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The Application of Computers for Design In Architecture

by

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ABSTRACT

Since the introduction of computers into architecture much debate has surrounded their present and future role in the design process, but to date there have been very few documents that have quantified the actual state of computer aided architectural design. This thesis sets out to enable designers to make more informed judgements as to the appropriateness of computers as a tool for design in architecture.

The first part of the thesis reviews historical articles concerning the suitability of technology to provide a satisfactory environment for design and also tracks the changes that were taking place in the organisation of architectural practices as a consequence of utilising computer facilities. From these studies, the factors that seemed most likely to limit the application of computers for design in architecture were identified as:

> The inability of an electronic process to provide a satisfactory environment for design.
>
> The relatively small proportion of designers (as opposed) to technicians who operate the systems.
>
> Drawing software which is written to exploit the construction phase of architecture.
>
> The high cost and low performance of hardware.
>
> The high cost of writing and developing software.

The survey sets out to determine the scope of present day CAD systems, and factors that are most likely to limit what can be achieved. The main conclusion from the results is that experience of using computers (particularly for design work) is the single greatest barrier to success. Therefore, computer systems that manage to combine an intuitive interface, with highly functional design tools will have the greatest chance of being used successfully.

The final chapter identifies some of the shortcomings of today's computer design technology and highlights areas in which developments would be beneficial to designers.

INTRODUCTION

Since the potential of computers in architecture was first realised in the 1960's there have always been many strong views on the subject of the appropriateness of computers for design in architecture, but very often a lack of understanding as to how the issues surrounding the subject have evolved. This thesis looks at the criteria that have shaped the development of computer aided design in architecture, and the factors that have limited the computer's usefulness as a design tool.

CHAPTER 1 — 1.1 - 1.13

Chapter 1 introduces the origination of CAD. The emphasis is on the predictions of the time concerning the future role of computers in the design process, and the factors that were most likely to limit progress.

CHAPTER 2 (1975-1985) — 2.1 - 2.23

Chapter 2 focuses on the problems of developing suitable tools to aid the designer, and the consequent reorganization of the design process that the implementation of the technology perpetuated.

CHAPTER 3 (1985-1990) — 3.1 -3.36

Chapter 3 acknowledges that affordable desktop hardware has at last arrived and that suitable software is on offer. And whilst there are still limitations with the technology, human factors play a more significant role in achieving success.

CHAPTER 4 4.1 - 4.24

Chapter 4 presents the results of a survey sent to 250 architectural practices and returned by 78 respondents. The results measure the success of using CAD across all stages of design and provides a profile of the technology and organisation of the computer facilities that exist within those practices. The majority of the respondents were designers, and it is their experiences which are examined.

CHAPTER 5 5.1 - 5.25

Chapter 5 is an analysis and discussion of the results presented in chapter 4.

CHAPTER 6 6.1 -6.9

Chapter 6 reiterates the important issues that were raised in the first three chapters and the light thrown on them by the results of the survey. Finally, further areas for research are identified as well as what might be done to improve the role of CAD as a design tool in architecture.

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A blank sample of the questionnaire and cover letter.

APPENDIX III

The spreadsheet data that was used to analyse the results of the survey.

APPENDIX IV

A more detailed description of the content of each chapter.

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TECHNOLOGY

Computers were applied in scientific work, engineering and accounting in the early 1950's, but only aroused interest in the architectural field in the early 1960's. The first software was in the form of batch programs for solving problems such as stress analysis and production of bills of quantity.

In design software there were two distinct but related streams of development: The limited program designed to solve a particular task and the more ambitious attempts to link all phases from brief to completion. Early optimism for rapidly achieving the dream of the 'push-button' designer quickly subsided. Despite the realization that it wasn't going to happen overnight it was felt that present development could, in time, look after all the technical, managerial and statutory constraints, leaving only a simple range of design decision for the lay client to make.

The first RIBA list of approved programs appeared in 1966, the same year in which the government formed a Committee on the Application of Computers in the Construction Industry (CACCI). From 1969 onwards the frontiers of development in CAD were in the universities, although their research tended to be done with business-like application rather than in pursuit of academic knowledge. Progress slowed right down as the experts began to attack the complex task of achieving CAD on the computer.

CAD development outside the universities concentrated on programs that would enable the rapid design solution and documentation of repetitive and/or large building types, namely hospitals, schools and housing.

TECHNOLOGY

By 1967 the first commercial time-sharing system of remote terminals linked by GPO lines had become available. A terminal with teletype and a screen driven by mini-computer, with hard copy facilities, linked to a large central machine was envisaged as being the norm for architects offices in the future. It was felt that likely development would be along the lines of a national spiders web of terminals such that anyone, anywhere would be able to plug into a program.

Pen plotters (drum or flatbed) were available in the early 1970's the mechanics of their operation being very similar to today's machines. The major difference was in the way data was fed to the plotter, which was very often a two stage process, involving transferring data to magnetic tape for subsequent replay to drive the plotter (Direct connection was considered to be a waste of expensive computer time). Early line printers were available for output of text but their ability to reproduce graphics was virtually non-existent.

THE ROLE OF COMPUTERS IN DESIGN

At York in December 1972 the RIBA took part in a conference organised jointly with the Department of the Environment (DOE) & the British Computer Society. Around forty papers dealt with state of the art computing and most had an intense preoccupation with CAD, and the dream of the push-button designer. The optimism surrounding the use of graphics and CAD soon became soured when the true cost of the resources necessary for development were realised. The advice from one of the experts at the conference was,

> *"either spend a lot of money developing computers or leave them alone."*
> (Fairweather, Leslie 1972)

The wide gap between the computer industry and the architectural profession was largely responsible for the poor development of software available for architects.

> *"Surely we must progress with the realisation that computers will only do what we instruct them to do, which puts a great burden of integrity on those preparing systems - a responsibility which will not be helped by the profession opting out."*
> (Paterson, John 1974)

THE ROLE OF COMPUTERS IN DESIGN

In 1973 the attitude of the RIBA was that:

> *"use of computers as an aid to design is likely to be extremely limited for a long time to come" .."but in areas of management and production, it is a very different picture and the sooner the profession wakes up to the benefits to be gained the better."*
> (Carter, John 1973)a

All the expertise at the time seemed to concentrate on what computers could do rather than how they could be applied in the building industry. Human and social implications were seldom discussed; there were very few case studies or practical demonstrations; the use of computers seemed very limited in scope. It was generally agreed that computers were important and they were here to stay, but there was less agreement on the role they should play in design.

> *"Problems we may suffer will be caused by our own lack of understanding and not by the technology with which we are provided."*
> (Auger, Boyd 1974)

The computer was seen as a tool for producing better buildings more quickly, but there were concerns that it should not be consigned to a place at the end of the production line. Capabilities at the time made computers more valuable in appraising solutions than in generating design.

> *"There is a tendency to divide drawing from the design function, to imply that the design activity can be divided arbitrarily into that which is creative and that which is non-creative, and then to suggest that the drawing function is the non-creative part.... best handled by a computer ..to fragment skill into narrow sectors to de-skill them and have them performed at an increasing tempo."*
> (M.J. Cooley (AUEW) at Conference on Computer Aided Draughting Systems: London 1973. See Carter, John 1973)b

The computer was seldom considered as a catalyst for better architectural design but rather evaluated as a machine to save time, reduce drudgery and achieve the optimum.

> *"It is possible to design a school in a couple of days, saving approximately four months."*
> (Carter, John 1973)b

During the time operators were working, they often became extremely frustrated to have to wait a couple of minutes for the program to perform calculations. Rather than giving more time for creative work, the computer tended subtly to increase the stress and anxiety on its users.

> *"From the field of applications of CAD design in engineering, there have been vociferous complaints that in actual practice, economics do NOT permit designers to apply more or even as much consideration to comfort, convenience, aesthetics and the expansion of man 's sport. Is this going to be true of computer-aided architectural design as well? The answer lies as much in the state of the art of designing as it does in the science of computing."*
> (Bruce Archer: 1972 York Conference. See Carter, John 1973)b

One of the most optimistic views was that the Architect could regain some of the responsibilities that he had contracted out to other professions over the past 150 years, and still have more time for designing. On the other hand it could not be certain that the real designers were the people who were writing the comprehensive design programs.

> *"When people speak of success or otherwise of a CAD program, they mean, not that the building worked well for its occupants and appealed to the poetic sensibility of the passer-by, but that the program worked."*
> (Carter, John 1973)b

In the 1970's the public were very critical of the form, style and scale of architecture; this occurred at a time in history in which more detailed information had been gathered about buildings than ever before.

> *"If instant architecture shops are going to spring up the profession's answer should not be to imitate them but to offer a higher level of creative understanding. The computer can aid it, but the real root of the skill lies in understanding people, not in amassing and processing information about them."*
> (Carter, John 1973)b

> *"We can look forward to a time in which designers, sitting before their screens have virtually nothing but creative decisions to make which should lead to an Architecture of higher quality."*
> (Carter, John 1973)b

A lot of the traditional process of design involves repetitive tasks; if these are removed in favour of standardisation for economic reasons, it may not necessarily lead to a higher quality of design.

Typical "design" software enabled the effect of one variable on all the other variables to be monitored by the computer during the design process, e.g. How changing the shape and U-value of the building affects the size of the plant room. Use of such software promised a better fit between form and function for the future, but not necessarily a superior quality of building.

The "Computer" part of the "Aided Design" was largely in producing statistics for environmental and structural calculations that were so time intensive by hand. Perspective drawing was in its infancy and tended to be crude and to require hand finishing.

Computers were used in Schools of Architecture largely to decrease the time taken to solve many of the technological problems of Architecture. It was felt that solving the technical design constraints would lead to more rational design methods. There was no desire for programs covering the whole design process such as were being developed at Edinburgh, Strathclyde and Leeds. (Bradshaw W.T. 1974)

The future then, as now, depended on the extent to which CAD changed, replaced or complemented old methods of working. The real need was to develop forms of working that made greater not smaller demands on individual initiative and responsibility.

It was thought by many people at the time that much of the computer development was directed at out-of-date problems of technique and management. Debate tended to concentrate on one man sitting at the screen receiving information, not on a whole industry computerised. The computer programs at the time were solutions in search of problems rather than attempts to work out solutions to the real problems within the industry.

> *"It is a damaging illusion that to a mass a great deal of information about a building with the aid of a computer means that you understand it. Understanding requires among other things interdisciplinary collaboration and some direct muddy boot experience of designing and building."*
> (Carter, John 1973)b

The Government developed an interest in information structure of computers and put forward a co-ordinated information system for the whole country. However it never proved to be the grand scheme it set out to be and the Government turned to providing aid in the form of research and development grants via the Department of Trade and Industry (DTI), the Science Research Council (SRC) and the National Economic Development Council (NEDC).

The following describes the operation of a program used to assess project feasibility

Typically the input of information to the computer was by keyboard. The kind of information that the software required in order to function were length and width of the site, permissible plot ratio and a few other constraints. Within minutes of typing in the information a printer gave information on total floor area, most economical number of storeys etc. The input of information could then be revised and expanded and the computer responded with final details of population of building, most economical number of lifts for a given speed, average waiting time for lifts, total heat load, size of plant room, number of male and female WC's required to meet the Offices, Shops and Railway Premises Act 1963, daylighting, number of escape stairs required, floor area (divided into office, circulation, lifts and stairs), time required to evacuate the building, man-days to design it and complete production documents.

In those days this represented about £5 worth of computer time; it was thought that to complete the equivalent task by hand would require 3-4 weeks and cost in the region of £400 - £500.

The computer time would be bought on a teletype terminal connected to a large mainframe through the GPO lines at an annual cost of £2500 per annum. However, that excluded the biggest cost item - writing the program! (Architects' Journal 03.10.73). The fact that writing a program (for what is essentially a mathematical calculation) was so expensive highlights the astronomical costs involved in the development of computer aided drawing facilities.

A Typical CAD Installation

In the early 1970's CAD installations were very expensive and beyond the reach of the individual architect's office. A local authority might fund an installation capable of running CAD across all its departments, where typically the computer equipment would fill an entire room.

Drawings were produced using a light pen pressed to the screen; elements being selected from a menu. At the design stage a building could be tested for daylight and modified accordingly. Thermal performance could be analysed after selection of the various criteria, ending with the total heat load and size of plant required. When the "design" was complete the perspective drawing program could be switched in. It was claimed that using such systems one could:

> *"...design a building in the afternoon and by the next morning have all production documents and a tender ready."*
> (Carter, John 1973)3

CONCLUSION

In the early 1960's the potential of computers as a future aid to design was realised. The first design orientated software began to appear in the early 1970's and these programs concentrated on evaluating, rather than generating design. Debate on the role computers could play in design tended to be very optimistic, with the vision of architects sitting at terminals making solely creative decisions. In practice the opposite was true, with operators struggling to produce the increased output that was expected from them.

Computers tended to be used as a means for producing drawings more quickly rather than for increasing the quality of design. This had the undesirable effect of removing drawing from the design function. Much of the work of the early computer operators involved inputting hand-drawn information with the result that few designers were willing to use the machines. The limitations of the software and poor management of computer installations were largely to blame. System purchase was limited to all but the largest practices, and the universities. However, the operators of the early systems were the pioneers of computer use in architecture.

Many of the early systems were designed to cope with all aspects of drawing from design, through working drawings, to completion . Many systems concentrated on the ability of computers to perform calculations on the building envelope, in the hope that this would improve the overall design. It became obvious through experience and discussion that true computer aided design was still a long way off. The ability to conceptualize on the available technology was severely limited, perspectives were crude, working in three dimensions was cumbersome.

CONCLUSION

Despite being unable to fulfil the dreams of the architects, computers had their uses in design providing the working methods of a practice were adapted to cope with the idiosyncrasies of the new technology. This often resulted in the creation of a Bureau, where non-architecturally trained draughtsmen could feed data into the machines for processing. This then became a management problem of organising the flow of information between the computer operators and the design staff.

This was the era of computer aided draughting, not computer aided design . It can be concluded that architectural design on computer was and would continue to limited by;

> The inability of an electronic process to provide a satisfactory environment for design. (The majority of design software was limited to deriving design solutions from the processing of numerical criteria)
>
> The relatively small proportion of designers (as opposed) to technicians who operate the systems.
>
> Drawing software which is written to exploit the construction phase of architecture.
>
> The high cost and low performance of hardware.
>
> The high cost of writing and developing software.

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THE DEVELOPMENT OF SOFTWARE

Development of CAD software in architecture slowed in the mid 1970's, as research tended to play safe in technical areas or in developing established programs. That way the program writers could give their sponsors more immediate results for their money.

A mood of realism and defeatism began to set in. Approaches to software design tended to be based on logic with the inevitable danger that the architectural design process became disintegrated. The computer users were faced with a situation where they were not aware of the possibilities and limitations of programs they did not write.

Towards the end of the 1970's a considerable number of architects were using computers in the form of pocket calculators. In their programmable form they were seen as being suitable for simple calculations of cost, thermal performance, etc. The Architects Journal predicted a future in which it would publish programs for general use. A programmable calculator printer and energy program cost in the region of £400. Such software mechanised existing methods of calculation as opposed to providing more sophisticated models of building performance.

THE DEVELOPMENT OF SOFTWARE

The six draughting system's that were available in 1978 and developed principally for the construction industry were:

CADRAW	Ove Arup Partnership
CADS	Cusdin Burden & Howitt
CARBS	CARBS Ltd. /Clwyd County Council
GDS	Applied Research of Cambridge
GIPSYS	Scot Wilson Kirkpatrick & Partners
RUCAPS	Gollins Melvin Ward Computers Ltd.

All these systems costing the region of £75,000 to £250,000 and were therefore suited to large practices undertaking major building projects. Most of the drafting systems allowed jigsaw like assembly of basic graphic elements and pre-drawn components into production drawings. Several had some form of scheduling facility; few offered aspects of 3-dimensional drawing (Architects' Journal 17.12.80).

"Gable" was primarily a system for modelling buildings in order to understand their performance in terms of space, energy, daylighting and acoustics. This contrasts with draughting systems whose priority is drawing production. Gable began as an educational and research venture at Sheffield University School of Architecture. By June 1982 it was competing in a market with large draughting systems. Gable software then cost in the region of £20,000 up wards and was taken on by Schools of Architecture at Nottingham, Dublin and Huddersfield with others soon to follow. It experienced problems with further development due to lack of funds rather than lack of ideas. New pressure too came from recently formed users groups of the commercial Gable system.

Many computer users from the construction industry joined a group called DOC (Design Office Consortium) initially supported by the DOE. The group acted as a forum for discussion of experiences and also published a list of evaluation reports on the available programs which were well documented.

By the middle of 1982 the complexity and similarity of the draughting systems made it difficult to assess the different software. GDS had produced enhancements to its own system outside simple drawings; Rucaps and Computer Vision were offering lower price basic draughting systems; Building Design Partnership was selling its in-house Acropolis Draughting System; D'Arcy Race partnership was offering computer draughting as a service to other practices.

GDS like all draughting systems offered software enhancements from time to time. A typical enhancement in 1982 involved allowing text and numerical information to be attached to drawn elements. Following completion of some phase of design all the data could be collected and tabulated to form a schedule. At this time the software for two work stations cost £30,000, with hardware at £80,000.

Acropolis was developed as a full 3 dimensional modelling system. Scheduling was not integrated with graphics in 1982. Designing was based on a component library built up by users.

Rucaps offered a 2-dimensional draughting software with a basic range of equipment; the software cost in the region of £65.000.

Drawing systems were dedicated to drafting and microcomputers were general purpose. Microcomputers were not fast or powerful enough for the heavy work load and complex drawings of drawing systems.

> *"No system is perfect. All are under development".*
> (Architects' Journal 1982)b

An increasing number of drawing systems came from two backgrounds; either produced by and for the Construction Industry (special purpose system) or developed for general usage (general purpose systems). General purpose systems had a wider range of users so more feed back, and being developed by computing based companies they tended to be smoother in use and more thoroughly tested. Special purpose systems tended to be more sympathetic to architectural users, but financial resources were seldom available to develop the systems to their full potential.

For many architects who were not sure whether to invest in CAD one of the most difficult tasks was choosing a system. The written word has a limited role in helping to select a system, and there proved to be no substitute for "Hands on experience." As a broad indication gaining familiarity takes days, competence weeks, and mastery takes months.

> *"The key to the usefulness of the microcomputer is who writes the software. Computer Aided Drawing packages are horrendously expensive and unlikely to be within the reach of the average small practice, at least in the foreseeable future."*
> (Jolly, Brian 1982)

The absence of programs at sketch scheme stage for comparing alternative designs was identified, as was the reluctance by architects to develop such systems. There was a general agreement that there was a lack of,

> *"Well written, well documented and well supposed programs."*
> (Architects' Journal 1982)c

> *"Most people use 2-dimensional systems but are expecting to have full 3-dimensional systems in the future."*
> (Architects' Journal 1982)c

The decline of the mainframe

Main frame computers cost in the region of £1,000,000 and could be found in big organisations such as calculating and distributing rate demands in a local authorities. They were huge pieces of equipment typically filling an entire room. Their use in architecture gradually declined as smaller, cheaper and more accessible systems emerged.

