THE EFFECTS OF COMPUTER AIDED DRAUGHTING ON ARCHITECTURAL PRACTICE

John McEwen Trushell

THESIS SUBMITTED FOR THE DEGREE OF MASTER OF LETTERS

University Of Glasgow
Department of Management Studies
September 1988

PREFACE

This thesis would have been impossible but for the help of many people. My sincere thanks to them all, but especially to the following:-

Professor David Weir and Dr David Buchanan for their patient encouragement, advice and support throughout the lengthy preparation of this study.

The partners and members of staff of the two architectural practices which are the principal subjects of this study.

Joan Rawcliffe, Debbie Whittaker, Pauline Mullen and Joyce Quinn who decyphered my writing and harnessed the new power of word-processing to set down this study.

CONTENTS

			Page No
PREFACE			i
SUMMARY			v
CHAPTER 1	-	INTRODUCTION	
		Objectives	2
		Interest in the research	3
		Difficulties with the research	4
		Choice of research methodology	6
CHAPTER 2	-	THE DESIGN PROCESS	
		Introduction	9
		Design Team Working	10
		Plan of Work	13
		Role of the Computer	19
CHAPTER 3	-	THEORETICAL UNDERPINNINGS	
		Introduction	24
		The Impact of Computer - Aided Draughting on Organizations and Individual Architects	24
		A Model of the Transformation of the Firm	33
CHAPTER 4	-	COMPUTER DRAUGHTING	
		Introduction	37
		General Systems	38
		Individual Systems	50
		RUCAPS	50
		GDS	55
CHAPTER 5	-	CASE STUDY NO. 1 REIACH & HALL/BLYTH & BLYTH	
		Introduction	66
		The Organization	66
		Management Objectives	69
		The Decision Process	72
		Organization Structure	73
		Management Role	76
		Related Professional Groups	77
		Work Organization	80
		Skills and Creativity	86
		Careers	88
		Organization Performance	90
		Main Conclusions	93

CHAPTER 6	-	CASE STUDY NO. 2: COMPUTER GRAPHIC DESIGN	
		Introduction	98
		The Organization	99
		Management Objectives	99
		The Decision Process	101
		Organization Structure	103
		Finance	106
		Careers	107
		Marketing	108
		Productivity	110
		Design	111
		Work Organization	113
		Relationships	116
		Main Conclusions	118
CHAPTER 7	-	DISCUSSION ON FINDINGS	
		Introduction	123
		Decision Making	123
		Structure	124
		Job Characteristics	126
		Performance	130
		Cooley's Indicators	136
		Pettigrew's Model	143
CHAPTER 8	-	CONCLUSIONS	
		Introduction	147
		Conclusions	147
		Recommendations	149
		Areas For Further Research	150
APPENDICES I	-	Computer Aided Draughting Systems	152
II	-	RUCAPS System Drawings	156
III	-	GDS System Drawings	163
BIBLIOGRAPHY			170

LIST OF TABLES

1	Summary of Findings	122

LIST OF DIAGRAMS

Fig. 1	Comparative Distribution of Resources	27
Fig. 2	Comparative Man Hour Requirements	27
Fig. 3	Pettigrew's Model of Strategic Change	34
Fig. 4	General Principles of Draughting Systems	38
Fig. 5	Idealised Structure of a Draughting System	39
Fig. 6	Tree Structure of Draughting System	40
Fig. 7	Global and Local Origins	42
Fig. 8	Translation	43
Fig. 9	Rotation	44
Fig. 10	Mirroring	44
Fig. 11	Windowing	45
Fig. 12	Scaling	45
Fig. 13	Drum Plotter	46
Fig. 14	Flatbed Plotter	47
Fig. 15	Cursor	49
Fig. 16	GDS Geometric Construction Facilities	57
Fig. 17	GDS Drawing Creation	59
Fig. 18	Reiach and Hall, Organization Chart	67
Fig. 19	Blyth and Blyth, Outline Organization Chart	68
Fig. 20	The Consortium's Computer Management Structure	74
Fig. 21	The Organizational Structures of Computer Graphic Design and Baxter Clark and Paul	105
Fig. 22	Traditional Structure of Design Team	132
Fig. 23	Structure of Computerized Design Team	132
Fig. 24	Particular Components of Pettigrew's Model of Strategic Change	145

SUMMARY

This thesis argues that computer aided draughting (CAD) can be introduced successfully into an organization and can benefit all those engaged in the construction process. It concludes that CAD is the single most important tool to be introduced into the practice of architecture in recent times and, whilst the foregoing proposition is true, there is a cost to the organizations and individuals involved.

The study begins with the author's interest in the research as a Chartered Quantity Surveyor working professionally with a firm of architects who installed a CAD system. It identifies several difficulties with the research and justifies the case study research methodology. The study then examines design team working in the context of the RIBA plan of work and identifies the role of the computer in this work. A search of the literature reveals various factors which impact on an organization and on individual architects on computerization. Cooley's fourteen indicators following the installation of a computer draughting system are examined and used as a framework for analysis of the human factors. Pettigrew's model of strategic change is selected as the framework of analysis in understanding the factors present in the transformation of the firm from manual to computer draughting. A substantial section of the study is devoted to a description of the technology of computer aided draughting as this is essential to a clear understanding of the benefits and drawbacks of such systems.

The major sections of the research relate to case studies of two architectural practices which installed computer aided draughting systems. Each case looked particularly at the decision-making process involved in making the strategic change to CAD, the changes in organization structure implemented on computerziation, the changes to operating job characteristics and the experience of work resulting from CAD operations, and the effect of CAD on the role of management and on organizational performance.

Analysis of the findings of the research reveals that the reasons for computerization were to improve product quality and increase organizational capacity. Subsidiary reasons included improving client service, gaining a commercial edge over competitors, and easing managerial control problems.

The two case studies revealed widely differing approaches to organization structure following computerization. One firm set up a separate computing partnership whilst the other simply reinforced its existing structures. Advantages and disadvantages resulting from each approach are identified.

Computer aided draughting brought many changes to the working lives of architects. Work patterns were altered by extending the working day and by shift working, machine prompting paced their work, and intermediate deadlines introduced stressful working. Other causes of stress arose from machine noise and isolated working. Working methods altered too and creativity was ambiguously affected, depending upon the capabilities of the technology. Employment levels were greatly reduced and it was widely believed that the traditional role of the architectural technician would have to change as architects became computer operators. CAD also brought changes in design team working with the architect moving from his central, co-ordinating position to be replaced by the computer.

Only half of Cooley's indicators are positively confirmed and the other half either denied or found to be ambivalent. Pettigrew's model of strategic change is largely validated, but found to be rather over-simplistic.

Conclusions are drawn from the research and recommendations made for future installations. Areas of further research are identified.

CHAPTER 1

INTRODUCTION

The objectives of this chapter are :-

- to set out the objectives for this thesis.
- to describe the author's interest in the research.
- to highlight the difficulties encountered with the research.
- to substantiate the choice of research methodology.

OBJECTIVES

A thesis is defined by the Shorter Oxford English Dictionary (1984) as, "A proposition laid down or stated, especially as a theme to be discussed and proved, or to be maintained against attack."

The proposition set out in this thesis is that the technology of computer aided draughting can be used to the benefit of all those engaged in the construction process.

The thesis examines the design process and suggests ways in which computer aided draughting might assist designers. A review of the somewhat limited literature available enables areas of interest to be identified and generates questions to be asked in the two case studies which follow a detailed examination of the technology itself. The findings are then discussed, conclusions reached and areas for further research identified.

The conclusions cannot be "proved" in the mathematical sense, but it is shown that the use of the new technology is beneficial to many, if at some personal cost to a few.

INTEREST IN THE RESEARCH

This research into the effects of computer aided draughting on the architectural profession was undertaken as a result of the author's personal involvement with this technological development on a large construction project. Some of the effects which it had on the architects, engineers and himself were seen clearly enough and this created interest and speculation as to what other, as yet unobserved, effects there might be.

Of major interest was how an inherently conservative profession such as architecture would react to the major technological change brought about by computer aided draughting. Although architects are well used to investigating and adapting technological changes in the fabric of buildings and in construction techniques, the technology within their own offices had remained practically unaltered for very many years.

Architecture is not a capital intensive business. Before the advent of computer aided draughting it was labour intensive and consequently investment decisions were on the scale of purchasing/renting/leasing office accommodation, motor cars, photocopiers and other general office equipment. How the decision-making process worked in as major a capital investment as a computer system was worthy of study.

An architect is a fairly unique blend of aesthete and technologist. His design skills must be complemented by a sound grasp of what is technically possible and desirable, otherwise his design concepts will never materialise. The degree to which the new technology would inhibit or accentuate his creativity was of some fascination.

DIFFICULTIES WITH THE RESEARCH

Computer aided draughting had only been available to the architectural profession since the late 1970s and at the commencement of the research very few installations were available for study. Only one was located in Scotland at Reiach and Hall, Edinburgh and this system was the object of the first study. At the time of writing, April 1988 there were still less than a dozen installations in Scotland. The newness of the technology itself, coupled with the low number of installations, obviously limited the research to the very few Scottish architectural practices which had computerized. This limitation steered the research methodology towards the case study method where detailed qualitative data could be obtained rather than a wide ranging data collection and analysis method. One reason for researching this new technology was that an opportunity presented itself at Computer Graphic Design, Glasgow, of commencing research almost from the moment the technology was delivered to the organization. This in turn permitted a longitudinal study to be carried out as the impact of the technology was felt and the organization and people adapted to it.

A major difficulty encountered in the research was the paucity of literature from which to establish a theoretical framework. An extensive literature exists on the impact of computerization on many manufacturing and commercial organizations, but little on professions. Industry and commerce had computerized many of their operations some time before which allowed time for research and publication. The professions have only recently entered this field as the cost of computing has fallen and the appropriate software has become available. This research commenced with few pre-conceptions as to what might be the effects of computerization, but concentrated on establishing exactly what were the effects.

Professions are essentially private. The dominant organizational form is the partnership which meets the requirements of privacy very well. Partners are only answerable to their clients and fellow partners and not to shareholders. Partnerships are not required to file accounts with the Registrar of Companies and so their financial status and performance remain private. With the possible exception of architectural competitions the means by which work is obtained remains private as does the operational functions carried out by the professions. This privacy makes research difficult as professionals are reluctant to divulge details of their operational activities which may be of commercial value to their fellow professionals. The reluctance to speak openly of operational problems is compounded by the lack of performance data. The professions have been reluctant to introduce any of the work measurement techniques widely practised in industry. There is a general misconception in the professions that work study methods cannot be applied to office work and so very little data is available on individual or company performance. The only performance data to be found in an architectural practice is usually time sheets completed by each member of staff. The information contained therein is used for job costing purposes but is insufficiently detailed to permit analysis of individual performance. The absence of relevant data made it impossible to prepare a data analysis of performance under manual and computerized conditions. This too steered the research methodology towards a qualitative rather than a quantitative base.

CHOICE OF RESEARCH METHODOLOGY

Buchanan and Boddy (1983) assert that it is not technology that determines organization structure, but how technology is used. Managerial choices as to how work is organized and structured around technology are the key issues and not the technology itself. This research therefore examines the nature of managerial choice and the obvious way to investigate the problem was by interviewing managers. The choice of the case study method was reinforced by the two other factors referred to previously. Firstly, the lack of a literature-based theoretical frame of reference meant that the research area could not be adequately structured before investigation. Secondly, the lack of performance data negated the use of statistical analysis. These three factors together made the choice of the case study method almost obligatory. The precise methodology employed is described in the introduction to each case study.

Although the case study method brings out rich and interesting qualitative date, it does have inherent problems. A large number of variables arise and it can be difficult to establish causal links from all the interrelationships. The twin pillars of research methodology, internal reliability and external validity, raise problems. Moser and Kalton (1971) defined reliability as, "The extent to which repeat measurements made by a scale or test under constant conditions will give the same result, assuming no change in the basic characteristics being measured". Sieber (1976b) pointed out however that the quantitative view of reliability is in many respects inapplicable in qualitative data collection. "Certain kinds of reliability must be intentionally violated in order to gain a depth of understanding about the situation (ie the observer's behaviour must change from subject to object, unique questions must be asked of different subjects...)".

Validation relates to the extent to which results unique to one situation can be generalised to the whole and is also defined by Moser and Kalton (1971) as, "The success of a scale in measuring what it sets out to measure, so that differences between individuals' scores can be taken as representing true differences in the characteristic under study." Miles (1979) advocated that, when dealing with qualitative rather than quantitative data, "Validation through feedback to sites" was one possible method of substituting for the usual statistical tests. In this system semi-final drafts were given to interviewers who were then invited to correct errors of fact and supply alternative interpretations to those made by the author. This research found, as had Miles, that there was self-aggrandizing and self-protective responses from individuals. Objections were made to direct quotes or specific characterizations of behaviour, words like "crisis" and "awkward" were changed to "demands" and "complex". It is appreciated that the research findings can only be generalized into a limited number of similar circumstances. The conditions obtaining throughout the architectural profession are however similar enough for the findings to be generally valid.

CHAPTER 2

THE DESIGN PROCESS

The objectives of this chapter are:-

- to identify the principal participants in the design process.
- to describe the design process.
- to identify the role of the computer in the design process.

INTRODUCTION

All but the simplest construction projects required the skills of many participants to achieve a satisfactory conclusion. The number of participants was determined to a large extent by the scale and complexity of the project, but in most cases there had to be a Client, an Architect and a Builder. A whole range of Consultants was engaged to transform the Client's Requirements into a form which a Builder could understand and construct. These consultants comprised a Structural Engineer, Mechanical and Electrical Engineers, and a Quantity Surveyor. On larger and more sophisticated projects further consultants such as Lift Engineers, Acoustic Engineers, Landscape Architects and Interior Designers may have been required. All these consultants came together to form the Design Team.

The Client's role was crucial to a successful building project as he had to define his exact requirements, express these by way of a Brief to an architect, appoint the consultants, agree to the design solutions and finance the project. Indecision and vacillation by a Client was anathema to efficient design team working.

The role of the Builder had, until recently, only started when the design was largely complete. His job traditionally was simply to construct the project in accordance with the drawings, specifications and conditions of contract. Increasingly however, the builder played a part in the design process as advisor to the Design Team, but as this study deals only with the design stages of the construction process the role of the builder was largely ignored.

DESIGN TEAM WORKING

Design Teams carried out their duties in recent times in accordance with the Royal Institute of British Architects' Plan of Work for Design Team Operation (1969). Non-traditional methods of working also existed, but were again outwith the scope of this study and therefore ignored. The architect's role involved him in the following activities during the full course of a construction project:-

Analysis and definition of client requirements so that initial recommendations could be made as to the form in which the project was to proceed.

Development of the client's brief to formulate decisions on particular proposals, including planning arrangements, appearance, constructional method, outline specification and cost.

Full design of every part and component of the project.

Preparation of final production information comprising drawings, schedules and specifications.

Supervision of tender document preparation and selection of contractor.

Supervision of site operations, including approval of constructional techniques, amendment of design details to overcome practical difficulties, and adjudicating on contractual disputes.

Ensuring that all work was completed in accordance with the contract and handing over to the client for occupation.

The work of an architect could therefore be sub-divided into three main areas:-

(a) Design - the formulation of an acceptable solution to the client's requirements,

(b) Production Information - the provision of all necessary information to enable a contractor to be appointed and to build the project, and

(c) Site Supervision - the regulation of site operations.

<u>Design</u>

The process of design involved the architect in first determining precisely what his client wanted in terms of accommodation, standards of construction, and cost. This was sometimes not an easy task in itself, but having defined these requirements the architect set about providing an acceptable solution which involved examination of a whole range of alternatives in terms of planning arrangements, massing of buildings, methods of construction and the use of materials. The solution finally arrived at might necessarily be a compromise in many respects, but it met the basic parameters of space, standards and cost, and complied with all planning and building regulation requirements.

An integral facet of the design process was the number of interested parties with whom the architect liaised and whose work was co-ordinated to arrive at an integrated design. These people included not only other members of the Design Team but also advisory bodies, the building users and statutory bodies such as Planning Departments, Firemasters and Building Control Authorities.

Production Information

Having arrived at a particular and acceptable solution to his client's requirements the architect designed every detailed component of the building and also co-ordinated the design inputs from the other design disciplines. He prepared full production information in the form of drawings, schedules of components etc and specifications of materials and workmanship.

Site Supervision

The architect was responsible in ensuring that the building was constructed in a safe, workmanlike manner and in strict accordance with his designs and all statutory requirements. The architect was therefore involved in supervising the contractor's site operations and in solving constructional difficulties, for certifying stage payments to the contractor, and for ascertaining the sum of money which the contractor was finally paid for the project. The architect was finally responsible for inspecting and approving all materials and workmanship at the completion of the contract and for handing over the building in a fit state for the clients's use.

PLAN OF WORK

The RIBA Plan of Work fragmented the design process itself into discrete stages A - H inclusive. It should be noted however that in practice these stages ran into each other and even overlapped to meet the demands of the particular situation.

The recognised design stages were:-

A. Inception
B. Feasibility
C. Outline Proposals
D. Scheme Design
E. Detail Design
F. Production Information
G. Bills of Quantities
H. Tender Action

Further stages comprised Project Planning, Operations on Site, Completion and Feed-back which related to the construction stages.

A detailed examination of the design stages revealed the following purpose of work, decisions to be reached and tasks to be done:-

A. Inception

To prepare a general outline of requirements and plan future action. A client organization was set up to consider its requirements and to appoint an architect.

B. Feasibility

To provide the client with an appraisal and recommendation in order that he may determine the form in which the project was to proceed, ensuring that it was feasible functionally, technically and financially. Various studies were carried out of user requirements, site conditions, planning, design and cost etc to enable decisions to be reached.

C. Outline Proposals

To determine the general approach to layout, design and construction in order to obtain the client's authoritative approval of the outline proposals and accompanying report. Further studies were carried out on technical problems as necessary to reach decisions.

D. Scheme Design

To complete the Brief and decide on particular proposals including planning arrangement, appearance, constructional method, outline specification, and cost, and to obtain all necessary approvals. The Brief was finally developed, the project fully designed architecturally, the engineers completed their preliminary designs and the quantity surveyor prepared a cost plan. The Brief could not be modified after this point if abortive work were to be avoided.

E. Detail Design

To obtain final decisions on every single matter related to the design, specification, construction and cost of the project. Every part and component of the buildings was fully designed and these designs then cost checked against the cost plan.

F. Production Information

To prepare production information and make final detailed decisions to carry out the work. Final production information comprised drawings, schedules and specifications.

G. Bills of Quantities

To prepare and complete all information and arrangements to obtain a tender by preparing bills of quantities and other tender documents.

H. Tender Action

To receive and appraise tenders from builders and to recommend acceptance of an offer to build for a lump sum of money.

Amplification

The work carried out by the architect could be amplified for each design stage as follows and comprised both a management function and a design function:-

Inception

At Inception the architect accepted the appointment from the Client and obtained general background information to the project. The architect then held introductory meetings with the Client to inform him of his job responsibilities, professional practice, fees, conditions of engagement etc. The Client instructed the architect to examine the feasibility of the project and made initial statements of his requirements including proposed time scale and financial limits. The Architect then obtained site plans, ordnance survey maps and made an initial site visit.

Feasibility

At Feasibility stage the architect organised the nucleus of a design team which met to discuss the project, to establish responsibilities and to prepare a plan of work and timetable. The architect elicited all relevant information about the project from the Client by questionnaire, user studies etc. He carried out studies of the site, user information and local conditions to establish facts about boundaries, rights of way, rights of light, easements etc. Preliminary enquiries were made with Local Planning Authorities and outline planning consent obtained. This stage ended with the architect having prepared and presented to the Client a Feasibility Report.

Outline Proposals

At Outline Proposals stage the architect carried out further studies into analysis of similar projects, visiting them where possible, studying circulation and space association problems. Detailed planning solutions were tried and the effect on planning and other controls studied. Diagramatic analyses were produced and the inherent problems discussed with other design team members. A general approach to the project was thus produced and an outline scheme prepared which indicated such things as critical dimensions and main space locations and uses. The architect assisted the quantity survey prepare an outline cost plan which stated the cost ranges of the main elements of the building, such as external walls, upper floors and internal doors. A report was again prepared and submitted to the Client for approval.

Scheme Design

At Scheme Design stage the architect completed any outstanding user studies and carried out further visits and interviews as necessary. He developed detailed planning solutions in the light of all known information. A full scheme design was produced and passed to engineers and quantity surveyors for their own use and input. Outline specifications and presentation drawings were prepared and submitted to the Client, together with a fully developed Brief and explanation of operations which together formed the Scheme Design Report.

Detail Design

At Detail Design stage the architect carried out detailed design of every aspect of the project in close collaboration with the engineers and quantity surveyor. Engineers' and other specialist's drawings were received, co-ordinated and sent to the surveyor for cost checking against the cost plan allowances which were themselves examined and reviewed periodically during this stage. Any cost or constructional difficulties were reconciled at this stage as further changes in size, location, shape or cost resulted in abortive work.

Production Information

At Production Information stage the full set of drawings, specifications and schedules were prepared to enable the quantity surveyor to prepare bills of quantities. The contract particulars were agreed with design team members and the Client, and specialists' quotations obtained for inclusion in the contract documents. A list of possible contractors was compiled and questionnairs issued to enable a short list of potential contractors to be interviewed, which in turn enabled a tender list of definite contractors to be drawn up. Similar procedures were followed to select lists of specialist nominated sub-contractors and suppliers.

Bills of Quantities

At Bills of Quantities stage the architect answered queries raised by the quantity surveyor as he prepared the bills. The architect amended his drawings in the light of answers given. Letters of invitation to tender were issued to tendering contractors and confirmation received that bona-fide tenders would be submitted.

Tender Action

At Tender Action stage the architect opened the tenders received in the presence of the Client and design team members. After arithmetic checking and technical appraisal of tenders by the quantity surveyor the architect carried out any re-design necessary to reduce costs to within the Client's budget, if this were necessary. A recommendation to accept a tender was then made to the Client which led to the appointment of a Contractor and a start to actual construction work.

The Architect's Job

An architect's job was therefore both skilled and varied. It involved elements of artistic interpretation, scientific and legal knowledge, and managerial skills. Austin - Smith et al (1962) described how an architect's time was divided between attending meetings, researching information, drawing, site supervision and supervising the work of subordinates.

ROLE OF THE COMPUTER

The late nineteen sixties and early seventies saw the introduction of computing into architectural design. This computing was however far removed from the computer - aided draughting which forms the core of this study and instead harnessed the computer's calculating power with little or no graphical output. Campion (1968), Auger (1972) and Carter (1973) described the use of computers in handling large data sets, related particularly to Briefing information, whilst Chalmers (1972) illustrated the effect on staffing in the application of the CEDAR software. Two main features of the research carried out at that time emerged in the twin pillars of simulation programs and user participation in design. The unique power of computers to handle vast amounts of inter-related information was demonstrated in different ways by these two approaches.

Simulation Programes

Major promoters of building projects such as Central Government, Health Authorities and Housing Corporations realised at this time that computers could be used to simulate buildings themselves by constructing a numerical model of a particular building type. In this way the effects of the many variables influencing building design could be tried and tested in a variety of permutations with much less effort than by the manual alternative. This facility encouraged designers to modify conceptual layouts with a minimum of abortive work before deciding on a particular design. These optimising programs where prepared by a number of agencies, both academic and professional, for a small number of building types. They have been described by Chalmers (ibid), Davis (1975), Derbyshire (1975) and others and cover such important building types as schools (the SPACES program), hospitals (PHASE) and housing (SSHA). These large software program had the following characteristics:-

Limited applications, usually to only one building type,
Strong permutating and evaluating facilities,
Few operatives engaged to run them,
Required main frame computer operations,
Little effect on professional architectural office structure or on individual architects.

The application of these simulations perhaps reached their zenith with an imaginary automobile drive around a three-dimensional townscape, with constantly changing perspectives, drawn by computer as described by Negropoint (1970). On a more practical note however, the hospital project described in Chapter 5 was evaluated by Strathclyde University's main frame computer whereby the fundamental departmental relationships and massing of the structure were optimised in twenty three iterative applications of the PHASE program.

X Spelling

Participation

The power of the computer was also harnessed to produce graphical output which could be more easily understood by lay people than were conventional architectural drawings. The early to mid Nineteen Seventies saw a movement towards participative architecture whereby the ultimate building user was involved from the very early stages in the making of design decisions. This work was extensively recorded by Coleman (1973), Cross and Maver (1973), Maver (1976), Cakin (1976) and others. The cardinal principle of this decision-making style was even recently, 1987, propounded by a Royal Patron of architecture.

Computer Draughting

The most modern use of computers was in the computer draughting systems fully described in Chapter 4. These systems also relied upon the computer's ability to store, sort and manipulate masses of data, but the output was almost wholly graphical in nature with subsidiary outputs in the form of printed schedules. The role of the computer had therefore changed during the past twenty years from a purely number-crunching machine to a sophisticated draughter. It will no doubt continue to change in the future as the cost of computer hardware reduces, the power of micro-computers increases, computing becomes more widely accepted, and individual's resistance is overcome.

Examples of the draughting capabilities of the two systems studied form Appendices II and III.

CHAPTER 3

THEORETICAL UNDERPINNINGS

The objectives of this chapter are:-

- to identify the common elements in the available literature.
- to promote a particular theoretical model of organization change

INTRODUCTION

A review of the available literature on computer-aided draughting in architecture revealed a remarkable paucity of solid research - based work. A proliferation of articles dealt with the many technical aspects of computer-aided draughting, but few writers attempted to predict the impact of computerization on an organization or indeed even to report the effects of new installations, other than in purely technical terms. Ignoring technical reports, the literature was classified in terms of the following subject areas covered:- Work Patterns, Effects on Resources, Benefits of CAD, and Criticism of Working Practices.

In contrast, writings on New Technology abounded and indeed it was difficult to find a focus of opinion in the wide spectrum of current views. In the end however, Pettigrew's model of the transformation of the firm was selected as the basis of analysis for what was subsequently discovered in the two case studies reported hereinafter.

THE IMPACT OF COMPUTER-AIDED DRAUGHTING ON ORGANIZATIONS AND INDIVIDUAL ARCHITECTS

The writings examined concentrated on the effects of CAD on the patterns of working within a single organization or within a design team, and on the distribution of resources throughout the lifespan of construction projects. Other writings debated the benefits and drawbacks experienced with computer-aided draughting at both an organizational and an individual level of analysis.

Work Patterns

Hamilton and Winterkorn (1985) claimed that the successful installation of a computer-aided draughting system depended on a high level of commitment by senior managers and warned of the dangers in over-relying on one individual to achieve success. They found that CAD systems had to be utilised twelve to eighteen hours per day to maximise the return on such a high capital investment which, in turn, necessitated a multi-shift system of operation. They concluded that the computer was best suited to larger projects which involved repetitive layouts and/or component utilisation. Staff had reacted positively to computerization, although those over 40 years of age adjusted less easily to the new methods.

Reynolds (1980) again recognised the dangers of a single "whizz kid" erecting barriers around the computer system to secure his own position within the firm. Integration of all staff with the computer system was believed to be an essential element in a successful implementation, as was the establishment of a trustful and co-operative climate of working with others. He believed that it took two years from the date of installation for a system to work properly.

Evans (1981) placed great emphasis on the adequacy of staff training for CAD work and believed that this could take some three to six months.

Guttridge and Wainwright (1973) contrasted the traditional position of the architect achieving a measure of satisfaction from the graphic representation of his design with the computer-aided situation where he was faced with the more automated form of presentation. They equated this change with a loss of some job satisfaction.

Trickett (1980) emphasised the need for management functions within a computer-aided design system. By this means a project manager could control design work by allocating work areas to designers either physically, eg Pump House, or by types of components, eg internal doors. The designer was permitted to access and modify his own area of work and to access only other designers' areas.

Overview

The implications of the foregoing were that the introduction of computer-aided draughting would impinge quite dramatically on both the organization as a whole and on the individual in particular. The magnitude of the capital investment demanded the attention of senior managers in the organization to ensure success. Careful integration of the computer system into the organization was requred involving as many people as practicable with reliance on only a few key individuals to be avoided.

For the individual architect the foregoing heralded some major changes in their working lives. Shift working, tighter managerial controls, longer working days, more stress, different work methods were all forecasted following the introducation of CAD.

Resources

Mitchell (1977) reported a shift in the distribution of resources when using computer-aided draughting systems on construction projects. Whereas the maximum resources were employed during the Production Information stage of a manually drawn project, the computer system demanded fewer resources at that time but a greater input at Briefing and Scheme Design stages. The comparative graphs are shown in Fig. 1 which also demonstrated the smaller fluctuation in resources requirements during the currency of a computer-drawn project then in the manual alternative.

