           4.3400        "
ANO            9.5400        "
PR            13.4000    METRES
PF            13.4000       "

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                       - TYPE HELP FOR OPTIONS
VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM07


 OVERLAPPING                                 PENALTIES
    PAIR        1:1    1:2    1:3    2:1    2:2    2:3    3:1    3:2    3:3

DOOR  /SBED                                 0.630
DOOR  /SBED                                 0.630
SBED  /SBED                                 1.800
BDSTOR/BDSTOR                                                           0.120
DESK  /DESK                                                             0.480

    TOTALS     0.000  0.000  0.000  0.000  3.060  0.000  0.000  0.000  0.600

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                       - TYPE HELP FOR OPTIONS
NE
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OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM08	2.7666	2.7895	1.0231	0.9694
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM08

RATIOS	COMPONENTS		
	OP	PP	AP
EA01*W01 OR (P1*P2)	3.1800		
A01	1.1400		
PR		14.2000	
SQRT(AR)*4		13.8795	
AS/AFMO			0.5298
ANSR/AFMO			0.4396
AU(UNION)/AFMO			0.3881
AE(UNION)/AFMO			0.9179
ABR/AFMO			0.0515
AU(TOT)/AFMO			0.4702
A01/AFMO			0.0918
A02/AFMO			0.0097
AOU/AFMO			0.0725
ANO/AFMO			0.8454
2*A02/AFMO			0.0193

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM08

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES)								
	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DDOR /SBED					0.210				
DDOR /SBED					0.210				
SBED /SBED					0.600				
BDSTOR/BDSTOR									0.120
TOTALS	0.000	0.000	0.000	0.000	1.020	0.000	0.000	0.000	0.120

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WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                      - TYPE HELP FOR OPTIONS
PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM08


PARAMETER      VALUE    UNITS

AR            12.0400   SQ. METRES
ABR            0.6400       "
AF            11.4000       "
A01            1.1400       "
A02            0.1200       "
AOU            0.9000       "
A03            1.0200       "
AS             6.5800       "
AU(TOT)        5.3400       "
AFMO          12.4200       "
AU(UNION)      4.8200       "
AE(UNION)     11.4000       "
ANSR           5.4600       "
ANSF           4.8200       "
ANO           10.5000       "
PR            14.2000   METRES
PF            14.2000      "

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                      - TYPE HELP FOR OPTIONS
VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM08


 OVERLAPPING                                PENALTIES
    PAIR          1:1   1:2   1:3   2:1   2:2   2:3   3:1   3:2   3:3

DOOR  /SBED                                0.630
DOOR  /SBED                                0.630
SBED  /SBED                                1.800
BDSTOR/BDSTOR                                                    0.120

   TOTALS       0.000 0.000 0.000 0.000 3.060 0.000 0.000 0.000 0.120

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                      - TYPE HELP FOR OPTIONS
NE
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OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM09	2.4200	2.4400	1.0231	0.9694
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM09

RATIOS	COMPONENTS		
	OP	PP	AP
EA01*W01 OR (P1*P2)	3.6600		
A01	1.5000		
FR		14.2000	
SQRT(AR)*4		13.8795	
AS/AFMO			0.5298
ANSR/AFMO			0.4396
AU(UNION)/AFMO			0.3591
AE(UNION)/AFMO			0.8889
ABR/AFMO			0.0805
AU(TOT)/AFMO			0.4702
A01/AFMO			0.1208
A02/AFMO			0.0097
AOU/AFMO			0.1014
ANO/AFMO			0.7874
2*A02/AFMO			0.0193

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM09

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES)								
	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.210				
DOOR /SBED					0.210				
SBED /SBED					0.600				
BDSTOR/DESK						0.120			
BDSTOR/DESK									0.180
BDSTOR/DESK									0.180
TOTALS	0.000	0.000	0.000	0.000	1.020	0.120	0.000	0.000	0.360