The rise of the minicomputers

One of the major emerging changes in hardware was the growth of development of the minicomputer, whose potential was seen for taking over many of the small jobs that were presently processed on time sharing terminals running on a mainframe. As they began to fall in price, usage became more widespread; initially their main applications were as sophisticated calculators for private management tasks and rudimentary graphics. Towards the middle of the 1980's the mini-computer became more suited for graphic applications, and became the workhouse for large design systems. For Architects the most common application of mini computers was in the integrated drafting systems which cost anything from £20,000 to £200,000.

The rise of the microcomputer

By 1980 only a handful of big design systems were being developed. The dream of a future of large computers driving remote workstations, where architects would draw on screens with light pens had largely disintegrated. Computer uses had changed and diversified into office administration, telecommunications, and building management systems. This largely came about due to the arrival of the microcomputer. This was a cheap "user friendly" computer that was starting to find its use in many offices for routine calculation procedures. Computers now came in three sizes:

> *"Large (mainframe)*
> *Medium (minicomputers)*
> *Small (microcomputers)"*
> (Architects' Journal 1980)

Microcomputers could be used widely for administration and some graphics. They cost in the region of several hundred to a few thousand pounds. Personal computers were at the cheap end of this range. It was reckoned that personal computers would soon have more architectural users than all other types of computer system. As a drafting facility personal computer systems were still feeble.

"To date there is a lot of interest in microcomputers and drawing systems but rather less action on the ground. Our estimate is that in the construction industry as a whole there are about 60 installed drawing systems and around 500 microcomputer systems."
(Architects' Journal 1982)a

A Commodore Pet 2001, complete with computer, monitor, keyboard, cassette storage and printer could be bought for around £2000. Storage on floppy disk was soon to follow but the role they could play in design was still highly limited by their lack of power and sophistication. (For example, they were unable to out put the drawn data to a plotter). Computer installations that were capable of accurate drawing and output to plotters were still in the £10,000 to £50,000+ range.

By 1982 architects were beginning to take computing more seriously. Questions at the RIBA conference were more about how rather than whether to use computers:

The need to look first at how the microcomputer could be applied, then at the available software and finally the hardware required to run it was stressed. There was also a concern about a lack of information for choosing systems. The interest of newcomers is often centred around the hardware as the most visible and fascinating aspect of computing.

> *"In practice, over a life span of 5 years, hardware is the least expensive of all the items that make up a successful system."*
> (Chalmers, John 1982)

The above article goes on to say that software including training will exceed the cost of hardware. And that hardware should be considered as subservient to the needs of the application required.

As the spread of CAD terminals increased, the need to communicate readily by linking one terminal to another was desirable. Various general systems for achieving this were under development, such as the Cambridge Ring Ethernet.

Much discussion about CAD suggested that the use of computers in design was wholly beneficial, however, there were contrasting views of the relationship between the designer and the computer.

> *"CAD tends to deskill the designer, subordinate the designer to the machine and give rise to alienation. Indeed, most computerised design environments begin to display those elements which are regarded as constituting industrial alienation: In particular powerlessness, meaninglessness, loss of self and normality."*
> (Cooley, M.J.E. 1980)

The introduction of computer based systems in office work is often referred to as the "Automation" of traditional work procedures. In industry this has sometimes resulted in a skilled job becoming totally unskilled and the operator merely operating a machine to do the work an artisan used to do. Many designers have been - and still are - suspicious of computer aided design.

> *"The decisions left to the operator of the system are reduced to routine choices between fixed alternatives. His skill as a designer is not used and decays. He is subject to pressure to match his speed of working to that of the machine, and may be asked to work shifts in order to utilise the expensive capital equipment. His task ceases to be that of the designer in the proper sense, and comes to resemble that of the assembly line worker."*
> (Rosebrock, 1977)

One of the strongest critics of the implication of CAD is Dr. Michael Cooley who has worked as an engineer in the Aerospace Industry, as a trade union leader, and as an academic researching the effects of CAD. From his book "Impact of CAD on the designer and the design function", Cooley draws our attention to some of the dangers of introducing CAD. CAD, when introduced on narrow grounds of so called efficiency, may give rise to a deskilling of the design function and a loss of job security particularly to the older man. In the man-machine interaction, man is slow, inconsistent, unreliable and highly creative. The machine is fast, consistent, reliable and totally non-creative. The computer can produce quantitative data at an incredible rate, and as the operator tries to keep abreast of this the stress upon him can be truly enormous. Instances were found where the decision making rate was forced up by approximately 1900%.

The process by which the designer reviews quantitative information he has assembled and then makes qualitative judgement is extremely complex. Those who introduce CAD into this interaction, and who frequently suggest that the quantitative and qualitative can be arbitrarily divided, and that the computer can handle quantitative elements, may have to face very serious consequence. The crude introduction of computers into the design activity for speed alone may well result in deterioration of the design quality.

CEDAR 3 software developed by the PSA enabled the designer to create and store a three dimensional block model of a building within the computer. This had obvious appeal particularly in massing studies and the evaluation of alternative formats in the early design stage. The ability to produce perspectives on screen in under 30 seconds was seen as a fantastic aid to design. Hidden line removal was not yet available and this limited the effectiveness of some views. The objective in developing CEDAR 3 was to provide a common building description on which all the disciplines in the design team could perform their analysis. However, there were still some critical restrictions in the graphics capabilities of Cedar 3 that prevented it becoming widely accepted by architects.

> *"If CEDAR 3 is to realise its full potential we believe that development should continue, with the emphasis on user acceptance rather than on elements of interest to computer specialists, in particular a more sophisticated geometry and easy entry and re-entry would be well received. CEDAR 3 in no way supplants the designers role more detailed information readily available in the early stages of a design can only improve its quality if carefully used."*
> (Cannon, J. & Young, J. 1979)

Whether or not to use the 3-dimensional abilities of CAD was still a subject for debate; Architects Holme Chadwick and partnership wrote off 3 dimensional work as requiring;

> *"too much data input."*
> (Chadwick, Andrew 1982)

Even with all the developments occurring the actual effects of computer aids on design quality and design practice were seldom evaluated or discussed. The designers themselves were often the pioneers of computer use, thinking out new roles for computers from scratch, trying new equipment, and writing their own programs. Although the resulting systems were not always ideal what was learned from their experiences was invaluable in ensuring a more secure path to the future.

Andrew Chadwick, an architect and partner in Holme Chadwick & Partners and chairman of the RIBA computer group, describes the use of CAD in a typical project: He sees computer use as much more organic process than by hand, where the design process, like the briefing, takes place over a period of weeks or months, slowly revealing to the client the final solution.

> *"The ability to manipulate shapes on the computer produces answers in a very creative way which you would rarely get in the direct confrontation type presentation."*
> (Chadwick, Andrew 1982)

Chadwick argues that draughting by computer varies from manual draughting in that one is working with co-ordinates rather than lines, and, co-ordinates stored in electromagnetic form are a great deal more accurate than when conventionally drawn.

> *"It is fundamentally the beginning of the building process, rather than part of the drawing process. It leads to a more structured thinking, in relation to the way projects are conceived, because architects strive to order their conceptions so as to make them both buildable and beautiful."*
> (Chadwick, Andrew 1982)

Chadwick concludes that by inputting the scheme in detail during the design stage, three quarters of the production drawings can be done before it is time to actually carry them out. Moreover, these drawings are not pieces of paper but a co-ordinated history of the work, and all graphic and non graphic information can be derived from the drawings.

> *"Clients insist on multiple design concepts and keep their options open until the last minute. We are in competition with design/build contractors and must work faster and more accurately."*
> *(Chadwick, Andrew 1982)*

Finally, an advantage of the computer is that data files representing the building as it has been built can be given to the client for management of the building in the future.

Architects Cusdin Burden and Howitt purchased CAD in 1978, when it was felt that they could use their computer to streamline production drawings and control standards. Initially small sketches were produced manually, and when the main elements had been transferred to the computer an accurate plot was produced at 1:50. This was used to mark on corrections and for further input. Using an overlay system of data storage, drawn elements could then be plotted in combinations to suit the purpose of drawing. They state:

> *"The computer system has not limited draughting."*
> (Campion, David 1979)

They identify CAD as being most cost effective when projects can be rationalised so that graphical elements representing components are located relative to grids at 50 mm increments, and that using such methods a three-fold increase in productivity can be attained. They were only able to draw sectional and elevational material where repetition justified the cost. The article goes on to state:-

> *"The system's being two-dimensional has proved no limitation."*
> (Campion, David 1 979)

Architects Atkins Sheppard Fiddler & Associates reported using highly ordered draughting procedures.

> *"After preliminary design the system enables all specialists in the multi-disciplinary consultancy to assemble components in a database (codex) and produce co-ordinated design drawings....*
> *..the documentation system can extract printed schedules or automatically plot drawings from stored information."*
> (Collins E.B. 1979)

As well as having these draughting capabilities their full system had routines for heating, lighting, ventilation, circulation and some costs. The principal benefits of using the computer are identified as: "automatic" plotting at different scales, "automatic" repetitive draughting, and "automatic" scheduling.

> *"Architectural staff can concentrate on design matters while the computer does the repetitive draughting automatically."*
> (Campion, David 1979)

> *"To feed in the basic information is very laborious but subsequent fast production of drawings with limited content is proving to be worthwhile."*
> (Collins E.B. 1979)

Computer graphics began to take hold in one particular area of design namely building systems. Unlike traditional design the complete range of components and all their inter-relations could be described fairly concisely and so a menu of graphic manipulation could be devised. Even so, programs that were developed to cater for this demand tended to be crude and restricted, and the 'architecture' that was produced by using such systems was often of little merit.

Computer aided draughting was also beginning to find its application in other areas of the building industry.

> *"Where there is repetition of components, machine drawing can be much quicker if not cheaper or more eloquent than hand drawing - important for fast production of working drawings, e.g. for the Middle East. This is usually practicable only on large and for very repetitive jobs."*
> (Evans, Barrie 1978)

STAFF, TRAINING AND MANAGEMENT

Productivity was the main criterion usually used to assess the performance of drafting systems. Figures were quoted for productivity of up to 1:10 that is, one draughtsman plus computer system can do the work of ten. The global productivity figure does not work well because some tasks are quicker than manual drafting, some are slower. One of the most difficult problems to come to terms with was management.

> *"High quality staff are important to make the maximum use of the system."*
> (Campion, David 1979)

> *"You cannot simply hand the system to the technicians and tell them to get on with it."*
> (Architects' Journal 1982)b

Restructuring of the staff hierarchy was often required in order to cope with the complex operation of computer systems. Architects Cusdin Burden and Howitt set up a "core team" to control and use their system, comprising an associate supported by two architectural assistants and a technical clerk. Specialist support was available from Atkins Research & Development. Data input was achieved by architects producing free-hand sketches for core team input. During the overall period of a typical project it was reckoned that production of finished drawings could be increased two-fold. The article states:

"Architects could concentrate on detail design not needing to concern themselves with producing drawings of submission quality."
(Collins E.B. 1979)

The architects did not need to produce finished drawings; they were designing by positioning components for subsequent input to computer. To try and prevent the formation of a specialist group through which all work was filtered, anyone interested in CAD was encouraged to train and help future project development. This they hoped would in turn:

"Eliminate the possibility of those involved in projects feeling divorced from the means of creating them."
(Collins E.B. 1979)

D'Arcy Race Partnership was one of the first practices to offer a draughting service; drawings were worked up from clients hand drawn information. It was reckoned that an A1 drawing could be produced in an average of 4 to 8 hours and cost less than £200. Charges were based on an hourly system plus operator rate; a budget or price per drawing could be quoted, subsequent alterations being priced separately.

CONCLUSION

1975-1985 saw a long struggle of development undertaken to produce suitable CAD systems for architects. As predicted the cost of this development was astronomical and no competent systems emerged that were readily affordable for all architects.

By the start of the 1980's much of the early software that had been developed by and for architects was in competition with general purpose draughting software. The general purpose software was developed largely by computer based companies, and tended to be less likely to breakdown, cheaper and easier to use, but limited in scope. Much of the general purpose software focused on the ability to draw quickly and accurately rather than to provide any tools for design purposes. The resultant systems were ideally suited to technicians and operators, rather than architects, and so not surprisingly the former became the users of the systems. In order to cope with a technology that designers would clearly struggle to use, radical reorganisation of staff structures and working practices were often necessary, in order to set up channels of communication between the computer departments and the rest of the practice.

The fact that little design work was being undertaken on the machines meant there was not much feed back to the developers and as a consequence the development of design software suffered. An important factor in assisting software development was the 'user group': general purpose systems tend to have more users and therefore greater feedback.

CONCLUSION

> *"These groups are providing an effective forum in computer-aided design, as in other computer fields, for users to share experience and to indicate desirable future facilities to system suppliers."*
> (Architects' Journal 1983)

The success of software was largely determined by the extent to which the computer industry had co-operated with the architects in the design of their systems.

Many architects purchased CAD without much understanding or forethought as to how they would integrate it with their current working methods. Junior staff who seem to take to computer technology far faster than more experienced staff were quick to see the benefits of using CAD systems. The experienced staff witnessed computers producing information faster than they could by hand. Rather than committing themselves to training programs many practices simply developed working methods that enabled them to use the computer operators to produce the required drawings. This led to computer staff becoming the computer experts and a breakdown in the communication between those who have architectural experience and those who are operating the system. In its worst situation a mystique developed around the use of computers, and the potential of using them as a design tool was further eroded.

CONCLUSION

Those practices using systems that attempted to provide total integration from inception to completion experienced problems of training staff to use the resultant highly complex systems. Radical changes in office and design procedure and huge training programs have enabled some practices running such systems to become very efficient, particularly in handling very large technically complex projects. The actual contribution such installations were making to design was questionable.

Hardware development tended to move steadily on, becoming increasingly smaller, cheaper, faster and more versatile. The difference in price/performance between the top and bottom of the range continued to fall. Peripherals increased in sophistication, variety and availability. Alternatives to the pen plotter began to emerge, as did the adoption of data exchange standards to enable more efficient communication. Networks were developed to provide efficient links between all sorts of machines The barriers between different operating systems were broken down not by adopting one standard, as was predicted in the 1960's but, by the use of translators.

Architecture had always been a profession which had never before had to invest in capital intensive equipment and was now being faced with a situation where it needed to invest in technology in order to compete for clients against competitors. By nature sophisticated equipment is expensive, and this gave rise to a new type of Architectural Bureau, "The Equipment Bureaux". Here the Architect could utilise the latest AO full colour plotter or the AO flatbed scanner.

CONCLUSION

Design quality hardly figured as a benefit of computer drafting, although the ability to satisfy environmental criteria that would probably would not have been undertaken by manual methods was a spin-off. Other commonly identified advantages included the more systematic co-ordination of up-to-date project data throughout the design period and across the design team.

The potential of computers as an aid to design was there, but until affordable design systems came on the market there were unlikely to be any significant changes. Fortunately the personal computer was on the way and a new era of computer aided design was about to unfold. Until then the limiting factors to using computers for design would remain;

> The inability of an electronic process to provide a satisfactory environment for design.
>
> The relatively small proportion of designers as opposed to technicians operating the systems.
>
> Drawing software written to exploit the construction phase of architecture.
>
> The high cost and low performance of hardware.
>
> The high cost of writing and developing software.

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INTRODUCTION

The five years from 1985-1990 has witnessed something of a revolution in the availability and suitability of CAD systems in architecture. The arrival of the IBM PC and compatibles, the MacII and cheaper Unix workstations has put CAD within the reach of the majority of practices. As sales of these machines have increased worldwide, so has the proliferation of CAD software.

The days of rooms filled with computers have been replaced with smaller more connectable machines. Problems of choosing systems are less often concerned with whether one is available, but more with which, out of a number available, is best suited to the requirements of the practice.

The burdens of management have increased as many practices struggle to get to grips with the influx of the new technology. Computer systems do not manage themselves and practices that have left this task to non-architecturally trained staff have all too often suffered problems of communication and underachievement.

This chapter refers to old issues raised in previous chapters; looks at many of the new issues brought on by the widespread success of CAD in architecture, and identifies some of the areas that may shape the limitations of CAD for designers in the future.

The range of software available is so vast, and the nature of operation of particular packages is so involved, that direct comparisons cannot easily be made within the scope of this document.

THE DEVELOPMENT OF SOFTWARE

Paul Richens has written perhaps the most detailed comparison of microcomputer CAD software to date. Entitled "MicroCAD Software Evaluated", the report evaluates 10 systems (Archicad, Archway, Autocad, Cadbuild, Caddie, Cadvance, Druid, Microstation, Robocad and Versacad). The report compares the functionality of these systems against the level of sophistication offered by more expensive systems in the market.

In general software can be described in terms of how data is stored and presented and whether the software is essentially 2D or 3D and how the 2D and 3D models interact within a given system. Within 3D modelling there are sub sections: wire frames, surface modelling or section solids. Important differences occur in the way the different systems actually generate drawings: with some it is a question of design being seen in the terms of interrelated 2-dimensional sheets: in others the plotted drawings are selected portions of a 3D model.

All software demands time to learn to use it, and since in practice the functions an architect has to perform are many and varied, the faster effective use of software can be achieved the better.

Other important aspects of CAD software that are commonly overlooked are the output devices they support and their ability to import and export different file formats.

Possibly the most difficult decision facing any architectural practice is knowing what software to purchase. A recent survey of the top 100 design and build companies shows that the biggest obstacle to the use of CAD is system selection at 87%. In America the AIA is a distributor of one proprietary system; whereas in England the market leader is recognized as representing the industry standard. American Tom Lazear (Versacad) suggests that...

> *"The AIA would do better to endorse all systems meeting uniform standards, not just one."*
> (Hoyt, Charles K. 1989)

The same is surely true for the RIBA in England, John Elliot (a Director of a networking consultancy) takes this one stage further with the onus put on the software producers...

> *"I like the idea of documenting known problems: it will save users lots of time and ought to be made statutory for all documentation."*
> (Elliot, John 1990)

THE DEVELOPMENT OF HARDWARE

Architects Russell and Feilden in 1986 concluded that trying to run sophisticated software on less than adequate hardware is limiting on the capabilities of any system.

By 1990 CAD hardware had come of age. High powered systems are now available at less than a tenth of the cost of top-end systems of ten years ago. The problem now is not finding a system powerful enough to run the software, but rather choosing a platform from those available within a budget. The minicomputer has disappeared in all but the largest practices and new adaptable, compatible and connectable alternatives have emerged.