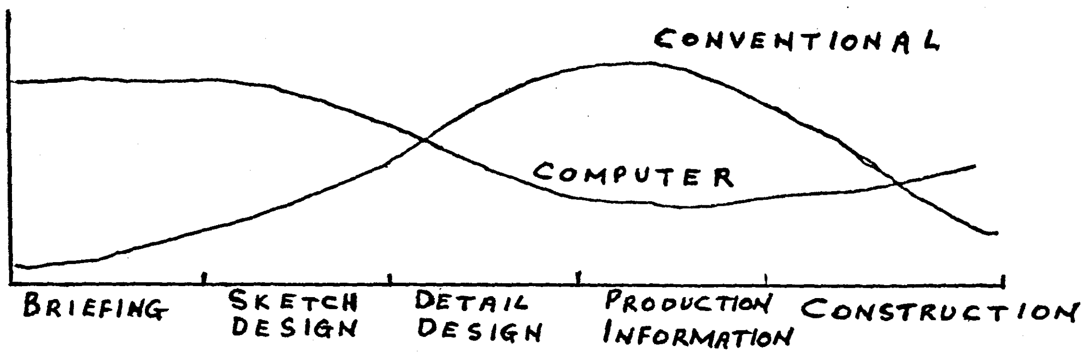


Fig. 1 : Comparative Distribution of Resources

Davison (1980) graphed the comparison of man hour savings between an actual computer-drawn scheme and the estimated manual alternative on a major Middle Eastern project. Fig. 2 illustrates this comparison and showed not only the total absence of peaks and troughs in computer resources, but also the much lower level of human resources required.

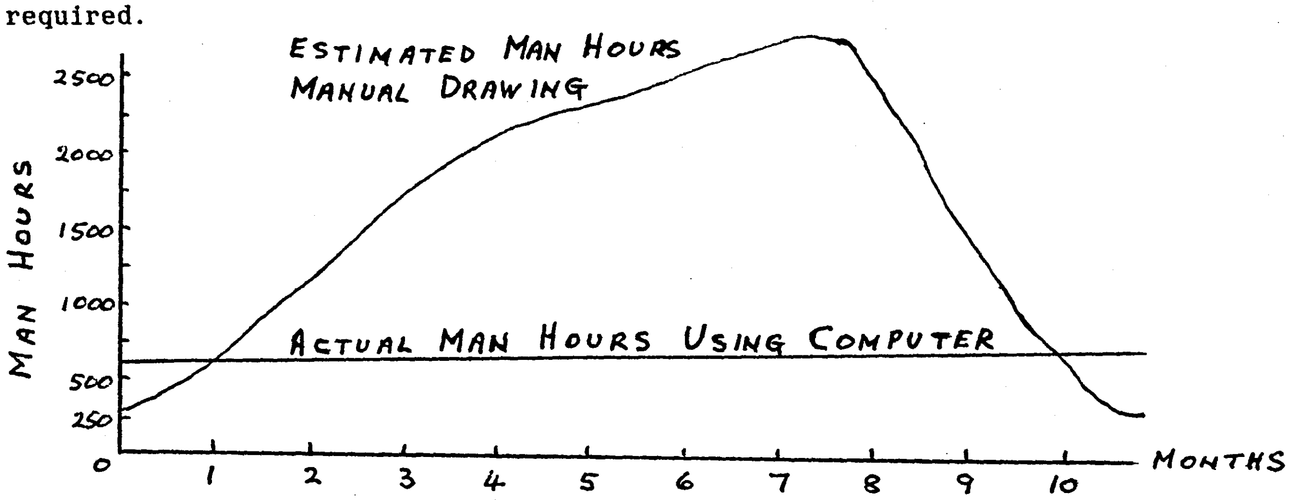


Fig. 2 : Comparative Man Hour Requirements

Overview

The potential major effects of computer-aided draughting emerged from the foregoing in terms of the computer's ability to smooth out sometimes large fluctuations in production requirements. This capacity to accommodate fluctuating demands was regarded as of fundamental importance which had major implications on human resource requirements, project management within design offices and long-term employment levels of architects.

Benefits of Computer-Aided Draughting

Guttridge and Wainwright (1973) identified a number of important problem areas in architectural practice which a computer draughting system could help resolve. The areas were:-

Staff	- quality, cost, effective use of, and turnover
Administration	- resources allocation, estimation of staff capability, crises handling
Accommodation	- physical space for office staff
Specialist Consultants	- need to communicate with and co-ordinate other professionals
Clients	- dealing with client's changes
Client's Brief	- identifying client's requirements
Production Information	- timing and communicating information

Maver (1978) reviewed the computer-aided draughting systems then installed in Cheshire County Council, Scottish Health Service, Oxford Regional Health Authority, Scottish Special Housing Association, GMW Partnership and Strathclyde Regional Council. He concluded that significant benefits in design quality and efficiency had already been enjoyed with these installations and that the potential for development of these aids to design decision - making and management was virtually limitless.

Hamilton (1981) believed that much of the potential benefits of multi-disciplinary use of a draughting system would be derived from the fact that drawings were held by the computer as numerical models. Thus, given the correct structuring of the model, it would be possible for each profession to extract selectively from the model and operate on information created as a drawing by another member of the design team.

Davison (1980) identified both tactical and strategic advantages accruing from the installation of a RUCAPS draughting system. Apart from purely technical considerations, the tactical advantages lay in speed of drawing production, cheapness of operation because fewer man hours were required for a given level of output, the use of smaller project teams which in turn released senior staff from traditional control and co-ordination duties and enabled them to spend more time in solving design problems, and the computer's ability to issue final drawings which incorporated all late revisions. The strategic advantages of RUCAPS lay in programming of work through the office by smoothing out the peaks and troughs of the workload, and in not hiring and firing staff; in staffing where CAD was perceived to be a positive solution to expected worsening staff shortages; in competition with other architectural practices by giving a competitive edge in the face of competition as fee bidding became part of normal practice.

Campion (1980) listed the benefits of computer-aided draughting in a medium sized architectural practice as:-

Single Project Representation - each component was drawn only once

Multiple Scale Drawings - any scale was drawn from full size numerical model

Elemental/Composite Drawings - differenct drawings produced for different uses or recipients

Quality, Accuracy, Speed - all superior to manual equivalent

Automated Schedule Production - a free by-product of drawn information

Better Use of Standards - encouraged the use of standard drawings

Greater Throughput - ability to handle peak drawing workloads

Better Management of Workload - easy manipulation of data.

Collins (1980) reported major benefits using the BDS System in terms of cost and time in drawing production achieved. Designers could concentrate on design or detailed design in sketch form and allow the drawn output to be dealt with by the computer.

Reynolds (1980) calculated that as a realistically powerful interactive graphics device cost the same as employing two draughtsmen, and as the machine required one man to operate it, productively had to be at least three times greater than manual draughting for CAD to be cost effective.

Overview

From the foregoing it was clear that computer-aided draughting brought major benefits to architectural practice which were achieved at both tactical and strategic levels of the organization. At the tactical level the benefits were gained through greater productivity, reduced costs, easier management and control functions, increased product quality, concentration of designers on design as opposed to drawing production. At the strategic level CAD gave a competitive edge to the organization, smoothed variances in workload, facilitated greater throughput and resolved staffing difficulties.

Criticism of Working Practices

Cross (1978) assessed computer-aided draughting systems and found that designers' work-rate was intensified, the job was more stressful, the design process was fragmented and rationalised, and designers were put out of work.

Cooley (1973), (1980) and (1987) consistently argued that the use of CAD lead to the deskilling of the design function and a loss of job security, particularly for older men, giving way to structural unemployment. He tabled fourteen "indicators" which followed the introduction of a computer-aided draughting system:-

1. The subordination of the designer to the requirements of the computer with shift work or systematic overtime to counter the increasing rate of obsolescence of the machine.
2. Emphasis upon machine centred systems rather than human centred ones.
3. Limitation of the creativity of the designer by standard routines and optimisation.

4. Domination of the subjective value judgements of the designer by the objective decisions of the system ie the quantitative elements of design will be treated as more important than the qualitative ones.
5. Alienation of the designer from his work.
6. Abtraction of the design activity from the real world.
7. A fragmentation of design skills (over specialisation) with a loss of panoramic view, together with the introduction of scientific management techniques and work measurement.
8. De-skilling the design function.
9. Increased work tempo as the designer is paced by the computer.
10. Increased stress, both physical and mental.
11. Loss of control over one's work environment.
12. Growing job insecurity, particularly for older men.
13. Knowledge obsolescence.
14. The gradual proletarianisation of the design community as a result of the tendencies indicated above, and in consequence of this, the considerable increase in trade union membership and industrial militancy.

Cross and Cooley provided a comprehensive and damning criticism of the human consequences of introducing computer-aided draughting into a design organization. So much so that these criticisms provided a checklist against which the findings of the case studies reported hereinafter were compared. The degree of agreement or otherwise found between the foregoing and the research field work determined the conclusions reached by this study.

A MODEL OF THE TRANSFORMATION OF THE FIRM

The interpretation of organizational changes depended to some extent on the perspective from which it was viewed. Thus, there were currently a whole range of available perspectives ranging from incrementalism, Quinn (1980), to garbage can, March and Olsen (1976), to political and cultured views of process, Pettigrew (1985a). The perspective of the author was important as was time, which set a frame of reference for what changes were seen and how these changes were explained.

In his studies of the importance of leadership in the transformation process Pettigrew (1987) sought not prematurely to downplay the explanatory role of leadership behaviour in any theory of strategic change, but to address questions about leadership within a sufficiently broad analytical approach. He warned of the singular theory of transformation process or of social and organizational change. Instead, he urged the researcher to look for continuity and change, patterns and idiosycrasies, the actions of individuals and groups, and for processes or structuring.

Having identified the weaknesses in the current literature on leadership and on change, Pettigrew (1985b) suggested that one way to respond was to encourage a form of research which was both contextualist and processual in character.

The starting point of Pettigrew's analysis of strategic change was the notion that formulating the "content" of any new strategy inevitably entailed managing its "context" and "process". Context itself was subdivided into outer and inner components. Outer context referred to the social, economic, political, and competitive environment in which the firm operated. Inner context referred to the structure, corporate culture, and political context within the firm through which ideas for change had to proceed. Content referred to the particular areas of transformation under examination. The process of change referred to the actions, reactions, and interactions from the various interested parties as they sought to move the firm from its then present to its future state. The "what" of change was encapsulated under the label content, much of the "why" of change was derived from an analysis of inner and outer context, and the "how" of change could be understood from an analysis of process

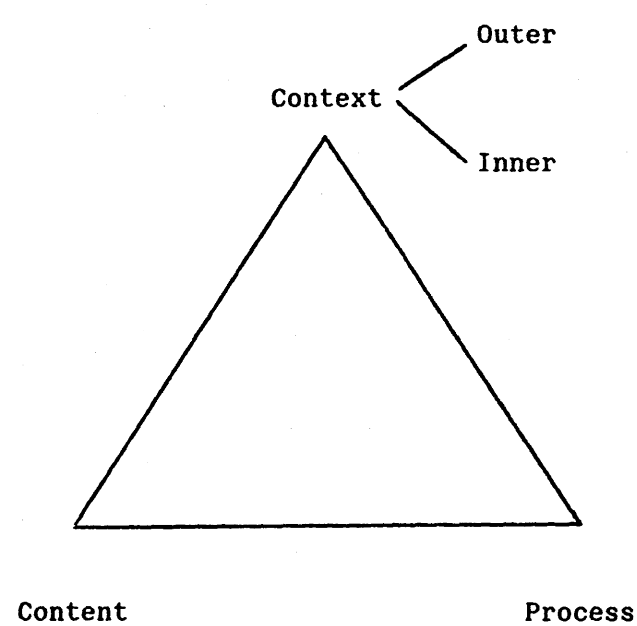


Fig. 3: Pettigrew's Model of Strategic Change

Pettigrew's analysis of the impressively researched ICI Case Study (1985a) was that real strategic change required crisis conditions; and, by implication, senior executives who may have been pushing for change in pre-crisis circumstances did not have sufficient leverage to break through the pattern of organizational inertia. He did not however argue that the process and content of strategic changes could be explained solely by economic and business-related environmental disturbance. Also present were processes of managerial perception, choice, and action influenced by and influencing perceptions of the operating environment of the firm and its structure, culture, and systems of power and control. Crucial to the character and content of the strategic changes made at the revolutionary points when those changes were actually delivered were the antecedent factors and processes of the precrisis period. Crucial in the precrisis period was the process through which the dominating ideology mentioned in earlier contexts was first challenged and then changed.

The foregoing model of strategic change was used as the basis of analysis of the findings of the case studies reported in chapters 5 and 6 hereinafter and analysed in chapter 7.

CHAPTER 4

COMPUTER DRAUGHTING

The objectives of this chapter are:-

- o to examine the functions and capabilities of generic computer draughting systems
- o to identify the particular facilities of the RUCAPS and GDS systems
- o to summarise the features of the two systems in terms of information capture, storage, manipulation and distribution
- o to list the known computer draughting systems and their users

INTRODUCTION

Computer draughting was a method of preparing drawings by means of a computer instead of by a traditional draughtsman. Dimensional information was input into a computer which first stored and then manipulated it as the operator required. Appropriate instructions were then transmitted by the computer to an electronically operated plotter which physically drew the required output on to paper by means of a pen. This system emerged in the late 1970's and was also known by the slightly extended title of computer aided draughting (CAD).

Computer aided architectural design (CAAD) had been available to the architectural profession since the mid 1960's, transforming large data sets but with little graphical output. These systems could, for example, transform a school curriculum into schedules of classroom accommodation requirements and calculate the relative merits of placing different permutations of house types on a sloping site.

GENERAL SYSTEMS

The hardware configuration of a general draughting system is shown in fig. 4 below. Certain items of equipment may be remote from the user, e.g. the computer, disk storage unit and plotter were frequently situated in their own glass-fronted, air-conditioned room.

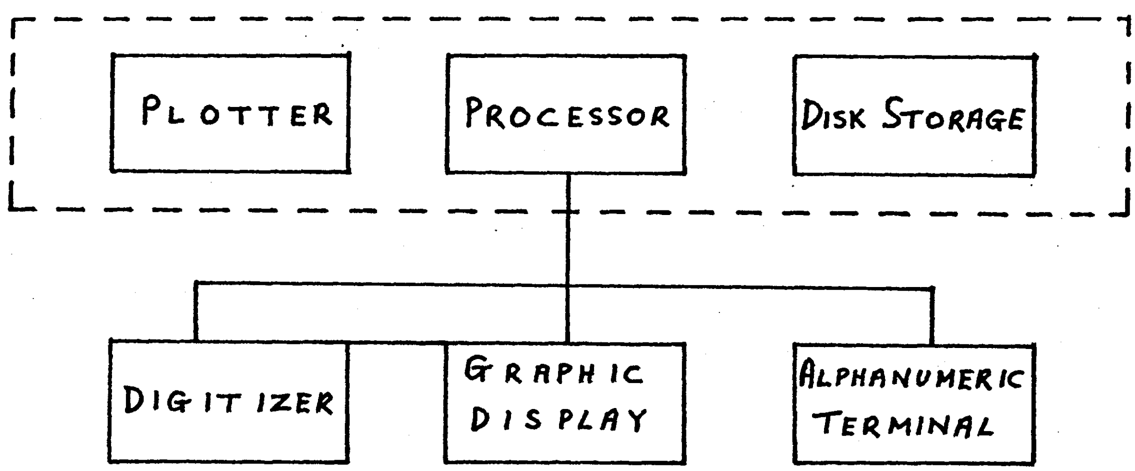


Fig. 4: General Principles of Draughting Systems

The actual equipment operated by the user was normally described as the workstation and consisted of a visual display unit (VDU) and a digitizer. Some draughting systems did not permit direct access to any equipment at all and, in these cases, the user prepared the drawing description on coding sheets using a drawing language or set of instructions which were subsequently input to the computer via punched cards or other non-graphical means.

The method of input varied with the draughting system. Interactive systems produced a display of the drawing as it was input so that checking for errors and correcting them could be carried out continuously. This was an important facility because the input of drawing data was normally lengthy and error prone.

The overall structure of a draughting system could be divided into four main components whose interrelationships are shown in fig. 5.

a method of drawing description and storage;

a set of user controlled functions;

a library of details;

a drawing output.

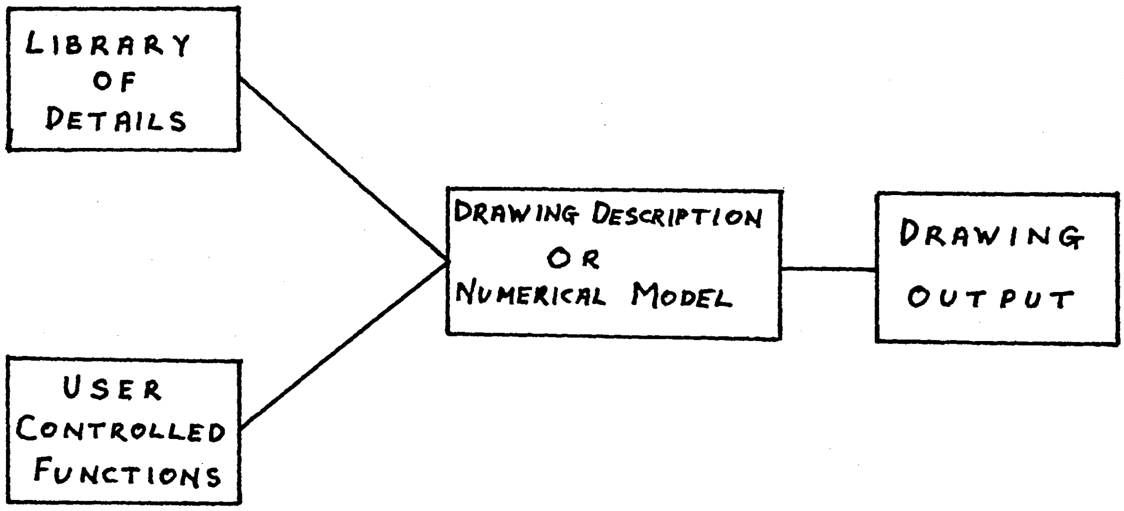


Fig. 5: Idealised Structure of a Draughting System

Method of Drawing Description and Storage

One of the fundamental principles of a draughting system was the creation, storage and manipulation of a numerical model of a drawing or set of drawings. The precise nature of this model varied with each system and the user might not even be aware of its existence.

The input or drawing creation stage in the use of a draughting system was important, not only because it employed more computing and man-time than any subsequent stage, but also because decisions taken at this stage could have significant effect on the way in which the data could be used. In manual draughting, each drawing was a separate entity but nothing could be further from the case in the effective use of computer draughting. It was in the ability to store and re-use parts or all of previously created drawings that many of the potential benefits of computer draughting lay. A drawing in draughting system terms could be a structural combination of various items of line work and text which may or may not have been complete drawings in themselves. The precise nature of this structure and the terminology used varied with each draughting system and fig. 6 illustrated the general principles.

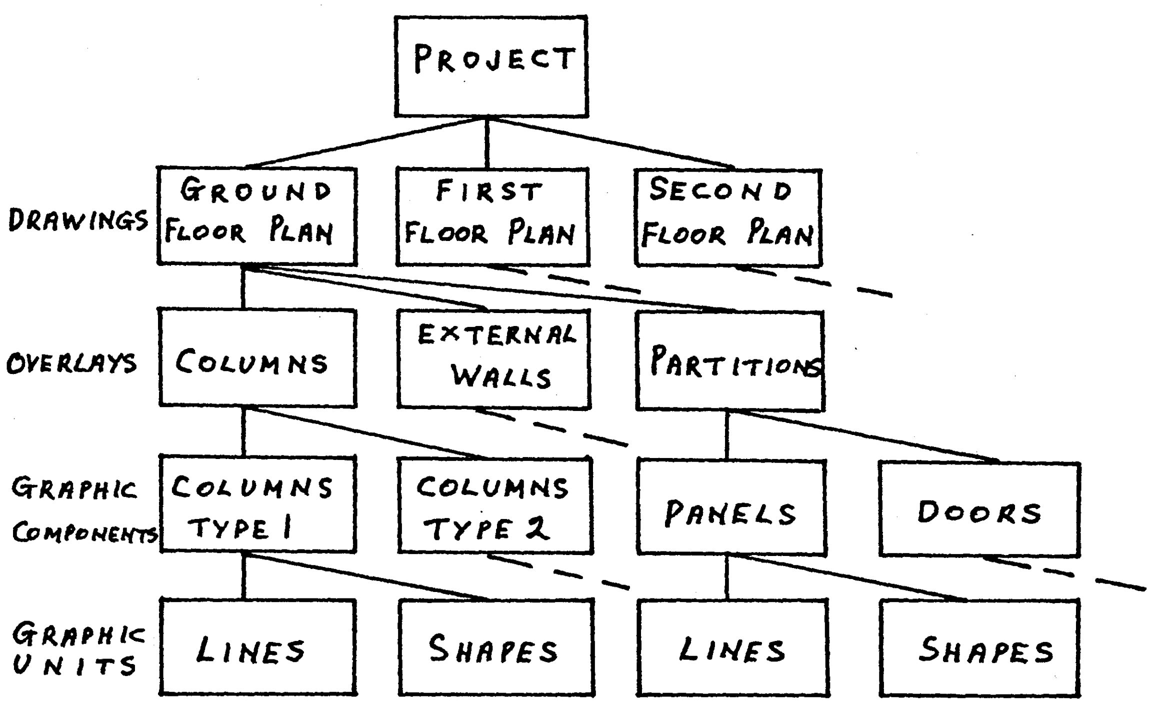


Fig. 6: Tree Structure of Draughting System

Library of Details

The identification, storage and manipulation of details was another of the fundamental principles of computer draughting. These details may have been simple geometric shapes which were simply an aid to drawing production or complex shapes representing either building components or parts of a building.

Systems were supplied complete with libraries of basic shapes or organizations built up their own library as required. Although the effort required in setting up these custom-built libraries was considerable, the subsequent re-use and control that this provided over drawing content and quality yielded major benefits.

Drawing Output

Much of the work of producing the drawing description or numerical model involved viewing parts of the required drawing on the visual display unit screen. Due to the problems of distinguishing detail, it was difficult to view all of a drawing of any size and complexity on a screen. Thus it was only on plots of drawings that the content could be seen in its entirety at a reasonable size. The computer's numerical model may not have been in a form which could be plotted directly and additional work may have been required by the user to produce an output from the model which could then be plotted. The plotter may have been remote from the user and some time could elapse before the finished plotted copy of the drawing was received.

User Controlled Functions

A number of common user controlled functions could be identified:

Basic Linework - the ability to draw lines, circles, arcs of circles, etc. to create details for the building or to produce parts of the drawing not represented by such pre-defined details.

Positioning - the provision of a grid or coordinate axis system which enabled details or shapes to be located accurately. Positioning could have been either absolutely with reference to some global axis or origin, or relatively by

reference to some nearer point or "local" origin.

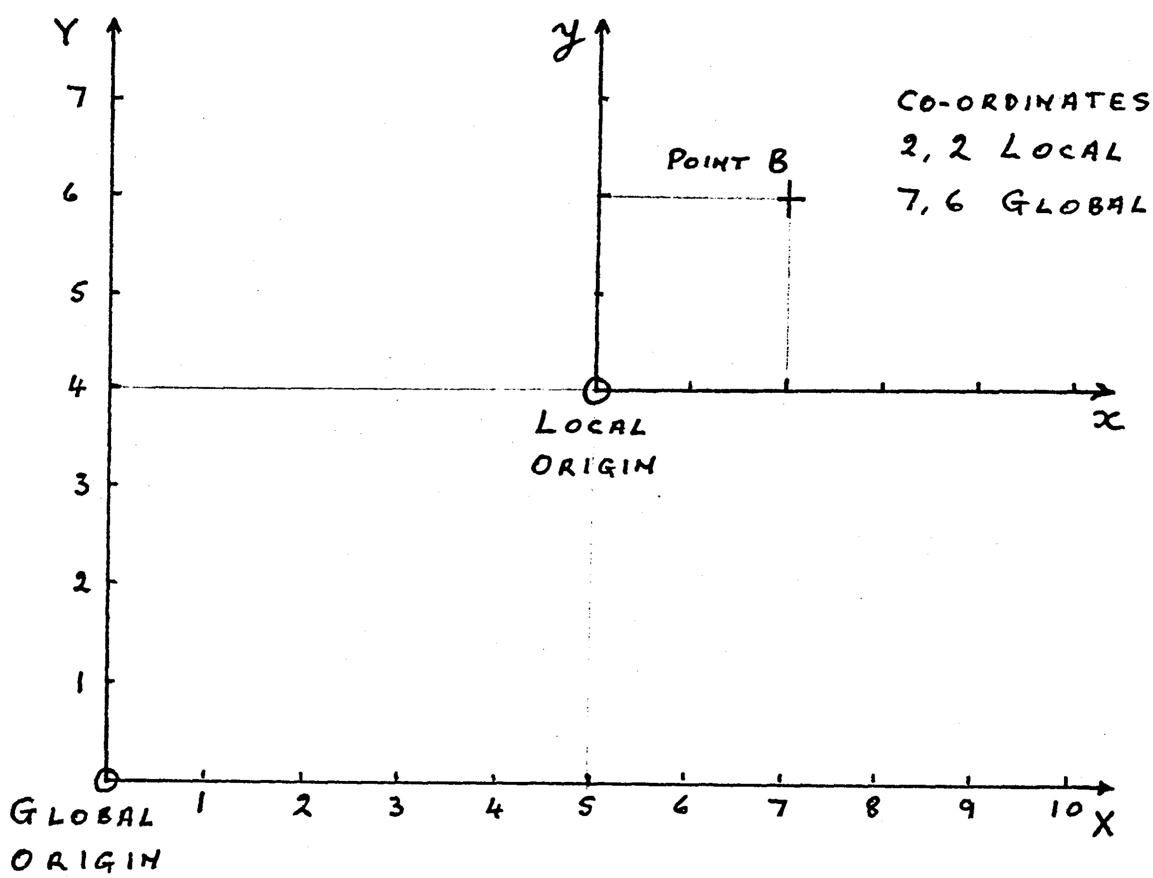


Fig. 7: Global and Local Origins

Deleting - the ability to delete details or parts of a drawing without having to reconstruct all or major parts of the drawing.

Adding - the ability to add graphical information to existing work.

Editing - the ability to modify drawings or details without having to repeat the entire process of creation.

Translation - the movement of a detail to a new position with preservation of orientation and scale.

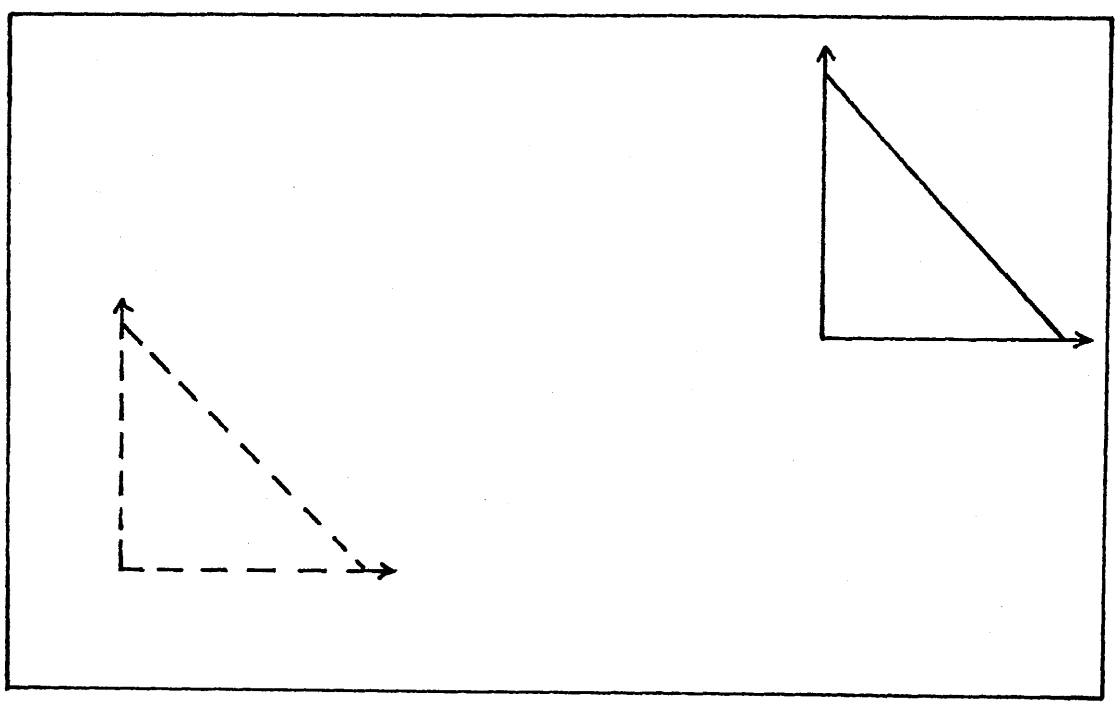


Fig. 8: Translation

Rotation - the rotation of a detail about a centre, not necessarily within the detail.