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM09

PARAMETER	VALUE	UNITS
AR	12.0400	SQ. METRES
ABR	1.0000	"
AF	11.0400	"
A01	1.5000	"
A02	0.1200	"
AOU	1.2600	"
A03	1.3800	"
AS	6.5800	"
AU(TOT)	5.3400	"
AFMO	12.4200	"
AU(UNION)	4.4600	"
AE(UNION)	11.0400	"
ANSR	5.4600	"
ANSF	4.4600	"
ANO	9.7800	"
PR	14.2000	METRES
PF	14.2000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM09

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DDOR /SBED					0.630				
DDOR /SBED					0.630				
SBED /SBED					1.800				
BDSTOR/DESK						0.240			
BDSTOR/DESK									0.180
BDSTOR/DESK									0.130
TOTALS	0.000	0.000	0.000	0.000	3.060	0.240	0.000	0.000	0.360

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

ME

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM10	2.2887	2.3077	1.0231	0.9694
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM10

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	3.6000		
A01	1.5600		
PR		14.2000	
SQRT(AR)*4		13.8795	
AS/AFMO			0.5298
ANSR/AFMO			0.4396
AU(UNION)/AFMO			0.3543
AE(UNION)/AFMO			0.3841
ABR/AFMO			0.0853
AU(TOT)/AFMO			0.4702
A01/AFMO			0.1256
A02/AFMO			0.0097
AOU/AFMO			0.1063
ANO/AFMO			0.7778
2*A02/AFMO			0.0193

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM10

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.210				
DOOR /SBED					0.210				
SBED /SBED					0.600				
BDSTOR/DESK									0.180
DESK /DESK									0.360
TOTALS	0.000	0.000	0.000	0.000	1.020	0.000	0.000	0.000	0.540

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM10

PARAMETER	VALUE	UNITS
AR	12.0400	SQ. METRES
ABR	1.0600	"
AF	10.9800	"
A01	1.5600	"
A02	0.1200	"
AOU	1.3200	"
A03	1.4400	"
AS	6.5800	"
AU(TOT)	5.3400	"
AFMO	12.4200	"
AU(UNION)	4.4000	"
AE(UNION)	10.9800	"
ANSR	5.4600	"
ANSF	4.4000	"
ANO	9.6600	"
PR	14.2000	METRES
PF	14.2000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM10

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.				

[SYSTEM GOING DOWN IN 60 MINUTES AT 7-APR-81 15:00:00]
630

OVERLAPPING PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.630				
SBED /SBED					1.800				
BDSTOR/DESK									0.180
DESK /DESK									0.360
TOTALS	0.000	0.000	0.000	0.000	3.060	0.000	0.000	0.000	0.540

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM11	1.8454	2.3125	1.0011	0.7971
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM11

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	6.6600		
A01	2.8800		
PR		12.6000	
SQRT(AR)*4		12.5857	
AS/AFMO			0.5298
ANSR/AFMO			0.2673
AU(UNION)/AFMO			0.2673
AE(UNION)/AFMO			0.7971
ABR/AFMO			0.0000
AU(TOT)/AFMO			0.4702
A01/AFMO			0.2319
A02/AFMO			0.0290
AOU/AFMO			0.1739
ANO/AFMO			0.6232
2*A02/AFMO			0.0580

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM11

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
SBED /BDSTOR					0.360				
SBED /BDSTOR					0.060				
SBED /SBED					0.300				
BDSTOR/SBED					0.060				
BDSTOR/SBED					0.360				
SBED /BDSTOR						0.180			
SBED /BDSTOR						0.030			
SBED /BDSTOR						0.030			
SBED /BDSTOR						0.180			
DOOR /DESK						0.540			
DOOR /DESK						0.540			
DESK /DESK									0.240
TOTALS	0.000	0.000	0.000	0.000	1.140	1.500	0.000	0.000	0.240

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM11

PARAMETER	VALUE	UNITS
AR	9.9000	SQ. METRES
ABR	0.0000	"
AF	9.9000	"
A01	2.8300	"
A02	0.3600	"
AOU	2.1600	"
A03	2.5200	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	3.3200	"
AE(UNION)	9.9000	"
ANSR	3.3200	"
ANSF	3.3200	"
ANO	7.7400	"
PR	12.6000	METRES
PF	12.6000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