> *"The great survivors of the evolutionary process are IBM pc compatibles, Apple Macintoshes and Unix Workstations."*
> (Building Design 1990)

However for complex rendering of building models, purpose-designed graphics workstations remain the only sensible choice.

THE DEVELOPMENT OF HARDWARE

The chicken and egg argument can be applied to the relative importance of hardware and software. Shaun Clark, general manager of Cimlinc, believes that hardware will become less significant and that hardware and software vendors will join forces to offer total solutions.

> *"Manufacturers who persist in promoting low cost 'boxes' with functional software and poor levels of support, on the pretext that hardware is more profitable than software, will almost certainly flounder."*
> (Clark, Shaun 1990)

The reverse argument is also valid; because there is such a vast range of software that is available and applicable to the work of an architectural practice, the functionality of many installations would suffer disastrously if the choice/ availability was restricted.

It seems more likely that software will be written to take advantage of converging standards of operating systems and hardware so as to gain the maximum market.

A detailed discussion of the pros and cons of different operating systems is a very complex topic, well beyond the scope of this document. However, it is one of the most important considerations in the purchase of computer systems; an inappropriate choice of operating system can vastly reduce the effectiveness of the software, and may result in many problems associated with the configuration of the hardware. Purchasers tend to stick to the one they know and are usually reluctant to change. Over the years operating systems have generally tended to become more alike, but there are still vast differences. As end users we can only hope that movement towards common standards will result in user-friendly interfaces, better connectivity between systems and easier purchase decisions.

The user friendly interface was pioneered by Apple, with their own operating system, and the rest of the computer world has now followed suit. In the IBM pc compatible world there is Microsoft windows version 3. Under the Unix operating system there is X-windows which commands the support of 75% of the worlds' computer hardware manufacturers.

A computer can be used very effectively with a limited knowledge of the operating system although a good understanding is undoubtedly beneficial. If you have an expert knowledge it is unlikely that you are a designer, and if you are, a career change would probably be financially rewarding. As with design software, the more easily designers can tailor the operating system to suit their working methods the more likely they are to get the most out of the system.

As with operating systems, standards for the exchange of data between software and operating systems are many and varied. A British standard BS1192: Part 5 is a guide to the structuring of computer graphic data for transfer between different systems. A working party from the National Economic Development Council (NEDC) published a report stating:

> *"CAD users in the construction industry should make use of DXF for transfer of 2D design data between CAD systems."*
> (CADD 1990)

The council acknowledged that Autocads' DXF may not always be ideal and other formats such as IGES and purpose written translators are valid options. Autodesks' response was that whilst DXF has been an unofficial standard for some time,

> *"A standard will take a lot of the present confusion out of the market."*
> (CADD 1990)

The International Standards Committee TC1 84/SC4 was formed in July 1984 to centralise all data exchange development. A new standard is in draft form known as Product Data Exchange (PDES) in the US and the Standard for the Exchange of Product Model Data (STEP) in Europe.

> *"When PDES/STEP becomes available it is expected to handle more sophisticated and complex translation tasks. In doing so, it should replace all existing standards."*
> (Holt, S.P. 1990)

NETWORKS

With more than one computer an office will soon develop a need to do at least one of the following: share peripherals (printers, plotters, fax, modem etc.), share data, share processing power, improve data security, store files centrally, and pass messages.

Failure to network will undoubtedly lead to inefficient use of peripherals, duplication of data and backup difficulties. Workstation manufacturers have always considered networking to be fundamental to the success of their computer, Sun Microsystems' slogan only recently abandoned, was

> *"The Network is the Computer."*
> (Jackson, Peter 1990)

Under the Unix operating system highly flexible configurations can be achieved with processing power being channelled where and when it is needed.

> *"...but flexibility comes at a price and that price is system management."*
> (Building Design 1990)2

At the opposite end of the scale, Appletalk networks are simple plug in and go systems, designed for easy sharing of files and peripherals. Their main drawback is slow speed and lack of functionality. As more software is written to exploit the suitability of networks for sharing and managing project data, networks are likely to become ever more vital to the efficiency of CAD systems.

The basic problem of modelling buildings has been solved by many software packages. There tend to be two levels of modelling software: those packages that allow simple geometry to be input easily at the expense of making complex geometry very difficult to generate; and those packages that allow an experienced operator to build models of great complexity.

> *"Only when complex geometry can be generated as easily, or more easily, than simple ones will CAD have the conceptual richness to be a useful design tool."*
> (Coates, Paul 1989)

It is often not the initial modelling that is difficult but the subsequent alteration of that model. Those packages that allow the designer to define rules that govern relationships between components seem to allow the greatest possibilities for reworking models.

Software is designed with varying degrees of accessibility for the end user to alter and enhance its capabilities. Those systems which have open structures are worth developing; not only does this make the task of drawing more pleasurable, it greatly enhances the speed and efficiency of the package. A general purpose draughting software that does not allow designers to develop drawing operations to suit their requirements will never be wholly satisfactory. Closed systems may prevent the users from tailoring the system to their needs and require the purchase of costly upgrades for what might on other systems be a few minutes work.

"All that is needed is a little fine tuning of the general purpose system to make CAD really sing for you rather than just being a turbo-charged drawing board."
(Billesdon, Roger 1990)

The need for adaptable systems equally applies to the construction as well as to the design phases although it could be argued that the need is greater in design because individual requirements are far less predictable. However, the means to alter the software need to be within the reach of the designer, which is seldom the case in systems available today. Indeed, some practices dedicate whole departments to software development, often resulting in highly efficient versions of commercial software or else in a new product altogether.

Depending on the complexity of the software it might be possible to tailor it to the needs of the practice in house without bringing in outside expertise. The more expensive software tends to require a greater in-depth knowledge to adapt, but those who market it usually argue that it is so good there should be no need to change it.

Unlike a drawing board where what you see is what you get, CAD software has many hidden depths waiting to be discovered. It is only by continued creative development that the potential can be enhanced.

"Every practice works differently, you have to be able to modify the system to suit your needs."
(CADdesk 1991)

Computers can affect the entire way architects think about design. Architect Donald Gibbs argues for working within set parameters

> *"...adapted to computers' way of working."*
> (Hoyt, Charles K. 1989)

Gibbs explains that by adopting this approach architects can concentrate on the way buildings go together and thus develop far more refined systems of building rather than being preoccupied by new forms.

> *"Computer aided design is a technique in which man and machine are blended into a problem solving machine intimately coupled with the best characteristics of each. The result of this combination works better than either man and machine would work alone, and by using a multi-disciplinary approach it offers the advantage of integrated teamwork."*
> (Dessant & Lui 1986)

Architects Stuart Riddick and Partners first purchased a Gable CAD system in November 1985. A year later a report outlined some of the changes in design methodology that the CAD system has perpetuated.

> *"Finding the level of tolerance to work with is an important feature of using the CAD which tends to require very accurate data to function."*
> (Twinch, Richard 1986)

Architects Pascall and Watson perceive the requirement for accuracy as a barrier to the design process.

> *"Our argument is that there ought to be a period before one commits oneself to the machine, a period of total freedom - looseness to design approach, unfettered by machine requirements."*
> (Hewson Dudley, 1990)

Other architects do not find the accuracy such a problem and see CAD having a much more positive role.

> *"... The notion that the computer is an aid or a tool, like a 3B pencil or a rotring is out of date. We are moving into a era of computer generated design."*
> (Hutchinson, Maxwell 1989)

As an example Hutchinson uses a recently completed scheme for a hotel in Islington that was generated by computer.

> *"It involved the most comprehensive use of the technology we have tried so far, and we found ourselves doing things that would not have been possible without computer generated images. The roof we put in was a complicated paraboloid. With the computer, you simply call up a flat grid, tweak it and glide it into the building on screen. All kinds of geometry are possible."*
> (Hutchinson, Maxwell 1989)

Hutchinson reminds us of the complex mathematics that was necessary to produce the vast spans of the roofs of the buildings in the Festival of Britain and the vast skeletal domes of Buckminster Fuller. The maths consisted of straight lines crossing endlessly at critical points to produce curves. A computer is able to produce similar complex geometry with relative ease, its success depends on the designer's ability to use the tools; such potential is unlikely to ever be fully explored by non-designers.

Many Architects believe that the computer will never replace the sketch pad. A survey by the University of Bath in 1985 of 400 professionals stated that no cases were found where computers were used in the early (Creative Design) work. CAD was used mainly by the automated technician to churn out general arrangements and working drawings of scales of up to 1:200. It is perhaps this area of CAD that has changed more than any other over the last five years. CAD software is becoming easier to use, so it is no longer necessary for CAD systems to be used only by specialist operators.

> *"We are moving away from the gurus in their CAD ghettos."*
> (Nicholson, Paul 1990)

Systems are becoming cheaper and consequently the opportunities to use them in a more relaxed experimental way. Technology is available to combine images from different sources, and intuitive yet versatile modelling packages are emerging. Although the underlying process of using software to create building models on computer is still foreign to many designers, more and more of the architecture built as a result demonstrates the success of using computers. Far more accurate visualization is now possible: 3D software is coming of age. Design staff willing to embrace the new technology can use it to enhance their creative skills. However, the argument that CAD cannot be used early in design is still common place.

> *"There is still no substitute for pencil on paper early in design."*
> (Nicholson, Paul 1990)

Indeed much 3D CAD work tends to be an 'after the event' product. This particularly applies to many of the sophisticated images used to present realistic visualisations of building models. They have their place, but tend to be the product of highly trained specialist operators rather than designers. If you want to try and pretend CAD is a scruffy bit of paper and you are using a 4b you are bound to be disappointed, but after all computers are a totally new media and we have to adapt our working methods to get the most out of them.

> *"When I develop design on plan it is a dynamic process. I can try numerous alternatives in rapid succession; to me it is in many cases far more flexible than a pencil."*
> (Hutchinson, Maxwell 1989)

Previous to using the computer, production of three dimensional information was very time consuming and an after the event luxury. Technology is allowing designers to start to design in 3D, as opposed to the more traditional process of visualising the third dimension as we transfer our thoughts to plan form. Many architects would admit that the opportunity to develop truly 3-Dimensional design on the drawing board is very limited.

As the use of CAD has become more widespread the opportunity to explore the third dimension has become more readily available at all stages of design. Unlike the process of creating working drawings, which like the traditional drawing board process is typically 2-Dimensional, the use of 3D on computer demands far more from the designer and the technology.

> *"Designers have to navigate around a screen representation of 3D space and learn new procedures for building models."*
> (Webb, Steve 1990)

Although 3D is desirable, it can also be dangerous

> *"users should not concern themselves too much with meeting the demands of full 3D modelling at the expense of time and missed deadlines."*
> (Postlethwaite, Andrew 1990)

As an ideal, one full 3D model of a building from which all design data can be extracted can hardly be bettered. In terms of appropriate software, hardware and management it is still a long way off, and those systems that come closest are very expensive, and difficult to learn. Approaches to the use of 3D are many and varied: experience will determine when and to what extent it should be used, appropriate to the project in question.

> *"You don't need to build a fully detailed 3D model of a design. Only particular parts of a structure should be developed to certain levels of detail, sufficient to make the necessary decisions or to gain the required information or effect."*
> (Mitchell, Mark 1990)

It is no longer economic to carry out comprehensive research and development on the back of a current project and work should be carried out within the abilities of the current system configuration.

3D models are now being demanded by clients and can be invaluable for winning contracts. An added benefit identified by a KPMG Peat Marwick McLintock report, is that 3D computing actively promotes organisational integration. (Peat Marwick McLintocks' report is entitled, " The Competitive benefit of 3D computing." [CADD 1990])

Architects in the Richard Rogers practice used their Intergraph 3D modelling system to produce a 1 square mile model of St. Pauls and its surroundings, for the Paternoster site. The resultant hidden line model projections from the air were very impressive. It is interesting to note that subsequent design use of the model was very limited. This can be largely put down to a reluctance to those not familiar with the system to work with it. A parallel of this can be drawn at the cheaper end of software market a firm called Architeknic work with wire line drawings and then produce manual overlay perspectives. This is done because they find the eye sorts out hidden lines far faster and more efficiently than the computer.

The conclusion must be that all architects will find benefits in using 3D CAD in some form.

> *"Designers who stick to two dimensional systems do so at their peril."*
> (Webb, Steve 1990)

THE ROLE OF COMPUTERS IN PRESENTATION

There has been an explosion of hardware and software facilities to cope with presentation of architectural information. On the hardware side there are a wide range of black and white, greyscale and colour input/output devices, slide making facilities, video linkups etc. On the software side there are animation, rendering, and painting packages, desktop publishing and slide making facilities.

Technology for presentation has entered a second phase, where the only limits are the imagination of the designer and the budget.

The technology for the efficient production of working drawings is available and relatively cheap. With suitable equipment many of the problems that occur are due to the inefficiencies of the operator rather than the deficiencies of the hardware and software. Dimensional accuracy is far easier to attain, as are co-ordination of plan, section and elevation and moving information between scales. Armed with these state of the art tools a competent architect/technician could hardly want for anything better. The main problems that do occur are of management of people, machines and information.

One of the major advantages of putting general arrangement drawings on the computer at an early design stage is that the buildings can be set out on the site to a very high degree of accuracy. This prevents the "drawing board scenario" of finding out that there is not enough space at later design stages.

It should be noted that initial input of information may be no quicker than by hand; it is in the subsequent alteration and even redesigns that the computer really pays. The efficient storage and retrieval of standard components will greatly enhance speed of operations.

What may appear simple in the manual will require time to put into effective action. Well designed libraries do not happen overnight, and automatic scheduling is not automatic.

The importance of output devices should not be underestimated, they are the limiting factor on quality of output from the system. For large sheet (AO and A1) pen plotters continue to hold the largest share of the market. Their basic design has changed little over the years but price has steadily fallen with increased performance and features. Recent innovations in pencil plotting has done much to overcome the problem of ink pens such as blockages, lack of fine lines, media restrictions, missing lines (plotter watching) and subsequent alteration.

> *"The flexibility, speed and cost-effectiveness offered by the pen/pencil combination should be carefully considered by any organisation considering the purchase of a plotter."*
> *(Batty, John 1990)*

Several alternatives are now available in the shape of thermal transfer, laser, inkjet, electrostatic, dye-sublimation and doubtless others to follow. There are four main criteria to consider when drawing comparisons,

> *"Plot quality, throughput, purchase price and cost of operation."*
> (Lees, John 1990)

OUTPUT CONSIDERATIONS

It is estimated that pen plotters will remain the dominant force in A1/AO plotting with an estimated 50% of all current output device expenditure (1991). Pen plotters are relatively slow and may take over an hour for a detailed AO plot. Apart from the problem of pens drying, often, having seen the final plot, changes are required or mistakes are noticed necessitating a re-plot. This scenario can be overcome by producing a test plot which can then be checked prior to production of the final plot, but this is wasteful of materials and time. It is far more efficient to check the content of drawings on screen and the best placed person to do this is the creator of the drawing, reinforcing the need for experienced operators and not untrained computer "whiz kids".

Pen plots of minor revisions are very wasteful of time and materials, updating the original by hand may be quicker and easier but should be done with caution as the CAD file will now be out of date.

Thermal and electrostatic technology go a long way towards overcoming speed problems but tend to be expensive, and line quality may suffer with low resolutions models.

A report brought out in 1985 by the University of Bath investigates the impact of the new technology on the building team and the building process. The study was prompted to see what had changed in inter disciplinary relationships since the influential studies by Higgins and Jessop in 1965.

> *" With the new communication paths which are being opened up it is believed by many that the confusions and complexities which are associated with yesterday's more primitive information systems are becoming a thing of the past."*
> (Twinch, Richard 1985)

The investigation is a result of a postal survey of 400 professionals. The report concludes that the typical attitudes of the main building team has changed little in the last 20 years and,

> *"to date a general change in interdisciplinary attitudes occasioned by the arrival of new technology is virtually absent".*
> (Twinch, Richard 1985)

This conclusion would not have surprised Higgins and Jessop whose view 20 years ago was that the pattern of relationships and the division of responsibilities in any building team have more effect on the way communications function than any particular aspects of the techniques of communications themselves.

Working with consultants who can share CAD data has obvious benefits for co-ordination of dimensions, structure and services.

> *"The ultimate goal is a single building model, accessible to all, and holding data from the feasibility stage through to property management."*
> (Howard, Rob 1990)

The technology to do this is becoming available. The main problem is one of management: who controls the model and how information passes between team members.

Management of a CAD installation in an architectural office is not an easy task, but its importance cannot be understated...

> *"The key to a successful computer system is efficient management."*
> (Bartle-Tubbs, Colin 1990)

Whatever working methodology and office structure architects adopt as a result of introducing CAD, the technical aspects of the system must always be considered. These are problems of data handling whether it be computer speed, screen definition or storage. Depending on the complexity of the system, this may mean employing specialist staff and new management structures. Any CAD installation must have the full backing and active support of those at the top of the practice.

> *"It cannot be simply be left to those who operate it. Management has to have a continued interest."*
> (CADdesk 1991)

When practices first invest in CAD they perceive problems as being machine, technology and money related.

> *In reality they lie with people; their attitudes, application and training. It's as much about people as it is about equipment."*
> (Hewson, Dudley 1990)

The dangers of employing non-architecturally trained staff to operate computers should not be understated.

> *"Any tool however superb it might be it's only as good as the person using it."*
> *(Hutchinson, Maxwell 1989)*

despite repeated warnings from journals and other experts,

> *"CAD has tended to become the preserve of junior architects and technicians."*
> (Twinch, Richard 1990)

It may be that the complexity of the system has determined the end users.

> *"The sophistication of the systems require constant use to remain fluent, and to this end BDP have computer specialists who act on behalf of the architects."*
> (Twinch, Richard 1987)

These specialists are essentially highly skilled technicians rather than designers using computers. If non-architecturally trained operators become specialists, architectural staff and computer staff tend to become very divided, with neither entirely sure what the other is doing. Operators tend to become frustrated and suffer from a lack of involvement or responsibility in their work; their interest and thus efficiency will decrease. The end result will be a high turnover of staff with all the problems that go with it.

Watkins Gray International is an architectural practice with about 100 technical staff. In 1981 the practice invested in a minicomputer based CAD system running GDS software. In 1987 the practice was forced to reinvest; over the previous 6 year period they concluded that CAD had been no worse or better than manual drawing in terms of saving time and money. Drawing quality had improved, though not necessarily content and there was better co-ordination of the project set. On the other hand the management load had increased considerably.

GDS had to be worked by highly trained operators, working full-time at the system, effectively operating as an "elite" bureau (a fact resented by the "customers"). In re-investing the practice aimed to achieve three objectives: Firstly to bring CAD into the project teams; Secondly to remove the mystique surrounding CAD, and lastly to improve the general attitude of the practice toward CAD. All three objectives focused on the attitude and behaviour of people, rather than on technical issues.