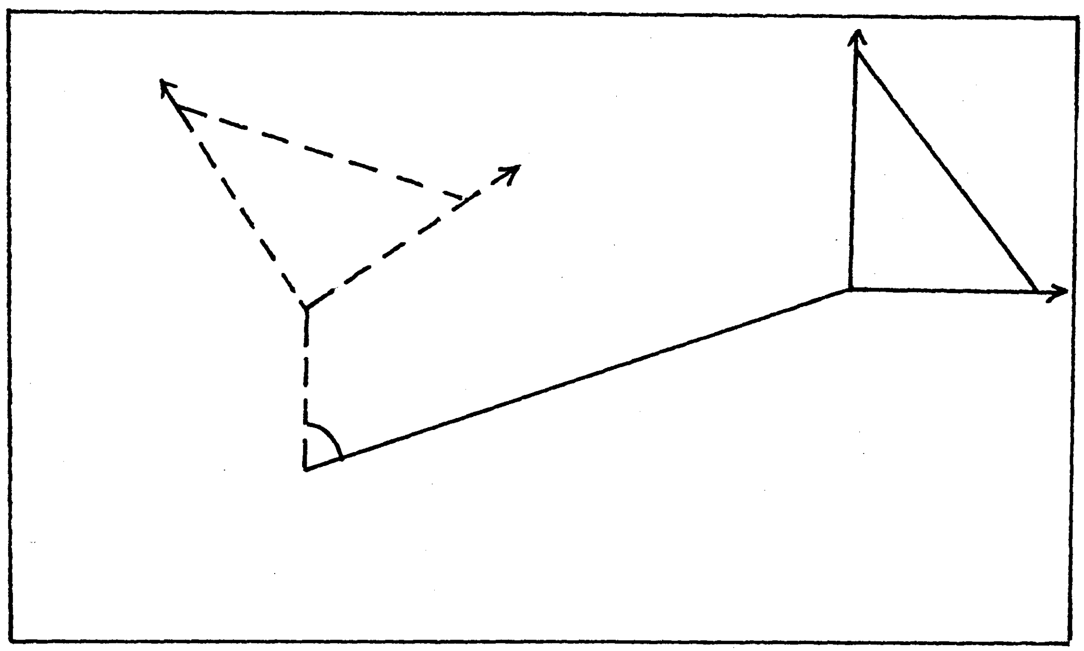


Fig. 9: Rotation

Mirroring - the flipping of a detail to produce a mirror image.

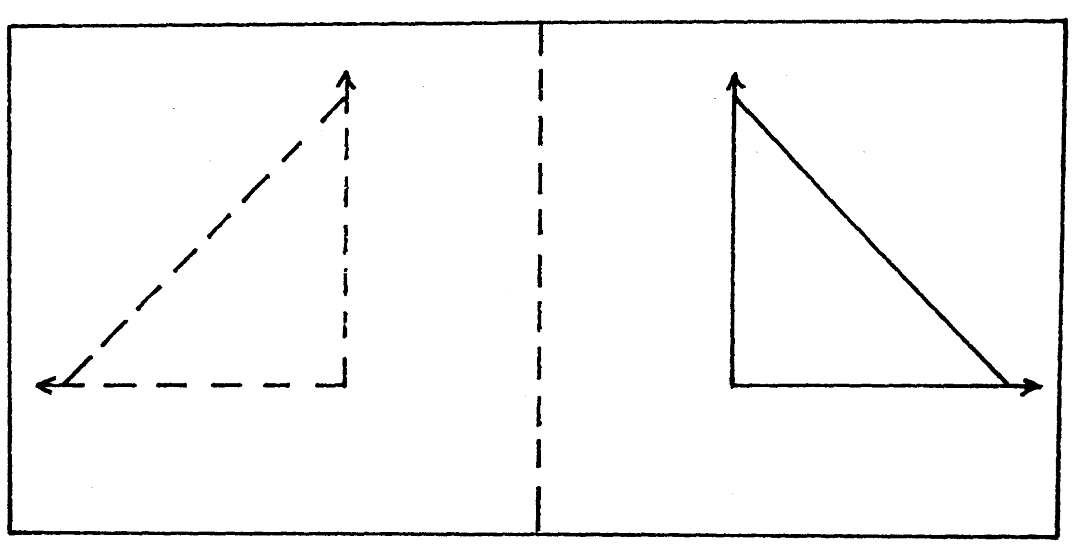


Fig.10: Mirroring

Windowing - the ability to view part of a whole drawing at the same scale as the drawing.

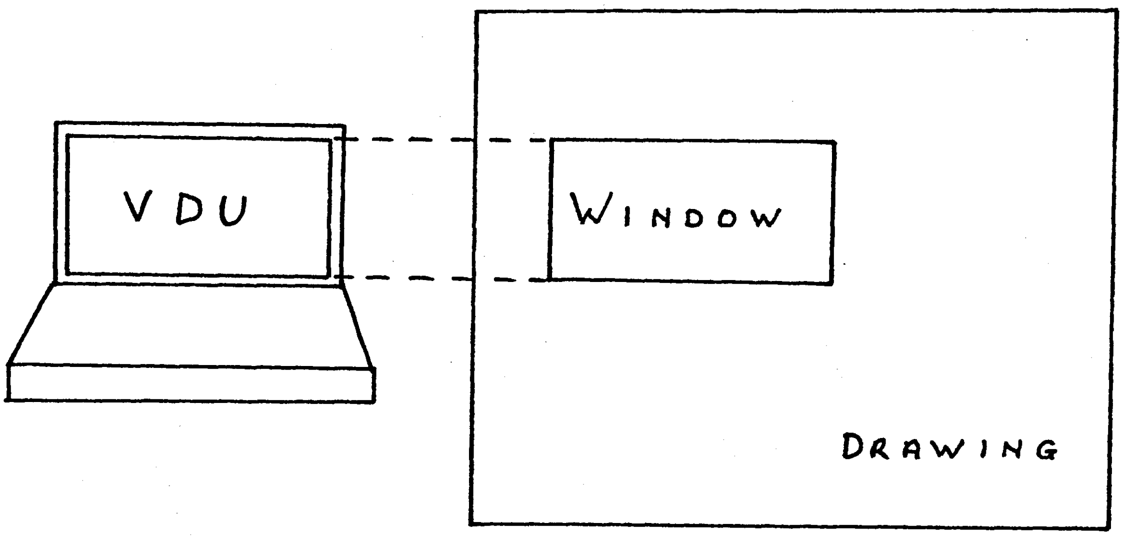


Fig. 11: Windowing

Overlays - a technique whereby a drawing could be composed of a number of layers, each of which could be produced as a separate drawing, e.g. furniture could be shown on a general arrangement drawing or as a separate furniture drawing.

Scaling - the process whereby a detail display on the screen could be enlarged or reduced by a given factor.

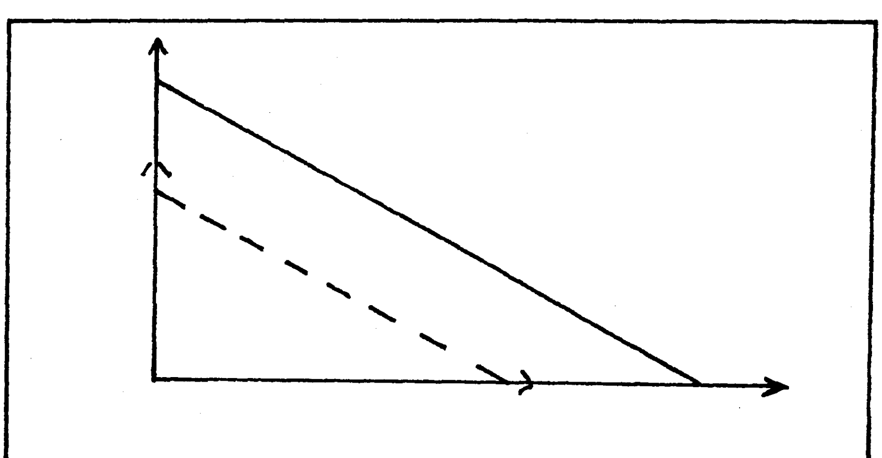


Fig. 12: Scaling

Scale - the ability to give input dimensions at full size and later specify the required drawing scale which could be different for different purposes.

General Description of Hardware

The core of a computer draughting system was a computer or central processor unit with a mass storage device, such as magnetic disk or tape. Connected to the computer were its peripherals comprising plotters, digitizers and visual display units.

Plotters

Three main types of plotters were available to produce the drawing output:

Drum plotters required special paper with perforations down both sides which engaged sprockets on the drum to give the necessary positional control

of the paper. A number of drawing pens of different thicknesses and colours moved along a fixed bar. Drawings were made by putting the appropriate pen to the paper surface and moving it along the bar or, if a transverse line was required, by rotating the drum against the stationary pen. The drawing could also be fully annotated in this way and detail, tracing or polyester paper could be used.

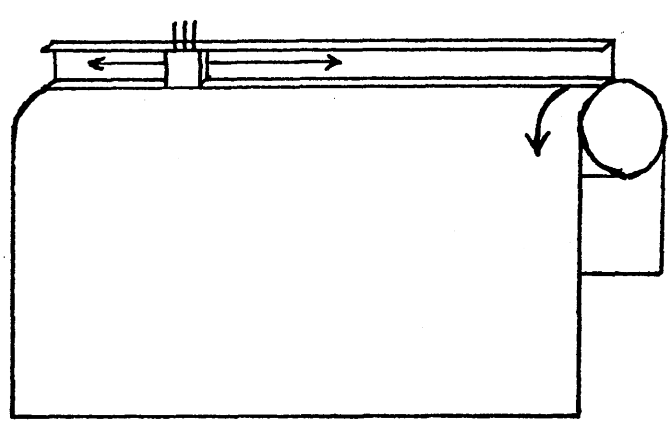


Fig. 13: Drum Plotter

Flatbed plotters had the paper or draughting film fixed to the plotter bed and the pen could move simultaneously in two perpendicular directions. This type of plotter was generally faster and more precise than the drum variety but was also much more expensive.

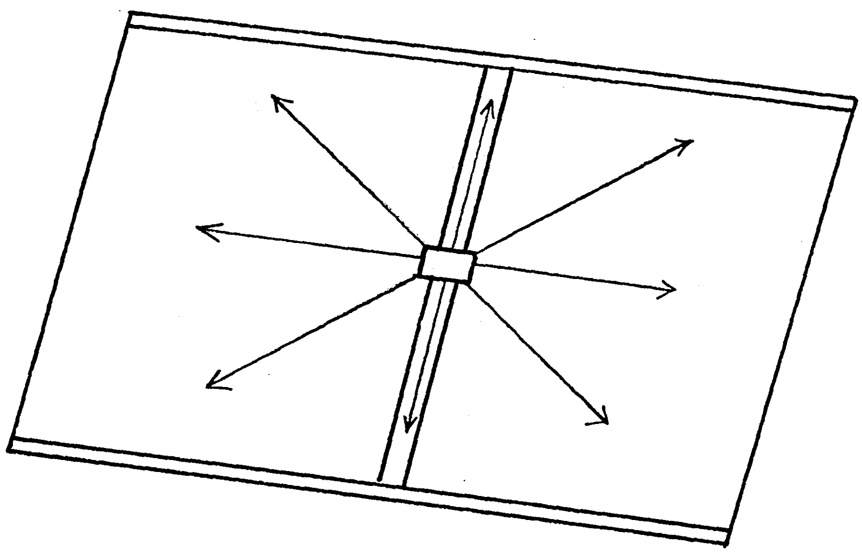


Fig. 14: Flatbed Plotter

Electrostatic plotters were fundamentally different from the other plotter types since they produced a drawing at a rate independent of the drawing complexity. Electrostatic plotters wrote on to paper moving across an array of fixed nibs at speeds of 2 to 10cm/second. Lines were represented by a series of dots and resolution depended on the size of the nibs. Speed of drawing was achieved at the expense of software and computing resources because, like a television picture, the whole drawing was first processed and stored in such a way that it could be scanned from top to bottom.

Digitizers

The digitizer board was used along with the visual display unit for putting information into the system and was the electronic equivalent of a drawing board. It was similar in appearance to a standard drawing board, the size of a small table, with a matrix of fine wires embedded under its surface and was controlled by a microprocessor. When a drawing was fixed to the board, a moveable "cursor" or "puck" was used to identify points on it.

The cursor was a small hand-held pad with fine cross wires for locating it as required on the board. When the button on the pad was pressed, the coordinates of its position were read by the controller and transmitted to the control processor.

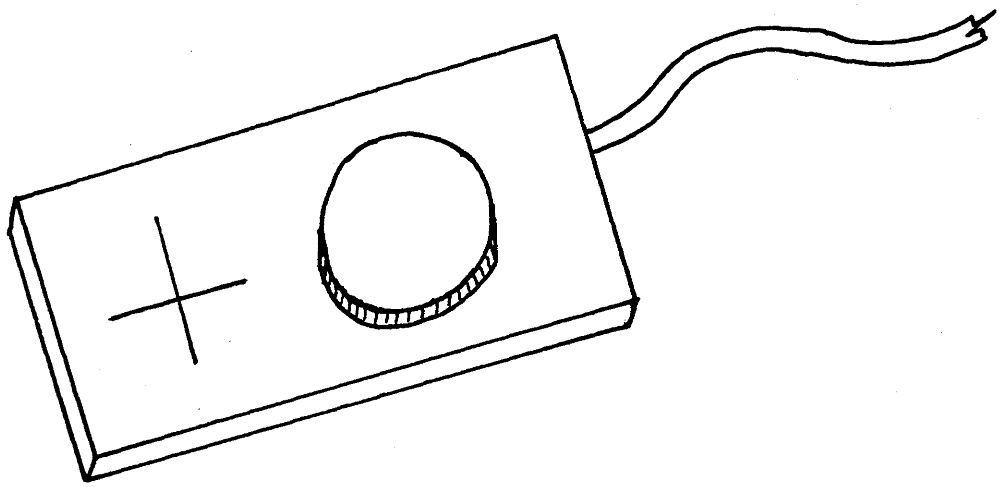


Fig. 15: Cursor

Visual Display Units

Again, there were three main types of visual display units available: storage tubes, refresh displays and raster scan schemes. The first two were vector displays, which were physically operated by a beam of electrons stimulating a phosphor coating on the tube to glow. The storage tube used a fine grid behind the phosphor which held the charge and kept the phosphor glowing. The refresh screen had no mesh and redrew the picture as the phosphor lost its glow. This involved drawing at high speed and required the screen to be relatively close to the processor.

Storage tubes had no facility for erasure of part of a display but could add to one. Deleted parts of a display were usually crossed out and removal of the deleted part required the display to be redrawn.

Refresh displays stored the picture image in a display file which required some memory and processing capacity to handle it and its manipulation. The constant need to redraw the picture could cause flicker to occur on the screen where a very high line content was being displayed. Refresh displays were usually equipped with a light pen with which it was possible to "point" to information in the display.

Raster scan displays were similar in nature to a television screen and were not normally able to provide the degree of precision required for a draughting system. Recent developments had improved the resolution of raster displays but they still could not match the vector displays for line resolution. They could, however, show colour and grey scales which could be useful.

INDIVIDUAL SYSTEMS

Reiach and Hall's system was known by the acronym RUCAPS, for Really Universal Computer Aided Production System. It cost £90,000 and was installed in March 1979. The equipment comprised:

a mini-computer central processor

a disk storage system

a teletype (a keyboard with printer)

a digitizer board and controller

a drum plotter

a visual display unit with keyboard

a remote terminal

The system was normally run 24 hours a day and often over weekends. It was not manned at night as the plotter could be left to work unattended. The central processor had 128 kilobytes of on-line memory and off-line storage was provided by two 5 and two 10 megabyte hard disk cartridges.

The teletype was used to give the system instructions and had special command keys as well as the full range of keys found on a typewriter. It was the main system control console, a terminal from which to drive the plotter and a printer for various listings such as components stored in the computer memory.

The digitizer had a command panel or "menu" on part of the board comprising a block of numbers and letters which were used to type in room names and other labelling for the drawing and a separate block of commands which could be used to manipulate the visual display, e.g. rotate components. These letters and commands were read by touching the appropriate point of the command panel with the cursor.

The visual display unit was a refresh type with a light pen used to locate components displayed on the screen as an alternative to the digitizer cursor. With the appropriate commands, a component could be moved around on the screen by "floating" it to the required position, among other methods of location.

The remote terminal was a raster scan screen with keyboard and was added to the installation later. It was located in a room adjacent to the computer room and allowed an operator to define drawings independently of, and at the same time as, the use of the main inputting devices by other operators. This increased the capacity of the system to produce drawings because a computer session on the principal input devices no longer had to be allocated to the essential but mundane task of telling the computer what to draw.

The RUCAPS computer aided draughting process had three main stages:

1. Preparation

Before the computer made a drawing, the architect had to define the components that would appear on the drawing and place these components in their correct relationships. A component could be an actual building element, such as a column or a door, or just a shape, such as a hexagon. The architect first defined the component on a component detail sheet, which listed the drawing pen choice, line style and pen movements required to draw the component. This information was put into a "component library" through the keyboard and was stored off line on disk.

The component library was specific to a current project but, once in the library, components could be recalled for any other projects to be drawn by the computer. This was useful because many basic building components are standard, such as windows and doors, and different types of buildings, such as hospitals and research laboratories, contain similar components. Each component was defined so that elevations, sections and plans could be drawn and was given a category number in order that the drawings could be built up as required. Individual components could be pre-assembled into larger components (called "super components"). The library at the time of this study contained four and a half thousand components.

The RUCAPS system had other special features that made the preparation work easier, including:

- o stretchables - it could effectively and easily create new components by altering a single dimension of a component that was already defined;
- o dimensionables - it could create lines running from a given point for a specified distance at any angle
- o text - it could put lettering and numbering on drawings as required;
- o sequential numbering - it could put successive room numbers on plan drawings;
- o intervisibility - when drawing elevations, it suppressed features that could not be seen from the particular viewpoint.

2. Drawing

The building model was established by the operator first recalling components one at a time from the component library on to the visual display screen. After rotating and adjusting as required, the components were positioned by the operator pressing the digitizer cursor at their anchor points on the drawing on the digitizer board, and were recorded on disk as being in that position. The components then appeared on the screen in position. Anchor points were defined with reference to grid lines set at desired intervals. Other lines not readily definable as building components were drawn as stretchable lines and annotations were added by defining their location and size, and spelling out the characters on the digitizer menu. When this procedure was complete, the drawing was defined in the drawing catalogue which could then be "requested" for plotting.

The architect at this stage defined:

- o the part of the building to be drawn;
- o the scale to which it was to be drawn;
- o the required view (plan, section or elevation);
- o the required combination of component categories.

Another use of the category coding system was the ability to distinguish between different "groups" of items. "Group 1" items could be those supplied by the building contractor. "Group 2" items could be those supplied by the client, but fitted by the contractor. "Group 3" items could be those supplied and fitted by the client. These could all be stored in the computer and shown on the plans but only group 1 items shown on elevation drawings.

Individual drawings could be combined on one sheet and these could also be rotated and "handed" (to produce a mirror image) on the sheet. Elevations and sections (vertical slices through a building) were drawn automatically from the component information and a room layout could be assembled showing a plan and an elevation of each wall of the room without any further input by the architect.

3. Editing

When changes had to be made to a drawing, new components could be substituted for the existing ones in the building model and all occurrences of a component to be changed would be altered. Incorrectly positioned components could be relocated. Editing was done using the digitizer board cursor or the lightpen on the visual display unit. Later drawing requests all contained the updated information.

Very little actual design work was done at the computer, although design alterations could be made easily in this way. The overall design concept was always completed before the component library was compiled and the model assembled in the computer. Editing mainly involved alterations to the positions of building elements.

Baxter Clark and Paul's system was known by the acronym GDS for General Draughting System. It cost £150,000 and was installed in March 1982. The equipment comprised:

a mini-computer central processor

a disk storage system

a drum plotter

two workstations, each comprising a visual display unit

and an alphanumeric visual display unit

a digitizer shared by the two workstations.

The central processor had 512 kilobytes of on-line storage and 64 megabytes of off-line hard disk storage.

The system was operated interactively. Graphic data was input and manipulated on the visual display unit and commands and text for drawings were input on the alphanumeric VDU. The digitizer was provided for the input of information direct from existing drawings and, while it could be used to "drive" the system, it was not an essential part of the workstation.

GDS was operated by groups of commands, each group providing a particular type of function. The commands were presented to the user in the form of a menu, either on the screen of the visual display unit or on the digitizer. The VDU was of the storage tube variety.

Unlike RUCAPS, the basic graphic unit of GDS was not a predefined component but an "object". A separate preparation phase was, therefore, unnecessary and drawing commenced immediately.

An object consisted of graphic blocks and, where appropriate, text blocks. A graphic block represented a continuous line consisting of straight and curved segments. An extensive range of geometrical construction facilities was available which enabled blocks and objects to be created on the VDU with the minimum of coordinates input by the user. These facilities allowed the line being created to be given a relationship to graphics elements already on the screens, e.g. through existing points, normal to existing lines, tangential to circles and arcs, etc. Absolute locations could be specified via the keyboard where required.

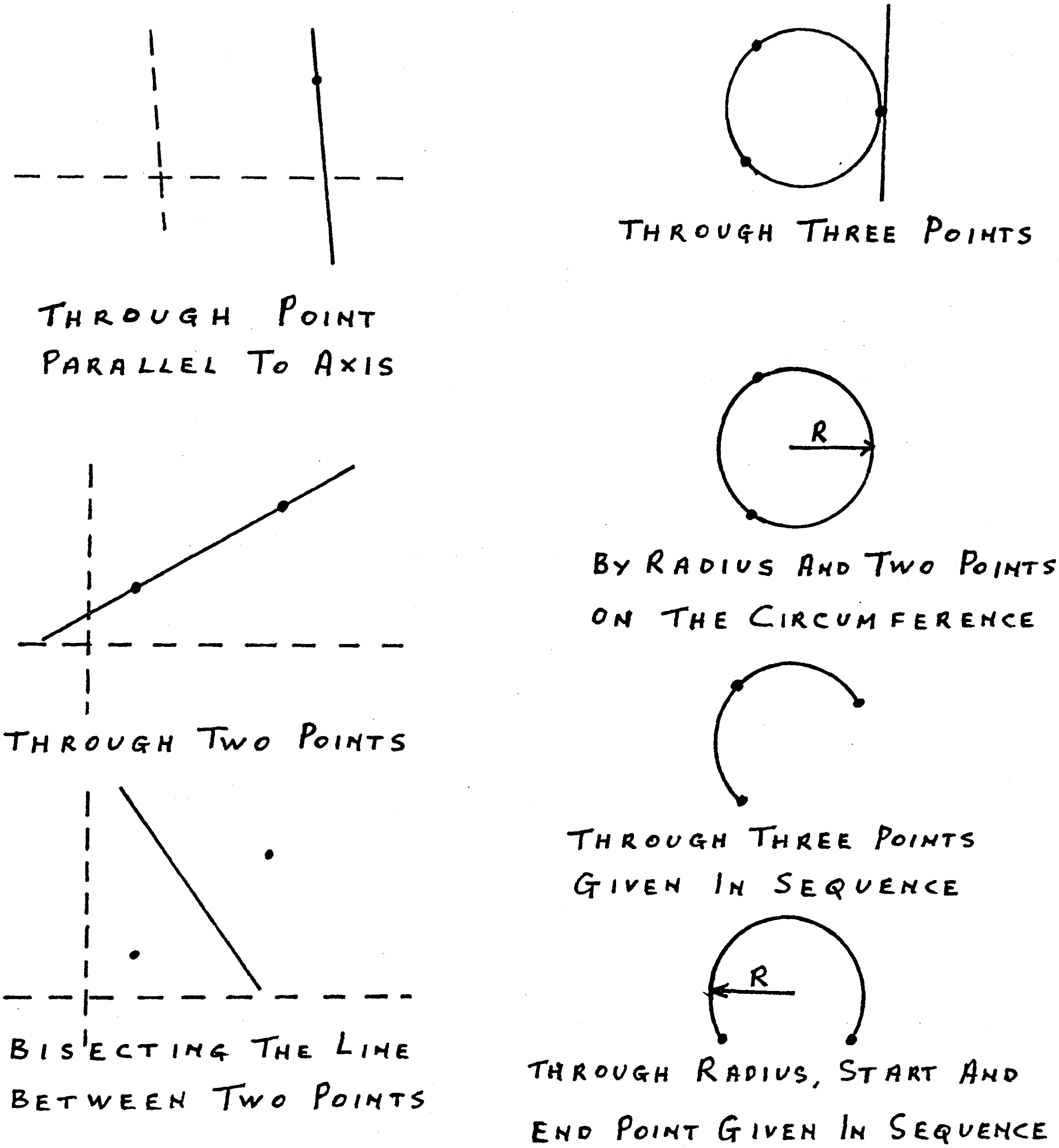


Fig. 16: GDS Geometric Construction Facilities

GDS provided several standard libraries of parametised shapes and users could also create their own special libraries. Objects were given a name and version number for selected drawing and editing. Other special features included:

text	-	could put lettering and numbering on drawings by means of text blocks.
measurement	-	it could calculate the distance between two points, the displacement in x and y between points, the angle between three points and the radius of an arc. For a closed block, it could compute the centroid, area, perimeter, moment of inertia and radius of gyration.
dimensioning	-	it could automatically draw dimension lines, projection lines and figures.
hatching	-	it could apply hatch lines to any combination of closed polygons and text blocks. The polygons could have holes in them and be bounded by lines, arcs or smooth curves.

Drawing

Although grids or coordinates could be used as a means of positioning, GDS relied mainly on the methods of relative positioning and draughting constructions for drawing. Relative positioning was illustrated in fig. 13, while draughting construction allowed lines, arcs, triangles, rectangles and polygons to be drawn in a variety of different ways to minimise user effort.

Drawings were created within a drawing file and objects were treated as individual drawings within the file. Libraries of objects were simply drawing files, the contents of which could be copied to a user's own drawing file at any stage.

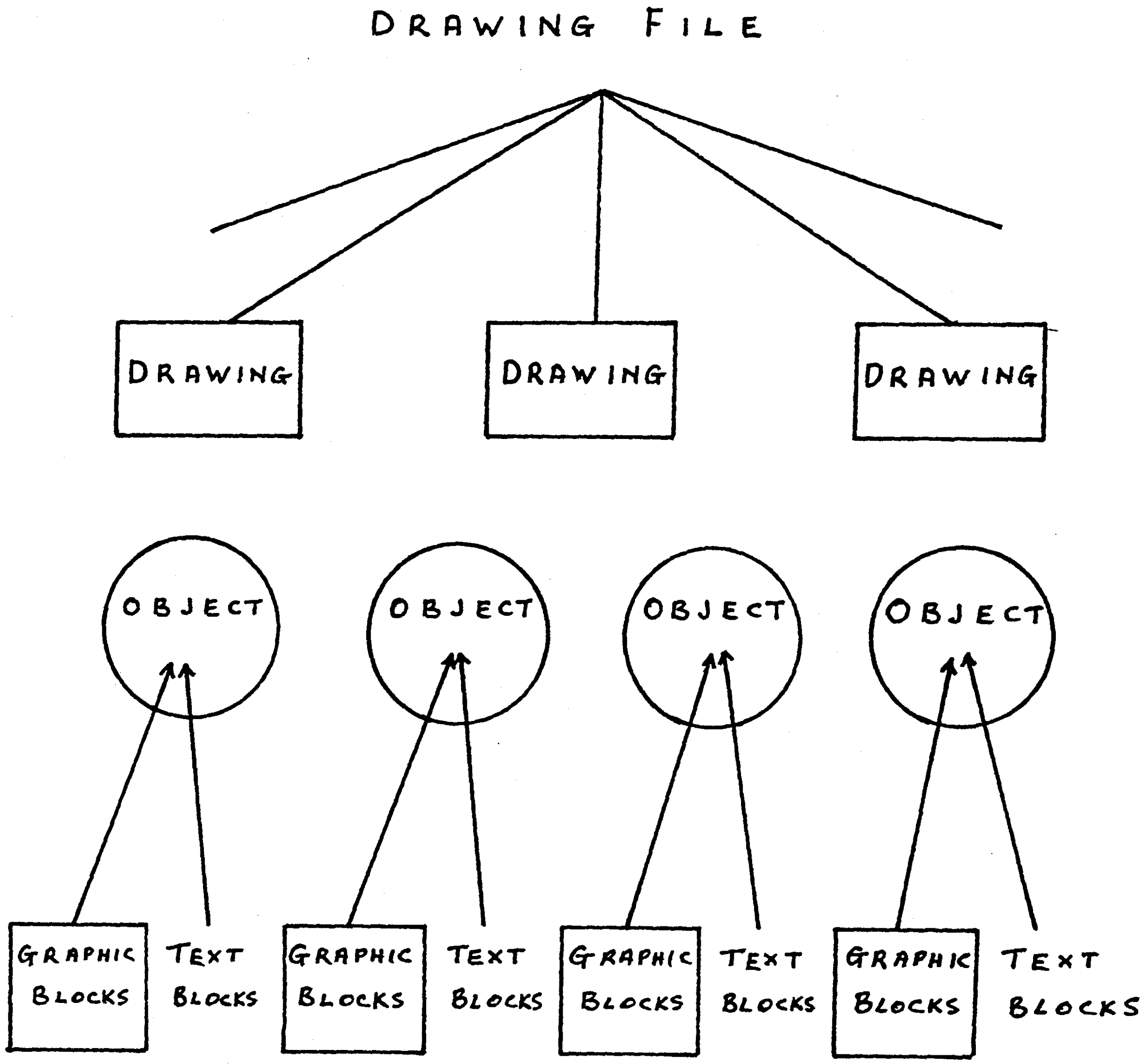


Fig. 17: GDS Drawing Creation

Drawings were thus created by withdrawing objects from the library, altering them as necessary, positioning them where required and linking them up with drawn lines. Objects were given names of up to six facets and overlaying was accomplished by specifying only the facets of the required objects. After viewing the completed drawing on the VDU, the user gave the required commands for the drawing to be sent to the plotter. The system was strictly two dimensional and no attempt was made to introduce the third dimension.