UA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM11

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
SBED /BDSTOR					1.080				
SBED /BDSTOR					0.180				
SBED /SBED					0.900				
BDSTOR/SBED					0.180				
BDSTOR/SBED					1.080				
SBED /BDSTOR						0.360			
SBED /BDSTOR						0.060			
SBED /BDSTOR						0.060			
SBED /BDSTOR						0.360			
DOOR /DESK						1.080			
DOOR /DESK						1.080			
DESK /DESK									0.240
TOTALS	0.000	0.000	0.000	0.000	3.420	3.000	0.000	0.000	0.240

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM12	2.9220	2.8400	1.0142	1.0145
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM12

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	2.1300		
A01	0.7500		
PR		14.4000	
SQRT(AR)*4		14.1986	
AS/AFM0			0.5298
ANSR/AFM0			0.4847
AU(UNION)/AFM0			0.4147
AE(UNION)/AFM0			0.9444
ABR/AFM0			0.0700
AU(TOT)/AFM0			0.4702
A01/AFM0			0.0604
A02/AFM0			0.0048
AOU/AFM0			0.0507
AJO/AFM0			0.8937
2*A02/AFM0			0.0097

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM12

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.180				
DOOR /SBED					0.180				
SBED /SBED					0.300				
BDSTOR/DESK						0.060			
BDSTOR/DESK									0.030
TOTALS	0.000	0.000	0.000	0.000	0.660	0.060	0.000	0.000	0.030

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM12

PARAMETER	VALUE	UNITS
AR	12.6000	SQ. METRES
ABR	0.8700	"
AF	11.7300	"
A01	0.7500	"
A02	0.0600	"
AOU	0.6300	"
A03	0.6900	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	5.1500	"
AE(UNION)	11.7300	"
ANSR	6.0200	"
ANSF	5.1500	"
ANO	11.1000	"
PR	14.4000	METRES
PF	14.4000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM12

OVERLAPPING	PENALTIES								
PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.540				
DOOR /SBED					0.540				
SBED /SBED					0.900				
BDSTOR/DESK						0.120			
BDSTOR/DESK									0.030
TOTALS	0.000	0.000	0.000	0.000	1.980	0.120	0.000	0.000	0.030

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM13	2.8074	2.7692	1.0009	1.0129
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM13

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	2.1600		
A01	0.7800		
PR		14.2000	
SQRT(AR)*4		14.1873	
AS/AFM0			0.5298
ANSR/AFM0			0.4331
AU(UNION)/AFM0			0.4074
AE(UNION)/AFM0			0.9372
ABR/AFM0			0.0757
AU(TOT)/AFM0			0.4702
A01/AFM0			0.0628
A02/AFM0			0.0000
AOU/AFM0			0.0628
ANO/AFM0			0.3744
2*A02/AFM0			0.0000

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM13

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.210				
DOOR /SBED					0.030				
BDSTOR/SBED					0.360				
SBED /BDSTOR						0.130			
TOTALS	0.000	0.000	0.000	0.000	0.600	0.180	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM13

PARAMETER	VALUE	UNITS
AR	12.5800	SQ. METRES
ABR	0.9400	"
AF	11.6400	"
A01	0.7800	"
A02	0.0000	"
AOU	0.7800	"
A03	0.7800	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	5.0600	"
AE(UNION)	11.6400	"
ANSR	6.0000	"
ANSF	5.0600	"
ANO	10.8600	"
PR	14.2000	METRES
PF	14.2000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

UA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM13

OVERLAPPING	PENALTIES								
PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.630				
DOOR /SBED					0.090				
BDSTOR/SBED					1.080				
SBED /BDSTOR						0.360			
TOTALS	0.000	0.000	0.000	0.000	1.800	0.360	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM14	2.8140	2.6967	1.0000	1.0435
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM14

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	3.2900		
A01	1.2200		
PR		14.4000	
SQRT(AR)*4		14.4000	
AS/AFMO			0.5298
ANSR/AFMO			0.5137
AU(UNION)/AFMO			0.3720
AE(UNION)/AFMO			0.9018
ABR/AFMO			0.1417
AU(TOT)/AFMO			0.4702
A01/AFMO			0.0982
A02/AFMO			0.0000
AOU/AFMO			0.0982
ANO/AFMO			0.8035
2*A02/AFMO			0.0000