The practice decided to run Autocad alongside the latest version of GDS. Significant problems have subsequently arisen when transferring data between the two systems, but on the whole the introduction of Autocad has increased the enthusiasm toward CAD. Project teams are now choosing to use CAD and much of the mystique has disappeared.
(AJ Supplement 1989)

The bureau with specialist operators have their problems, and the worst is very often one of communication between the architects and the operators. Many practices now recognise the problems associated with bureaux and have chosen instead to integrate CAD within design teams.

> *"This option was felt to be more effective than the creation of a central "CAD bureau", which limits the interaction between CAD staff and project staff."*
> (Hay, Alan 1990)

Working in project teams a computer may handle selected parts of the project, preferably those parts that are best suited to the software. The major advantages of being integrated in the project is that everyone will have contact with the computer: familiarity with computing concepts will increase; a greater understanding will lead to a more efficient usage.

> *"We have reaped the benefits of increased interest and awareness which aids interaction between CAD and other staff and a fuller utilisation of the system."*
> (Hay, Alan 1990)

The greatest difficulties of this approach are the management of human and machine resources. Questions such as who should use the machines and which projects are best suited to the computer need to be answered. There is a tendency to put the junior staff on the computer, with the result that their work must be constantly overseen and corrected by more knowledgeable staff, leading to duplication of work and reduced efficiency.

When working with computers it is far harder for non-computer staff to keep track and be aware of how much information is being held on computer. This is because all they ever see is the hard copy and the occasional glance at the screen; often they have little idea of what processes have been undertaken to achieve it. This problem is further compounded when working to tight deadlines, as much of the information is only seen for the first time very close to the deadline.

If all members of a project team were to use the computers, they stand to reap the highest benefit from their use.

> *"In the working practice, optimum cad-efficiency can only be reached when full CAD integration has been achieved."*
> (Hay, Alan 1990)

In a well structured organization information storage and retrieval can be very efficient. The production of repetitive information and standard drawings can be vastly increased. The confidence in the 3-Dimensional appearance and organisation of a building design can be realised before the project goes to site.

One of the consequences of introducing CAD is that new positions of responsibility and specialist skills will develop. It is important that management should take advantage of these new work areas and allow staff to develop specialist skills that will in time become an integral part of mainstream architecture. Job satisfaction in a CAD working environment depends on job design and office management factors rather than on the technological change brought about by CAD.

The growth of CAD has been paralleled by a boom in the design and construction industry. Since the down turn in work of the 1990's practices are beginning to realise that the employees who understand the computer are the core staff that they need to retain in order to protect their investment. Despite some systems appearing fairly easy to learn, in reality the learning curve can be much longer than originally estimated.

> *"After 9 months of using the system it was still reckoned that drawing by computer took as long as by hand."*
> (Twinch, Richard 1986)

It is however, a learning curve which everybody will have to go through in the next few years one way or another.

> *"If CAD is to be made cost-affective, rather than the add-on luxury it (too often) has been, then management and training need to come into force."*
> (Twinch, Richard 1990)

A structured approach to training is essential to maximise the potential of any system.

> *"Bad performance can be directly related to lack of, or poor training."*
> (Whitewood, David 1991)

Practices should be wary of the scenario of an in-house expert who is constantly interrupted which may lead to lost productivity and frustration. Research by Coopers and Lybrand Deloite suggest that:

> *"50% of a company's technology budget should be allocated to training."*
> (Bartle-Tubbs, Colin 1990)

It is pointless purchasing CAD with the hope that it will sort out problems of project planning. More than likely it will create more problems such as how to co-ordinate information produced by computer and hand drawn information. There is a tendency to demand more and more from the computer staff which can easily lead to bottlenecks at deadlines. The need to look at what projects are coming in to the office and what they entail in terms of time scale, number and types of drawings to be produced, and the manpower required to service them is more crucial in the computerised office, and harder to asses than ever before.

As more and more of the office data is held on computer the need for daily backup, systematic storage and retrieval, archive and security will require serious consideration. If these issues are ignored the resulting chaos will decrease the effectiveness and reliability of any computer installation.

> *"The profit potential relies upon how much information one can retrieve from a precise set of coordinated data."*
> (Bartle-Tubbs, Colin 1990)

Tight internal organisation and communication is vital; without it many of the benefits of CAD are wasted and result in increased fragmentation of the design process. The introduction of a CAD system often gives practices the chance to re-think organisational procedures, and thus simplify co-ordination, the process of design and management.

> *"Traditional project organisation will continue, but being unable to fully utilise the new technology will tend to decline, while new forms of management will emerge to utilise the new technology to the full."*
> (Twinch, Richard 1987)

The early function of computer bureaux was to loan the use of the very large main frame systems. As the demand for this type of service has disappeared, the function of the bureaux has changed to accommodate the market. Bureaux services have turned their attentions to more specialised areas of CAD such as central archive facilities for clients, that hold large central data bases that can be accessed by different clients working on the same project, central plotting facilities, technical support and advice, and pools of trained staff for helping out in peak workloads. Other areas of specialisation include presentation and 3D imaging.

To create fully rendered images, with multiple light sources and surface textures requires very powerful equipment and a large time investment.

> *"To get the most out of these systems requires not only great skill, but a good design sense. Getting a person trained to this level can take years."*
> (Building Design 1990)3

Not many practices have the demand or time to justify the cost of such specialism, and consequently imaging is an area in which bureaux now thrive.

Although the ergonomics of computer terminals can still be improved it seems that physical health problems amongst operators are related more to the design of their jobs rather than the design of their terminals. Complaints occur most frequently among workers with repetitive, mundane jobs, involving constant typing or data entry at a terminal.

American studies conclude that radiation from screens is not a cause of health problems and account for a very low percentage of the radiation we are exposed to from other sources.

Physiological health problems arising from the use of computer based systems confirm the view that decision making is paced by the computer, and not the person, leading to information overload and increased stress.

Ever since the introduction of VDU's in offices there have been complaints of eyestrain and headaches from operators. Poor lighting and furniture is largely to blame, and special consideration needs to be given to reduce reflections from overhead lights and windows. Uplighting the ceiling and a desk light is usually the best solution.

CONCLUSION

The greater the experience of the use of CAD systems in architecture, the more the users report formalised working procedures; this is very different from the informal personalised working procedures of conventional design practice. The routinisation of work activities is often a general feature of office automation Related to changes in working procedures is the issue of designers being deskilled by CAD systems. The reverse argument about the effects of CAD is also frequently presented. This is that CAD frees designers from low level menial and repetitive tasks and allows their skill to be developed and applied at higher levels. What often seems to happen in practice is that CAD systems are applied in ways that force further differentiation of skills amongst different grades of design staff.

New skills needed with CAD include the fluent use of symbols, the ability to work with information in different dimensions and planes, the ability to manipulate programs, and to develop personal strategies for problem solving. CAD inevitably entails some learning of new skills; at the higher levels of the office hierarchy these probably create new opportunities as well as imposing new demands. At the lower end they tend to deskill or replace altogether the jobs of junior staff.

CAD systems impose limitations on the kind of objects that can be designed in terms of the limited shape or range of components a system can handle. Conversely some objects could not be designed without computer aids. The difficulty of operating the system may mean the designers attention is not wholly on the object being designed and the design itself suffers. Although many CAD programs have a vast range of functions, from observation many designers tend to use a limited set of commands and stick to a restricted set of responses when interacting with the system.

CONCLUSION

A major advantage of CAD is thought to be the improved and quicker analysis in the evaluation of designs at conceptional design stage. Improved techniques reduce the time necessary for verifying the proposed designs, this allows more time at the concept stage as well as reducing the overall process time. It is normally at the analysis and evaluation stage that the interactive nature of the design process becomes evident, as the result of analysis forces a return to reconsider the details of the concept itself. It has been suggested that the rapid analysis techniques of CAD will allow many more variations to be performed within the overall time span of the process thus allowing convergence on a more nearly optimal design. CAD also introduces more sophisticated analysis techniques thus allowing the designer to be more certain in predicting the performance of a building.

We may see a change in the design process, which at present is the preserve of a very select group of people. Even clients can often find it difficult to have much influence on the process and the designs that result from it. This is partly due to the nature of traditional modelling techniques which largely remain in the designer's head or are externalized in limited, difficult-to-understand forms, thus making it very difficult for non-experts or non-designers either to make or evaluate proposals.

The necessary facilities are now available for using computers at the very early stages of design. The limitations of hardware and software are becoming less significant, and success is becoming much more dependent on the ability of individuals to work with the new tools with which they are provided.

CONCLUSION

The main obstacles to effective computer use are in adapting office procedures to cope with the new technology, managing resources and training.

Architectural design on computer will still continue to be limited by the relatively small proportion of designers as opposed to technicians who actually operate CAD systems. The fact that many years of development have concentrated on the construction phases of architecture, inevitably means that software for design is still in its early stages of evolution and is unlikely to be totally satisfactory for some years.

SURVEY

Given the fact that actual data was necessary in order to draw many of the issues discussed in the literature, and summarised in this thesis to a conclusion, an empirical study was required and the data gathering method chosen was a survey.
(See Moser, C.A. & Kalton, G 1971)

Objectives:

(1) To determine in which areas of design CAD is being used

When CAD was in its infancy back in the mid 1960's there were many predictions as to the future role it was likely to play in architectural design, with the ultimate vision of the architect as a,

"Push button Designer"

It was only by the mid 1980's that technology reached a level of sophistication to enable CAD to be a serious alternative to the drawing board. A survey by the University of Bath in 1985 concluded that very few architects were using CAD at the early stages of design.

An objective of the survey was to determine whether suitable hardware and software is available for use at the design stages of architecture and to establish the areas of design at which computers are currently most effective in practice. Many articles report that design is a fast growing area of CAD and it is hoped that the results of the survey will show a trend towards its successful utilisation at the early stages of design.

(2) To determine the degree of success designers are able to achieve as a result of using CAD.

One of the major concerns over the introduction of CAD into the architectural profession has been that the designer will become de-skilled, and that architecture will become an automated process with the designer becoming remote from the heart of the design.

The complexity of CAD installations tends to determine the likely end users, the more involved the operation of the computer facility the less likely it is to be used by designers. This often gives rise to computer departments, where non-architecturally trained operators do the drawings for the designers. As predicted this has lead to many problems, particularly in communication between designers and operators. It is hardly surprising that having undergone a lengthy professional training, few architects have been willing to undergo a second period of training to learn to use a technology that may not seem particularly orientated toward design. Now, with systems that are easier to use, a greater level of CAD awareness and a number of intuitive modelling programs emerging, the status of users should begin to veer towards the professionals.

A potentially serious problem has been highlighted by the recession of the 1990's and that is that very often core staff are computer staff, who are vital to protect the investment of a practice. If these staff are not architecturally trained the likelihood of the installation reaching its potential is vastly reduced. As computer systems have become easier to use, and training is beginning to play its part, the number of designers who utilise them have increased, and it is hoped that the results will show that they are able to successfully use CAD for design.

(3) To determine the effectiveness of communication both within the office and throughout the building team

In order to be efficient throughout the design process, communication of data is always going to be significant. The survey profiles the current state of data communications

(4) Office profile

As well as providing information about individuals the survey sets out to build a profile of practices in terms of staff and technology.

THE STRUCTURE OF THE QUESTIONS (SEE APPENDIX II)

Questions 1-4 are designed to establish the status, and experience of the respondent.

Question 5 is designed to establish in which areas of design the respondent is utilising computers out of a range of facilities available within the office.

Questions 6-10 measure the effectiveness of computer use from the respondents own experiences.

Questions 11-16 look at the organisation of the CAD facilities within the office as a whole, and at the state of communication within the office and the building team.

Questions 16-22 are designed to assess how long CAD facilities have been in use, the type of hardware that is in use and to give a broad indication of how much has been spent on hardware and software. It was intentional that the actual software packages should not be named individually as this survey is not intended to be an evaluation of software. Many detailed surveys and articles are available on this subject.

Question 23 is an open ended question designed to stimulate further points for discussion.

THE RESULTS EXPECTED

It is reasonable to expect the results to show that computers are still not fully utilised at the early stages of design, largely because the facilities are not available. If the facilities are available, it seems likely that they are under-utilised because the acknowledged strengths of CAD lie in the ability to generate production information. Similarly many of the respondents will feel that the constraints of the software prevent them designing on the computer and very few will report an improvement in their design skills.

Practices that have adopted a "Bureau type" organisation, utilising non-architecturally trained operators will demonstrate least satisfaction with the use of computers in the conceptual areas of design and are more likely to experience problems of communication of project data.

Contrary to previous reports it is expected that communication of project data both in-house and within the building team will show an improvement. This will have come about not only by improved standards for the exchange of electronic data, but also by improved dimensional co-ordination, and 3D visual communications of building projects. The greatest levels of improvement are likely to be attained in those offices that have adopted a complete replacement of manual drawing (not necessarily sketching) methods with computer.

COVERAGE

The survey is limited to architectural practices in the U.K., who already utilise CAD. At present this numbers around 1500 practices, 250 were targeted as a reasonable number to gain representative results within the limit of available resources.

Collection of data

Nine out of ten social surveys use a questionnaire of some kind:

> *"For a simple enquiry among an educated section of the population - say a professional group - and concerned with a subject of close interest to its members, a mail questionnaire might be adequate."*
> (Moser, C.A. & Kalton, G. 1971)

One of the biggest problems with postal questionnaires is lack of response (the RIBA warned to expect around 10%). To try and guard against such a poor response, letters were sent to named individuals within the company (Names were taken from lists of delegates at CAD conferences, magazine articles etc.). A promise to send those who were interested a summary of the results was also included as an incentive to reply. (see Appendix II)

THE RIBA SURVEYS OF COMPUTER USAGE

The RIBA has conducted three surveys to date on the subject of "Computer Usage among architects". The first was in 1980, the second in early 1987, and the most recent in 1989.

The latest survey was sent to all 5,300 UK private practices of which 3000 replied, the results confirmed the following: 2D CAD is now used by 25% of all practices up from 10% in 1987 and that 3D CAD is now used by 17%, up from 6% in 1987. In common with the 1987 survey the major issues raised were the need for objective information on choosing hardware and software and the need to allocate sufficient time to staff training.

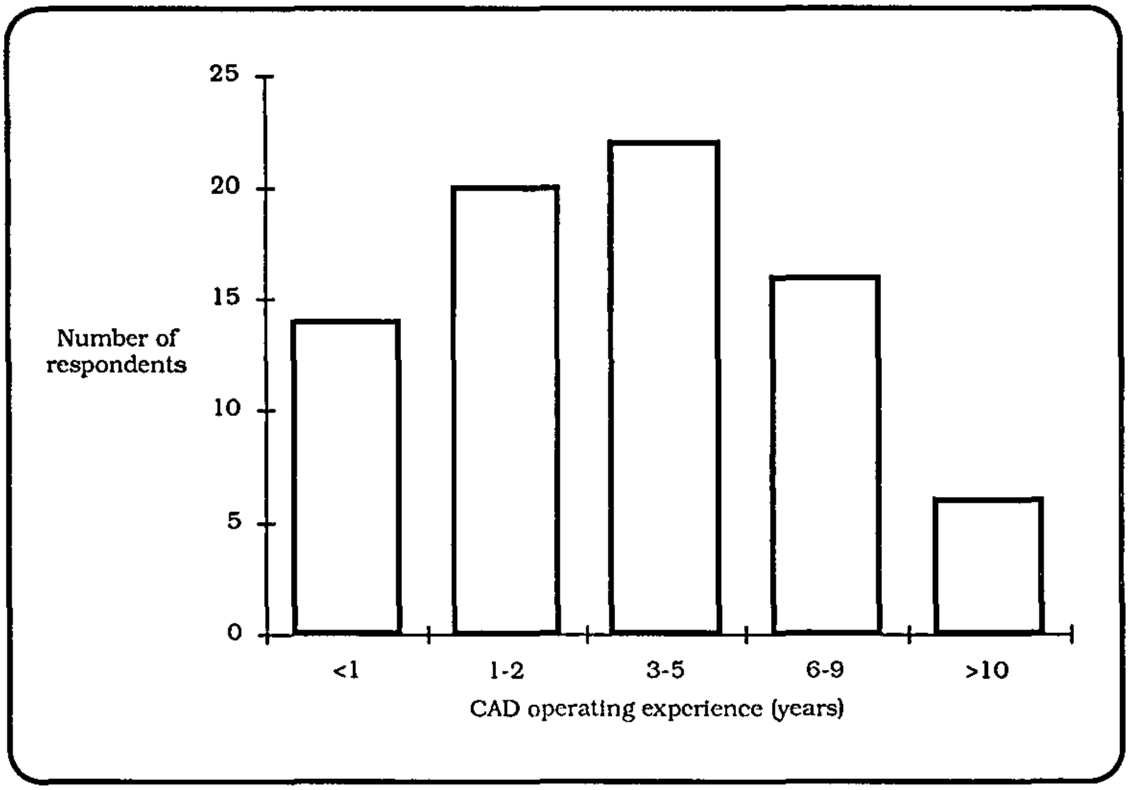
An analysis of the results by Richard Tanguy (Practice July/August 1990) focuses on the differences between large and small architectural practices. Large practices are able to spend more time researching their business requirements, and are able to allocate more resources to the purchase and development of CAD systems. By tailoring the operation of the CAD system (usually workstations) to provide up-to-date documentation in support of drawn information high levels of efficiency have been achieved. With the move toward standard data formats such systems are well placed to process information throughout the building team.

Smaller practices on the other hand tend to rely on learning to use packages they have bought from High Street dealers. The success of such installations frequently relies on the degree of co-operation between the members of the practice in adapting to the consequent changes in office administration.