Editing

Individual objects could be edited by deleting or moving lines, moving or inserting vertices, inserting fillets between lines and changing the radii of arcs. Whole drawings or parts of drawings were edited by range editing which included commands of move, rotate, scale, delete, substitute, superimpose, mirror and alterations to character style and line style.

Summary

The features of the two systems may be summarised as follows:

Information Capture

Details of the building's component parts were input by the architect who constructed either a two or three dimensional, full sized model of the proposed building in the computer.

Information Storage

Definitions of all components or objects were stored on magnetic disk in a library which could be interrogated as required. The building information for specific projects was stored separately which could be recalled in any required combination.

Information Manipulation

By various means, the building components could be rearranged as required and the result viewed on the screen. Drawings with different scales and levels of detail and combinations of components or objects could be produced from the same basic information. Drawings could also be combined in special relationships to make up single sheets. Data for one project could be incorporated in any other; components could be assembled in any configuration; components or objects and whole areas of the building could be duplicated into other locations and rotated and handed as required.

Information Distribution

The architect could see parts of the building and the changes being made during editing on the visual display screen. Multi-station systems were available where several architects could work on the same project simultaneously.

Operations Control

Drawing was done under computer control. Drawing requisitioning could be done through the visual display unit, without the need for the digitizer. The drum plotter could be used while further information was being keyed in. Every component was drawn and positioned to an accuracy of one millimetre and every drawing produced was dimensionally consistent with other current drawings and had every component precisely coordinated.

With RUCAPS there were, however, aspects of the drawing task that were difficult for the computer and drawings sometimes had to be "hand finished", usually by a technician. Irregular shapes and some annotations could be easier and faster to do by hand.

The two main advantages which computing brought to architectural draughting, therefore, were consistency and flexibility. Once building components had been defined and located, every drawing using the same information was consistent with every other, regardless of scale or part of the building concerned. This was a major advantage to the architect who previously had the extremely difficult task of coordinating the work of several draughtsmen, each of whom might make minor adjustments to the particular drawing on which they were working, accumulating errors.

If the builder got slightly inconsistent drawings, he needed clarification and this always introduced delays. The computer overcame that difficulty and also ensured that amendments were reflected in all subsequent drawings; this removed the error prone process of manual amendment.

Flexibility was achieved by the power of the computer to amend and add to stored information and to present it in a variety of different ways. The ease with which the computer could amend, exchange and relocate components was in sharp contrast to the laborious manual equivalent. This was particularly evident in room layout work. The initial drawing was presented to the client who invariably suggested amendments to improve it. The architect then had to amend the drawing as agreed and re-issue it to the client. In a building with a large number of rooms, such as a hospital, the manual effort required was enormous; the computer made the changes very quickly and consistently throughout the set of drawings.

Although traditional architects' drawings were occasionally produced for special purposes, most drawings showed as much information as possible to the builder who then used the same drawing for his several different purposes. The ability of the computer to draw only those components required for a given purpose meant that separate drawings could be prepared for the bricklayer, the joiner, the plumber and so on. This was an aid to both site operations and coordination. The technology also enabled the architect to respond rapidly to requests from the builder for drawn information because new layouts and details could be produced at the appropriate scale and drawn overnight for issue the following morning.

AVAILABLE SYSTEMS

In early 1982, a survey was undertaken to establish the number of computer draughting systems then currently available in Great Britain. Appendix 1 lists twenty such systems. Enquiries were then made to ascertain how many installations were operating within the architectural profession at that time and the results are again shown in Appendix 1.

Of the twenty systems then in existence, four did not give details of the number of installations, two refused on the grounds of confidentiality, three had no installations, seven had only one installation of which five were the originating system designers, and three had more than one installation.

Calcomp Limited, IGS 500, claimed twenty installations but did not provide a list of users, GMW Computers Limited, RUCAPS, named twenty two installations and Applied Research of Cambridge, GDC, named ten installations.

CHAPTER 5

CASE STUDY NO. 1

REIACH & HALL/BLYTH & BLYTH

The objectives of this chapter are:-

- o to examine the organization and investigate the decision-making process leading to the purchase of a computer.
- o to record the effects which computerization had on

  organization structure,

  management role,

  related professional groups,

  work organization,

  skills and creativity,

  careers,

  organization performance.

INTRODUCTION

This case study was researched between November 1980 and March 1981. Access to the organization was easily obtained because the author had worked with it in a professional capacity for the previous three years and all the principal personnel were personally known to him.

The research methodology comprised firstly two intensive joint interviews with an associate and a partner of the firm. Secondly, internal memoranda were then studied to corroborate and amplify the initial findings. Thirdly, semi-structured informal interviews were carried out with one associate, two architects, one engineer, two architectural technicians and one computer administrator. Of these, the associate, one architect and one technician were not computer users. Each interview lasted some 20-25 minutes. Further evidence was gathered informally over a period at working lunches with various members of staff.

Every facility for research was made available to the author, except of course the organization's accounts which, being a partnership, were private.

THE ORGANIZATION

The organisation studied was a consortium of two partnerships which, while maintaining their independence, had an existing multi-disciplinary practice and agreed to share the capital expenditure and running costs involved in computer aided draughting.

Reiach and Hall was a comparatively young architectural practice formed in 1965 from an amalgamation of two smaller practices. With a technical staff of 35, it was regarded as a large practice in Scotland, but was medium sized by English standards. Figure 18 shows the partnership's organization chart.

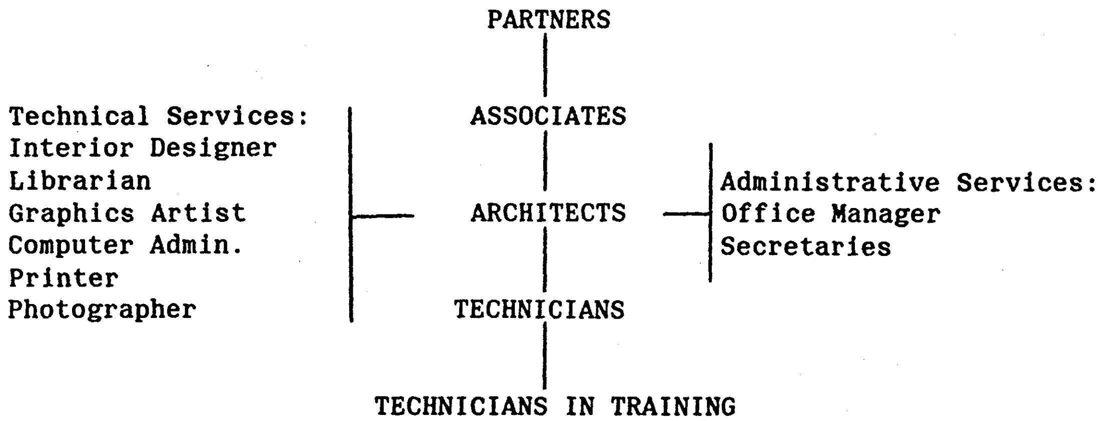


Figure 18: Reiach and Hall, organization chart

Blyth and Blyth was an old established civil engineering consultancy which had diversified into mechanical and electrical services and quantity surveying. (One of their most famous projects was designing the North Bridge in Edinburgh). It employed about 200 people, including clerical and service personnel. Figure 19 shows the consultancy's organization chart in outline.

The offices of the two companies were in the centre of Edinburgh, about 500 metres apart. The computer aided draughting equipment was housed in the basement at Reiach and Hall because their staff made more use of it, and they covered a larger share of the costs.

The consortium offered clients a full range of professional consultancy in building, but each partnership had its own commissions and could form part of design teams with other consultants. Commissions carried out by each practice ranged in size from single dwelling houses, through local authority housing, industrial buildings and schools to multi-million pound university, commercial and hospital developments. Both practices had good reputations in their respective fields and had won many design awards.

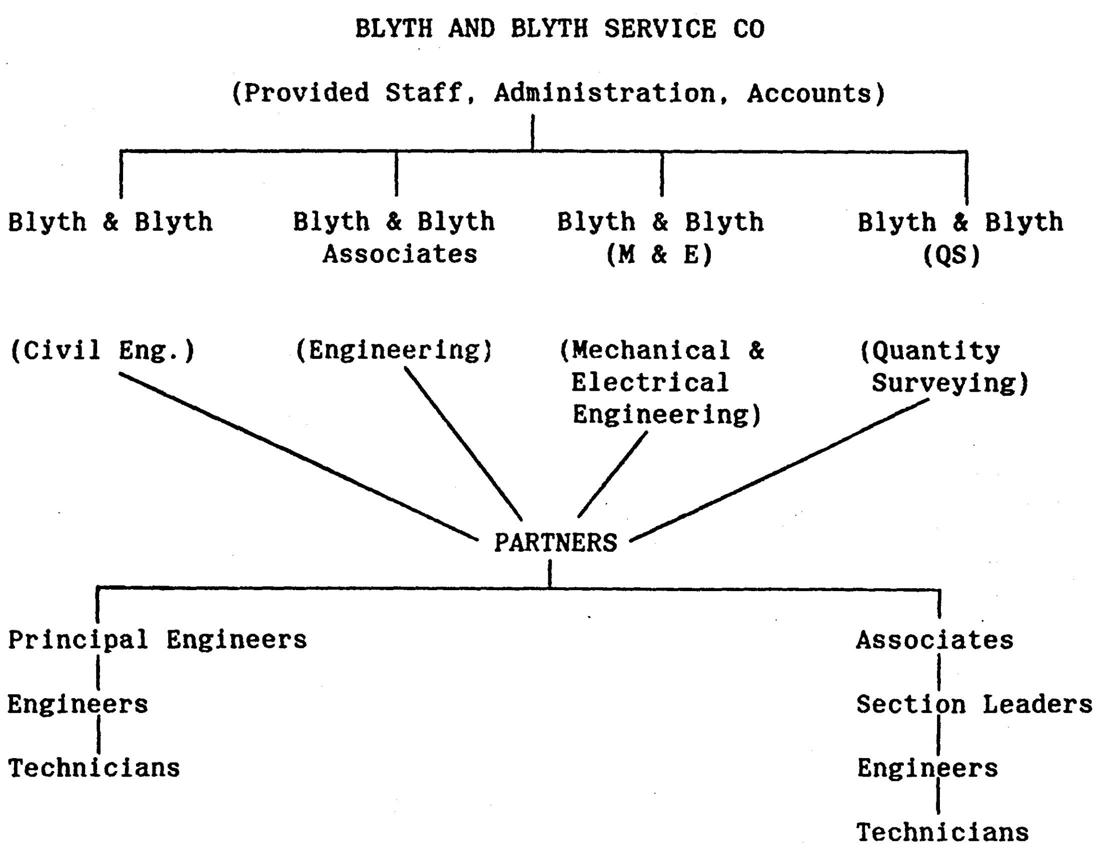


Figure 19: Blyth and Blyth, outline organization chart

MANAGEMENT OBJECTIVES

As a matter of policy, the partners of the respective firms of the consortium wished to stay at the forefront of developments in building design and the initial approach by the computer company was regarded positively. The consortium saw computer aided draughting as a powerful marketing asset which could be used to attract large commissions. When the decision to buy the system was finally made, in October 1978, only one other architectural practice in Britain had an equivalent system, although a few smaller systems were in use. The attraction of being market leaders in this field was compelling.

The fee system established by the Royal Institute of British Architects, and used by all architects, was at that time being investigated by the Monopolies Commission. It was expected that the Commission would recommend the abolition of this system and force the profession to adopt a competitive fee structure. This would potentially have reduced fee income, and a practice would only remain profitable by handling more commissions more efficiently. The possibilities for doing this by traditional manual methods without loss of quality were difficult, and so attention focussed on the power of computing.

In 1978, the consortium was providing the architectural and civil and structural engineering design work for a district general hospital project in Scotland. This large, complex, multi-million pound development was, at that time, maturing through the scheme design stage to detail design, where a design solution had to be found for every facet of the project. The overall time span of such a project, from inception to handing the keys over to the hospital staff, was around 10 years.

The traditional draughting approach to this stage would have employed many architects and technicians. Coordinating their work was always a major management problem. Computer aided draughting appeared to offer a solution to this problem by providing a central data base for the project from which everyone could work.

In the hospital project, room layout drawings were produced for every room type. The architect was concerned at this stage with designing a room that "works", that is, one that meets the needs of its users. For example, the "Preparation Room" in a hospital was where medication and dressings were prepared before medical procedures were carried out. The room layout drawings showed every aspect of the construction of the room on floor and ceiling plans, and side views of the walls. This included fixed furniture such as worktops and cabinets, moveable furniture such as tables and chairs, and equipment such as trolleys and refuse bins. These drawings showed whether all the required furniture was provided, and could fit into the room, whether trolleys could get through the door, whether the door would foul an electrical switch when it opened, whether a short nurse could reach the top shelf of a wall cupboard, and so on.

The requirement to produce room layouts meant repeating the same or similar drawings for however many room types occurred in the building. This was a daunting manual task. Small scale plans showing structural and detailed construction aspects were prepared for the builder, and the large scale room layouts could be produced automatically as a by-product of this process.

The consortium felt that the power of the computer could overcome a major problem of manpower planning. Most architectural practices experienced a "feast and famine" syndrome on staffing. When a large commission was secured, additional staff were often employed to handle the increased workload. If further commissions were not forthcoming, at just the right time to maintain continuity of work, some staff invariably became redundant. The consortium wished strongly to avoid hiring and firing. The computer system was seen as a way of coping with peak work loads without extra staff while, in slack periods, the machine and not people would be idle.

The preparation of drawings manually was a relatively slow and difficult process. In contrast, a computer physically drew much faster, could work through the night, was extremely accurate and could produce a variety of different drawings from the same basic information stored in its memory. The consortium felt that these attributes were important, considering the tight programmes which some clients (particularly industrial and overseas) demanded in the design process.

Three main financial implications influenced the decision to computerize. First, it was demonstrated that the system bought could be depreciated over five years. Second, an inevitable feature of all construction projects was the issue of "variation orders" to the builder on site to effect amendments to the design. It was calculated that, if half of these variation orders could be avoided using accurate, consistent computer drawings, the resultant saving in administrative costs would pay for the system. Third, as already noted, the room layouts were effectively obtained "free", as a product of another part of the design process.

Summary

The decision to introduce computer aided draughting was thus influenced by the equipment suppliers, and by the consortium's objectives to:

1. be at the forefront of professional developments;
2. acquire a powerful marketing asset;
3. improve efficiency and handle more commissions;
4. reduce project staff coordination problems;
5. reduce fluctuations in staffing levels;
6. draw production information quickly, flexibly and accurately;
7. reduce the costs of producing drawings.

THE DECISION PROCESS

In May 1978, a circular concerning computer aided draughting arrived in the office of Blyth and Blyth in London, and was forwarded to the Edinburgh office for information. The system appeared to be useful, but expensive, and the neighbouring partnership of Reiach and Hall was invited to consider a joint purchase. Agreement was reached between the individual partnerships and a consortium, RHB Computers, was formed.

Having been made aware of the potential of computer aided draughting by one computer company, the consortium's partners did some limited market research. The choice of systems was soon narrowed down, mainly by financial considerations, and the most acceptable system, RUCAPS, was technically evaluated in some depth. This system was the product of a computer company which was itself an offshoot of an architectural practice. This company could, therefore, demonstrate the computer's capabilities on live projects and also advise from its own experience on overcoming the likely problems arising from the use of its system. An exhaustive research and investigation effort into the full range of available systems was not carried out.

ORGANIZATION STRUCTURE

Work in the architect's office was organized on a project basis, with personnel allocated to a team for each building commission. Depending on the size of the project, the team normally included:

- a partner in charge;
- an associate;
- a project architect;
- architects;
- technicians. Central support staff were also available, including secretaries, printers, interior designers, librarians and specialist staff. At the time of this study, only one project team, from Reiach and Hall, were making significant use of the computer aided draughting system.

Computer aided draughting did not significantly alter the constitution of the project team, although it was reduced in size but, in this case, not all members actually operated the equipment. For example, the team that used the computer most had a partner, an associate, two architects and one technician who were computer operators, and one associate and one technician who were not.

From what they learned from other organizations' experience with the system, the consortium wanted to avoid a "high priest" syndrome developing around the operation of the computer. In one company, one individual controlled every aspect of the computer system and was regarded by all the other staff as the computer expert. The consortium sought to avoid this, first by forming a computer management structure (shown in figure 20) and second by offering training in the use of the equipment to every member of the technical staff who wanted it.

RHB COMPUTERS

(A Financial Holding Company)

COMPUTER MANAGEMENT GROUP

(The Partnership Executive)

COMPUTER MANAGER

(One of the Associates)

COMPUTER WORKING PARTY

(Professional Users From All Disciplines)

USERS

Fig.20: The consortium's computer management structure

This structure was designed to regulate the computing activities of both offices. The management group was responsible for the overall financial arrangements, for reviewing and implementing changes to the system equipment and programmes, vetting any necessary expenditure and deciding what jobs to computerize. The working party, comprising all those who operated the system, planned and coordinated the component library and provided a forum for training. The computer manager scheduled the day-to-day use of the equipment by its users and ensured that adequate supplies of stationery and drawing pens were provided. He also chaired the working party and was a member of the management group.

Once the computer was installed, it soon became apparent that it would not be possible to put every job on to it because of the machine's limited capacity. With one work station, only one user could input information at a time and there was just not enough time available to meet every project program. The large hospital project was thus given priority because of its size, complexity, special room layout requirements and importance. This was the first full project tackled on the computer by the consortium and site work had not begun at the time of the study.

The hospital's project team included the associate who had been involved in the initial computer appraisal and, in spite of the consortium's intention, this individual had acquired something of the role of "high priest". He did most of the original thinking required by the computer system, he was technically the best operator of the machine and had a strong influence in all strategic decision making regarding its use. His home was 30 metres from the offices of Reiach and Hall and he frequently visited the installation during weekends and evenings to make sure that the plotter was working smoothly when it had been left running.

This dependence on the expertise of one person had both advantages and disadvantages. When the consortium was asked to produce initial designs for two major overseas projects, at very short notice, the expert associate was able to use the existing component library to make both layout and detailed drawings in an incredibly short time. This would have been impossible to achieve manually and it impressed the prospective clients. But at first, if a programme fault arose during his holidays, very little could be done with the machine until he returned and put it right. This changed as other users gained expertise.

MANAGEMENT ROLE

By building a model of the building design within the computer, accurate and consistent information could be extracted and put to a variety of uses, greatly reducing the burden of coordination prevalent with the manual system. One major effect of this central computer model was that the "autocratic" management style previously used to achieve coordination and consistency within the design team could be relaxed. The computer took over this controlling role and disciplined the design team members by producing identical basic information for all users to apply to their particular aspect of the task, from door sizes to the layout of ceiling tiles. Management were, therefore, freed from handling what could often be difficult inter-personal problems, which kept them away from the drawing boards, to concentrate on other aspects of the project.

RELATED PROFESSIONAL GROUPS

Engineering Staff

The civil and structural engineers at Blyth and Blyth were disappointed with the computer system for several reasons.

Blyth and Blyth had a 30 per cent financial stake in the system and, by agreement, their computer use was limited to 30 per cent of the time available. At some points in the hospital design programme, this was inadequate and it proved difficult to meet all their requirements. The engineers felt like "poor relations" to the architects who had considerably more computer expertise. There appeared to be a problem arising from inadequate training of the engineers in the use of the equipment. Although the architects were helpful in dealing with their problems, the engineers were frustrated by their own inefficiency. These difficulties may not have arisen in a multi-disciplinary office with architects and engineers working together.

The engineers also met technical problems in using the system. They often wanted, for example, to define components in seven views but the system could only give up to five views. Road layout work demanded extreme mathematical precision to get the lines to join up. The computer was restricted to the use of circular curves only (there were mathematically more complex types of curve) and the system prevented the usual manual expediency of "making it work" by freehand drawing.

Structural design followed architectural planning and the engineer had to produce solutions from the architect's layout. The positions of columns and beams, therefore, was dictated by architectural considerations and the structural information was usually an adjunct to the architectural drawing. This meant that the computer system was of limited use to the structural engineers. In addition, structural components were not repeated large numbers of times in a building and the component library was of limited use to the structural engineers also. One major advantage of the system, however, was its ability to "copy down" from one floor level to the floor below, allowing the structural engineer to check that column positions were consistent from floor to floor and allowing him to establish the foundation layouts from the positions of ground floor walls and columns. It was found to be faster to hand finish most structural drawings rather than to input the additional information required into the computer and do the drawings again. (Computers have been used for structural analysis since the early 1960's.)

These difficulties and frustrations led the engineers to the conclusion that they would only use the computer system on projects where Reiach and Hall were the architects and where there was extensive repetition of detail, i.e. on large projects.

Clients

Architects' clients were usually not trained to read complex drawings. Computer draughting meant that clearer and easy to understand drawings could be presented to the client much earlier in the design process. In the hospital project, large scale room layout drawings were quickly and easily incorporated. All drawings issued subsequently carried all these amendments. Computer draughting thus improved the relationship between architect and client by improving the quality and usefulness of the information provided.

Builder

A major benefit for the builder expected from computer draughting was the standardization of drawings derived from a single data base. Inconsistent drawings were the source of many site problems and frustrations which the new system would overcome. Drawn information would also be available much faster than before, there would be different drawings made for different trades, such as bricklayers and joiners, and these would all be consistent with each other.
It was possible to separate physically the components of the computer system. There was no technical reason why they all had to be in the same room. If suitable land lines were available, a drum plotter and remote terminal could be located in a builder's site office. The builder could then request personally the drawings he required. The same information could be transferred by the architect handing over the set of computer storage disks for the builder to use on his own system.

Quantity Surveyor

The work of the quantity surveyor was also expected to be affected by computer draughting. The quantity surveyor was a "building economist" whose job involved estimating the total cost of the project, manipulating and advising on costs and cost control. The quantity surveyor took the architect's drawn information and translated it into a schedule of quantities that allowed the tendering process to be carried out equitably across several different builders - all tendering on the same basis with the same materials.

Computer aided draughting gave the quantity surveyor accurate information at an earlier stage in the process and this created more time and opportunity to control costs by generating alternative solutions. The system also provided information to assist with the initial estimation of costs. The system could produce a schedule of components in the building. This acted as a check on the physical count which was still necessary, as the computer could not, for example, distinguish between materials, and some drawings were hand finished. The information that the system provided was more comprehensive and internally consistent. It was also flexible as changes suggested by the quantity surveyor could be incorporated without creating major difficulties.

WORK ORGANIZATION

Semi-structured, informal interview were held with five members of the project team from Reiach and Hall most involved with the computer system, one of the engineers and with the new computer administrator, to discover their reactions to it.

The Computer Administrator

As the administrative demands of the computer system absorbed progressively more of expensive architect's time, the consortium decided to create a new post of Computer Administrator. In 1980, this full time job was filled from outside by a young female graduate who had no previous architectural training. Her duties were administrative, clerical and operational.

She was responsible for ordering paper, pens, cursors and other sundry items and for collating the timekeeping records used in job costing. She also handled the computer maintenance contracts and insurances and liaised with the computer engineers when equipment broke down. Under the direction of the computer manager, she allocated work sessions on the computer and administered the cost sharing agreement between the members of the consortium. Her clerical duties also included component filing and record keeping. Her operational duties involved defining drawings for production using the remote terminal and regular disk copying.

The Architectural Technicians

The job of an architectural technician was regarded as different from that of an architect. The technician had special skills in specific areas but these were more limited than those of the architect and did not include conceptual design. In conventional manual draughting, the technicians concentrated on the details of building construction. On large projects, work was usually subdivided so that each technician dealt with a separate part of the task, one dealing for example with all the partitions in a building and another dealing with all the doors and associated ironmongery.

The Architects

Working hours

The need to use fully the computer time and the division of that time into two hour sessions to reduce operator stress, led to an extension of the working day. The conventional 8.30 till 5.00 office routine was stretched to 8.30 till 8.30, divided into six sessions, over a five day week. The more experienced operators did double sessions as they learned to overcome stress problems. The four hour slot was felt by some to be more productive than two interrupted two hour sessions. The computer administrator and computer manager administered the booking system.

Architectural practices normally worked a seven and a half hour day but professional staff were expected to work overtime when necessary. Architects were hostile to a permanently extended working day. They did not expect to work outwith office hours as a matter of routine, their families objected, and to extend the hours beyond 8.30 in the evening was not welcomed.

The computer was housed in the office basement because of its weight and because that location ensured quietness and freedom from interruptions. However, this meant that the users had to work in isolation. The project team normally worked in one large drawing office which encouraged formal and informal interaction, essential for coordinating their activities. This isolation was offset as sessions on the computer were restricted in duration to two hours.

The experience of working alone on a two hour computer shift in normal office hours was novel but caused no real difficulties. The isolation was often welcomed because of the lack of interruptions. The remoteness from the rest of the project team created minor communications problems but these were usually dealt with over the office intercom. There were more problems over the operation of the computer system, in making it do what was required, than about architecture.

Work pace and stress

There was general agreement that operating the computer was more stressful than working manually. Members of the project team commented:

> "You can tell when someone has come off a computer session; they look drained."
>
> "My wife knows when I have been operating the computer."

This stress was caused by the concentration required to operate the equipment effectively. As sessions on the computer were restricted to two hours, there was a tendency to cram as much work as possible into this time and the operator felt the need to maintain the work pace. The operators also felt that the computer time was expensive and this compounded their desire not to waste time while using it. These pressures for "cramming" meant that the operator had to prepare carefully all the input ma terial before starting the session which, in turn, created new working deadlines and more stress. There was no technical barrier to doing preparation work at the machine, except that bulky reference manuals would occasionally have to be carried to it. The users simply felt that more effective use of their own and the computer's time was made if they did their preparation first. Decisions about the assembly of drawings were, however, made at the machine.

Accuracy was required if the components were to be assembled and drawn correctly. This made greater demands on the operator's concentration than traditional methods where errors were immediately obvious. The system could not identify dimensional errors and it was possible to draw walls that did not meet, or to put doors and and columns in the same place in the building. This increased concentration was reinforced by the isolation of the work station and lack of distractions and normal social contact. The system had a number of internal checks that caused bleeping sounds whenever material was incorrectly entered, with the wrong commands or with the wrong command sequence. This audible alarm was rather loud and could be heard by others in adjacent offices. Users felt that this was embarrassing as "the whole world knows that I got it wrong".

As it was interactive, the system had a series of prompts that told the user what to do next. The users felt that they had to respond immediately to these prompts and this introduced an element of machine pacing to the work. This was completely new to the traditional architect. One user claimed that the prompts were too slow and that it was frustrating when the user was ready to continue before the next prompt appeared. The computer thus inhibited the normal practice of working at the architect' s own pace.

Careful consideration was given to the lighting of the office housing the equipment and to the visual display screen colour, luminance and avoidance of flicker. One operator complained that, after looking at the green screen for more than an hour " the world could be viewed as though through rose tinted spectacles", red being the complementary colour of green. One factor that was criticized by all the users was the noise of the drum plotter as it drew. As it was independent of the input devices , the plotter could be drawing while the central processing unit handled other tasks. The whirling and chatter of the plotter was loud and distracting. Users felt that it should be isolated from the input station.

Some of the users had developed their own ways of coping with the stress induced by operating the system. They arranged that a variety of tasks had to be carried out during any one session and this avoided continuous effort on one facet of inputting. One brought in his cassette tape recorder and played classical music through stereo headphones while operating the system.

Task variety

The preparation of component details was a new activity for architects and demanded a complete reversal of the manual procedures for documenting a building.

Traditionally, architects worked from the whole building down to its component parts. They decided on the basic design concept and drew the overall layout first and filled in the details later. The computerized component assembly system required the design details to be prepared much earlier in the process, although it was still possible to use outline components initially and substitute them later by the required detail.

Operating the computer was itself a new task which, although not particularly difficult, demanded concentration and constant practice (unlike riding a bicycle which one never forgets). Regular use of the system was necessary to maintain high levels of efficiency; intermittent use was unsatisfactory. The sequence in which decisions were made and commands entered was different each time.

SKILLS AND CREATIVITY

Manual draughting was considered a craft at one time and individual styles were recognizable and appreciated. Several developments had however eroded that perception before the introduction of computer aided draughting. The use of drawing board surface typewriters, for example, had overcome the need for the draughtsman to have neat handwriting and the use of rub and stick on features had reduced the need for craftsmanship.

The creativity important to the architect lay in building design and not in draughting and that was why users of the computer system felt that it did not make onerous demands on their skills. Most of those interviewed felt that architectural creativity was not impaired by computer draughting and that the process was enhanced by the removal of the drudgery. Manual draughting could be tedious even though some tasks were delegated to technicians, leaving project architects to concentrate on design.

In computer draughting, a number of fundamental design decisions had to be taken before the work was transferred to the computer. Although the architect spent more time drawing at the computer and made less use of technicians, he did not consequently neglect the design process.

Architects did not object to drawing on the computer in this way. Architects on the whole felt that their creativity was unimpaired and one commented:

> "As all the information was being added to a data base which was internally consistent, it enabled the user to test the relative locations of components as though the data base was, in fact, a building prototype. Although the computer itself would not detect errors, it enabled the user to do so."