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM14

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
SBED /SBED		0.030							
BDSTOR/SBED					0.360				
BDSTOR/SBED					0.360				
SBED /SBED					0.070				
SBED /BDSTOR						0.180			
SBED /BDSTOR						0.180			
SBED /DESK						0.040			
TOTALS	0.000	0.030	0.000	0.000	0.790	0.400	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM14

PARAMETER	VALUE	UNITS
AR	12.9600	SQ. METRES
ABR	1.7600	"
AF	11.2000	"
A01	1.2200	"
A02	0.0000	"
AOU	1.2200	"
A03	1.2200	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	4.6200	"
AE(UNION)	11.2000	"
ANSR	6.3800	"
ANSF	4.6200	"
ANO	9.9800	"
PR	14.4000	METRES
PF	14.4000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM14

OVERLAPPING	PENALTIES								
PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
SBED /SBED		0.120							
BDSTOR/SBED					1.080				
BDSTOR/SBED					1.080				
SBED /SBED					0.210				
SBED /BDSTOR						0.360			
SBED /BDSTOR						0.360			
SBED /DESK						0.080			
TOTALS	0.000	0.120	0.000	0.000	2.370	0.800	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM15	3.2177	3.0000	1.0001	1.0725
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM15

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	0.5400		
A01	0.1800		
PR		14.6000	
SQRT(AR)*4		14.5986	
AS/AFMO			0.5298
ANSR/AFMO			0.5427
AU(UNION)/AFMO			0.4557
AE(UNION)/AFMO			0.9855
ABR/AFMO			0.0370
AU(TOT)/AFMO			0.4702
A01/AFMO			0.0145
A02/AFMO			0.0000
AOU/AFMO			0.0145
ANO/AFMO			0.9710
2*A02/AFMO			0.0000

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM15

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.090				
DOOR /SBED					0.090				
TOTALS	0.000	0.000	0.000	0.000	0.180	0.000	0.000	0.000	0.000

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WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                    - TYPE HELP FOR OPTIONS
PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM15


PARAMETER      VALUE     UNITS

AR            13.3200    SQ. METRES
ABR            1.0800       "
AF            12.2400       "
A01            0.1800       "
A02            0.0000       "
AOU            0.1800       "
A03            0.1800       "
AS             6.5800       "
AU(TOT)        5.8400       "
AFMO          12.4200       "
AU(UNION)      5.6600       "
AE(UNION)     12.2400       "
ANSR           6.7400       "
ANSF           5.6600       "
ANO           12.0600       "
PR            14.6000    METRES
PF            14.6000       "

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                    - TYPE HELP FOR OPTIONS
VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM15


OVERLAPPING                                  PENALTIES
   PAIR         1:1   1:2   1:3   2:1   2:2   2:3   3:1   3:2   3:3

DOOR  /SBED                                 0.270
DOOR  /SBED                                 0.270

   TOTALS     0.000 0.000 0.000 0.000 0.540 0.000 0.000 0.000 0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                    - TYPE HELP FOR OPTIONS
NE
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OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM16	2.5272	2.6441	1.0026	0.9533
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM16

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	3.1200		
A01	1.1800		
PR		13.8000	
SQRT(AR)*4		13.7637	
AS/AFMO			0.5298
ANSR/AFMO			0.4235
AU(UNION)/AFMO			0.3752
AE(UNION)/AFMO			0.9050
ABR/AFMO			0.0483
AU(TOT)/AFMO			0.4702
A01/AFMO			0.0950
A02/AFMO			0.0000
AOU/AFMO			0.0950
ANO/AFMO			0.8100
2*A02/AFMO			0.0000

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM16

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /DESK					0.040				
BDSTOR/SBED					0.360				
BDSTOR/SBED					0.360				
DOOR /DESK						0.060			
SBED /BDSTOR						0.180			
SBED /BDSTOR						0.180			
TOTALS	0.000	0.000	0.000	0.000	0.760	0.420	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM16