ANALYSIS OF THE RESULTS

Of 240 questionnaires dispatched 78 were returned. The task of analysing the data was too complex to perform by hand and so a spreadsheet (Microsoft Excel) was utilised. Having input the data, Excel can be used to count responses and produce graphs. The results of this analysis are presented in the pages that follow, and discussed in chapter 5. (see Appendix III)

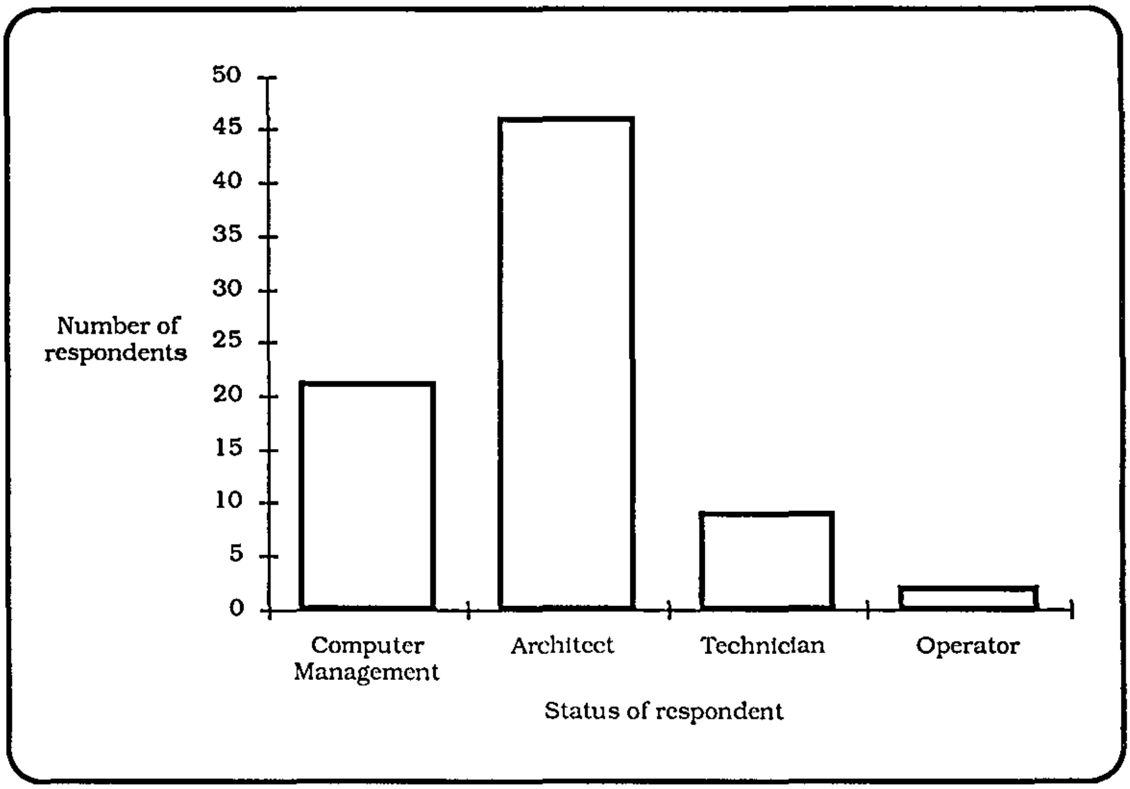
FIG. 4.1



Respondents were asked to indicate the number of years they had been utilising CAD facilities.

Fig. 4.1 shows that the number of years operating experience of the respondents are fairly evenly spread between 0-9 years and rapidly tails off after 10 years. This suggests that the answers to questions asked later in the survey should be fairly representative. It was expected that few respondents would have more than ten years experience on the grounds that computer installations were comparatively rare before 1980.

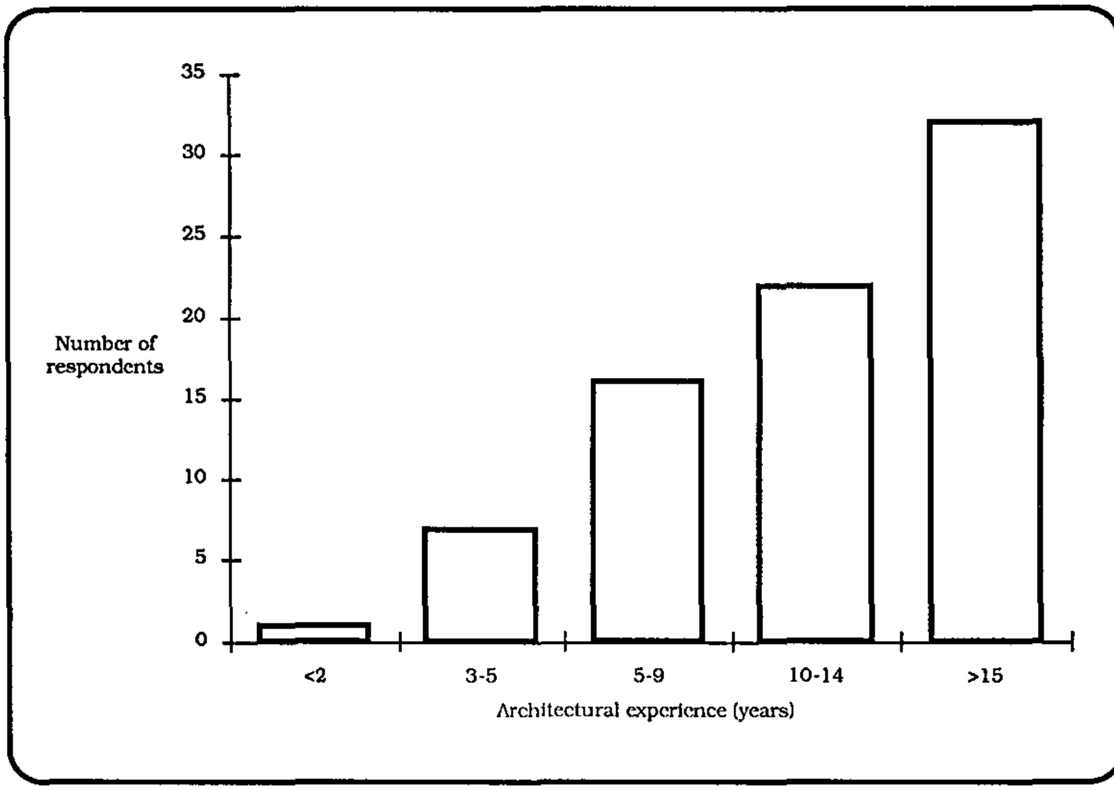
FIG. 4.2



Respondents were asked to indicate their status within the office.

It was hoped that the majority of questionnaires would reach 'designers', in order to eliminate the problem of non-designers being unable to exploit design facilities. Of all the respondents 87% considered themselves to be designers, this group included all except the 3 operators, 4 of the technicians and 3 of those in computer management.

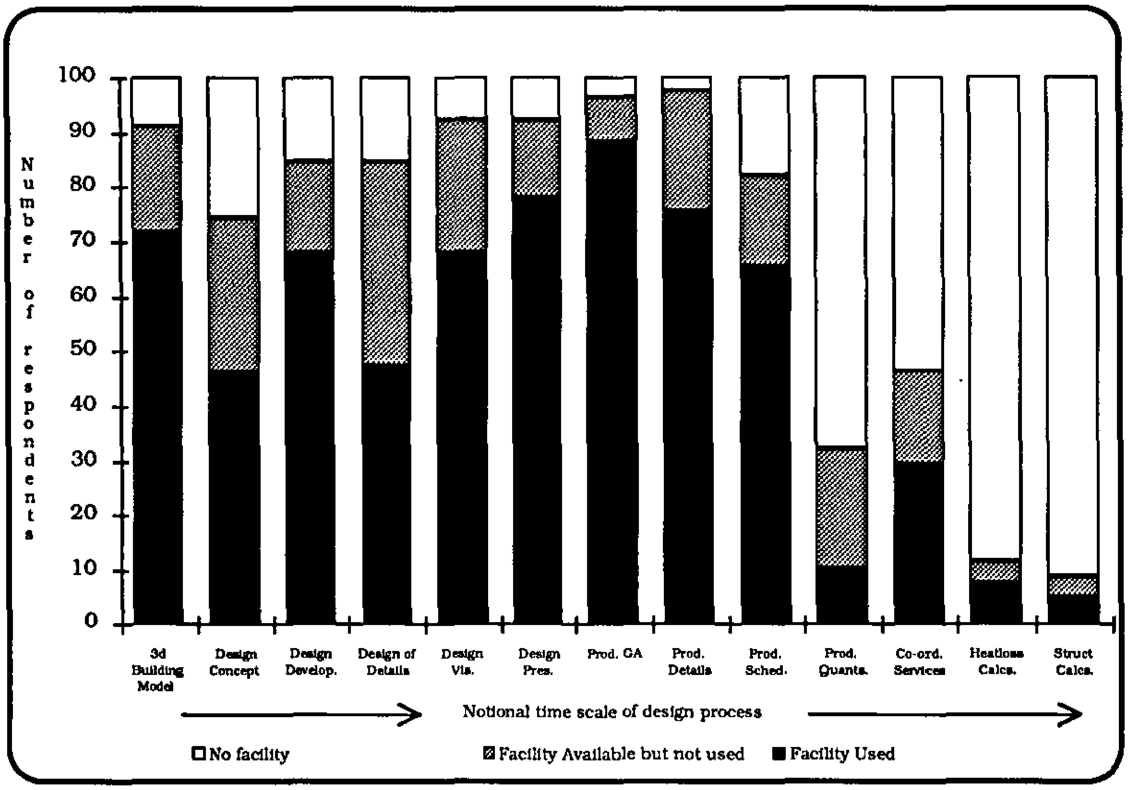
FIG. 4.3



Respondents were asked to indicate their number of years architectural experience

Fig. 4.3 shows that the vast majority have over 9 years architectural experience, which considering that an architect takes 7 years to qualify is to be expected. Although this demonstrates that the majority of respondents are fairly experienced, on reflection much broader band widths for recording number of years architectural experience might have produced more interesting and potentially more significant results. It may be that architects with over 30 years experience would have given significantly different responses to those with less than 15 years. The graph would also seem to indicate that most of the respondents are likely to have practical experience of architecture without CAD.

FIG. 4.4



In Fig. 4.4 the titles running across the x-axis of this graph represent stages in the design and construction of buildings. As far as is possible these have been arranged in a sequence from left to right, which represents the normal order in which the process of architectural design occurs. An exception to this is the production of a 3D building model which may cross any stage of design depending on why it is being produced and how the software can be used to manipulate the information held within it. However, the process of design varies tremendously between individuals and practices, as does the interpretation of what a stage may involve.

The real purpose of this graph is to ascertain in which areas of design computer use is most common, later graphs set out to determine the degree of success that can be achieved in the various stages.

FIG 4.4 EXPLANATION

The black portion of the bar represents a facility that is put to use, the grey area a facility that is available but not used and the white area where no facility is available to perform the particular task. The ratio of the length of the black bar to that of the grey bar therefore indicates the proportion of users that make use of a given facility.

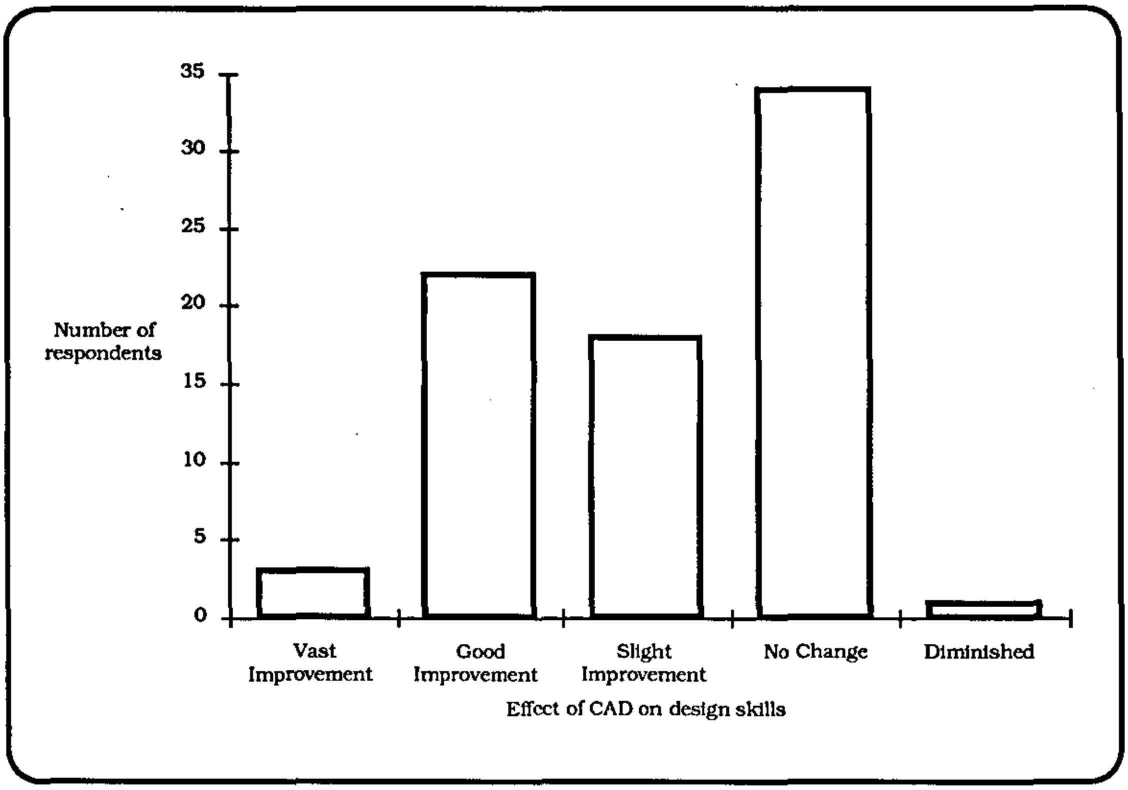
One third of all practices have a facility available for the production of quantities, and of those only one third of the respondents made use of it. In contrast around 96% of practices have a facility for the production of general arrangement drawings and the production of details, of those 92% of the respondents make use of the general arrangement and 78% of the respondents make use of the detail facility. The production of general arrangement drawings represents the most used of all the facilities.

74% of practices have a facility available for design conceptualising; of those only 62% of the respondents made use of it. This compares closely with the results for the design of details for which 85% of practices have a facility available and of those 56% of the respondents make use of it.

The results for design development, visualisation and presentation give similar results, with around 92% of practices having facilities available and of those around 78% of the respondents making use of them.

46% of practices reported having a facility available for the co-ordination of services, of those two thirds of the respondents put it to use. The least available facility was for heatloss and structural calculations at around 10%; of those only just over half of the respondents put them to use.

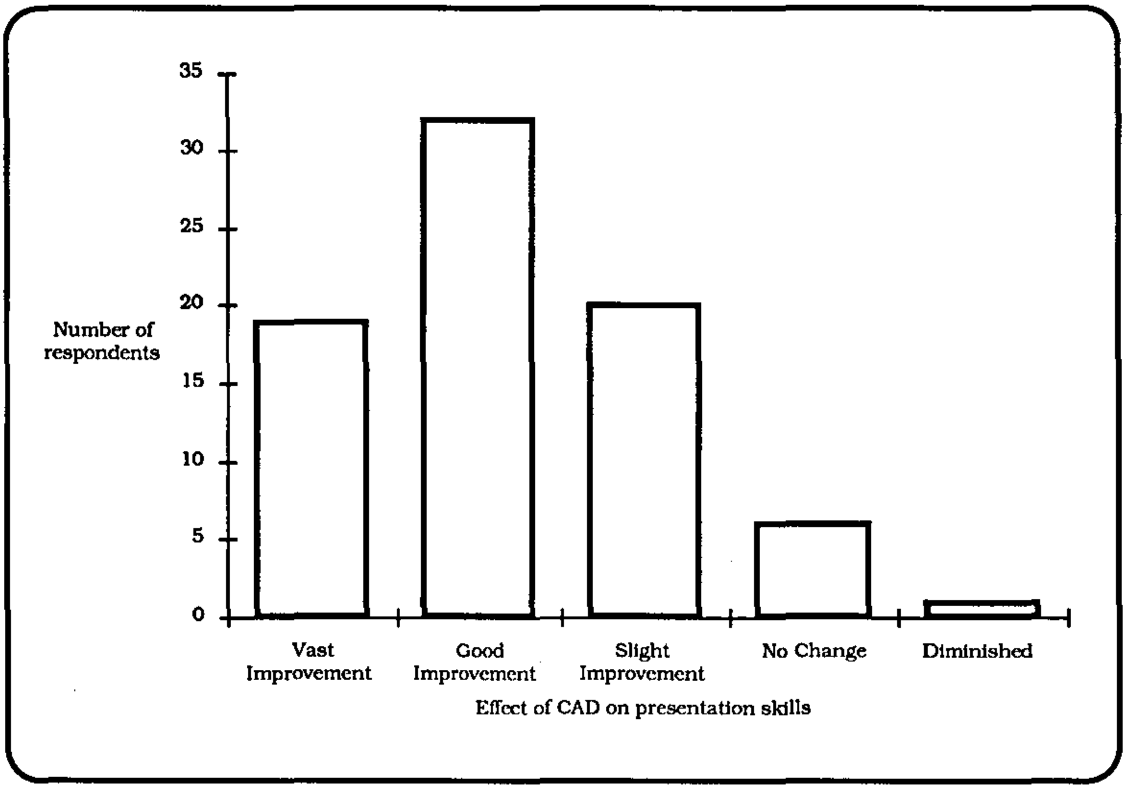
FIG. 4.5



Respondents were asked to indicate the effect of using CAD on their design skills.

Fig. 4.5 shows that only 2 of the respondents identified a vast improvement in their design skills, whilst over one half noticed a degree of positive change. 44% saw no change at all, whilst one felt that his design skills had actually diminished. Overall this is a very encouraging result demonstrating that CAD can be for design, contrary to many opinions to date that place CAD as an "after the event" process.

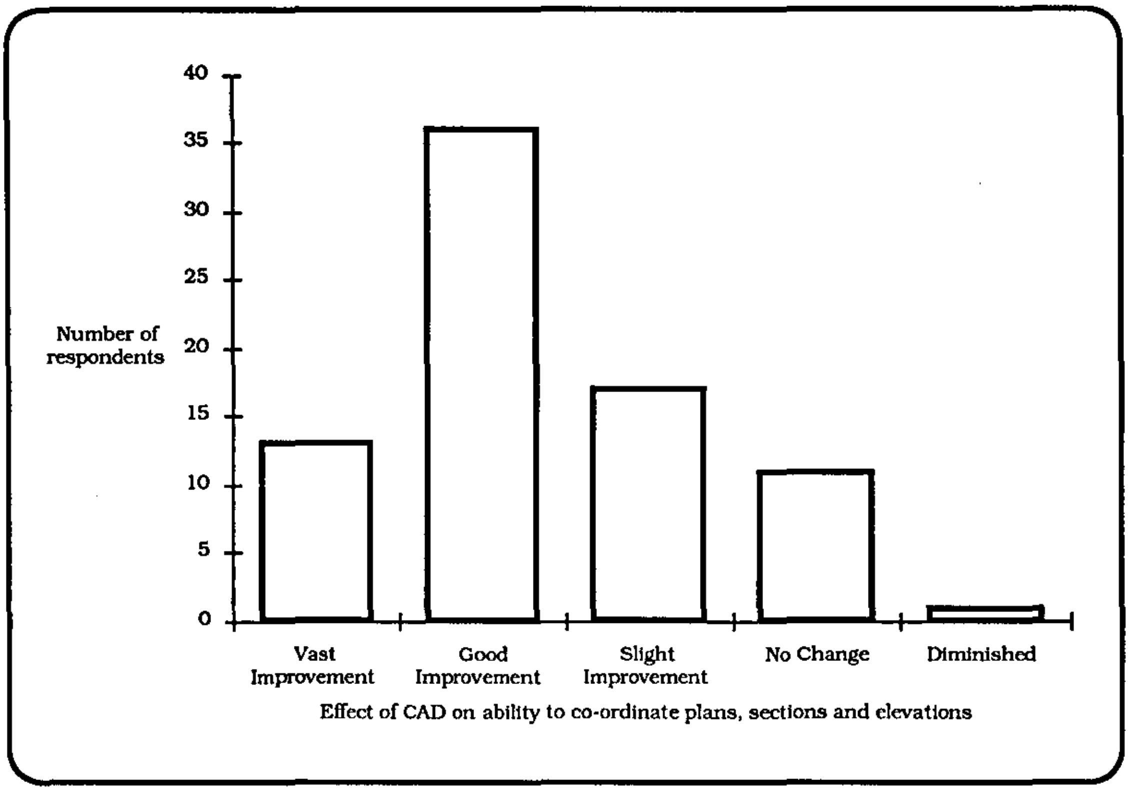
FIG. 4.6



Respondents were asked to measure the effect of using CAD on their presentation skills.