However, another architect felt that manual drawing could be an essential element of the design process and commented:

> "The physical act of putting a pencil to paper sharpens the design faculties and crystallizes the design concept. The removal of this element in computer draughting may lead to designs incompletely thought through and create errors."

When designing a building, the architect drew in order to check out ideas, to see whether they worked. The drawing showed what was possible and what was not. The computerized system speeded up the drawing process, cutting out time that was previously used for reflection on and adjustment of the design. There was, therefore, a feeling that designs could be rushed and not adequately considered with this system.

There was general agreement that the designer must be master of the technology rather than the other way around. This approach led in some instances to operators "lying" to the computer to make it do what they wanted, rather than what the system expected. Fears were expressed that, because some tasks were difficult to perform on the computer, these would be neglected in the design. For example, designs involving skewed grids and circular plan shapes which could have considerable merit for some /

projects might be rejected simply because they were difficult for the computer to draw. Technological constraints like this were seen as threats to the designer's cherished freedom of expression. The software was continually being developed to improve the computer's ability on these tasks and these initial difficulties were being overcome as architects developed expertise and ingenuity in handling the system.

CAREERS

Employment Levels

The effects of computer draughting on employment within the consortium was mixed. Fewer architects were employed on the hospital project than would have been required to do the work manually but a computer administrator was employed and the demands of the computer system changed the job requirements of some staff.

The experience of other design teams working on projects similar in size to the hospital led the consortium to expect a required workforce of between 16 and 20 architects and technicians to do the work by traditional manual methods. A partner and two associates would also be required to provide supervision and coordination. The impact of the computer was dramatic in this respect as the hospital project team comprised only one partner, two associates, two architects and two technicians. The team was augmented by one or two extra members to cope with peaks in the work load.

Partners and Associates

The reduction in the size of the design team by about two thirds made coordination and communications easier and enabled senior members to become directly involved in detailed design activities. The partner and two associates thus relinquished part of their traditional role as managers of the design team and became productive members of the team, as designers and computer operators who produced drawings, a task that using conventional methods they left to other members of the team.

Architects

No evidence was found to suggest that computer architects were held in any higher regard by their colleagues, but the partners were pleased at their willingness to acquire new skills. Being able to use the computer was not regarded as a prestigious, elevated or high status thing to do. It was generally felt that no significant skills were required to operate the computer system and that almost anyone could be trained to use it. Some users felt that being a computer architect tied the individual to the consortium as the only user of this type of system in Scotland and were not sure how other potential employers would value their experience. It was considered, however, that reversion to manual draughting posed no problems.

Architectural Technicians

In computer draughting, the technicians became computer operators and developed competence to define new components and assemble drawings. Their sphere of interest was widened to include all the elements of a building. Computerization thus enlarged the need for the role of the technician in the design team. This in turn reduced the need for the role of the technician in training as assistant to the technician. Technicians continued to be trained in conventional design teams and were transferred when competent to the computer group.

The Computer Administrator

The Administrator appointed was enthusiastic about computers and was keen to develop her computing skills. It was felt that, if suitable programs were available, she could do critical path analysis and job costing work. It was, however, not possible to offer her a career in the consortium and a few months after this study was done she left to pursue a career as a programmer.

ORGANIZATION PERFORMANCE

The continuing financial commitment that resulted from the decision to buy a computer system was not at first appreciated by the consortium. After it was installed, a number of further items of expenditure were made to improve the system and the consortium appeared to be on a "financial treadmill" in which it had to keep spending money on the system.

In July 1980, sixteen months after the system was installed, the central processor unit, disk drives, visual display unit and printer were updated to enable them to cope with developments in hardware. This cost £31,000. The vast amount of detail required to produce room layouts for the hospital project created an information storage capacity problem. This was not anticipated by the system designers because the hospital was the largest and most detailed project ever put through such a system.

This problem was solved in June 1981 when a new, enlarged disk storage system was installed, costing £10,500. A further £2,000 was spent in July 1981 to provide a remote terminal which permitted greater throughput of drawing production and full air conditioning for the computer room was installed in October 1981, costing £2,500. These were comparatively small sums of money in relation to the finances of the organizations concerned.

The air conditioning was needed because the drawing paper was supplied preconditioned at a given humidity. If the paper were used in a different atmosphere, say a very dry one, the paper shrank and created drawing inaccuracies and possibly plotter failures. In addition to the financial effects, the need to provide these extra facilities created disruptions to production which were not welcome on a project with a tight schedule.

The computer could also be used to manipulate large data sets. Component scheduling facilities enabled the number of each component type to be listed. As around 80 per cent of the items in bills of quantities were input by the designers, costings could be produced as a "free" by-product of the design process. Builders' prices could also be set against each component and the total value of the project calculated. Materials /

ordering could be assisted by the component scheduling facility and payments to builders in stages as the project progressed (called "stage payments") could be calculated more accurately than with manual methods. One problem with such large data sets was the slow response time. It could take up to ten minutes for a specified visual display of a drawing to appear on the screen.

The system had markedly improved the quality, consistency, flexibility and accuracy of drawings and their usefulness to clients. Everyone, therefore, considered the system a success and took pride and pleasure in its use.

MAIN CONCLUSIONS OF THIS CASE STUDY

The decision making process

- o The consortium's decision to introduce computer aided draughting was influenced by management's desires to:
  - o be market leaders with the new technology;
  - o increase capacity while reducing costs;
  - o reduce staff coordination problems;
  - o improve drawing quality, flexibility and consistency.
- o Once bought, several expensive improvements were found to be either necessary or desirable to exploit the system fully and efficiently.

Changes to organization structure

- o A new post of computer administrator was created to deal with the administrative tasks occasioned by the computer system.
- o The computer system did not affect the internal organization structure of the architectural practice, other than through the addition of a computer administrator. A computer management structure was established to deal with the financial aspects of the consortium's arrangement, and to coordinate and supervise the overall use of the system by the consortium.
- o The users of the system were initially dependent on the expertise of one individual who was most familiar with the system until others developed equivalent expertise.

Changes to operating job characteristics and the experience of work

- The job of the architects using the computer system was affected in several ways;
  - their working day was extended;
  - they worked in isolation, but welcomed the lack of interruptions;
  - they suffered more stress from the concentration required to maintain accuracy;
  - working to deadlines to fit the schedule;
  - cramming work into their timetabled session;
  - the interactive prompts, dictating the work pace;
  - the noise of the drum plotter;
  - their sequence of work changed as the computer system required the design detail work to be carried out much earlier than with conventional methods;
  - the less attractive elements of the job, such as amending drawings, were eliminated;
  - a uniform style of presenting drawings was produced without management enforcement.
  - The skills of manual draughting had been eroded before the introduction of computer aided draughting which was not seen as adding to or detracting from the architect's skills.
  - The manual draughting task was considered by some architects to be central to the creative process. It allowed time to think through the design concept and to identify what would be possible, and errors.
  - The computer aided draughting affected the creativity of the architect by:

- removing the need for manual draughting;
- speeding up the pace of the design work;
- causing the designer to avoid some design patterns which, although difficult for the machine to handle, could be useful for a given project.

- The job of the architectural technicians was enlarged when they became computer operators and no longer required assistant technicians. The assistant technicians were trained in conventional methods.
- The computer administrator was interested in developing computing skills, but had no career path within the consortium.

Effect on role of management

- The management task of coordinating staff effort was taken over by the working disciplines imposed on users by the computer system.
- The senior members became more closely involved with the work, operating the computer system and once again exercising their professional skills.

Effect on performance

- For one large project, the design team with the computer aided system had about a third of the members that a conventional team would have used.
- The engineers who used the system were not satisfied because:
    - their training in the use of the system was limited and they were dependent on the architects to resolve their problems;
    - the system had technical limitations that made it less suitable for some structural engineering work;

- the lack of repetition of structural components in a building meant that the computer's ability to copy from component libraries could not be effectively used.
- The computer system improved the relationship between architect and client because the information provided by the architect was more useful in form and better in quality.
- The computer system was expected to improve the relationship between architect and builder because the information provided by the architect would be consistent and accurate.
- The computer system was expected to provide the quantity surveyor with better and faster information.
- The quality of drawings was greatly improved.
- Drawings could be produced much faster with the computer system.

CHAPTER 6

CASE STUDY NO. 2

COMPUTER GRAPHIC DESIGN

The objectives of this chapter are:-

- to examine the organization and investigate the decision-making process leading to the purchase of a computer.
- to record the effects which computerization had on
  organization structure,
  finance,
  marketing,
  productivity,
  design,
  work organization,
  careers,
  relationships.

INTRODUCTION

This case study was researched between April 1982 and March 1984. Access to the organization was by introduction to one of Baxter Clark and Paul's partners by a mutual friend of the author who was a partner in another architectural practice.

The research methodology employed fell into three distinct phases. Firstly, a short general interview was held with the aforesaid partner to learn something of the organization. Secondly, an intensive interview lasting some 80 to 90 minutes was carried out with each of the two computer associates. These interviews were tape recorded and, from these, verbatim transcripts were prepared and sent to the interviewees for validation. Thereafter, another interview with each associate was held lasting 30 to 40 minutes. This third stage of the research examined in greater detail points brought out in the first interviews and also explored the longitudinal aspects of the study by investigating the experiences of and developments in computer operations since the first interviews.

The organizational and financial arrangements of the firm could best be researched by reference to its partners, but none of the five computer partners was willing to be interviewed. The reason(s) for declining was not given and the study is admittedly the weaker for the omission of this important contribution.

The sub-headings of this case study do not correspond exactly with those found in the Reiach & Hall/Blyth & Blyth study. During the course of this study, it was found that different aspects of this case required particular emphasis which sometimes demanded entirely different sections from that previously required.

THE ORGANIZATION

Computer Graphic Design was founded as a separate partnership in early 1982 by some of the partners of the established architectural practice of Baxter Clark and Paul. At the beginning of this study, the firm had only recently taken delivery of their computer and were commencing a three-month long period of familiarization and commissioning.

At its inception, Computer Graphic Design consisted of five partners, two associates and a secretary. Architectural commissions were obtained from the outset and indeed work commenced on these even before the familiarization period expired.

Baxter Clark and Paul was founded in 1867 and had grown into a large Scottish practice employing some 120 technical staff in offices in Glasgow, Dundee and Aberdeen. The practice was well respected in its field and offered the full range of architectural consultancy to its clients. Its commissions ranged from single dwelling houses, through local authority housing and industrial buildings to large-scale hospital developments.

MANAGEMENT OBJECTIVES

Baxter Clark and Paul had young, dynamic partners who recognised that changes had taken place in the architectural profession and that their practice had to move with the times to maintain its position in the profession.

The partners anticipated the opportunities afforded by the abolition of the Royal Institute of British Architects' mandatory fee scale in much the same way as had the Reiach & Hall/Blyth & Blyth consortium. The ability to compete commercially with other practices for commissions /

demanded that practices became more efficient and computer power appeared to offer this possibility. The computer gave the practice a competitive edge over its rivals not only because of its increased efficiency during Production Information stage, but also because of its ability to respond more quickly and flexibly to peak demands than manual methods.

The evidence of English practices which had computerized suggested that having a computer facility attracted commissions to a practice. This was particularly true of foreign commissions where the computer could more easily handle the tight time and fee-income constraints inherent in this work. Computing offered something new and different to potential clients who also received an improved standard of service. Clients had been known not to commission architects unless computer aided draughting was available, but the converse was unknown.

As a marketing asset, the computer was expected to open up new avenues of work not previously available to the practice. The production requirements of structural, mechanical and electrical engineers, and even other architects, could all be handled by a computer draughting bureau service.

Although many large industrial, commercial and public building projects had been successfully handled by the practice, Baxter Clark and Paul were perhaps best known for their local authority housing work.

The technical benefits of computer draughting were well recognised by the partners and the computer's ability to recall all previously drawn information, its inherent accuracy, its consistency both within and between drawings, and the long term promise of fully co-ordinating all construction information were powerful persuaders to purchase a system.

Summary

The decision to introduce computer aided draughting was thus influenced by the practice's objectives to:-

1. maintain their position within a changing professional environment
2. gain a competitive advantage over other practices
3. improve efficiency and handle more commissions
4. provide a better service to clients
5. create new opportunities for work
6. improve its image
7. harness the technical benefits of computing

THE DECISION PROCESS

Having become aware of the potential of computer aided draughting, the partners appointed an associate and a senior member of staff to prepare a feasibility study.

Selection criteria were established which demanded the following from the chosen computer draughting system:-

1. should not inhibit the architect in design work
2. should be an extant system capable of future development
3. provide maximum software support
4. be flexible in use
5. be capable of effectively handling at least the same scale of work as existing manual methods
6. be affordable

A comprehensive market research exercise was carried out which established a short list of potential systems. GENYSIS, INTERGRAPH, CALCOMP, RUCAPS and GDS were examined and major objections to the other systems quickly narrowed the options down to either RUCAPS or GDS. Both these systems had been developed by architects who appreciated the problems facing an architectural practice making such a fundamental purchasing decision.

RUCAPS was initially impressive, but its three-dimensional configuration had limitations, especially with non-orthogonal buildings. A draughting test had been prepared based on an actual project, then current in the practice, which had a particularly complex configuration. RUCAPS was unable to reproduce this drawing but this, in itself, did not eliminate the system entirely from consideration. The RUCAPS salesmen were somewhat "high powered" and, when it became known that the GDS system was also under active consideration, some questionable business tactics were employed which soured relationships with the investigators.

The GDS system was ultimately chosen because, notwithstanding its two-dimensional format, it was considered to be far and away the best pure draughting system on the market. The quality of the system was a decisive factor and its three-dimensional stablemate, Building Draughting System (BDS), was seen as a future complementary system. The GDS salesmen were open and friendly and the system had a short user personnel training period of only some eight weeks. This comparatively short period was attractive because in the proposed bureau situation operators from outwith the practice had only a limited time to acquire the necessary operating skills.

Having selected the system, careful consideration was given to the design of the computer suite within Baxter Clark and Paul's offices. Ergonomic factors were taken into account in the layout of the custom-built suite which resulted in the finest installation of its kind where the computer, plotter and general drawing office were all housed in separate rooms. A most attractive and efficient working environment was created.

Future system developments were considered from the outset and physical and financial provisions were made for a magnetic tape copy unit, another disk drive unit and a third workstation dedicated to BDS development.

ORGANIZATION STRUCTURE

Work in Baxter Clark and Paul's office was organised on the same project basis as was found in the Reiach & Hall/Blyth & Blyth consortium. The constituency of project teams and availability of central support staff were similar too.

The partners of BCP decided to set up a completely new partnership to handle computer draughting only. This new organisation, Computer Graphic Design (CGD) was completely separate from the parent practice and was owned by BCP's five senior partners. The two architects who had originally investigated and reported upon the feasibility of computer draughting became associates of the new firm.

This particular organizational form was chosen for financial, operational and commercial reasons.

The taxation advantages accruing to a new partnership facilitated the expenditure of a considerable amount of money on the computer system. These advantages came about because, for the first time, the 1981 Finance Act allowed partners' previous earnings to be offset against a new business's start-up costs. These advantages were clearly not available to /

the original Baxter Clark and Paul partnership and would have inhibited their decision to computerize.

There was an initial lack of commitment on the part of some BPC partners and senior staff to learn to use the computer. This was due to the time required to become proficient computer operators, coupled with the necessary divorce from conventional office work which computer draughting required. The creation of an independent, horizontally structured, service department-type organization helped to overcome these problems by creating a team of enthusiastic specialists. None of CGD's partners could operate the computer.

It was recognised that professional pride and jealousy might inhibit one architectural practice from employing another architect, i.e. CGD, to produce computer drawings. The establishment of an independent organization with a different name reduced these inhibitions, whilst it also attracted other potential clients, such as advertising agencies, who might otherwise have considered an architectural practice an unsuitable medium to carry out their requirements.

The organizational structure within Computer Graphic Design, and between it and Baxter Clark and Paul, is shown in fig. 21

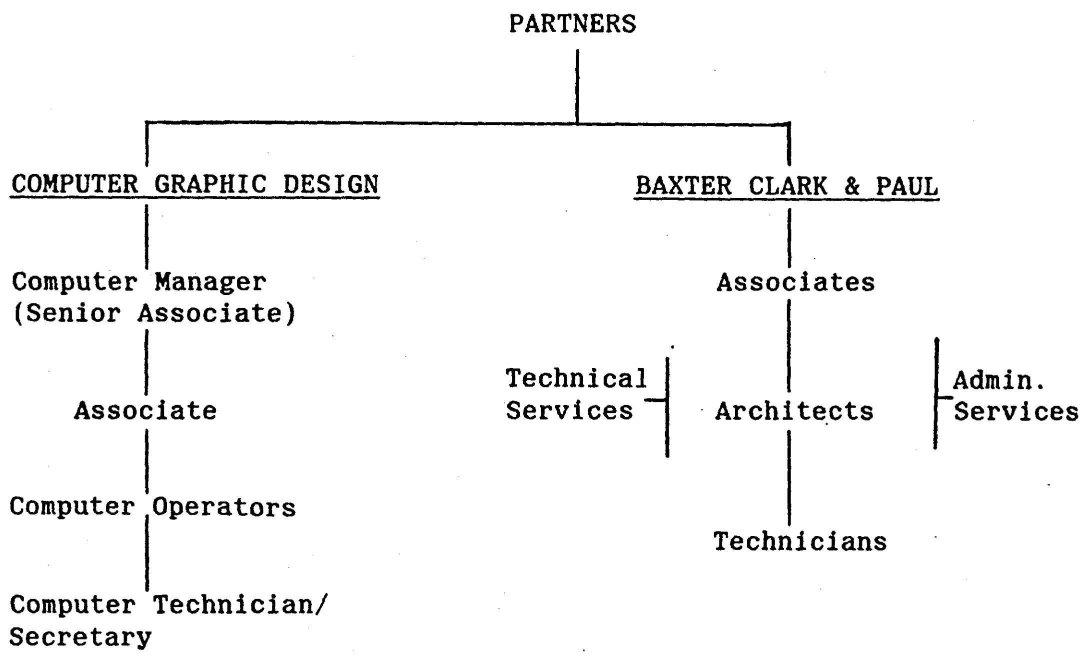


Fig. 21 The Organizational Structures of Computer Graphic Design and Baxter Clark and Paul.

The choice of organizational form gave rise initially to some difficulties in long-term planning, equipment procurement and investment decisions because the two associates had insufficient influence with the partners who controlled the finances. The associates also felt that they could not exercise the desired operational control for the same reason. Through the passage of time, however, the role of the two associates was more clearly defined and they increasingly influenced the decisions as to what work was done on the computer. The recent investment decisions too had been based on the advice offered by them.

The separate organization made cooperation with BCP more difficult and led to a certain conflict of objectives between the two partnerships. CGD might have pursued other avenues of work had it been entirely free to decide. As experience was gained of computer usage, the initial barriers between the two firms were broken down. A period of "coming to terms" with the system lasting several months was also evident before effective working relationships with BCP were established.

The potential problems of conflicting production requirements between BCP and other clients had not been resolved, although some ground rules had been established to minimise them.

FINANCE

Computer Graphic Design had an accounting system completely separate from that of Baxter Clark and Paul. As the computer suite was physically located within BCP's office, transfer charges were made against CGD for rent, heating, lighting, telephones, etc.

In order to recover running costs and pay back the capital invested, a certain (undisclosed) level of fee income had to be earned. This figure was set by the partners at the outset of operations but it was demonstrated that the initial establishment level of two computer operators could not achieve this target. Calculations showed that one, or even two, additional staff members were required to generate the necessary turnover.

Two additional staff members had been recruited, but both left the practice and the desired rate of payback had only been achieved in the first year by working extensive overtime. In the second year of operations, however, the budgetted turnover had been exceeded by more than fifty per cent.

CAREERS

The advent of computer aided draughting and the creation of Computer Graphic Design had a fairly dramatic effect on the lives of CGD's two associates. Having lived and worked in Dundee for many years, they uprooted themselves and their families and moved to Glasgow.

Working in computer draughting suspended normal architectural roles for the architects. What they did on a day-to-day basis bore no resemblance to what had been done previously in a manual draughting practice. It was admitted too that, because the computer did not design, a large part of an architect's training and culture was lost. The professional life of an architect was governed by a code of conduct and a set of ethics which were seen by some to be restrictive. Computer draughting, free as it could be from the control of the Royal Institute of British Architects and the necessity to be registered architects, freed the architectural designer from such restrictions and permitted him to be more commercially orientated.

People differed in their aptitude to use computers. Computers demanded personal disciplines just to accept them and also to operate them because they were logical in how they accepted information. Computers did not appreciate being mishandled. A young graduate architect quickly became a highly skilled computer operator while two BCP architects were slow to acquire the necessary computer skills. The graduate left CGD to work with a rival computer practice which highlighted the value of computer trained staff to other firms. Technicians were easier to train in computer draughting than architects. One technician, however, came to CGD as an experienced Calcomp operator but found GDS too complex to master and left the practice soon afterwards.

Two schools of thought emerged from the interviews regarding future employment patterns in computer practices. One body of opinion argued that, as the computer freed architects to concentrate on design, the actual computer operators would be technicians. This would lead to a polarization of professional functions resulting in a comparatively few, highly skilled designers and rather more computer operator technicians. The middle ranks of architects would disappear in this scenario. The contrary view was that the volume and, more particularly, quality of information demanded by the computer system required a designer to operate it to gain any benefit in efficiency. This, in turn, would lead to the demise of the traditional technician who no longer had a role to fulfill. It was agreed, however, that universal implementation of computer aided draughting systems throughout the architectural profession would lead to wholesale redundancies in one form or another. This arose because of the vastly reduced staffing levels required for the same throughput of commissions. Paradoxically, architects still rejected opportunities to train on the computer. Since the computer had been installed, BCP had not employed any new staff and natural wastage had not been replaced.

MARKETING

The marketing policy of Computer Graphic Design was to work from an established base of BCP's existing contacts with client organizations. The computer's ability to repeat and manipulate drawn information made it attractive for both local authority housing projects and speculative house builders. Clients had been secured in both these areas.

The computer's speed of production was ideally suited to the "Design and Build" market where construction companies were often faced with large design workloads and only limited architectural resources. No clients had emerged from this field as yet, but Baxter Clark and Paul had engaged CGD to overcome similar time constraints on specific projects.

As a computer bureau, the partnership had also secured engineers, other architects and public bodies as clients. The ease with which the computer handled awkward little drawings and exercises made it attractive to one-off clients too.

Although some market resistance to computer draughting from other architectural practices had been detected, the keen interest and patronage of graphic artists came as an unexpected bonus. This market had not been envisaged at the outset but proved to be an exciting and profitable development.

The structural steel detailing market proved to be uneconomic because of the low wages paid to steelwork draughtsmen in the competing manual draughting organizations.

As Computer Graphic Design became more widely known for its computer expertise, it was increasingly consulted by other computer practitioners seeking advice on the setting up and operation of similar systems. This fee-earning consultancy work developed into a formal training scheme where prospective computer operators were taught how to use CGD's system and then returned to their own practices. Again, this business had not been anticipated, but was most welcome.

PRODUCTIVITY

In order to realise the maximum efficiency of the computer system, it was necessary for the operators to learn a new language and new disciplines. The new language came from the user manuals which set out the commands required to operate and control the system. Mastery of these commands was essential to use the system effectively. The new disciplines came from the necessity to analyse thoroughly all information, procedures, office requirements and client requirements before starting to use the computer. These analyses were necessary so that the computer systems could be set up correctly to derive maximum benefit from the input information. As the major benefit came from the repetitive use and manipulation of this information, careful consideration was given to these preliminary tasks so as to avoid abortive work or non-optimal usage.

A 300 per cent increase in productivity over manual methods was expected from the system and, in some operations, this was more than achieved. The computer was more efficient at some tasks than others. Repetitive work, such as drawing a grid of columns and the re-use of existing information, such as drawing standard window details, were both done efficiently by the computer. In contrast, however, digitizing from existing drawings, for example, was neither efficient nor accurate in computing terms. Notwithstanding the high productivity levels achieved in individual operations, the overall system efficiency was reduced because of the presence of slack. Slack occurred because it was impossible to drive the technology as hard as theoretically possible due to external influences, such as incomplete information, errors, operator fatigue and machine downtime.

New software programs made the system even more user friendly than before and allowed the operator to "type ahead" of himself, i.e. issue projected commands whilst the computer carried out current operations. This facility was expected to give further improvements in productivity and make some computer tasks six or seven times faster than equivalent manual methods.

Computer productivity was governed by individual operator's productivity. Some operators were more productive than others and it had been found that young graduate architects produced a tremendous amount of output early in their computer careers.

DESIGN

The computers used in computer aided draughting systems did not design per se. As one operator described it,"... there are not design systems in architecture. There are design aids in architecture and certainly this system offers certain types of design aids. Basically, we construct the three-dimensional form from geometry and computers can handle geometry in a far more complex way than most people can because they can recognise the implications of doing something to one part of the construction as it relates to something else ... it's just an ability to store and to assimilate information ... but it has to be told how to do that. They act as design aids within specific restraints, they may handle environmental programs and structural programs, they may carry out certain repetitive tasks for you on a sort of semi-automatic basis, but they don't actually do any designing for you."

Although the original intention of the practice had been only to draw on the computer, some design work had been done by CGD when, on one project, it took Scheme Design information up to Production Information stage /

because late amendments to the drawings were easily effected by the computer.

One of the reasons why the GDS system had been chosen was because it did not inhibit the creativity of the designer. Indeed, the ease with which the computer handled some difficult drawing routines, such as circular walls and skewed grids, freed the designer from the constraints he would otherwise have experienced in manual draughting.

It was appreciated, however, that the complex information requirements and non-orthogonality of the three-dimensional BDS system would place restrictions on the designer if that program were installed.

The question of the practice's design liability to clients was clear cut. When acting as a draughting bureau, no design liability was accepted. If there were discrepancies in, or divergencies between, client's information, then the appropriate questions were raised and the answers incorporated. Personal opinions regarding the merit of design solutions were suppressed. If, however, CGD were designing as well as draughting, then the client was protected by the normal architectural acceptance of design liability.

In order to make the most efficient use of the computer, the practice required clients to provide the correct quality of design information at the appropriate time. Some clients found this difficult to achieve and were forced to adapt in response to the time and financial penalties incurred due to abortive work.

WORK ORGANIZATION

The Computer Manager

The senior of the two associates had other tasks in addition to being a normal computer operator. He managed the day-to-day running of the office, trained new operators and did all the three-dimensional draughting and graphic art work.

Architects

Project staffing the work was organized so that one computer operator could handle a particular project through all stages to completion. Larger projects demanded the use of two operators who then worked together closely to ensure mutual compatability of effort.

Working hours

The need to maximise computer usage led to an extension of the working day and a compensating contraction in the working week. The limited opportunities for doing work off-line meant that it was advantageous to work a three hour on-line shift first thing in the morning and last thing at night. This arrangement caused some slack to occur during off-line periods. Three hour long shifts were employed initially to limit operator stress.

The normal working day was thus extended to 12 hours but this reduced the working week to 4 days with the added attraction of a 4 day weekend every fortnight. This was considered more than compensation for the extended day. With four computer operators, the pattern was 4 days on, 4 days off, 4 days on and two days off.

This system of working was later abandoned as a norm and used only when production demanded it.

As the senior associate reported,"Getting up at 4.30 a.m. or getting home at 10.00 p.m. was no joke. The original work pattern was incompatible with professional life and a 10 to 12 hour day for 4 days on was too hard. Natural sleeping patterns couldn't adapt and work outwith an 8.00 a.m. to 6.00 p.m. core was unacceptable."
The theoretical 4 days off every second weekend seldom materialised, for the senior staff at least, because demands frequently arose which required a return to the office.

Work pace and stress

Working the computer was generally tiring and stressful and looking at a VDU for long periods caused eye strain and headaches. After one exceptionally long 7 hour on-line shift, the operator reported,"... at the end of it I couldn't drive home. I was just physically washed out completely by it. I found I couldn't think properly ... that I just couldn't drive. It was more dangerous to drive a car like that than to drive it drunk."
Individual operators had different tolerance levels to this stress however, but the threshold did not appear to rise the more experienced an operator became in using the computer. The shift duration was reduced to a standard 2.5 hours to reduce stress build-up but higher personal productivity resulted in no drop in overall output.

The computer system was "user friendly" (i.e. it employed a simple command structure) and was therefore comparatively straightforward to operate. There was a learning curve leading to maximum efficiency and this initially stretched the operator because of his unfamiliarity with the system. Although the system had prompts which told the operator what to do next, this was not found to machine pace the operator. On the contrary, the system's response time to command sequences informed the operator of how efficiently he was working.

The well designed working environment within the computer suite also did much to inhibit operator stress.

Personal considerations

One architect found computer draughting initially boring but came to enjoy it after a few months. He missed the personal contact with clients which traditional architecture gave him and visits to construction sites were now denied to him. The satisfaction which the computer's precision brought helped to compensate for his previous pleasure in "rattling pencil over paper" i.e. freehand designing.

The female computer technician employed to carry out ancillary tasks left the practice because she was inflexible in her outlook to her task, found no scope for programming activities, was inept at inputting graphic information and generally lacked commitment. She became a computer programmer in London.