PARAMETER	VALUE	UNITS
AR	11.8400	SQ. METRES
ABR	0.6000	"
AF	11.2400	"
A01	1.1800	"
A02	0.0000	"
AOU	1.1800	"
A03	1.1800	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	4.6600	"
AE(UNION)	11.2400	"
ANSR	5.2600	"
ANSF	4.6600	"
ANO	10.0600	"
PR	13.8000	METRES
PF	13.8000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

UA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM16

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /DESK					0.120				
BDSTOR/SBED					1.080				
BDSTOR/SBED					1.080				
DOOR /DESK						0.120			
SBED /BDSTOR						0.360			
SBED /BDSTOR						0.360			
TOTALS	0.000	0.000	0.000	0.000	2.280	0.840	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM17	2.9348	2.7363	1.0001	1.0725
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM17

RATIOS	COMPONENTS OP	PP	AP
ΣA01*W01 OR (P1*P2)	2.4900		
A01	0.9100		
PR		14.6000	
SQRT(AR)*4		14.5986	
AS/AFMO			0.5298
ANSR/AFMO			0.5427
AU(UNION)/AFMO			0.3969
AE(UNION)/AFMO			0.9267
ABR/AFMO			0.1457
AU(TOT)/AFMO			0.4702
A01/AFMO			0.0733
A02/AFMO			0.0000
AOU/AFMO			0.0733
ANO/AFMO			0.3535
2*A02/AFMO			0.0000

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM17

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
SBED /SBED		0.030							
DOOR /BDSTOR					0.180				
BDSTOR/SBED					0.360				
SBED /SBED					0.070				
DOOR /BDSTOR						0.090			
SBED /BDSTOR						0.180			
TOTALS	0.000	0.030	0.000	0.000	0.610	0.270	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM17

PARAMETER	VALUE	UNITS
AR	13.3200	SQ. METRES
ABR	1.8100	"
AF	11.5100	"
A01	0.9100	"
A02	0.0000	"
AOU	0.9100	"
A03	0.9100	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	4.9300	"
AE(UNION)	11.5100	"
ANSR	6.7400	"
ANSF	4.9300	"
ANO	10.6000	"
PR	14.6000	METRES
PF	14.6000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

UA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM17

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
SBED /SBED		0.120							
DOOR /BDSTOR					0.540				
BDSTOR/SBED					1.080				
SBED /SBED					0.210				
DOOR /BDSTOR						0.180			
SBED /BDSTOR						0.360			
TOTALS	0.000	0.120	0.000	0.000	1.830	0.540	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM18	2.3868	2.6915	1.0001	1.0725
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM18

RATIOS	COMPONENTS		
	OP	PP	AP
EA01*W01 OR (P1*P2)	2.5300		
A01	0.9400		
PR		14.6000	
SQRT(AR)*4		14.5986	
AS/AFM0			0.5298
AJSR/AFM0			0.5427
AU(UNION)/AFM0			0.3945
AE(UNION)/AFM0			0.9243
ABR/AFM0			0.1481
AU(TOT)/AFM0			0.4702
A01/AFM0			0.0757
A02/AFM0			0.0000
AOU/AFM0			0.0757
ANO/AFM0			0.8486
2*A02/AFM0			0.0000

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM18

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES)								
	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DESK /SBED		0.040							
SBED /SBED		0.030							
BDSTOR/SBED					0.360				
DESK /SBED					0.080				
SBED /SBED					0.070				
SBED /DESK						0.180			
SBED /BDSTOR						0.180			
TOTALS	0.000	0.070	0.000	0.000	0.510	0.360	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM18

PARAMETER	VALUE	UNITS
AR	13.3200	SQ. METRES
ABR	1.8400	"
AF	11.4800	"
A01	0.9400	"
A02	0.0000	"
AOU	0.9400	"
A03	0.9400	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	4.9000	"
AE(UNION)	11.4800	"
ANSR	6.7400	"
ANSF	4.9000	"
ANO	10.5400	"
PR	14.6000	METRES
PF	14.6000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

\A

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM18

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DESK /SBED		0.160							
SBED /SBED		0.120							
BDSTOR/SBED					1.080				
DESK /SBED					0.240				
SBED /SBED					0.210				
SBED /DESK						0.360			
SBED /BDSTOR						0.360			
TOTALS	0.000	0.280	0.000	0.000	1.530	0.720	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM19	2.3966	2.3673	1.0025	1.0097
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM19