Fig 4.6 shows that 92% recorded a positive improvement, with 24% showing a vast improvement, 41% a good improvement and 26% a slight improvement.

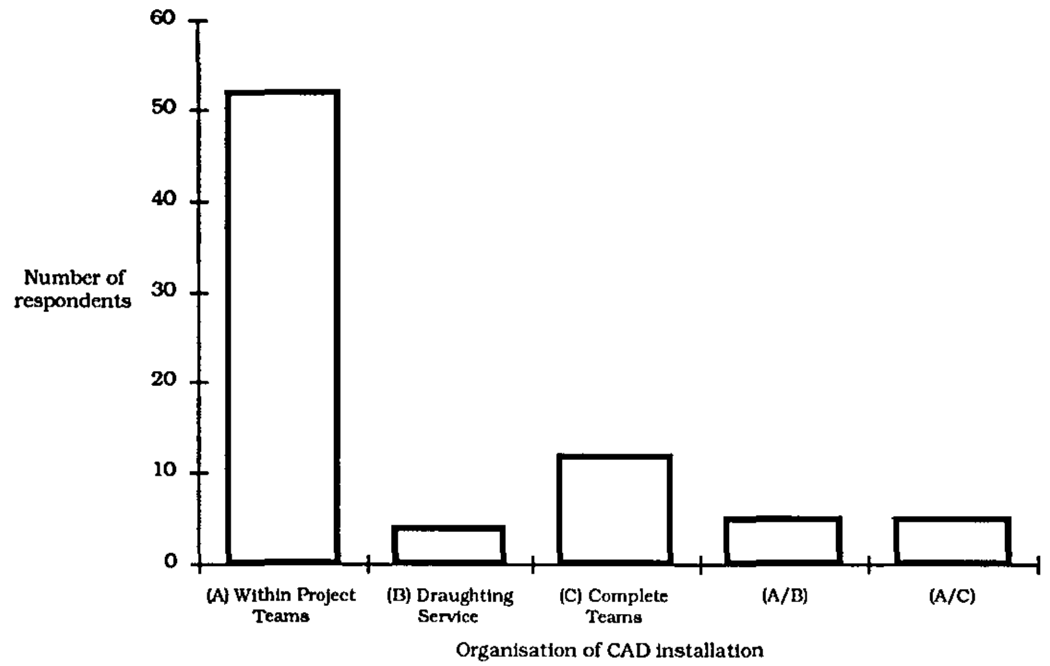
FIG. 4.7



Respondents were asked to assess the effect of CAD on their ability to coordinate plans, sections and elevations.

Fig. 4.7 shows that 85% recorded a positive improvement, with 17% showing a vast improvement, 46% a good improvement and 22% a slight improvement. 14% felt there had been no change and 1 respondent felt their ability had diminished.

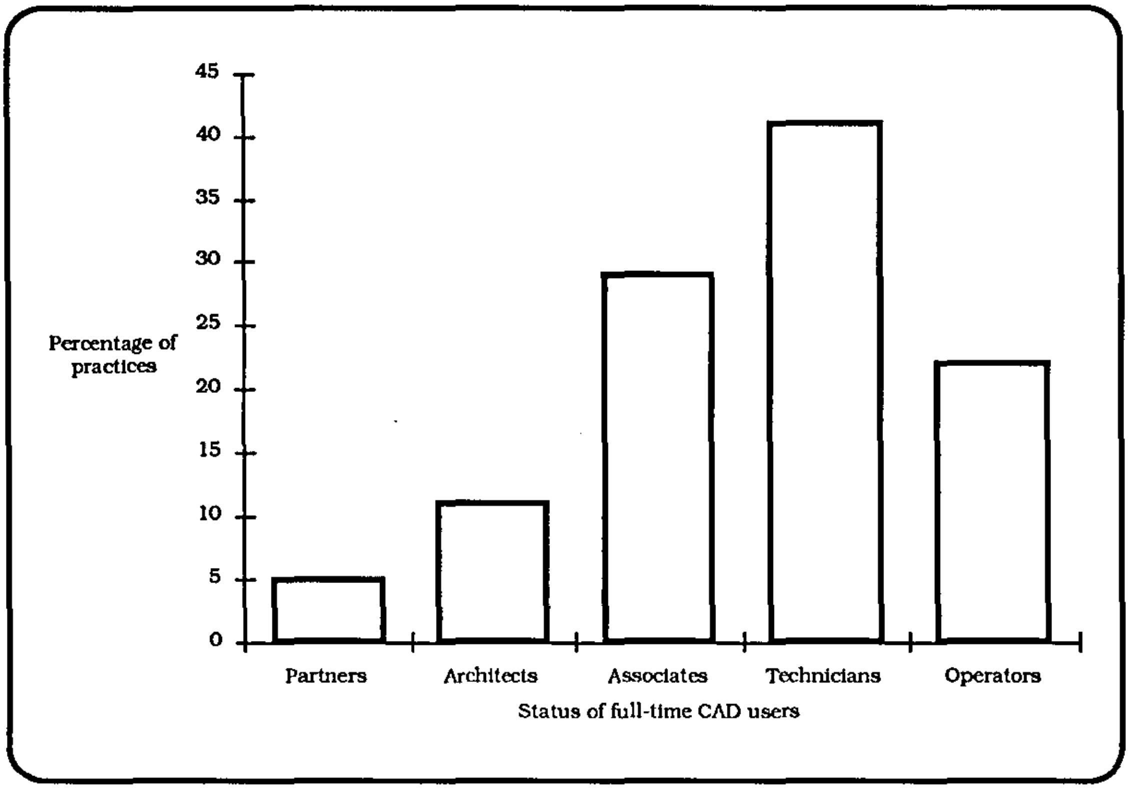
FIG. 4.8



Respondents were asked to indicate into which categories they felt the organisation of their CAD installations fell.

Fig. 4.8 shows that 67% of all practices indicated that their computers were distributed within project teams whilst around 5% used them as a draughting service and 15% of practices had completely replaced the drawing board with computers for whole design teams. A further 6% recorded a mixture of using CAD within teams and as a draughting service, and 6% a mixture of within teams and complete teams.

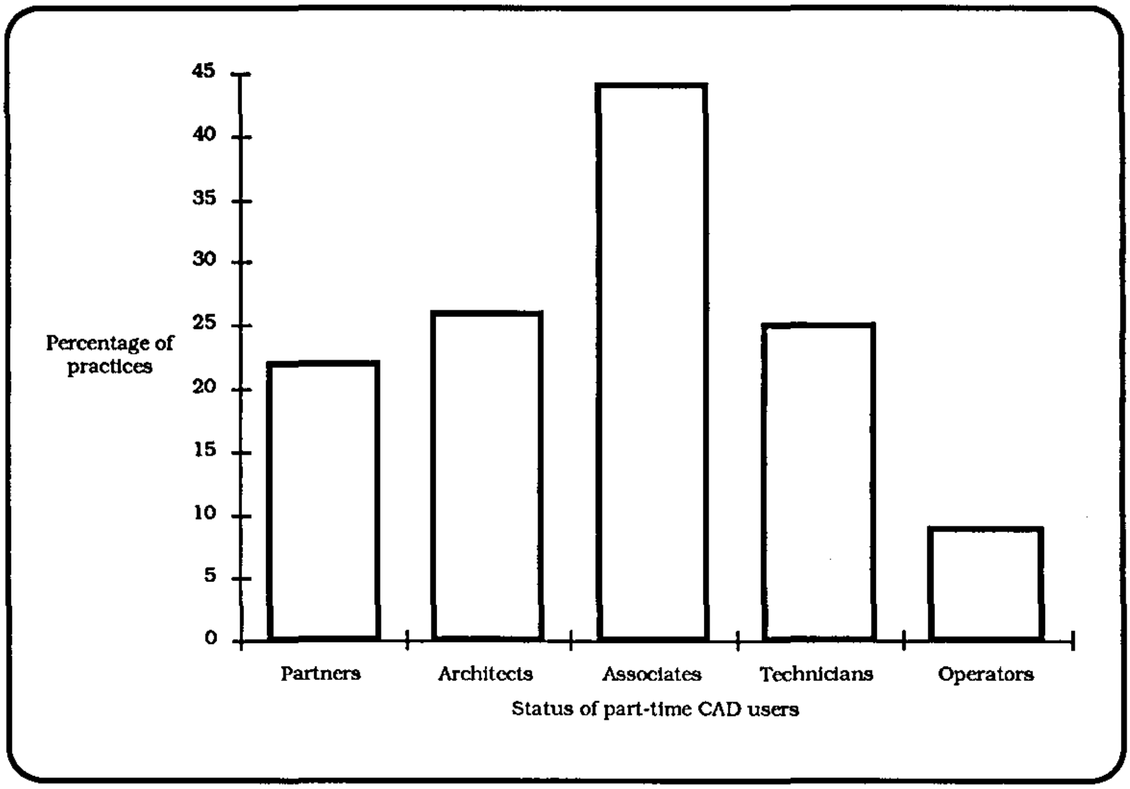
FIG. 4.9



Respondents were asked to indicate the status of those who use CAD within their office on a full-time basis (i.e. it is their equivalent to a drawing board).

Fig 4.9 shows that technicians constitute the highest percentage of users of CAD in their practices at 38%, associates account for 27%, operators 20%, architects 10% and partners account for 5%.

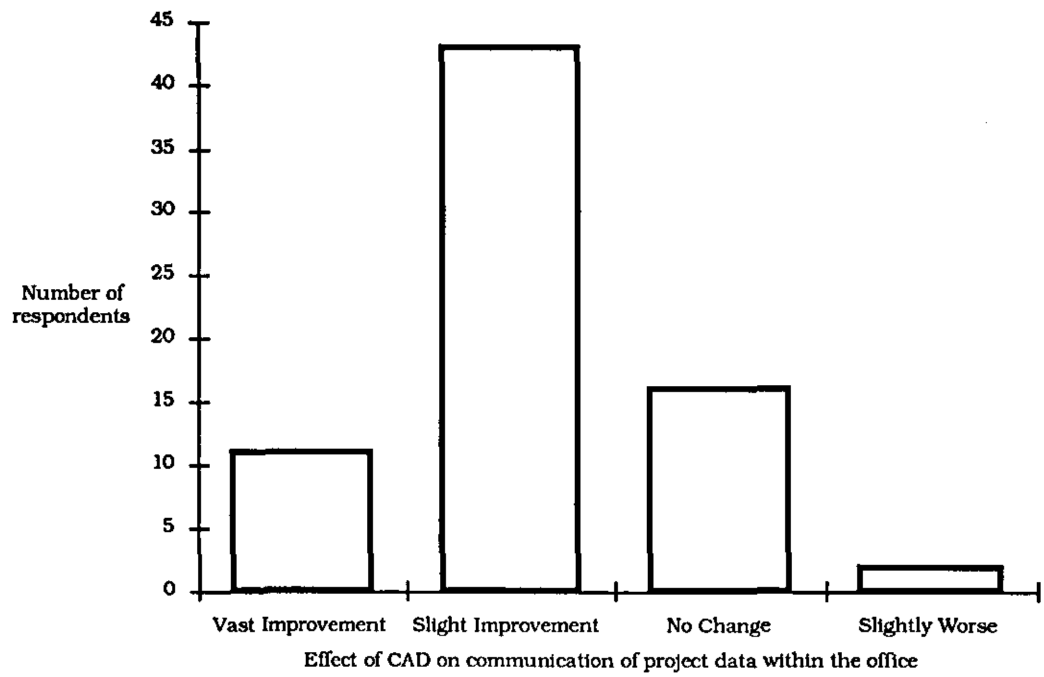
FIG. 4.10



Respondents were asked to indicate the status of those who use CAD within their office on a part-time basis (i.e. they have occasional access to a CAD facility)

Fig. 4.10 shows that Associates constitute the highest percentage of part-time users of CAD in their practices at 35%, architects account for 21%, technicians 20%, partners 17% and operators 7%.

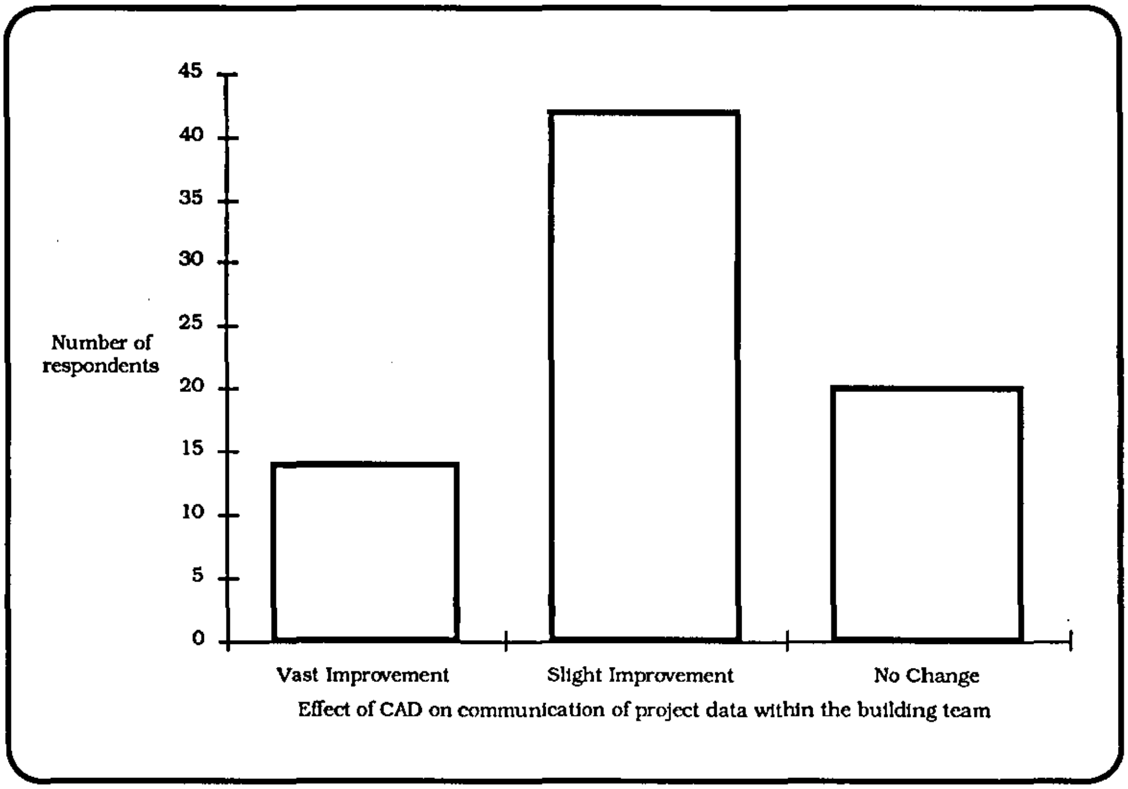
FIG. 4.11



Respondents were asked to indicate the changes in communication of project data within their office.

Fig. 4.11 shows that 17% identified a vast improvement, whilst 57% noticed a slight improvement, 23% saw no change and 2 respondents felt it was worse.

FIG 4.12

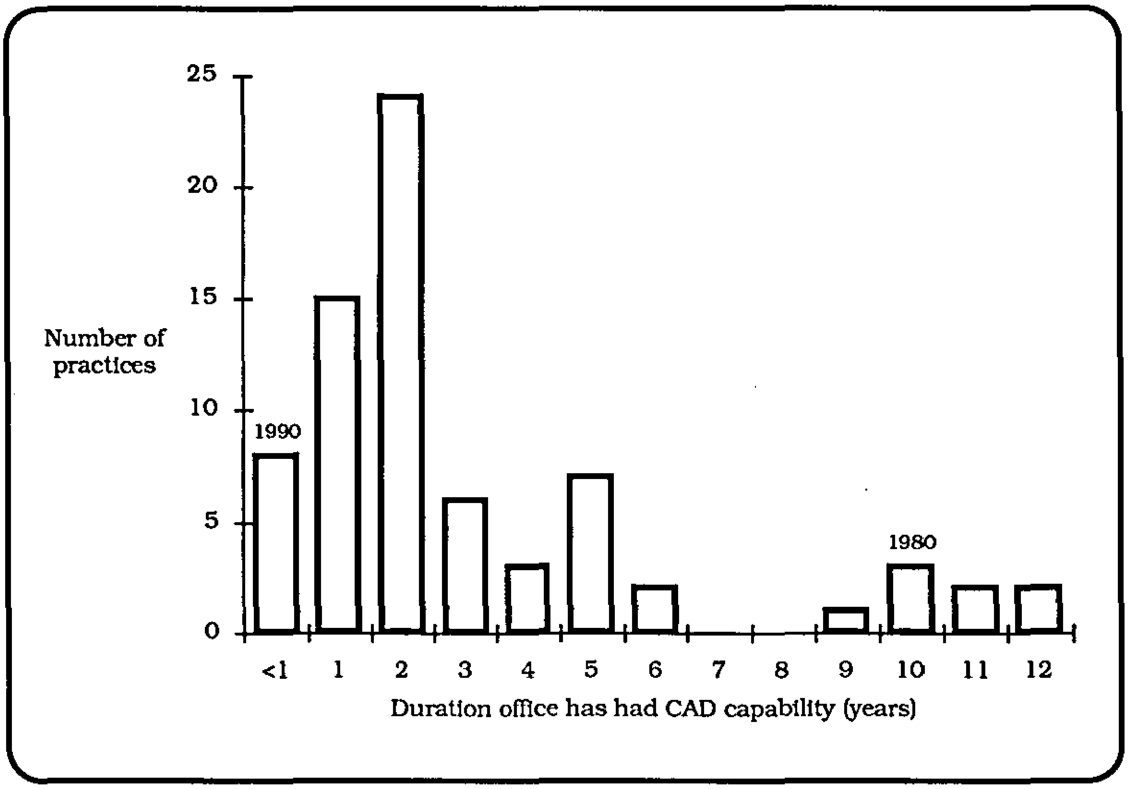


Respondents were asked to indicate the changes in communication of project data within the building team.