RELATIONSHIPS

Clients

In commercial terms, Computer Graphic Design did not discriminate either positively or negatively against their close relation, Baxter Clark and Paul. BCP were regarded exactly the same as any other client and received no preferential treatment.

Clients were told exactly what information CGD required in order to produce the drawings. Failure to deliver timeously the required information led to delays and waiting time charges.

Late amendments to drawings could be handled easily by the computer which gave clients some flexibility in information requirements. This facility, coupled with the high standard of drawings produced by the computer, led to excellent working relationships with clients.

Quantity Surveyors

The quantity surveyor's role in the Design Team was expected to change with computer draughting. The previous emphasis on preparation of bills of quantities diminished because of the computer's facility for data manipulation. Lists of constituent parts of the building, e.g. doors, windows and sinks, could be printed out on schedules. This reduced the need of the surveyor to quantify some aspects of the work.

On the positive side, however, the computer's ability to shorten the Production Information stage of the design process made it more essential that the quantity surveyor provided early and accurate cost advice to enable the architect to make correct design decisions.

Engineers

The computer's ability to coordinate the work of all design disciplines was well recognised but not fully implemented. The technology was available but the will to do it was lacking. Coordination between disciplines would only occur when all engineers (civil, structural, mechanical, electrical and lifts) input their particular information directly into the computer. This had not happened at the practice and only one fully coordinated building had been tackled. Feedback from site indicated, however, that, within the context of architectural drawings, the computer had improved the coordination of information. It was believed that the full benefits of computer coordination would only be derived from a full three-dimensional system located within a multi-disciplinary office where all design team members worked under one roof.

This situation illustrated the belief that in future Design Team operations the computer would take up a central position and architects, engineers and surveyors would occupy a peripheral position, feeding into and drawing from a central data bank.

Builders

The computer produced high quality drawings and the builder received better and more complete drawings sooner than under a manual draughting operation. All computer drawings were accurate and consistent which alleviated many site problems, whilst the issue of different drawings for different site operations facilitated information dissemination at that level.

MAIN CONCLUSIONS OF THIS CASE STUDY

The decision making process

o The practice's decision to introduce computer aided draughting was influenced by management's desires to:

o maintain their professional position and improve their image;

o gain a competitive advantage over other practices;

o improve efficiency and increase capacity;

o create new opportunities for work;

o render a better service to clients.

Changes to organization structure

o A new practice dedicated to computer draughting was established. It had its own internal hierarchical management structure which had operational but no strategic control of the organisation.

o A new post of computer technician/secretary was created to deal with the administrative tasks occasioned by the computer system.

Changes to operating job characteristics and the experience of work

- The job of the architects using the computer system was affected in several ways:
- their working day was extended and weekly pattern of work cycle altered;
- they suffered more stress from the concentration required to maintain accuracy;
- they had to develop personal disciplines to understand and operate the system effectively;
- analyses of information and production requirements were necessary before draughting commenced;
- the interactive prompts told them how efficiently they were working;
- The drudgery of manual draughting was removed.
- Computer draughting could cope with difficult geometric constructions which were sometimes avoided in manual draughting. The creativity of the architect was thus released from the inhibitions which manual techniques sometimes imposed.
- Computer draughting gave architects the opportunity to work in new fields, such as graphic work.
- Architects lost personal contact with clients and were denied site visits.
- The computer technician was unable to develop fully her computer skills.

Effect on performance

- Some computer draughting tasks were three times faster than manual methods. New programs promised increases of six or seven times.
- Individual operations had different production outputs and overall system slack was evident.
- Employment levels were lower than would have been required for manual draughting.
- Higher initial standards of information were required timeously of clients.
- The computer system improved the relationship between the architect and client because the drawings were of higher quality and late amendments could be accommodated.
- The computer system would reduce the quantity surveyor's pre-occupation with quantifying, but demanded of him early and more accurate cost advice.
- The computer system had the potential to coordinate all construction information.
- The computer system improved the relationship between architect and builder because the information was accurate and consistent.
- The quality of drawings was greatly improved.
- Drawings were produced much faster with the computer system.

CHAPTER 7

DISCUSSION ON FINDINGS

The objectives of this chapter are:-

o to summarise and discuss the findings of the two case studies reported in terms of

decision making,

structure,

job characteristics,

performance,

Cooley's Indicators,

Pettigrew's Model

TABLE 1

SUMMARY OF FINDINGS

Common to both organizations	Peculiar to Reiach & Hall/Blyth & Blyth	Peculiar to Computer Graphic Design
1. REASONS FOR COMPUTERIZING		
increase capacity of practice	become market leaders	gain commercial edge over rival practices
improve quality of product	reduce co-ordination problems between staff	provide better service to clients
		obtain new work
2. CHOICE OF ORGANIZATION STRUCTURE		
required new computer administrator	integrated organization with originating firm	separate organization from originating firm
	became dependent on one expert	
ROLE OF MANAGEMENT		
	co-ordination of staff effort taken over by computer disciplines	senior staff not using computer
	senior staff using computer	
WORK ORGANIZATION		
extended working day	isolation of operator	shortened working week
increased operator stress	changes in work sequence	imposed personal disciplines
removal of drudgery	suppression of drawing style	information analyses required
unfullfilled technician	inhibition of creativity	new fields of work obtained
	job of technicians enlarged	operators lost client contact and denied site visits
ORGANIZATION PERFORMANCE		
staffing levels reduced	engineers dissatisfied	higher standard of client information required
relationships with clients and builders reduced		
role of quantity surveyor changed		
drawing quality improved		
drawing production rate increased		
potential for better co-ordination of drawn information		

INTRODUCTION

The findings of the two case studies detailed in chapters 5 and 6 are summarised in table 1 opposite. It can be seen that some findings were common to both organizations whilst others were peculiar to each.

DECISION MAKING

The decision to computerize was heavily influenced in both organizations by the desire to improve the quality of their immediate product, ie drawings, and to increase the capacity of their practice. This latter aspect was in response to changes in the business and professional environments in which they operated. Marketing awareness was evident in Reiach and Hall's desire for market leadership in computer aided draughting, whilst Baxter Clark and Paul sought to gain a commercial edge over their competitors, to secure new avenues of work, and to give clients a better service. Reiach and Hall also looked to computer aided draughting to reduce the management problems of co-ordinating staff effort. Computerizing was in both cases a strategic business decision and not merely a solution to operational difficulties. Both organizations perceived their computer as a facilitator of commercial advantage in their respective market places. They sought competitive superiority over other practices and not merely internal efficiencies within their own business.

Technology was therefore very much a means to desired ends and not merely an end in itself. Both organizations perceived powerful commercial reasons for computerizing and were encouraged to their decision by both external pressures and internal enthusiasm. Although partners instigated the decision process in both cases the value of internal "promoters", as described by Buchanan and Boddy (1983), was very much in evidence. The value of these enthusiasts could not be underestimated because their presence was vitally important for the continuing successful use of a computer system. Professor Macnab (a former partner of Reiach and Hall and a current GDS user, of the University of the Orange Free State, South Africa) cites anecdotal evidence of even large computer systems, purchased for reasons of prestige, lying idle for want of enthusiastic users.

STRUCTURE

The organizational forms adopted by each practice could hardly have been more different. Reiach and Hall favoured the integrated, "vertical slice" format whereby their existing structure was adapted and reinforced to accommodate the computer operation. Although no taxation advantage accrued to this form all the partners shared the computer's costs and profits. They therefore wanted the system to succeed and be profitable. The benefits of partners actually operating the technology were clear and included their awareness of the operational difficulties with the system. This, in turn, gave them credibility in the eyes of their staff and caused them to promote computing both within and outwith the partnership. This organizational form integrated the computer into the practice so that staff did not perceive a "them and us" situation between computer operators and others. The number of computer users within the practice was limited only by the computer time available to train them. This diffusion of computer knowledge throughout the staff allowed more projects to be computerized and limited the possibility of the partners being held to commercial ransome by one expert user. On the other hand however the integrated structure had two undesireable features. Firstly, it limited the type of work done on the computer to almost exclusively architecture. Other possible non-architectural clients who could utilise computer draughting were inhibited from using Reiach and Hall simply because they did not associate their type of work with architects. Secondly, the work done on the computer was restricted, however unintentionally, to those who held common commissions with Reiach and Hall. No other architectural practice would be inclined to use a rival practice to do their work, nor would enginers and surveyors, for similar professional reasons.

Baxter Clark and Paul adopted the "new practice" format whereby a completely separate organization was set up exclusively for the purpose of computer draughting. This organizational form was encouraged by taxation advantages in the start-up situation, but not all of BCP's partners participated in the new venture. This structure widened the commercial horizons of the new practice and facilitated the introduction of not only other architects, engineers and surveyors, but also unexpected clients such as graphic artists and advertising agencies. The dissociation from the professional constraints of architecture brought commercial freedom and permitted the practice to advertise freely, to set their own scales of charges, and to limit their design responsibility. The fact that partners did not operate the technology caused some separation between them and the senior staff who felt unable to influence decisions. Strategic decision making was vested exclusively in the partners who lacked operational experience. This led to some difficulties regarding long-term planning and equipment procurement. The partners left the operational running of the practice to two associates who clearly held /

considerable commercial power. In the event of their leaving the practice a sizeable investment would grind to a halt. There were thus advantages and disadvantages with either form of organization structure. The current divorce of BCP's partners from the operational running of the computer system, with the implicit lack of commitment at the top, was considered by the author to be perhaps a fatal flaw for the long-term prosperity of that practice.

The contrast between these two organizational forms does not however preclude the possibility of other commercially advantageous structures. It just so happened that the organizations had evolved widely different forms for very good, internally consistent, reasons. Other practices may well have other circumstances giving rise to other organizational structures which are equally valid and successful. Much will depend on the prevailing conditions and policies, coupled with the personalities and objectives of the dominant figures in the practice. The choice of form may therefore be as much a political decision as a cold, logical management science decision.

JOB CHARACTERISTICS

Work Patterns

The commercial desire to utilise fully the time available to the computer by extending the working day was understandable, but was incompatible with professional life. In most cases architects came to computing from an established working routine which, in accord with most professions, ran from 8am to 5pm five days a week, with occasional overtime worked as required. The continued necessity of working outwith these hours was unacceptable and the promised compensation of a four day week had been exposed as illusionary. It appeared that practices simply had to accept this /

constraint or offer financial incentives to encourage staff to adapt to shift working patterns.

Operator stress was evident in both organizations, although a wider variety of causes was reported in Reiach and Hall due to the particular technology and ergonomic layout found in that practice. Looking at a visual display unit for any length of time was stressful to the operators and caused headaches and fatigue. The counter-measures adopted were to introduce a shift pattern of working within the working day and to limit the length of on-line periods to between 2 and 3 hours duration. These were generally successful in limiting operator stress and permitted ancillary, preparatory work to be done before going on-line. Some operators grew accustomed to these stresses and were able to work for longer periods, but others did not. For most operators, efficiency declined noticeably during long on-line periods.

Machine prompting also gave rise to operator stress in Reiach and Hall, but Baxter Clark and Paul's operators perceived similar prompts as aids to efficient working. The technology said the same thing in different ways which were acceptable only to BCP's operators. Reiach and Hall's operators experienced stress due to new time constraints imposed by computer draughting. Striving to make the best possible use of on-line shifts led to cramming of work into the session and hence gave rise to stress. New overall deadlines were imposed to meet the drawing programme which compounded the stress problem. It was not altogether true that computer time was expensive. The expense of purchasing the system was a "sunk cost" and therefore irrecoverable in accounting terms. Only the running costs mattered and, as they were comparatively minor, there was little necessity to work exceptionally hard to maximise return. It was easier to sub-divide overall project programmes in the computer system and /

the draughting time required could be more easily assessed than in manual draughting. This fragmentation created new deadlines and, notwithstanding the increased operator stress which it induced, the advantages of this seemed overwhelming.

The stress suffered by Reiach and Hall's operators caused by the noisy plotter was totally avoidable. Isolating the plotter in a different room from the work station would have eliminated this problem at a stroke and it was surprising that the conditions were tolerated at all. Computer Graphic Design's computer suite was a model of ergonomic design and efficiency which other practices could do well to emulate.

The isolation experienced when operating the computer was in contrast to the social interaction enjoyed in a traditional drawing office. The effect of this isolation was the removal of distractions on the one hand but the reinforcement of concentrated effort and hence stress on the other.

Working Methods

The computer system demanded changes in the working methods employed by an architect. Reiach and Hall's system required detail design to be done much earlier in the design sequence and both systems required careful product requirement analysis to be done before work commenced. This required flexibility and adaptability on the computer architects part which had implications for personnel selection and recruitment.

Creativity

The contradictory views as to whether computer draughting inhibited or released architects' creativity was largely due to the technology employed. Reiach and Hall's RUCAPS system was a three dimensional, component based, orthogonal system which could not draw skewed grids.

At the time of the study it also drew curves and arcs very poorly, these being merely a series of short straight lines. Given these technological constraints it was hardly surprising that its users felt creatively restricted in what they could draw. In contrast, Baxter Clark and Paul's GDS system was exceedingly good at handling difficult geometric constructions, including perfect circles etc. With this technological assistance it was axiomatic that its users felt creatively released by the computer. Generalizations about creativity should therefore be tempered by an understanding of the technology employed.

Computer Administrators

The unfortunate experience which both organizations had with their computer administrators/technicians was probably not coincidental. The aspirations of the personnel selected for this task were unfilled and the inference was that the wrong type of people were recruited. Both girls wanted to do computer programming which was a redundant skill in organizations which were dependent on bought-in, commercially produced software for draughting. The computer companies would not allow users to amend or otherwise interfere with their programs. Even if extending the range of computer operations away from draughting, into for example critical path analysis or office accounting, the organizations probably preferred to buy ready-made programs. One way of possibly retaining this staff would have been to enlarge their jobs into general office administration, with special emphasis on computing. This job description required general administrators with an interest in computing rather than computer specialists with only a passing interest in administration.

Role of Management

Reiach and Hall's experience that the management's task of coordinating staff effort was taken over by the working desciplines imposed on users by the computer system had fundamental implications for the senior staff who previously carried out that function. Although the coordinating task was made redundant by the computer the expertise and experience of these senior staff could not be lost to the practice and new roles had to be found for them. The obvious course was to train them as computer operators where their professional skills were once again exercised "on the drawing board". This lent weight to the argument that senior staff did in fact have the time available to operate the computer system.

PERFORMANCE

Employment Levels

The reduced staffing levels required by computer aided draughting had serious implications for the profession. The magnitude of the problem was directly related to the speed of installation of computer systems throughout the profession. When this study commenced in 1980 only Reiach and Hall had a computer system in Scotland, whereas in January 1984 there were five. It was difficult to determine whether the rate of implementation of computer technology was increasing, decreasing or static. It could be argued that those who might computerize had already done so, but there were still several major Scottish practices without a system. The cost of the technology was not falling to any extent because the reduced hardware costs were offset by the increased cost of more sophisticated software.

Smaller practices might therefore not be attracted into the field. It was very difficult to speculate on employment levels on a profession-wide basis. Those practices which had computerized required fewer staff, but neither firm studied had made anyone redundant due to the computer directly.

Employment Mix

The senior staff of Computer Graphic Design were convinced initially that the computer system should be operated by technicians. The poor quality of information coming from their clients caused at least one associate to change his mind to believe that architects should be the computer operators. Reiach and Hall used architects by and large. This divergence of opinion resulted from the business strategy pursued by each practice. Reiach and Hall were architects using the computer for their own production information requirements. It was therefore more advantageous for their designers to operate the technology directly than to give it to a technician to do. CGD was fundamentally a draughting bureau which took fully designed schemes from clients and simply drew the required plans by computer. So long as the client's information was of a sufficiently high standard then technicians could handle this work, but when that did not happen it was necessary to use architects to operate the computer. There were therefore circumstances when both technicians and architects were used effectively. Within a normal professional practice however the tendency appeared to be to use architects as computer operators. This in turn would lead to the demise of the traditional architectural technician.

Design Team Working

The advent of computer aided draughting heralded potentially significant changes in design team working. The classic structure placed the architect in a central position as shown in Fig 22 with engineers and surveyors on the perimeter, feeding from him.

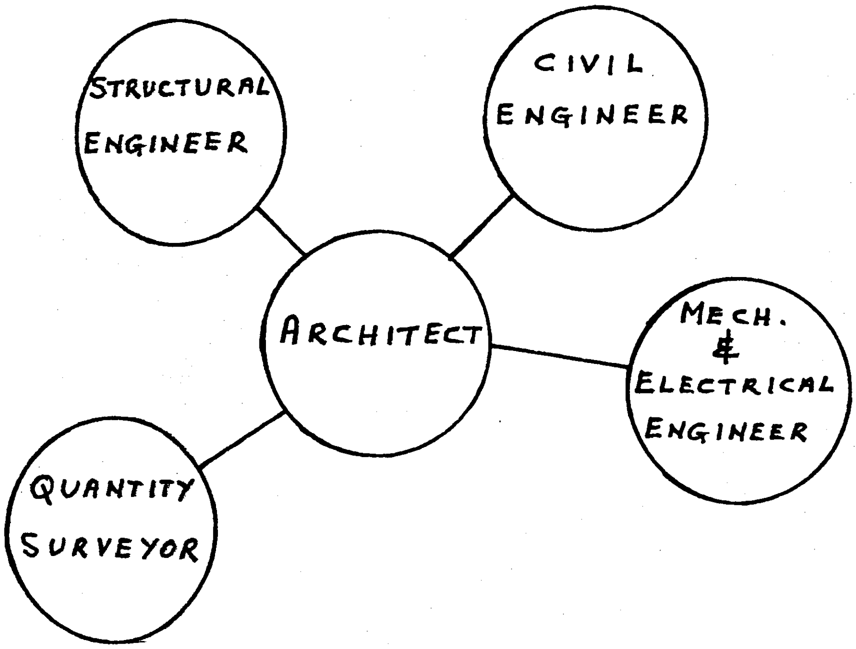


Fig.22:Traditional Structure of Design Team

The computer changed that because of its huge data banks which became available to all design team mambers, and its ability to coordinate all construction information. A structure as shown in Fig 23 which placed the computer, and not the architect, in the dominant central position was therefore most appropriate.

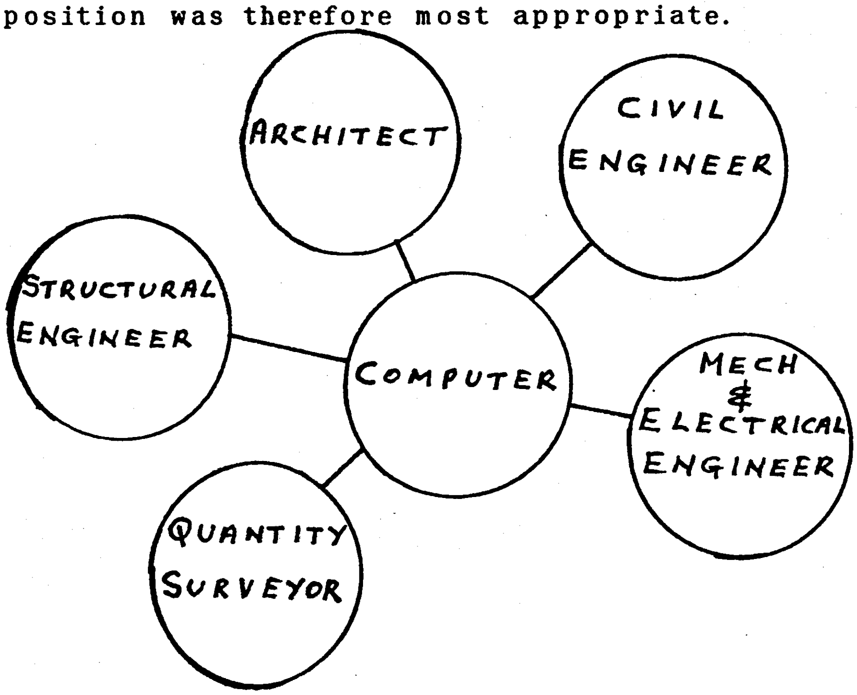


Fig.23:Structure of Computerized Design Team.

This arrangement envisaged all non-architectural designers inputting their own particular contributions to the overall design directly into the computer. All this information would supplement the architectural data already in the computer and thus create a single, comprehensive and internally consistent data base from which all design team members worked. Quantity surveyors would interrogate the data and the computer would provide print-outs of component schedules and other quantity data. Fully coordinated drawings, schedules and bills of quantities would thus emerge in this scheme. Unfortunately, several factors worked against this utopian situation and neither Reiach and Hall nor Baxter Clark and Paul had achieved this degree of design team integration. Even assuming that the huge information storage requirements were met, resistance to this idea was caused by

- o the physical location of design team members;
- o the training of design team personnel;
- o the subtleties of quantity surveying.

In traditional design team working it was not uncommon for design team members to be located in different cities, let alone different parts of the same city. On their hospital project Reiach and Hall and their structural engineers were in Edinburgh, their mechanical and electrical engineers were based in Newcastle Upon Tyne, and their quantity surveyors came from Glasgow. This physical separation was tolerable in the manual draughting situation because senior members only needed to gather together for meetings. Computer draughting demanded operations to be locally based in view of the computer operating time required. The non-architectural design team members faced a very real difficulty in staff training for computing. Blyth and Blyth's difficulties /

in learning to use the consortium's computer were noted previously and this highlighted the need for comprehensive teaching programmes and continued support for new operators. These individual difficulties were compounded by the realization that each design team member practice worked within many design teams for different projects. If each architect had a different computer system then the learning process was enormous. This also inhibited these members from buying their own computer draughting system because no two systems were compatible. They were dependent on basic architectural information to which they added their own input, but which of the many systems available should they buy? It was an impossible dilemma.

The universally proposed solution was multi-disciplinary design teams where all disciplines were members of one common organization and were physically located under one roof. The fragmented nature of the construction professions, professional jealousies, and professional rules of conduct had all combined to inhibit more widespread adoption of this organizational form. The theoretical ease of coordination inherent in this form was, to some, imaginary and Andrew Mirrylees, a partner in a large architectural practice with vast experience of complex coordinated buildings, remarked at a conference, "Coordination is where the mind is, not where the bum is".

The ease with which the computer manipulated large data sets and produced schedules of components assisted the quantity surveyor. The belief that this facility would negate the need for a surveyor to product bills of quantities was based on a naive concept of how quantities were generated. Although some bill items were enumerated, very many more were measured in lineal, square and cubic units which were much more difficult for the computer to produce automatically. In addition, the quantities were subject to many intricate rules of measurement prescribed by a central body for the construction industry. This measurement task required intellectual judgement and discretion on the part of the surveyor. His demise at the hands of the computer was, for the moment, premature.

Relationships with Clients and Builders

The better relationships brought about by computer aided draughting between architects and clients, and between architects and builders, were very real. Clients received a better, faster service than with manual draughting and they could incorporate late drawing amendments fairly easily. In Baxter Clark and Paul's draughting bureau clients had to adapt to provide the correct quality of information for computing, but this was not impossible.

The builder gained a great deal from computer aided draughting. All computer drawings were accurate and consistent, unlike their manually drawn equivalents. The builder could obtain separate drawings for specialised purposes which facilitated his site operations. There were no disadvantages to the builder arising from computer draughting, only advantages.

Analysis Of The Findings In Terms Of Cooley's "Indicators"

Chapter 3 indentified fourteen "Indicators" which Cooley (1987) tabled as inevitably followed from the introduction of a computer-aided draughting system. The findings of the two case studies reported in Chapters 5 and 6 were analysed in terms of these "indicators" and the following was observed:-

1 **The subordination of the designer to the requirements of the computer with shift work and systematic overtime.**

This was confirmed. The extension of the normal working day, shift work, and regular overtime working were all found in both case studies. These working conditions were generally unacceptable to architects who were used to professional office hours. Enforcement of these conditions over a protracted period would inevitably lead to the alienation of the workforce

2 **Emphasis upon machine centred systems rather than human centred ones.**

This was confirmed. Changes in working practices were invariably designed to accommodate machine requirements, rather than human demands. Reiach and Hall's designers worked physically close to the computer and were therefore isolated from the society of other designers. There were no overwhelming technical reasons for such an arrangement and remote workstations were quite practicable. This was evidenced by CGD's computer suite which preserved a traditional layout where project team members were in close physical proximity to each other thus facilitating inter-relationships and fostering team spirit.

3 **Limitation of the creativity of the designer by standard routines and optimisation.**

The evidence was ambivalent on this point. Standard routines and optimisation were encountered, but were perceived as aids to remove drudgery rather than to inhibit creativity. In one case the limitations of the technology precluded the use of some design solutions, but in the other case the capabilities of the technology actually released creativity. The technology must be made capable of at least replicating all drawing functions available in the manual alternative so as not to restrict the choice of design solutions.

4 **Domination of the subjective value judgements of the designer by the objective decisions of the system.**

This was confirmed to a limited extent. As in 3 above, it depended on the constraints/capabilities of the technology in use. Thus, for example, a technological restriction on the use only of circular curves in a situation where mathematically more complex curves would be appropriate lead to the subordination of the designer's preferred solution.

5 **Alienation of the designer from his work.**

This was denied. No evidence was found to suggest that designers became estranged from their work because of CAD systems. This happy situation would only continue as long as computer systems did not impinge to any marked extent on the motivation, job satisfaction and working conditions of architects. As speculated in 1 above, the enforcement of regular overtime working, for example, might well alter this finding.

6 **Abstraction of the design activity from the real world.**

This was denied. The essentially pragmatic nature of architecture ensured that designers were well aware of the practical implications of their design work. Continued feed-back from end users of CAD output, such as builders and site-based staff, was essential to maintain contact with the real world.

7 **A fragmentation of design skills with a loss of panoramic view.**

This was confirmed. Designers were conscious of our-specialisation in CAD and deprecated the loss of opportunity to practise all aspects of their skills and training. Such opportunities had to be given by rotating computer operators back into mainstream architecture so as to permit practise of the full range of architects' skills.

8 **De-skilling the design function.**

This was largely denied. As almost all design work was done away from the computer, design skills were not eroded to any great extent. Manual draughting skills however were lost. When limited design work was done on the computer the speed of operations compressed the time available for thought and reflection and this impaired the quality of some design processes. Such time should be made available to avoid less than optimal solutions.

9 **Increased work tempo as the designer is paced by the computer.**

This was confirmed. Machine prompts caused increased work tempi, but slow prompts also caused frustration. Architects' perception of the prompts had to be changed to recognising them as measures of personal efficiency rather than demands for increased work pace. This change in perception should be coupled with a realization that computer time is not expensive per se.

10 **Increased stress, both physical and mental.**

This was emphatically confirmed. Isolated working, higher levels of concentration, increased deadlines, cramming work into limited computer sessions, interactive machine prompts, electro-mechanical noise levels and VDU glare all contributed to increased stress levels. Some of this stress, such as work cramming, was self-induced and could therefore be relieved by changing personal attitudes to work requirements. Good ergonomic design could overcome some of the stress-inducing factors but others were almost inherent in CAD operations, eg high concentration levels. Task variety alone might alleviate this factor.

11 **Loss of control over one's work environment.**

The evidence was ambivalent on this point. It did not flow inevitably from CAD operations, but occurred where insufficient thought had been given to ergonomic considerations. CGD's computer suite was a model of modern office design which no doubt contributed to efficient and harmonious working.

12 **Growing job insecurity, particularly for older men.**

This was denied. Despite the dramatic reductions in staffing levels achieved when operating CAD systems, no evidence of job insecurity amongst designers was recorded. It was certainly evident that younger men showed more aptitude for CAD operations and achieved higher outputs, but older men had other skills to contribute based on their experience.

13 **Knowledge obsolescence.**

This was confirmed. As in 7 above, designers perceived aspects of their personal knowledge going out of date through lack of practice. This was not peculiar to computer operations and architects were aware of the need to keep up to date in aspects of the profession in which they were not currently engaged.

14 The gradual proletarianisation of the design community, the considerable increase in trade union membership and industrial militancy.

This was emphatically denied. No evidence whatsoever was gathered to support this assertion. This only reflected the non-unionised nature of current professional architecture and did not preclude a change of attitude in the future should commercial circumstances favour a few indispensible computer operators.

Of Cooley's fourteen indicators, the research confirmed seven (1, 2, 4, 7, 9, 10 and 13), denied five (5, 6, 8, 12 and 14) and found two to be ambivalent (3 and 11). Almost all of the confirmed indicators related directly to the man-machine interaction whereby machine demands overwhelmed human preferences and so caused negative reactions. The indicators which were denied by the research related in the main to people's perceptions of their work and the effect of technology upon it. The ambivalence of the two remaining indicators was explained by the variable capabilities of the technology in one case and by inadequate managerial planning in the other.

Analysis Of The Findings In Terms Of Pettigrew's Model of Strategic Change

Chapter 3 also identified Pettigrew's model of strategic change which comprised Content, Process and Context (subdivided into outer and inner components). The findings of the two case studies reported in chapters 5 and 6 were analysed in terms of this model and the following was observed:-

Content

Content of the strategic change was primarily the change from manual to computer aided draughting methods. Secondary objectives were also observed however related to increased efficiency and capacity, gaining a competitive advantage, providing a better service to clients, and improving corporate image and product quality. These secondary objectives flowed from the achievement of the primary objective.