RATIOS	COMPONENTS		
	OP	PP	AP
EA01*W01 OR (P1*P2)	2.0600		
A01	0.8700		
PR		14.2000	
SQRT(AR)*4		14.1647	
AS/AFMO			0.5298
ANSR/AFMO			0.4799
AU(UNION)/AFMO			0.4002
AE(UNION)/AFMO			0.9300
ABR/AFMO			0.0797
AU(TOT)/AFMO			0.4702
A01/AFMO			0.0700
A02/AFMO			0.0000
AOU/AFMO			0.0700
ANO/AFMO			0.8599
2*A02/AFMO			0.0000

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM19

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES)								
	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DESK /SBED		0.040							
DESK /SBED		0.040							
SBED /DESK					0.080				
DESK /SBED					0.080				
DOOR /BDSTOR						0.090			
DOOR /BDSTOR						0.180			
SBED /DESK						0.180			
SBED /DESK						0.180			
TOTALS	0.000	0.080	0.000	0.000	0.160	0.630	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM19

PARAMETER	VALUE	UNITS
AR	12.5400	SQ. METRES
ABR	0.9900	"
AF	11.5500	"
A01	0.8700	"
A02	0.0000	"
AOU	0.8700	"
A03	0.8700	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	4.9700	"
AE(UNION)	11.5500	"
ANSR	5.9600	"
ANSF	4.9700	"
ANO	10.6800	"
PR	14.2000	METRES
PF	14.2000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM19

OVERLAPPING PAIR	PENALTIES 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DESK /SBED		0.160							
DESK /SBED		0.160							
SBED /DESK					0.240				
DESK /SBED					0.240				
DOOR /BDSTOR						0.180			
DOOR /BDSTOR						0.360			
SBED /DESK						0.360			
SBED /DESK						0.360			
TOTALS	0.000	0.320	0.000	0.000	0.480	1.260	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM20	2.8660	2.6842	1.0046	1.0628
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM20

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	3.0600		
A01	1.1400		
PR		14.6000	
SQRT(AR)*4		14.5327	
AS/AFMO			0.5298
ANSR/AFMO			0.5330
AU(UNION)/AFMO			0.3784
AE(UNION)/AFMO			0.9082
ABR/AFMO			0.1546
AU(TOT)/AFMO			0.4702
A01/AFMO			0.0918
A02/AFMO			0.0000
AOU/AFMO			0.0918
ANO/AFMO			0.8164
2*A02/AFMO			0.0000

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM20

OVERLAPPING PAIR	OVERLAPPING AREAS (SQ. METRES) 1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
DOOR /SBED					0.030				
DOOR /SBED					0.030				
BDSTOR/SBED					0.360				
BDSTOR/SBED					0.360				
SBED /BDSTOR						0.180			
SBED /BDSTOR						0.180			
TOTALS	0.000	0.000	0.200	0.000	0.780	0.360	0.000	0.000	0.000

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WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                   - TYPE HELP FOR OPTIONS
PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM20


PARAMETER      VALUE      UNITS

AR            13.2000    SQ. METRES
ABR            1.9200        "
AF            11.2800        "
A01            1.1400        "
A02            0.0000        "
AOU            1.1400        "
A03            1.1400        "
AS             6.5800        "
AU(TOT)        5.8400        "
AFM0          12.4200        "
AU(UNION)      4.7000        "
AE(UNION)     11.2800        "
ANSR           6.6200        "
ANSF           4.7000        "
ANO           10.1400        "
PR            14.6000    METRES
PF            14.6000       "

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                   - TYPE HELP FOR OPTIONS
VA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM20


OVERLAPPING                                     PENALTIES
   PAIR         1:1    1:2    1:3    2:1    2:2    2:3    3:1    3:2    3:3

DOOR  /SBED                                 0.090
DOOR  /SBED                                 0.090
BDSTOR/SBED                                 1.080
BDSTOR/SBED                                 1.080
SBED  /BDSTOR                                      0.360
SBED  /BDSTOR                                      0.360