Fig 4.12 shows that 18% identified a vast improvement, whilst 56% noticed a slight improvement, 26% saw no change and no respondents felt it was any worse.

42% of all respondents reported utilising a network.

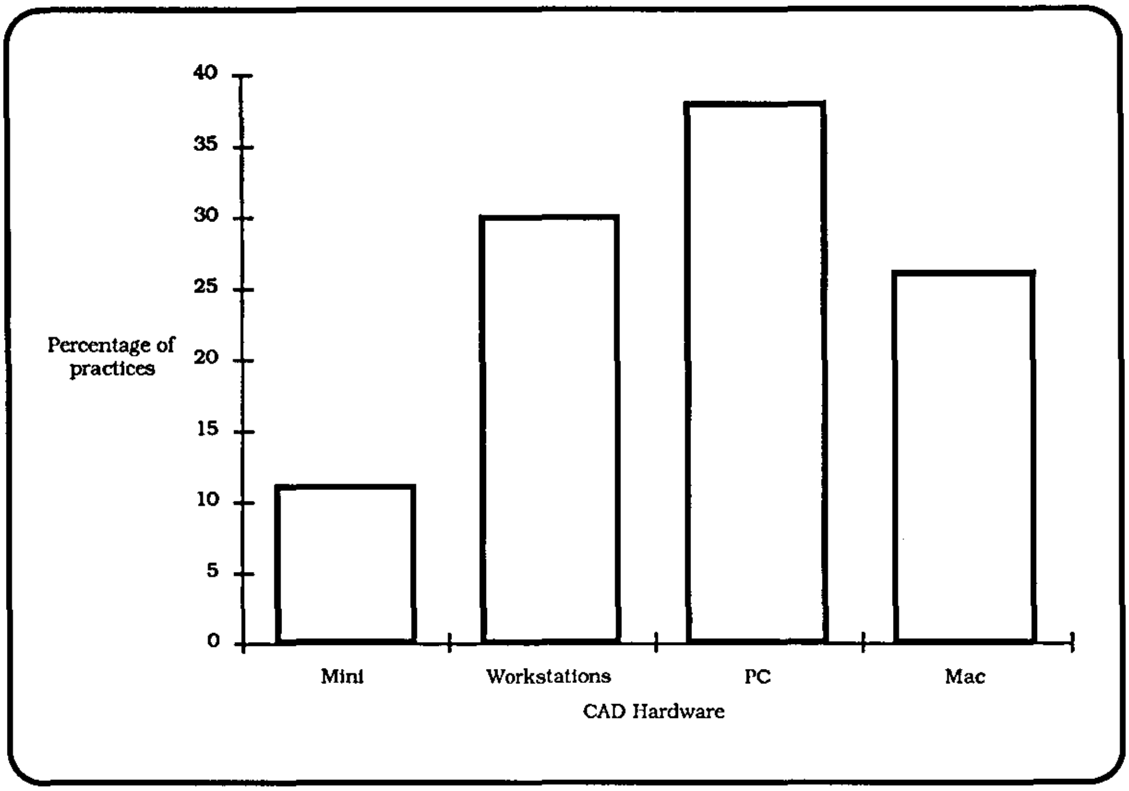
FIG. 4.13



The results show that 65% of the practices that responded to the questionnaire have purchased CAD in the last 3 years (1988-1990). The lack of purchase in the early 1980's occurs at a time when choice of system was limited to expensive mainframe or mini-computer installations. Those practices that became involved in CAD in its early days had probably already made the bulk of their purchases and were waiting for the promise of a new generation of machines.

By the mid 1980's the microcomputer was emerging with its promise of affordable desktop computing. System purchase began to pick up as usefulness of these machines was discovered. The peak of system purchase in 1988/89 coincides with a boom in the construction industry, and the availability of the Mac II, 386 DOS machines and cheaper Unix workstations.

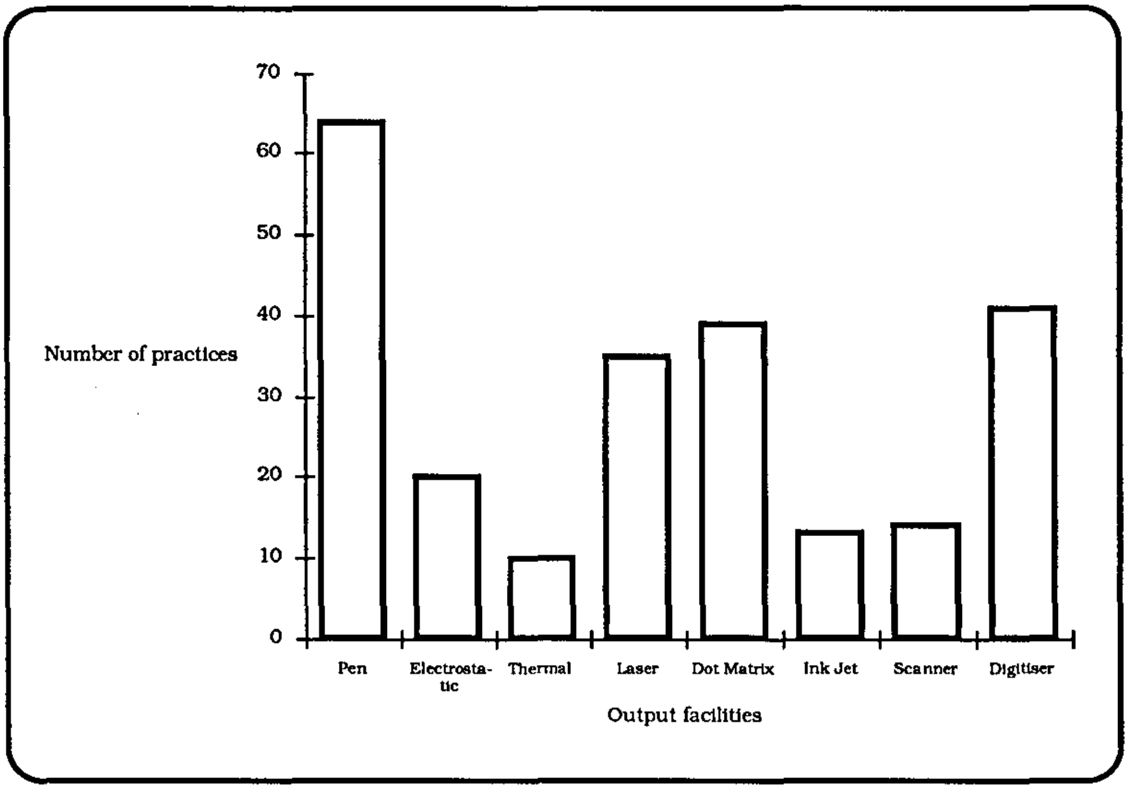
FIG. 4.14



For information of trends in hardware purchases, the RIBA surveys of computer usage are an excellent source. Whilst these results do not have any historical content, they represent the current distribution of hardware amongst the respondents.

From Fig. 4.14 it is clear that despite reports of minicomputer purchases dying out, they are still being used by a significant number of practices (10%). The remaining purchases are fairly evenly spread amongst workstations, PC's and Macintosh. Although workstations and Macintosh probably account for the higher percentage of recent purchases, it is difficult to predict which will emerge as the dominant force. The best hope amongst end users must be that all four technologies become more compatible and connectable and then each can be used on its merits.

FIG 4.15



These results confirm the domination of the pen plotter as the most popular output device. On price/performance and quality grounds it is likely to be some years before they are matched by electrostatic and thermal.

Of all the respondents, only 34% felt that their output devices adequately matched the capabilities of their software, confirming that often output is the weakest link in the chain.

The cost of software averaged 25% of the cost of hardware, a complete reversal of the mid 1970's where hardware was perceived as the least expensive item that make up a successful system.

DISCUSSION

From the results of the survey the following conclusions were drawn:

CAD is used across all phases of design.

The highest usage of computers occurs in the construction phases of the design process.

Facilities for the production of quantities and environmental calculations are scarce.

Over half the respondents realised an improvement in their design skills as a consequence of using CAD.

92% of the respondents realised an improvement in their presentation skills as a consequence of using CAD.

85% of the respondents realised an improvement in their ability to co-ordinate plan section and elevation as a consequence of using CAD.

It was initially thought that a possible explanation of the varying improvements that the respondents achieved might be related to their number of years architectural experience. However, a comparison of the responses for each of the 'experience groups' in Fig. 4.3 did not shed any light on this proposition. A greater range of 'experience groups' might have produced different results. It may be that individuals with more than 30 years architectural experience would differ significantly in their assessment of CAD than those with less than fifteen years architectural experience.

DISCUSSION

The processes that enable a designer to externalise design are highly complex and the equivalent of rapid brain-to-hand-to-paper interaction are extremely difficult to provide electronically. Only three quarters of the respondents felt that their CAD system had a facility available for conceptual work. The shortcomings of facilities designed for this task is supported by the fact that of the respondents who felt they had facilities available only 62% made use of them.

The design of details showed a similar pattern to conceptual design, possibility indicating the problems of producing inaccurate yet meaningful diagrams on computer. Whilst around 85% of practices had a facility available for this task, only 56% of the respondents made use of it.

Given that the majority of the respondents considered they were designers, other factors need to be taken into account in order to explain the varying levels of improvement achieved in design skill. Question 5 asked respondents to indicate in which areas of design a CAD facility is available. Respondents with less than 1 years' CAD operating experience recorded a greater range of available facilities than those with more operating experience. This would seem to indicate that their it may take several years to become aware of the capabilities of the system.

Architectural experience of the designer had no direct relationship to the improvements that could be attained in design skills, presentation skills or the ability to co-ordinate plan, section and elevation. However, the degree to which the number of years CAD operating experience affected improvements in the three areas listed above was interesting.

The findings are presented and discussed on the pages that follow.

FIG. 5.1

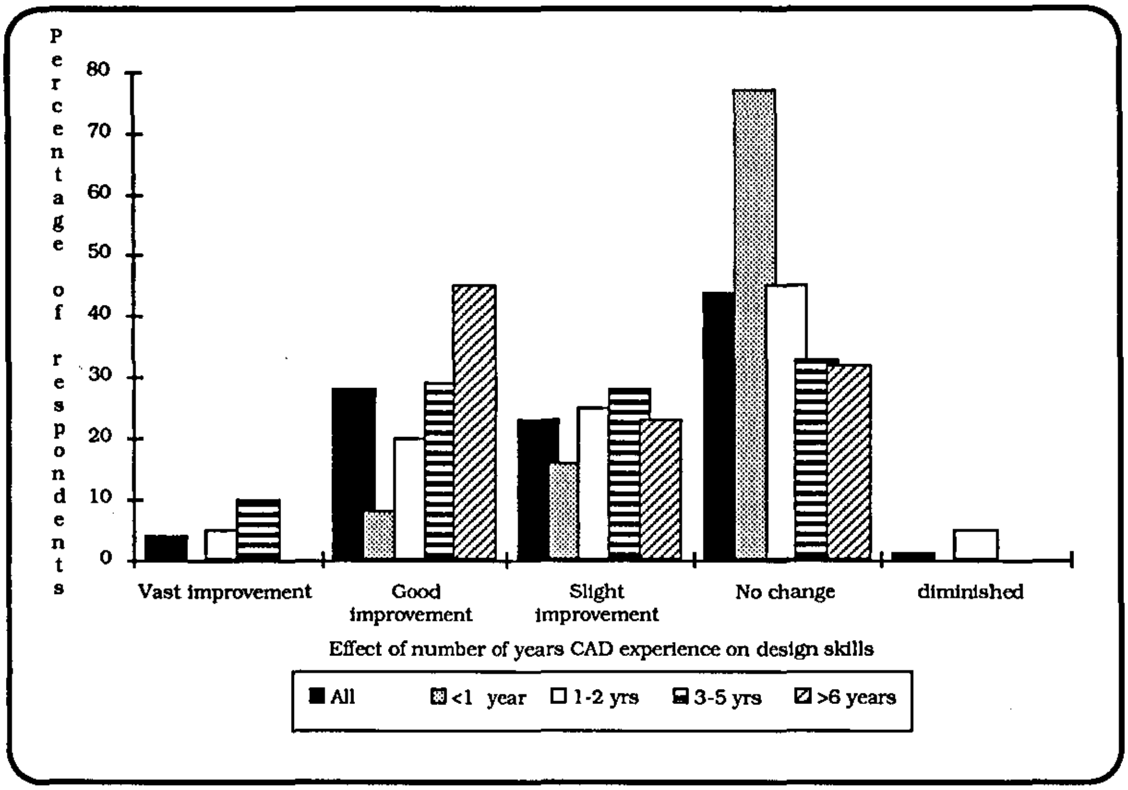


Fig. 5.1 shows the relationship between the number of years operating experience and improvements in design skill.

Fig 5.1 shows that 77% of respondents with less than 1 year CAD experience saw no change in their design skills, with 1-2 years experience this figure has dropped to 45%, with more than 3 years experience it falls to around 33%. The highest percentage for realising a good improvement in design skills is for those with over 6 years CAD operating experience at 45%, with 3-5 years it is 29%, with 1-2 years it has fallen to 20% and with less than 1 year operating experience the chance of seeing a good improvement in design skill is only 8%.

FIG. 5.1 EXPLANATION

In Fig 5.1 it is interesting to note that no respondent with more than six years operating experience realised a vast improvement in their design skills. Perhaps they are users of the early mini/mainframe systems, and have been unable to progress beyond a certain level. Unfortunately the manner in which the data was collected did not allow a separate analysis of mini/mainframe users.

In Fig 5.1 the results of vast improvement in design skills added to the good improvement figures, show that the results for 3-5 and over 6 years CAD operating experience are very similar, suggesting that improvements do not continue to increase with time. This is to be expected, analogies can be drawn with other media, where mastery takes a finite length of time; improvements continue after this point, but tend to be more subtle. The crucial factor is the length of time required to achieve mastery, in the case of using CAD for design around 45% of the respondents realised a good or vast improvement in their design skills after more than 3 years operating experience. After 1-2 years CAD operating experience only 25% realised a good or vast improvement in their design skills, and with less than 1 years' experience this figure drops to less than 10%.

FIG. 5. 2

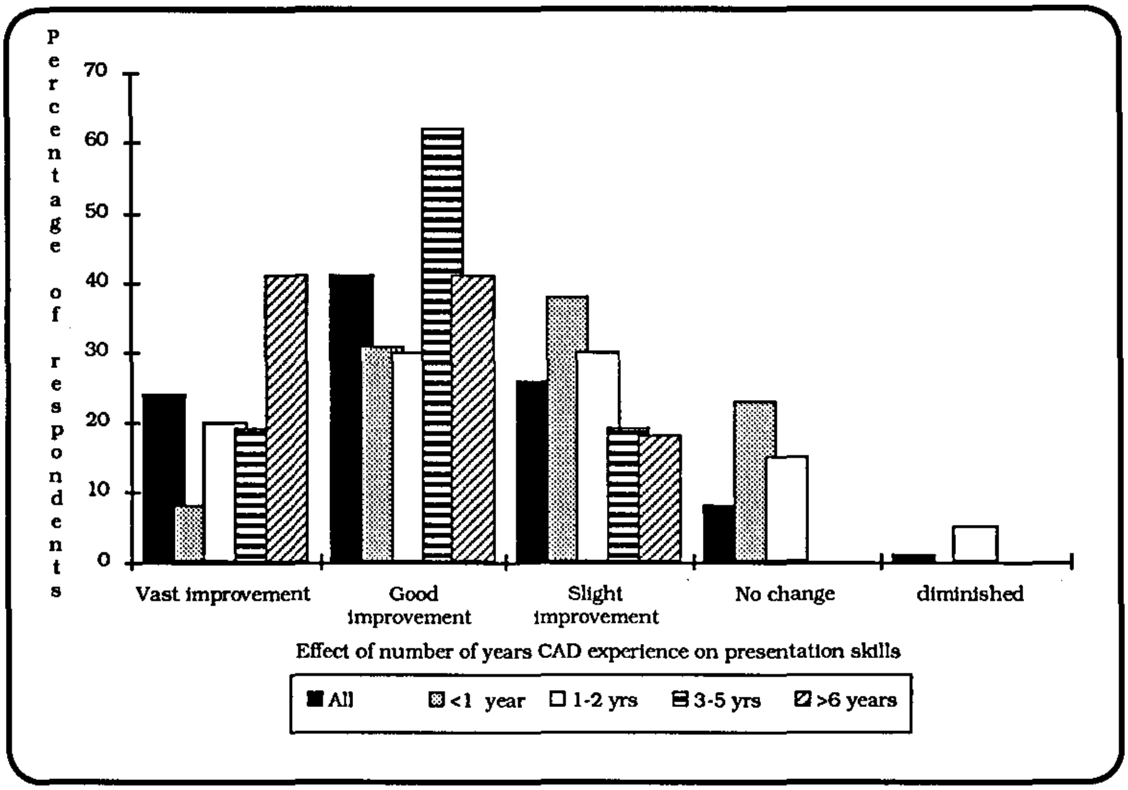


Fig. 5.2 shows the relationship between the number of years operating experience and improvements in presentation skill.

Fig 5.2 shows that 23% of respondents with less than 1 year of CAD operating experience saw no change in their presentation skills, with 1-2 years experience this figure has dropped to 15%, with more than 3 years experience all respondents perceived a positive change in their presentation skills.

A slight improvement was recorded at a similar level for all respondents. A good improvement was recorded by around 30% of respondents with less than 3 years experience, 62% with 3-5 and 41% with over 6. A vast improvement was recorded by 8% with less than 1 year, around 20% with 1-5, and 41% with over 6.

FIG. 5.2 EXPLANATION

Fig. 5.2 demonstrates that the number of years CAD operating experience are less significant in attaining some improvement in presentation skills. Nearly 80% of respondents with less than 1 year's operating experience show a positive change. However, the respondents with greater years of operating experience show consistently higher levels of improvement.

Again, if the results for vast and good improvement are added together, the results for 3-5 and over 6 years operating experience are very similar, at around 80%. After 1-2 years operating experience, 50% of the respondents record a good or vast improvement in their presentation skills. Even 40% of those with less than 1 years operating experience realised a good or vast improvement in their presentation skills.