Context

The outer context in which the firms operated related to a Governmental political objective of abolishing mandatory fee scales and therefore the creation of a competitive market place. This in turn demanded increased efficiency to maintain profit levels and increased capacity to improve throughput at lower profit margins.

The inner context related to a partnership organizational form whereby the capital cost of the technology was spread throughout the partners before taxation. This small, non-bureaucratic structure clearly facilitated decision-making, control and support during change. The transformation also created different new structures - one replicating the existing structure and the other changing it completely. From the perspective of the changed firms this was an inner contextual matter, but from the perspective of the original firms this may well have been reviewed in an outer context. The corporate cultures were receptive to change with forward-looking, dynamic partners and the internal political contexts were amendable to change.

Process

The process of change was closely related to the important role of "promoters" within each organization. These individuals or groups sought to facilitate the change to CAD by doing the market research, preparing the appraisal reports and negotiating the transformation process with the partners of the firm. Their role changed over time and having promoted the change they then had to justify it by being proficient operators themselves, demonstrating the benefits to senior management, and promoting the facilities to clients.

Summary

The particular components of Pettigrew's model revealed by the two case studies were therefore:-

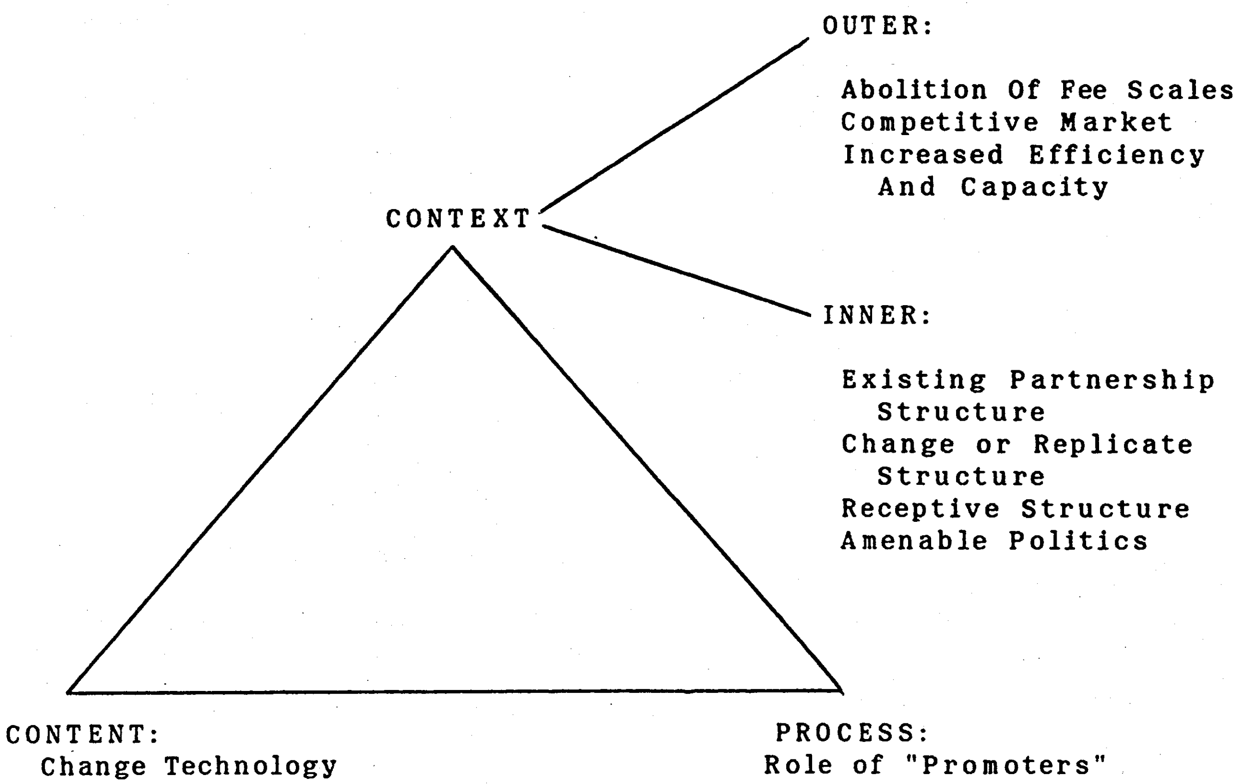


Fig. 24: Particular Components of Pettigrew's Model of Strategic Change

The original model was validated to a large extent, although it was also shown to be somewhat over-simplistic. The perspective of the observer affected whether contextual issues were outer or inner, and an apparently singular objective of change had in fact several sub-objectives.

CHAPTER 8

CONCLUSIONS

The objectives of this chapter are:-

- to draw conclusions from the research
- to make recommendations for future installations
- to identify areas for further research

INTRODUCTION

The objective of this thesis was set out in Chapter 1 in the following terms:-

The proposition set out in this thesis is that the technology of computer aided draughting can be used to the benefit of all those engaged in the construction process.

Having reviewed the literature, prepared case studies within two separate organizations, and discussed the findings derived therefrom, a conclusion can now be reached.

CONCLUSION

The conclusion is:-

Computer aided draughting is the single most important tool to be introduced into the practice of architecture since the invention of tracing paper in the mid-nineteenth century, and its widespread use has far-reaching implications for architectural firms, individual architects and all those engaged in the construction process.

Computer aided draughting generates both strategic and tactical changes in parent organizations and presents architectural firms with the technological capability to embrace the fundamental changes in the external environment in which the profession now operates.

The everyday work of architects is materially altered by CAD operations and these changes are, on balance, to the disadvantage of individuals.

CAD also affects the way in which Clients, other Members of Design Teams, and Builders operate and changes in working methods are required to reap fully the benefits of computing.

It is clear therefore that although computer aided draughting can be introduced successfully into an organization and can benefit all those engaged in the construction process, there is a cost to the organization and individuals involved.

The benefits derived from CAD devolved on both clients and members of the design team. Benefits were also believed to accrue to the builder, but this aspect was not researched. The benefits comprised better client and inter-professional relationships, increased product quality and capacity, and easier managerial controls.

The cost to the organizations was in terms of a substantial and continuing financial commitment to the technology. Additional organizational structures and requirements were demanded for effective management of the technology.

The cost to the individuals within the organizations could be high in terms of new working conditions and methods, increased stress, and restrictions on professional fulfillment.

On balance, however, careful planning and sensitive management could ensure the successful implementation of the new technology.

RECOMMENDATIONS

The following recommendations are made to ensure the successful implementation of a computer aided draughting system within an architectural practice:-

- Ensure full support, understanding and commitment of the highest level of management.
- Select the proposed organization structure carefully, as this may dictate the future direction of the business.
- Undertake extensive market research before purchasing technology.
- Recognise the inevitability of the financial treadmill inherent in new technology and make provision for same.
- Establish an effective computer management structure and systems.
- Take cognizance of ergonomic factors when determining machine and office layouts.
- Provide adequate training for all system users.
- Avoid the "high priest" syndrome by dispersing computer knowledge throughout the organization.
- Encourage the active participation of senior staff in computer operations.
- Expand the benefits of computing to other members of the design team.

- Anticipate changes in working practices.
- Avoid unsocial working outwith normal office hours.
- Minimise operator stress by careful work scheduling and altering perceptions of machine prompts.
- Limit on-line shifts to 2-2.5 hours duration.
- Recognise dangers of personal over-specialisation and ensure long-term satisfaction of all professional skills.
- Beware the restrictions on the computer administrator's career path and expand their job specification.

AREAS FOR FUTURE RESEARCH

The research undertaken for this study looked only at the impact which computer aided draughting had on the design stages of the construction process. Potential effects on the post-contract construction stage were speculated upon, but this is clearly a major area for future research. The quality and consistency of computer drawings should negate many traditional site problems and it is essential that this area be researched to confirm or deny that speculation.

The partnership form of organization structure exhibited by the two architectural practices in the research denied any opportunity to make a full economic evaluation of the costs and benefits of computer aided draughting. Such an examination, perhaps coupled with some form of comparative work study with manual draughting methods, is clearly desirable. The claims of computer manufacturers, software houses, and indeed system users, all of whom have vested interests to support, would then be put to the test.

APPENDIX 1

COMPUTER AIDED DRAUGHTING SYSTEMS

COMPUTER AIDED DRAUGHTING SYSTEMS

System		No. of Installations
APPLICON:	Applicon, Regent House, Heaton Lane, Stockport, SK4 1DA	Not given
AUTOTROL:	Davy Computing Limited, Moorfoot House, 2 Clarence Lane, Sheffield, S3 7UZ	Not given
CADAM:	I B M, 17 Addiscombe Road, Croydon, CR9 6HS	Confidential
CADEC:	Calma, United House, 56-64 Leonard Street, London, EC2 4AH	Nil
CADRAW:	Ove Arup Partnership, 13 Fitzroy Street, London, W1P 6BQ	1
CADS	Cusdin Burden & Howitt, Greencoat House, 5th Floor, Francis Street, London, SW1P 1DB	1
CARBS:	Clwyd County Council, Shire Hall, Mold, Clwyd, CH7 6NH	1
COMPUTERVISION:	Computervision Limited, Computervision House, Penn Street, Amersham, HP7 OPY	Not given
DOGS:	Perkin-Elmer Data Systems Limited, 227 Bath Road, Slough, SL1 4AX	Not given
DRAGON:	Compeda Limited, Compeda House, Walkern Road, Stevenage, SG1 3QP	Nil
FERRANTICETEC:	Ferranti CetecGraphics Limited, Cetec House, Lincoln Road, High Wycombe, HP12 3RD	Confidential

System		No. of Installations
GDC	Applied Research of Cambridge, 4 Jesus Lane, Cambridge, CB5 8BA	10
GERBER:	Gerber Scientific Instrument Co., 27 Rue E Steend, 1160 Brussels, Belgium	Not given
GIPSYS:	Scott Wilson Kilpatrick & Partners, Scott House, Basingstoke, RG21 2JG	1
IGS 500:	Calcomp Limited, Cory House, 20 The Ring, Bracknell, RG12 1ER	(List not provided)
MEDUSA:	C I S, Quayside, Cambridge, CB5 8AB	1
RUCAPS:	G M W Computers Limited, Castle Mill, Lower Kings Road, Berkhampstead, HP4 2AD	22
SUE:	Tom Stout & Partners, 6 College Avenue, Formby, Liverpool, L37 3JJ	Nil
SUMMAGRAPHICS:	Terminal Display Systems, Hillside, Whitebirk Industrial Estate, Blackburn, BB1 5SN	1
UNIGRAPHICS:	McDonnel Douglas Corporation, Scotia House, 66 Goldsworth Road, Woking, GU21 1LQ	1

1. Single Installations

System		User
CADRAW	:	Ove Arup Partnership, London
CADS	:	Cusdin Bunden & Howitt, London
CARBS	:	Clwyd County Council, Clwyd
GIPSYS	:	Scott Wilson Kilpatrick,London
MEDUSA	:	Cusdin Bunden & Howitt, London
SUMMAGRAPHICS	:	Astrawall, Purley
UNIGRAPHICS	:	Greater London Council, London

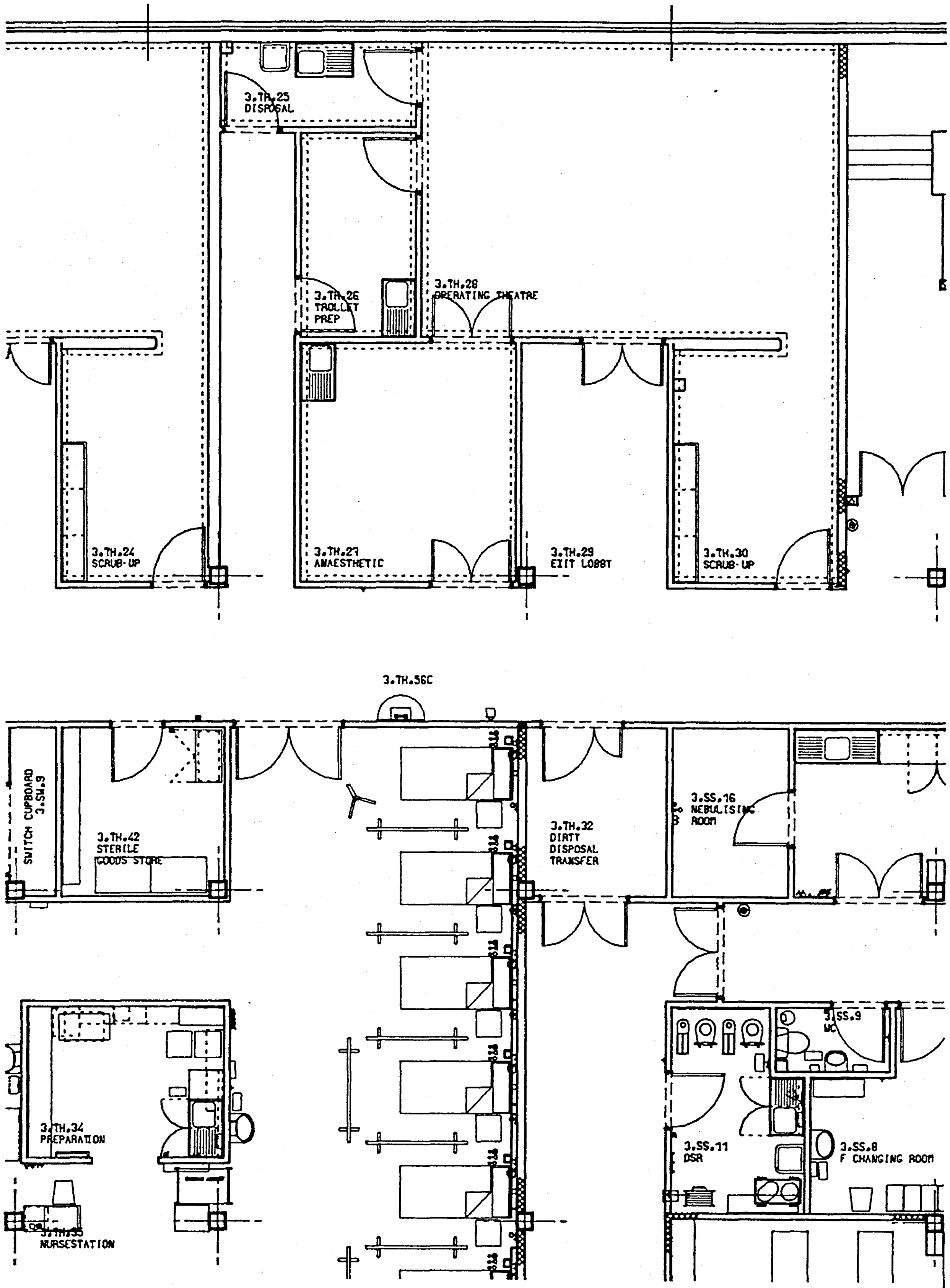
System	User

2. Multiple Installations

GDS	:	Atkin Shepherd & Fiddler, Epsom
	:	Baxter Clark & Paul, Glasgow
	:	John F. Bonnington, St. Albans
	:	D'Arcy Race, Oxford
	:	Devon County Council, Devon
	:	D.O.E. Property Services, Cambridge
	:	Elsom Pack & Roberts, London
	:	London Transport, London
	:	Scott Brownrigg & Turner, Guildford
	:	Thomas Saunders, London
	:	Travis Morgan Engineering, London
	:	Twist & Wickley, Cambridge
	:	Watkins Gray International UK, Orpington
RUCAPS	:	Abbey & Hanson Rowe, Huddersfield
	:	A C D P, Maidenhead
	:	Architects Co. Partnership, Potters Bar
	:	Baldwin Brattle Conelly, Stevenage
	:	D.Y. Davies, London
	:	Diamond Redfern, London
	:	Fairhursts, Manchester
	:	Facility Management Institute, U S A
	:	George Trew Dunn Beckles Willson Bowes, London
	:	Arthur Gibney, Dublin
	:	Leonard J. Moulton, Birmingham
	:	G M W Partnership, London
	:	John Lewis, London
	:	Llewelyn-Davies Weeks, London
	:	Reiach & Hall, Edinburgh
	:	Frank Shore, Chesterfield
	:	Sir Richard Siefert, London
	:	A.P. Skelton, London
	:	S.R.Z. Architects, Brussels
	:	Stanford Eatwell, London
	:	Harry Weedon, Birmingham
	:	Whites, Sweden