   TOTALS     0.000  0.000  0.000  0.000  2.340  0.720  0.000  0.000  0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
                   - TYPE HELP FOR OPTIONS
NE
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OUTPUT OF LAYOUT EFFICIENCY COMPONENT VALUES

ENTER NAMES OF RESULTS FILES TO BE INCLUDED

ACTIVITY SPACE	ER	OP	PP	AP
BDRM21	2.9507	2.6250	1.0073	1.1159
	0.0000	0.0000	0.0000	0.0000

LAYOUT EFFICIENCY COMPONENT RATIOS FOR ACTIVITY SPACE BDRM21

RATIOS	COMPONENTS OP	PP	AP
EA01*W01 OR (P1*P2)	3.3600		
A01	1.2800		
PR		15.0000	
SQRT(AR)*4		14.8916	
AS/AFMO			0.5298
ANSR/AFMO			0.5862
AU(UNION)/AFMO			0.3671
AE(UNION)/AFMO			0.8969
ABR/AFMO			0.2190
AU(TOT)/AFMO			0.4702
A01/AFMO			0.1031
A02/AFMO			0.0000
AOU/AFMO			0.1031
ANO/AFMO			0.7939
2*A02/AFMO			0.0000

OUTPUT OF 1ST. LEVEL OVERLAP AREAS FOR ACTIVITY SPACE BDRM21

OVERLAPPING PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
					OVERLAPPING AREAS (SQ. METRES)				
BDSTOR/SBED					0.360				
BDSTOR/SBED					0.360				
DESK /SBED					0.040				
DESK /SBED					0.040				
SBED /BDSTOR						0.180			
SBED /DESK						0.060			
SBED /BDSTOR						0.180			
SBED /DESK						0.060			
TOTALS	0.000	0.000	0.000	0.000	0.800	0.480	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

PA

PARAMETER VALUE OUTPUT FOR ACTIVITY SPACE BDRM21

PARAMETER	VALUE	UNITS
AR	13.8600	SQ. METRES
ABR	2.7200	"
AF	11.1400	"
A01	1.2800	"
A02	0.0000	"
AOU	1.2800	"
A03	1.2800	"
AS	6.5800	"
AU(TOT)	5.8400	"
AFMO	12.4200	"
AU(UNION)	4.5600	"
AE(UNION)	11.1400	"
ANSR	7.2800	"
ANSF	4.5600	"
ANO	9.8600	"
PR	15.0000	METRES
PF	15.0000	"

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

UA

OUTPUT OF OVERLAP PENALTY VALUES FOR ACTIVITY SPACE BDRM21

OVERLAPPING					PENALTIES				
PAIR	1:1	1:2	1:3	2:1	2:2	2:3	3:1	3:2	3:3
BDSTOR/SBED					1.080				
BDSTOR/SBED					1.080				
DESK /SBED					0.120				
DESK /SBED					0.120				
SBED /BDSTOR						0.360			
SBED /DESK						0.120			
SBED /BDSTOR						0.360			
SBED /DESK						0.120			
TOTALS	0.000	0.000	0.000	0.000	2.400	0.960	0.000	0.000	0.000

WHAT TYPE OF SYNOPTIC EVALUATION OUTPUT DO YOU REQUIRE?
- TYPE HELP FOR OPTIONS

NE

SECTION E: NOTE ON EXTERNAL SUPPLEMENTS TO THE THESIS

NOTE ON EXTERNAL SUPPLEMENTS TO THE THESIS.

The following material has been collected as external supplements to the thesis (Sections E1 and E2):

E1. Program listings of the following computer programs and files:

1.1. The GAEL 4A Synthesis Graphics Program.
1.2. The GAEL 4T Synthesis Graphics Program.
1.3. The CRUNCH Numerical Layout Appraisal Program.
1.4. The GRAFIT Graphical Layout Appraisal Program.
1.5. Necessary data files , control routines etc. for operation of the various programs.

E2. Drawings of the house and shop designs referred to in Sub-subsection 2.5.2, which were designed by the author using certain principles contained in the proposed design system.

These supplements do not formally belong to the thesis, but they are available as additional informal reference material and for the purpose of future work.