APPENDIX II

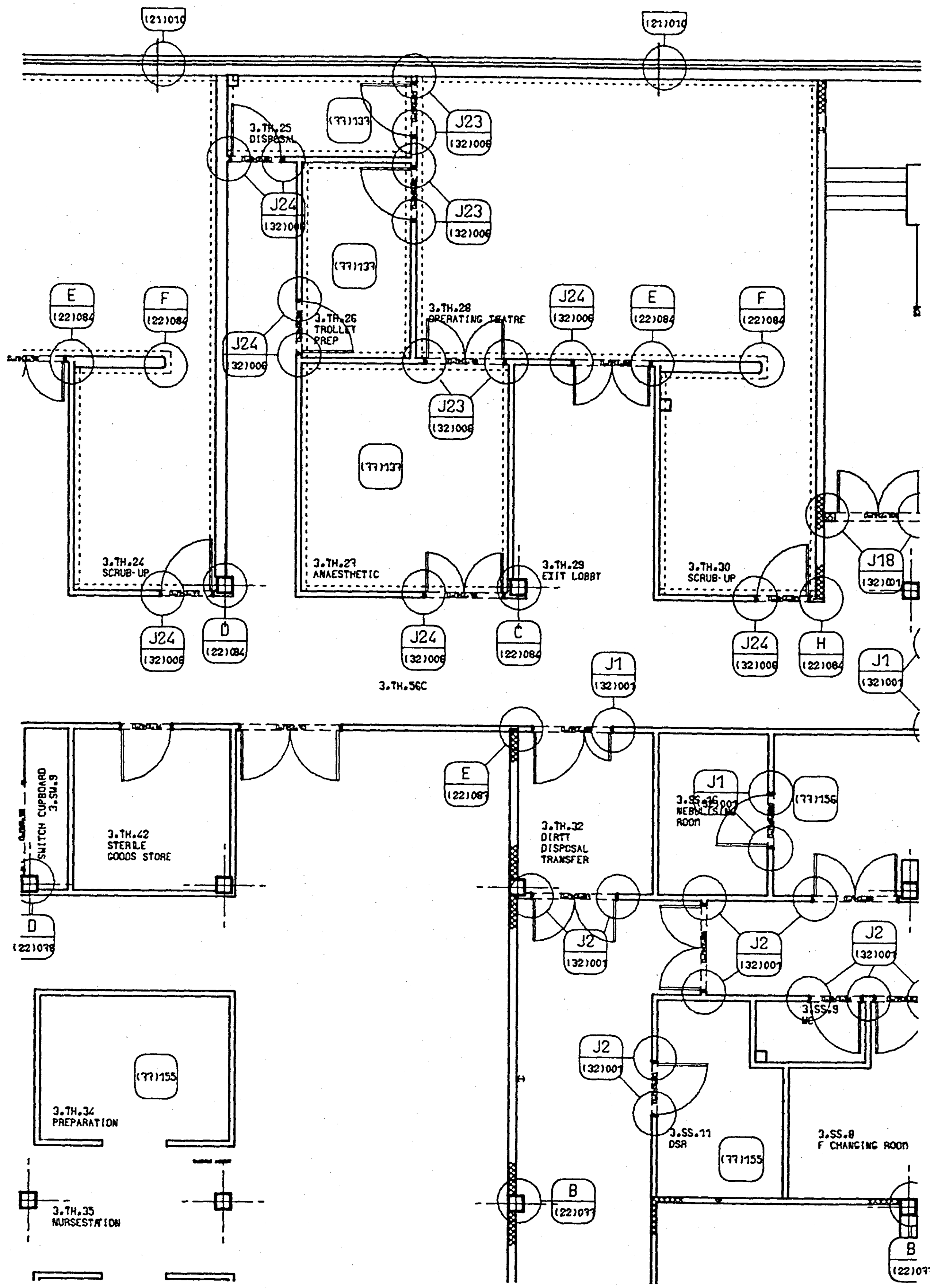
RUCAPS SYSTEM DRAWINGS



<u>RUCAPS SYSTEM DRAWING</u>

Drawing 1

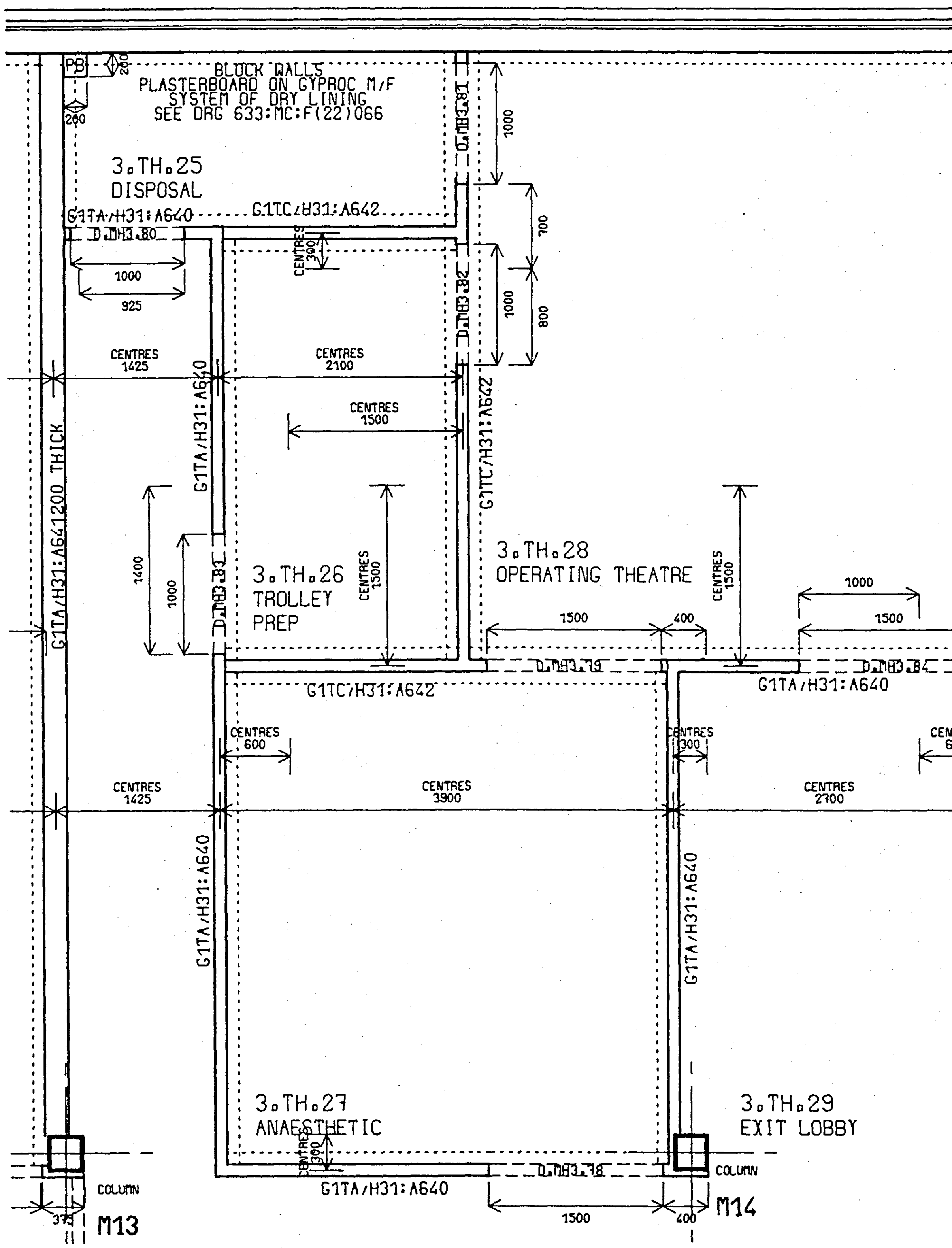
General Arrangement



RUCAPS SYSTEM DRAWING

Drawing 2

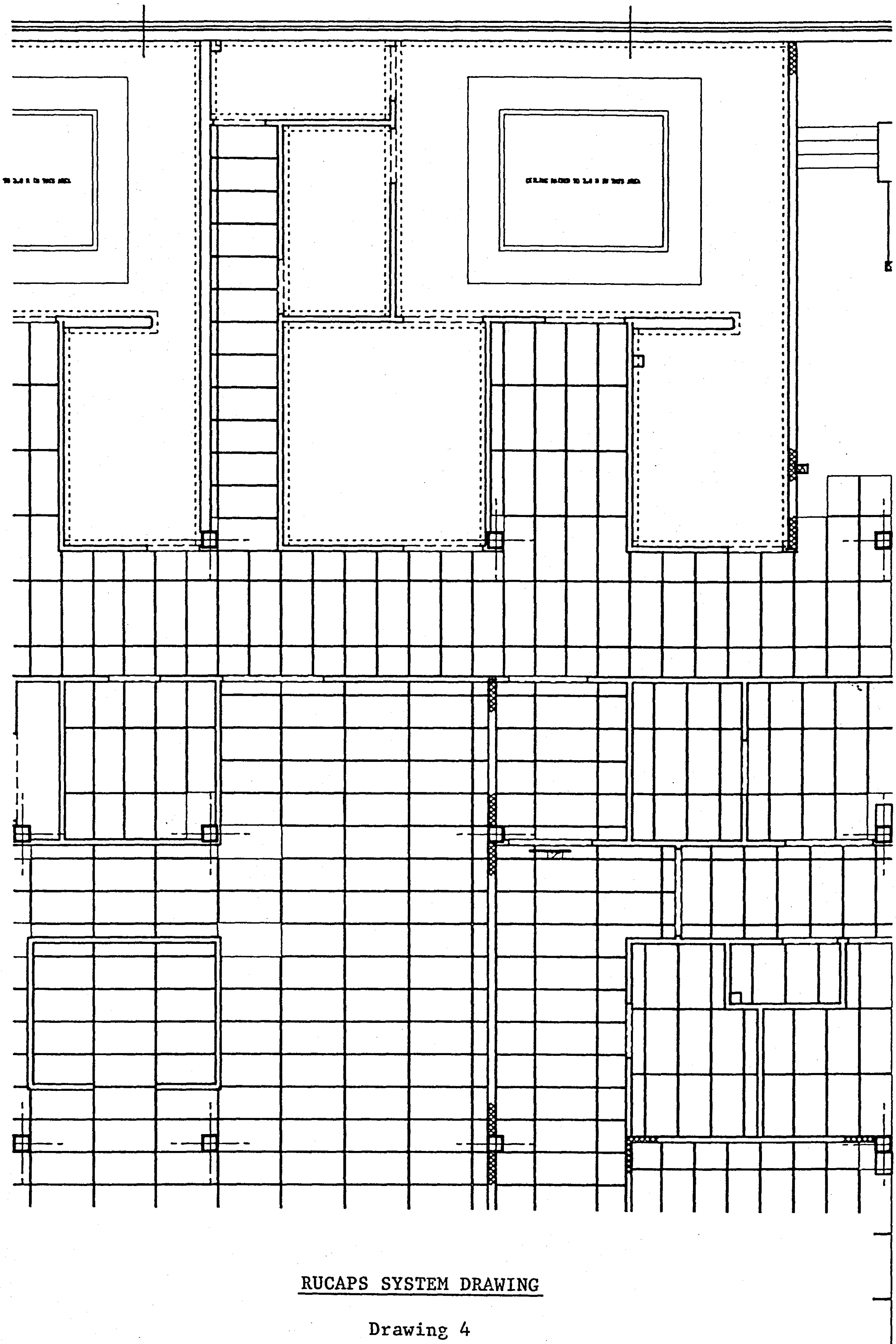
Wall Function Detail Codes



RUCAPS SYSTEM DRAWING

Drawing 3

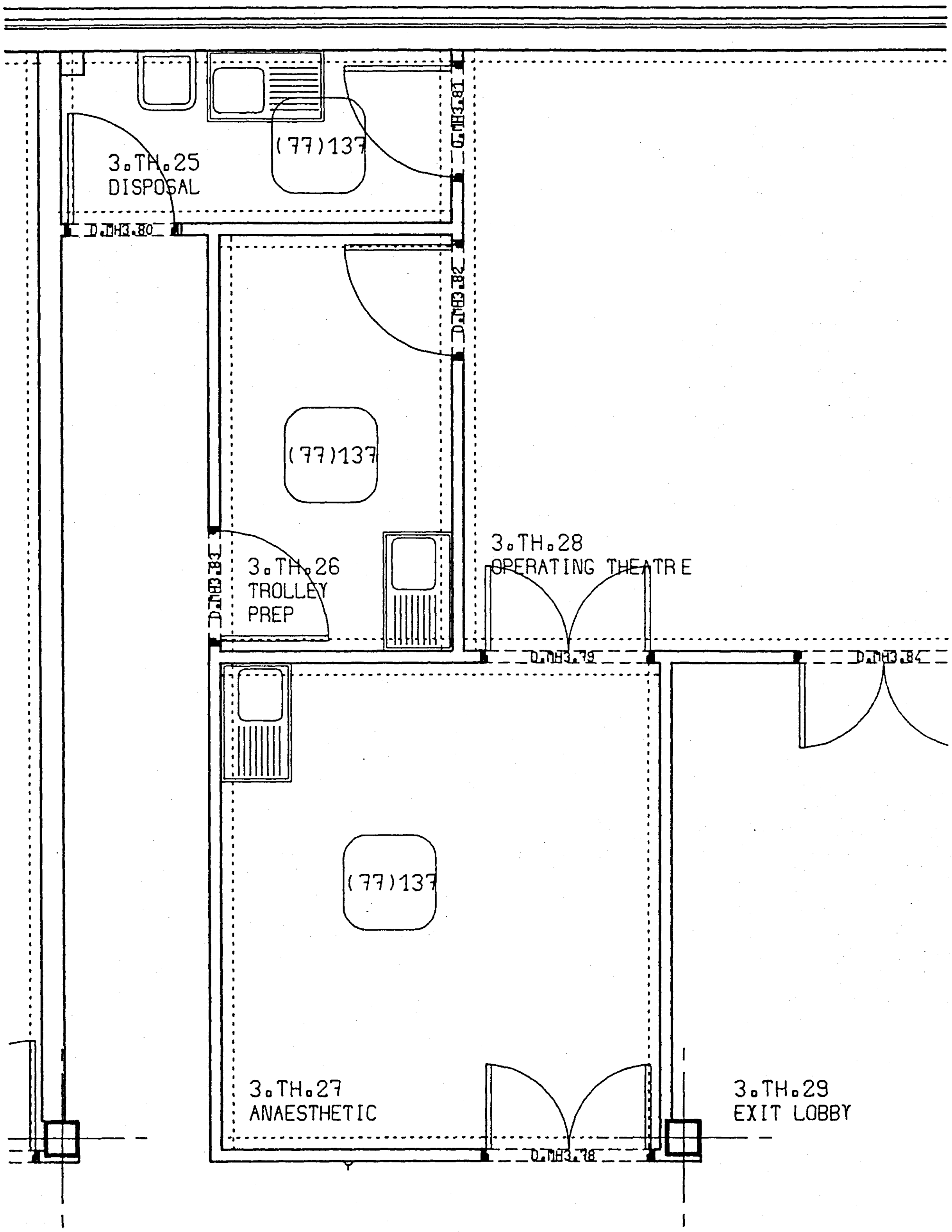
Dimensioned Layout



RUCAPS SYSTEM DRAWING

Drawing 4

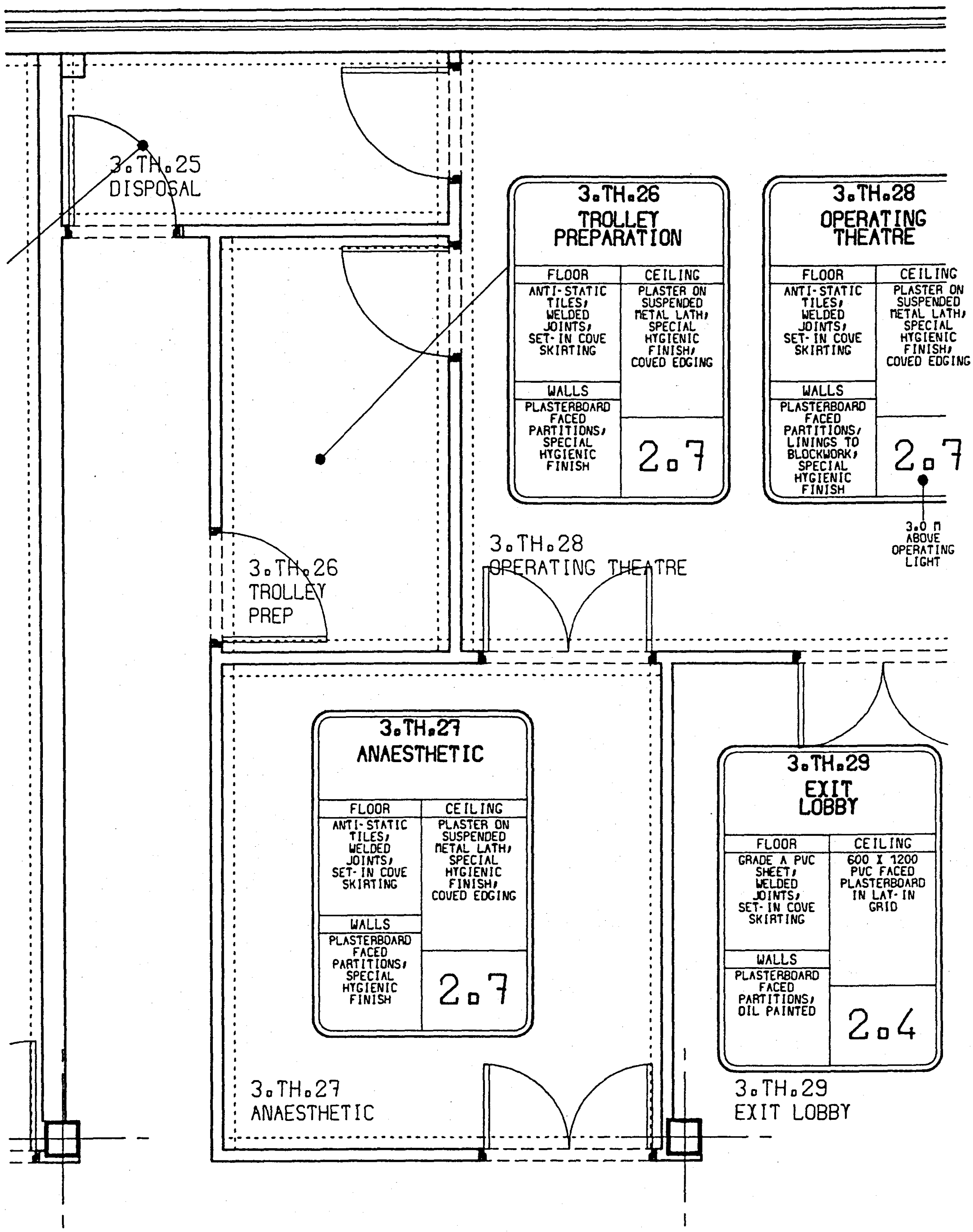
Ceiling Tile Layout



<u>RUCAPS SYSTEM DRAWING</u>

Drawing 5

Fitment Layout



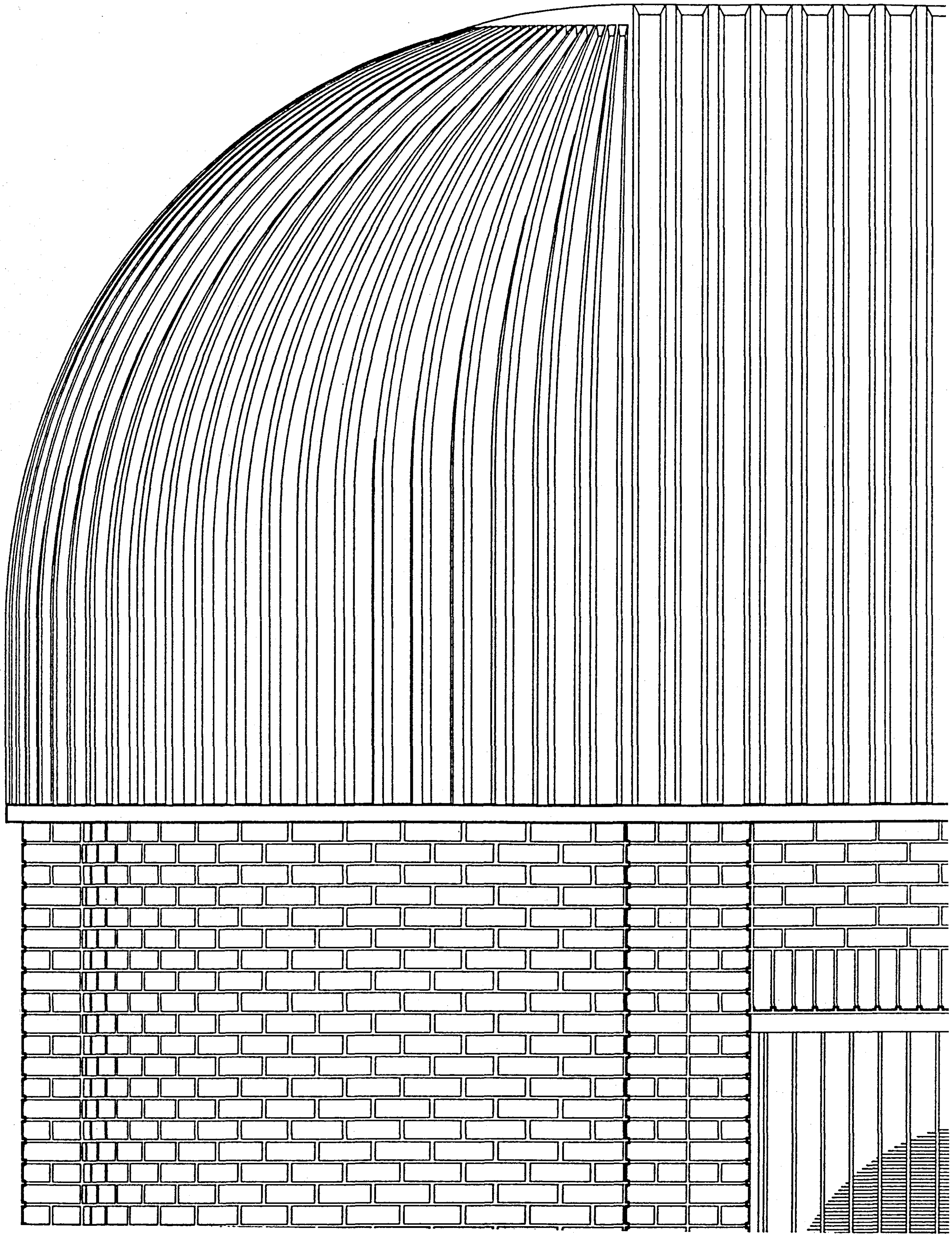
RUCAPS SYSTEM DRAWING

Drawing 6

Floor/Wall/Ceiling Finishes

APPENDIX III

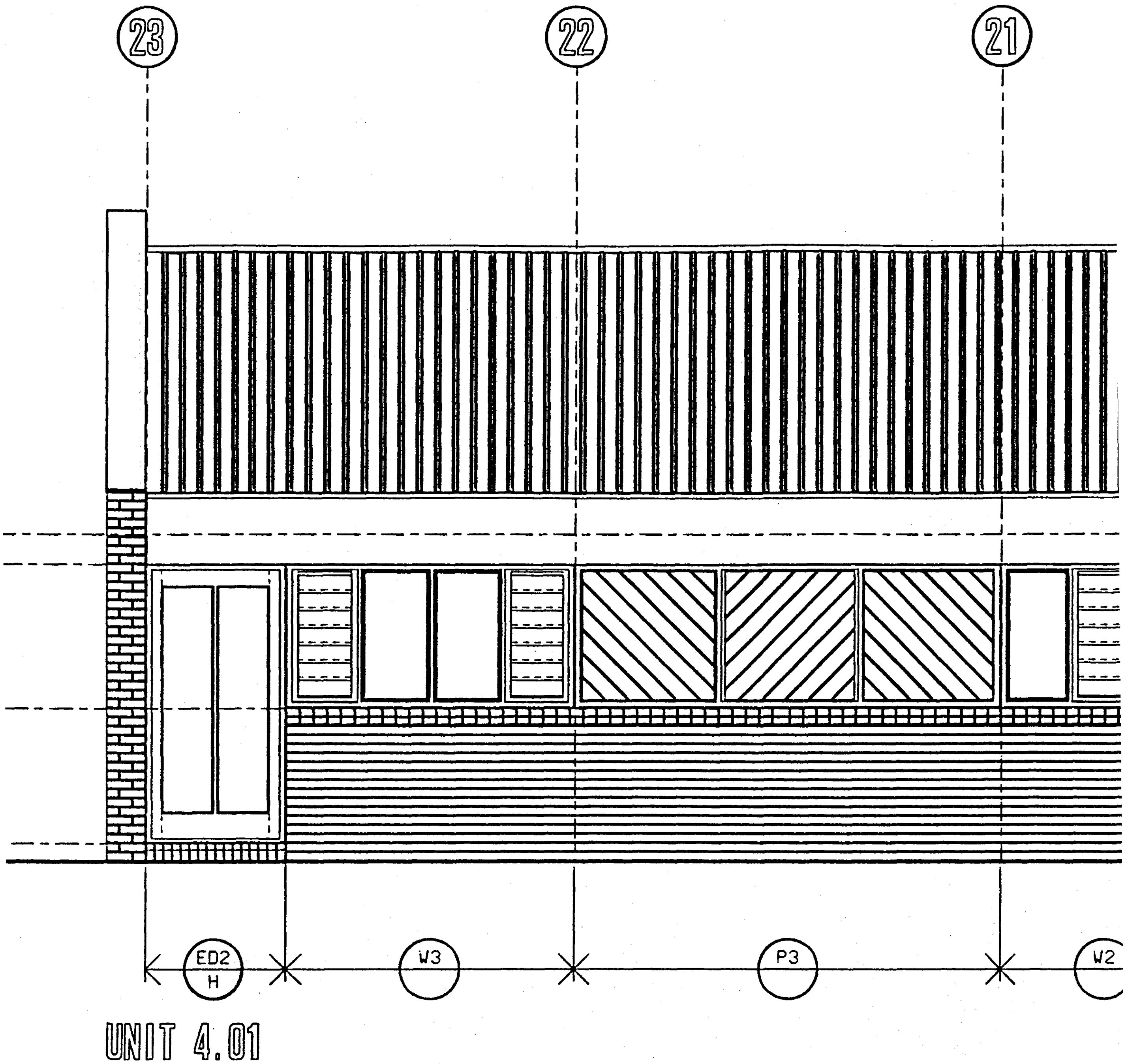
G D S SYSTEM DRAWINGS



G D S SYSTEM DRAWING

Drawing 1

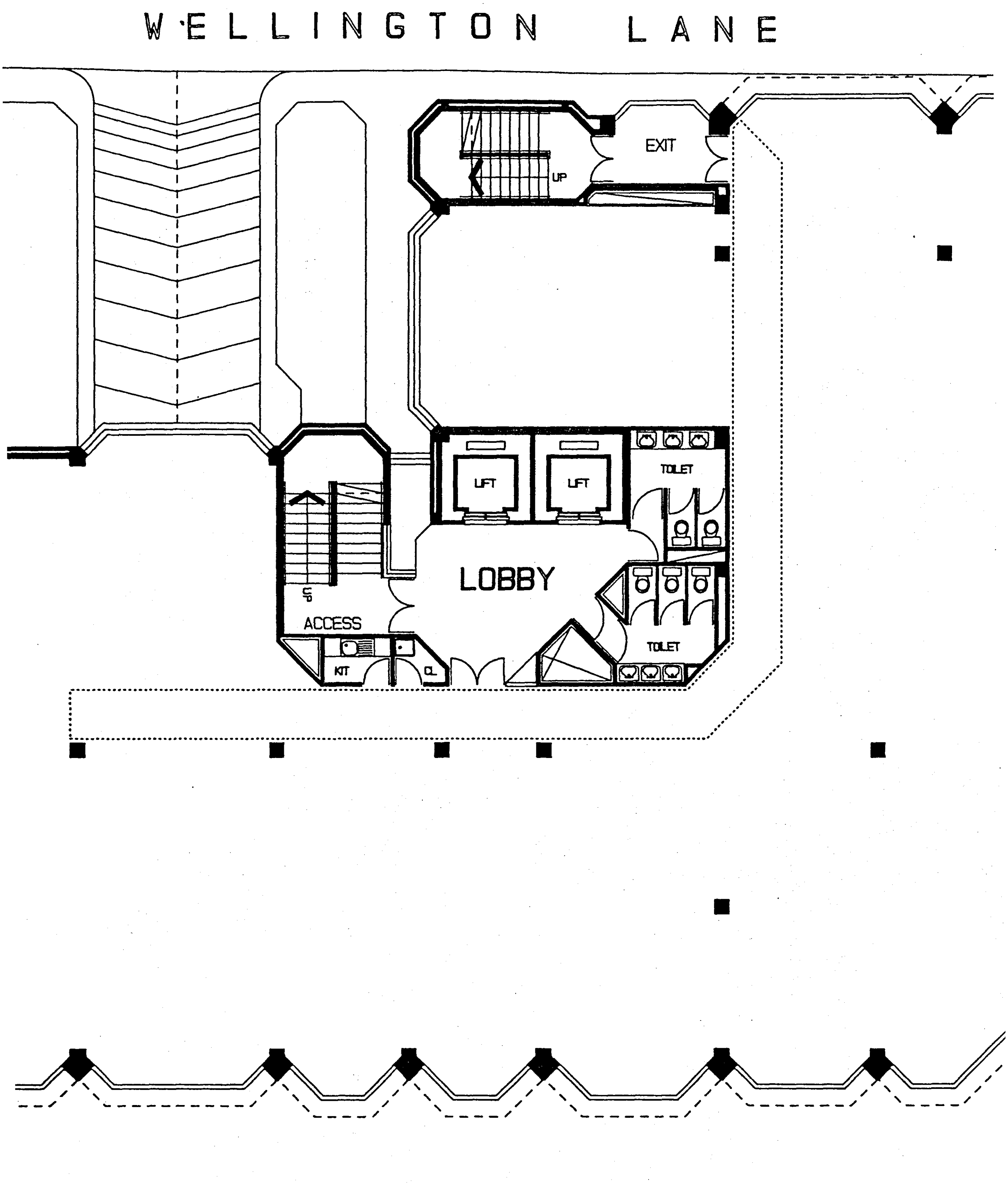
Factory External Elevation



G D S SYSTEM DRAWING

Drawing 2

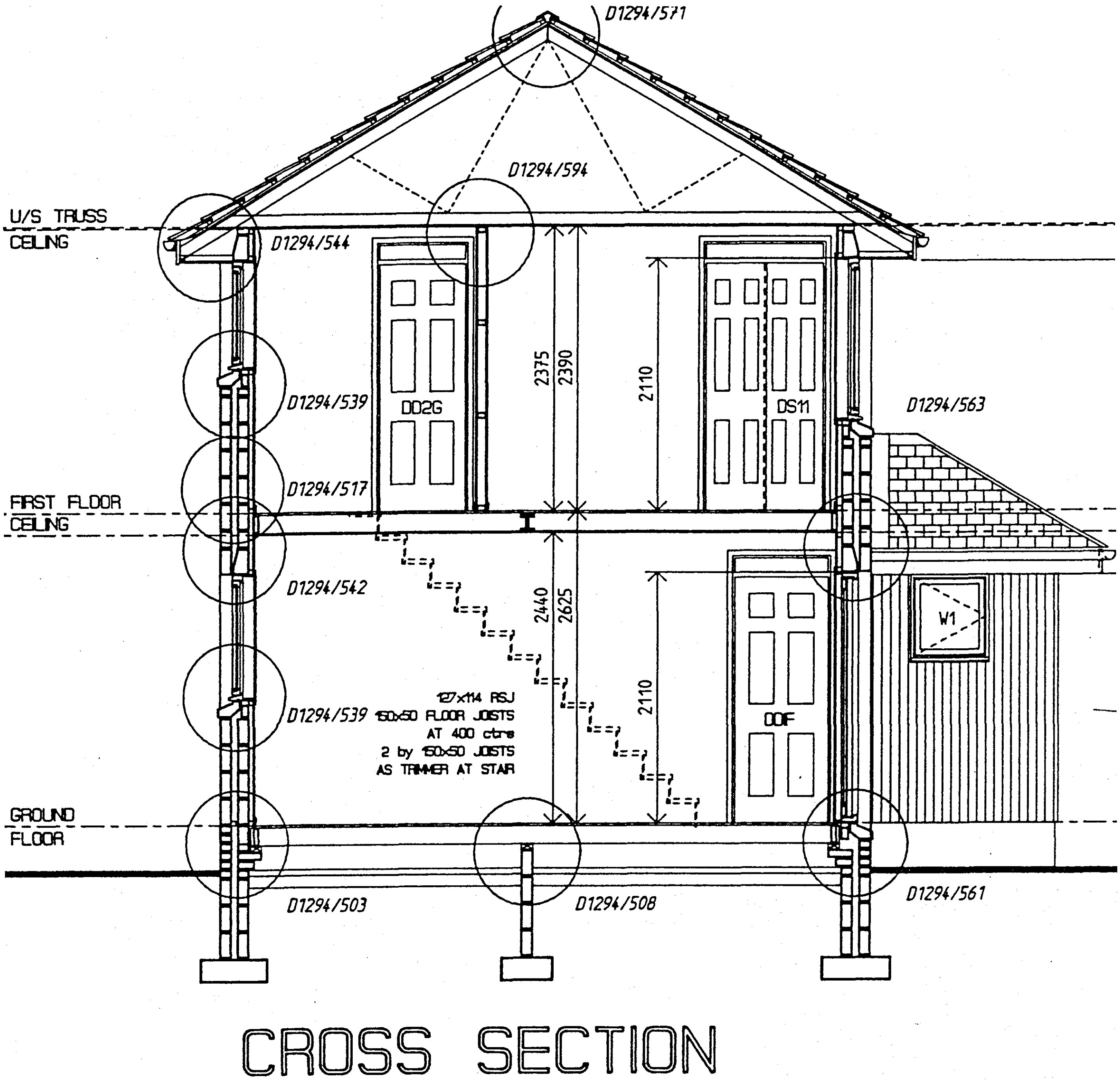
Factory External Elevation



G D S SYSTEM DRAWING

Drawing 3

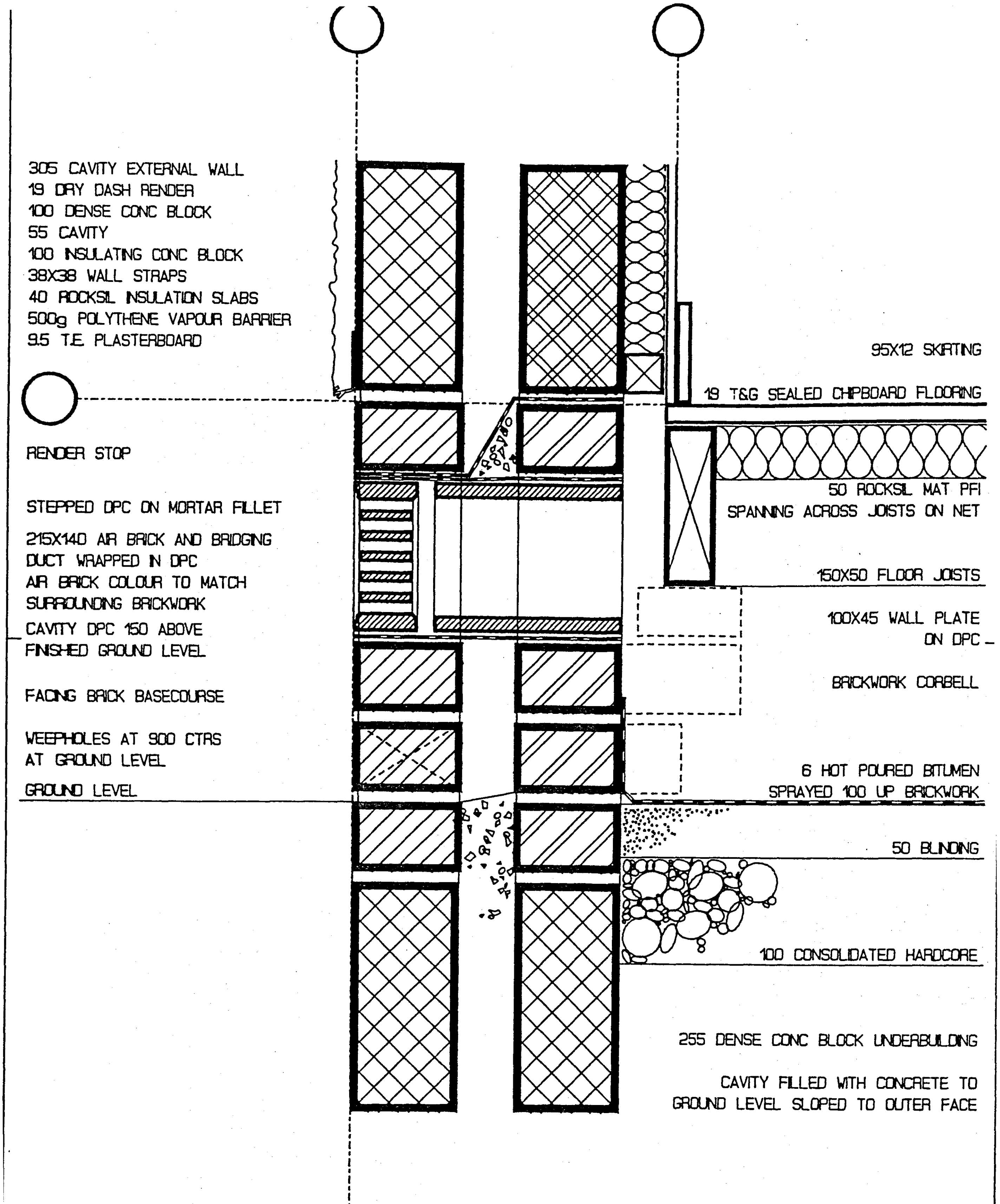
Office Plan



G D S SYSTEM DRAWING

Drawing 4

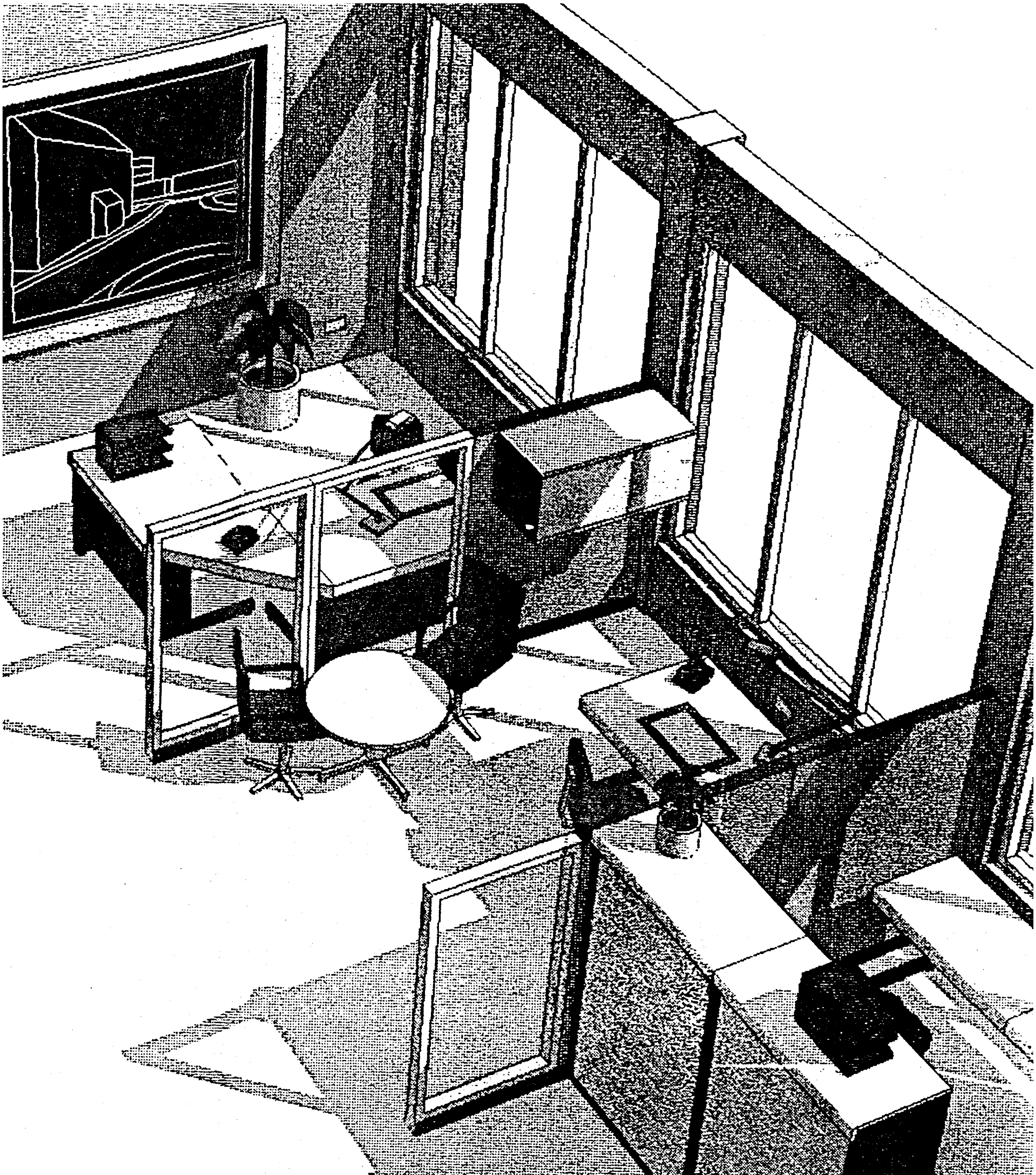
House Cross Section



G D S SYSTEM DRAWING

Drawing 5

External Wall Detail



G D S SYSTEM DRAWING

Drawing 6

Three Dimensional Layout

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