FIG. 5.3

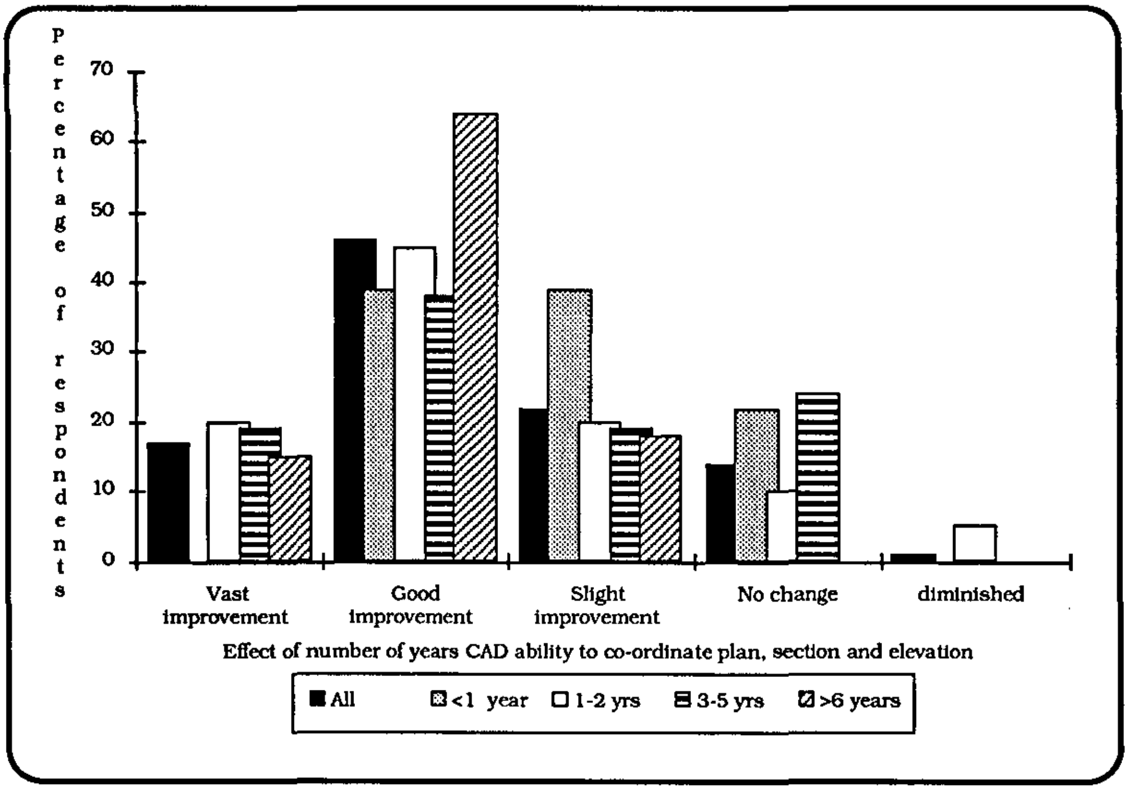


Fig. 5.3 shows the relationship between the number of years operating experience and improvements in their ability to co-ordinate plan, section and elevation.

In Fig. 5.3 respondents with more than 6 years CAD experience all recorded a positive change with 65% showing a good improvement, compared to round 40% in all other cases. Only those respondents with less than 1 year CAD experience failed to record a vast improvement; all other respondents recorded around 18% in this category. These results suggest that the new technology is accelerating the abilities of users to co-ordinate plan, section and elevation.

FIG. 5.4

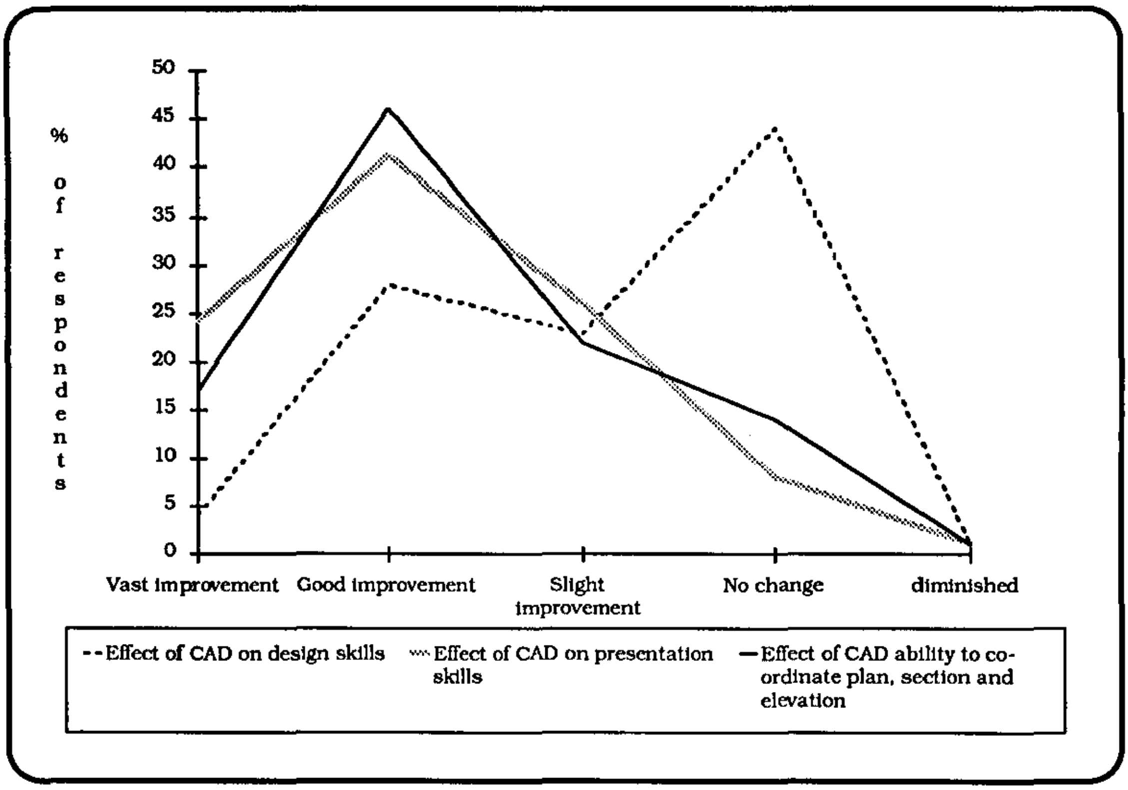


Fig 5.4, shows the relative improvements that were attained by all the respondents in: design skills, presentation skills and ability to co-ordinate plan section and elevation.

It demonstrates that most respondents saw a marked improvement in their presentation skills and ability to co-ordinate plan section and elevation, but design skill improvements were much harder to attain.

Despite many results that demonstrate the success of using CAD across all stages of design, 37% of respondents felt that the software restricted the way they would like to work. It was initially thought respondents with little operating experience would most likely be restricted by the software, however the results were unable to confirm this.

The fact that 56% felt that the software had changed the way they design, would seem to indicate that some designers are able to adapt their design methodologies to suit the computer.

In the areas of design development and visualisation around 88% reported having a facility and of those around three quarters use it. The high rate of usage is probably due to the fact that the conceptual phases have been completed and a certain amount of data can be input, and subsequent alteration and manipulation is well suited to the computer. However, the importance of design development cannot be understated, and the fact that computers are being used at all for these tasks is very significant.

Despite the existence of several respondents who have found success with computers for conceptual design, the consensus of opinion from the literature is usually that CAD is an 'after the event' tool to dress up and refine what has already been conceived. Certainly this view is supported by the result in the area of design presentation where, 90% of practices reported having a capability and of those 84% of the respondents made use of it.

Question 8 asked respondents to rate the effect of using CAD on their presentation skills, 89% recorded a positive improvement, further proof of the suitability of CAD systems to this task.

The lack of facilities available for the production of quantities, heatloss and structural calculations is somewhat surprising considering that the first CAD systems were built around the ability to solve numerical problems. Indeed, many of the predictions of the earliest users of CAD technology suggested that the ease with which computers could solve environmental problems would lead to a new style of architecture.

Even though production of quantities are available on one third of the installations only one third of those reported using the facility. Their lack of use must point to inadequacies in the method of their operation and shows that early beliefs that the architect would be able to dispense with consultants are unfounded.

THE ORGANISATION OF CAD INSTALLATIONS

76% of the respondents CAD installations are located within project teams, 5% operate as a draughting service and 15% as complete project teams.

Many practices that purchase systems, initially position equipment in a single location; for ease of use/training/cabling etc.. The first users of the system often become the sole users and over a period of time they develop into the expert computer users within the practice. Practices are then faced with a policy decision;

(1) Run a bureau within the office
(2) Distribute the computers amongst the project teams
(3) Provide computers for all/selected project teams

In the past many practices favoured the bureau approach, while the results of the survey show that distribution amongst the project teams is now the norm. It seems that at last the profession has taken the first step toward integrating the technology into the heart of the practice, and have therefore avoided the problems of communication and fragmentation of the design process that are normally associated with bureaux. The organisation of the practices in this survey had no direct relationship with any of the results obtained. In common with questions 11-22 they serve to provide a more complete picture of the organisation and capabilities of CAD in architecture.

HOW EFFECTIVE ARE COMPUTERS AS AN AID TO DESIGN?

Question 23 asked "how effective are computers as an aid to design?" This was an open ended question intended to stimulate further points for discussion. The following pages collate and discuss the responses which are categorized under the following subheadings;

COMMENTS ON THE EARLY STAGES OF DESIGN

From the following comments it would seem that CAD is ideally suited to design, but the results of the survey demonstrate that only around 30% of the respondents realised a good or vast improvement in their design skills as a consequence of using CAD. The following comments come from those 30%.

> *"Only in the last two to three years has the software become simple enough and cheap enough for really effective computer sketching and modelling. It depends on the designer's aptitude, approach and application to computers and their ability to visualise on screen rather than on the back of an envelope. Massing models are invaluable on inner city infill projects, giving confidence in the suitability of a design to its environs. Modelling improves spatial awareness and the ability to design 3-dimensionally."*

> *"Projects take just as long, if not longer, but are investigated more fully at an earlier stage than by manual methods."*

> *"Initial design takes as long by hand; changes to design are easier and faster and the design can remain fluid longer. Elimination of repetitive work allows more time for designing; it is easier and quicker to explore alternative solutions, making them ideally suited to feasibility studies."*

The following comments identify some of the shortcomings of CAD as an aid to design and account for the lack of improvements in design skills that the respondents were able to achieve.

> *"CAD replaces the drawing board completely as a draughting aid, but not as a thinking aid i.e. the freehand sketch/doodles to link brain to hand to paper will never be replaced. The inability of computers to be used as a sketchpad make them inappropriate for design."*

> *"As a means of visualisation computers are effective, but not as a conceptual tool. There is no "intelligent" input from machines, so computers can no more be thought of as an aid to design than can an axonometric or perspective."*

> *"They are most effective in certain types of design e.g. multi-storey, repetitive housing."*

"Depending how they are used they can limit design quality and diminish human creativity. Computers are effective as an "aid", but should not be allowed to dictate or restrict the design process."

"We must adapt our techniques to get the most out of the system."

"Until designers start thinking elementally and start conceptualising, computers will remain a draughting tool."

"Given guidance even a 2D system is beneficial to design."

The results of the survey show that 90% of the respondents have a 3D facility and of those around 70% make use of it. The impact of 3D CAD on design is not explored to any depth within the survey, but the following comments shed some light on its uses within the design process.

> *"Accurate 3D visualisation gives confidence to design decisions allowing more imaginative expression."*

> *"3D modelling software requires a lot of refinement to achieve realistic, sophisticated imagery. The 3D capabilities of software tend to be limited on complex buildings."*

> *"The ability to produce 3D wire frame and colour perspectives enables the designer to show the client views of the project at an earlier stage."*

> *"The speed with which one can work in 3D has a great bearing on the success."*

> *"After the initial conception using pencil and paper, rapid 3D modelling and quick flyround point to weaknesses at a much earlier stage. The early discovery of faults tempts users into inappropriate avenues of detail."*

"Full 3D models heighten the awareness of the necessity to co-ordinate in all 3 dimensions, an aspect of design that is not usually explored by hand draughting."

"The time required to produce 3D work is not economic."

ON THE SUBJECT OF PRESENTATION

The value of CAD for presentation is clearly identified in the results of the survey with 89% of the respondents realising a positive improvement in their presentation skills. However there is also a negative side, which is identified in the second comment.

"At all stages of design presentation looks better; accurate, consistent clear and legible."

"CAD disguises the built quality at the same time as bettering the shortcomings of designs."

ON THE SUBJECT OF PRODUCTION INFORMATION

For some years now, one of the acknowledged strengths of CAD has been its ability to handle production information. The results of the survey confirm this is still the case. Around 96% of the respondents reported having facilities available for the production of general arrangement drawings, and of those 90% make use of the facility. The following comments illustrate some of the reasons why CAD is so successful for the later stages of design.

> *"Very good for site survey information and accurate setting out. Excellent for geometric calculations of awkward forms, shapes, angles and curves."*

> *"The use of layers and the ability to change scale quickens the pace of production drawings."*

> *"Accuracy, consistency, co-ordination and layering enhance the structure of production information and enable levels of information not normally perceived as being connected to be analysed."*

> *"Accuracy is no longer a problem."*

> *"Time is money and the redraw/editing facilities are always going to be CAD's selling point."*

Despite these very favourable comments, the results of the survey show that not all respondents have realised improvements in their ability to co-ordinate plan, section and elevation. The following comment illustrates one of the problems that may be encountered.

> *"Computers excel at plan generating on different layers and levels but are very slow for elevations unless there is substantial repetition."*

A problem frequently expressed as a limitation to using CAD for early design is slow data entry. This also applies to the later stages, but is less critical as the following comment illustrates.

> *"Although initial data input is slow, the speed and accuracy at which changes can be made, make computers an essential part of modern fast track projects."*

ON THE SUBJECT OF COMMUNICATION OF DATA

The results of the survey show that communication of data both within the office and across the building team have improved; around 18% of the respondents identified a vast improvement, 56% a slight improvement and the remaining 26% realising no change. The degree to which CAD has flourished as an aid to communication of data is still variable as the two comments below illustrate.

> *"The ability to share data across professions, particularly in a multi-disciplinary practice is a terrific aid to coordination."*

> *"The potential for good co-ordination of services/ structure is undermined by fellow professionals not utilising CAD."*

42% of all the respondents reported utilising a network. Further analysis of the results demonstrated that those who utilised networks neither recorded improved CAD skills or better communications. Networks to date are largely utilised to attain more efficient data management, rather than to help with communication in design processes.

> *"Only one person can be at work at one time, the work load cannot be distributed."*

Early fears that CAD in architecture would become a factory process with operators detached from the heart of design have largely been dispelled. The survey results show that distribution of CAD facilities amongst projects teams is now the norm, with over 70% of practices adopting this approach. Even this has its problems as the following two comments illustrate.

> *"Very effective aid to design and production if the installation is integrated into the design team fully."*

> *"Mixed CAD and non CAD on the same team does not work."*

Bureaux still exist, with around 8% of the practices in the survey adopting this approach. Some of the problems associated with this type of implementation are illustrated by the following comment.

> *"In a situation where operators use CAD, architects enjoy the accuracy, but are reluctant to learn how to use or understand CAD. They tend to believe you can't design on computers even though they don't try. The operators are unhappy with the situation as they are not given any responsibility to their drawings: they are simply there to digitize the information."*

COMMENTS ON STAFF, TRAINING AND MANAGEMENT

Any tool is only as good as the person using it, the importance of having appropriate staff to use CAD installations is paramount. The high number of technicians who utilise CAD has ensured its success as a tool for production information. Conversely, the slow development of CAD as a design tool can partially be attributed to the relatively low proportions of designers who operate the systems.

> *"Limitations seem to be related to the capabilities of the user."*

> *"With good operators/technicians CAD could be a superb design tool - unfortunately designer/operators are not generally available."*

> *"In practice designers tend to be professionals and there has often been a lack of computer training in their education. All too often practices are reluctant to train "expensive" members of staff and CAD tends to be used as a replacement for the drawing board for use by technicians."*

> *"CAD is as effective as the way it is used; at present it is often used as a superior drawing board, way below its full potential. If more senior staff used the system, it would be more effective as a design tool."*

> *"Working through an operator limits the benefits in design terms; computers are only as effective as the designer operating them."*

With the explosion of CAD in architecture problems of effective management have become more critical.

> *"Invaluable so long as support is available from all members of the design team and management."*

> *"Very effective if a cohesive well thought out strategy for computer use and training is implemented otherwise forget it. Simple but effective management is usually underestimated and development and management problems should be scheduled in advance. Appropriate levels of training should be given to all members of staff. Computers can be a considerable aid to drawing management."*

> *"Success depends entirely on the implementation within the office and staff competence; limitations are generally due to staff not being computer literate. Computers undoubtedly aid visualisation and presentation but are difficult to manage effectively."*

> *"Full potential is never realised due to a lack of understanding and mismanagement."*

COMMENTS ON STAFF, TRAINING AND MANAGEMENT

"Problems often arise due to opposition to its use."

The analysis of the survey results, demonstrated that to realise improvements in CAD skills may take several years, a factor that only one of the respondents commented on.

"It is essential that staff are given adequate time to develop their new skills. It is hard to reach the stage where one can be more efficient most of the time - a dedicated machine is essential, Some degree of reorganisation of the design process will be necessary, ideally each designer should have his/her own machine."

COMMENTS ON HARDWARE AND SOFTWARE

Problems with appropriate hardware and software have always existed, although over the years they have become less critical, they still exist.

"Computers are still largely used as a draughting tool rather than as a design-generating aid due largely to the limitations of the hardware and software used."

"To maximise the benefits of computers depends on having the relevant software for a particular job."

"Much software does not lend itself to design."

The user interface has often been neglected, yet in order for CAD to become widely used and excepted by designers user interfaces must improve.

"In time, truly friendly systems that are capable, reliable and do not require the adoption of unfamiliar disciplines will emerge."

"The objective of the user interface should be to cope with a wide range of users all using the system to do what they do best."

"Thanks to the "user-friendly" nature of the Macintosh and the power of a IIFX, CAD is available to all architects."

COMMENTS ON OUTPUT DEVICES

Despite their problems pen plotters are likely to remain the dominant method of output for some years to come. Until alternatives that match pen plotters for price/performance emerge, they will continue to limit the use of CAD.

> *"It takes longer to plot a small amendment than to change it by hand on the drawing, indeed the ability to obtain hard copy is often underestimated. Time-effectiveness of CAD could be increased two-fold if the software potential was matched by the output devices. A drawback is the need for quick hardcopy for checking, as big schemes appear too small on screen."*

> *"Pen plotters are incapable of exploiting the capabilities of the software and drawing fine line detail."*

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CONCLUSION

Architectural CAD technology has advanced dramatically over the past 25 years. Contrary to predictions in the late 1960's that CAD development would lead to a national spiders web of terminals running off main frame computers, the arrival of desktop computing in the mid 1980's has enabled powerful, yet affordable equipment to be located within the drawing studio. The results of the survey confirm that Workstations, PC's and Macintosh equipment now account for around 90% of all installed computer systems in architectural practices.

In the early 1970's much software development concentrated on programs that would enable the rapid design solution and documentation of repetitive and/or large building types. Very often the 'design' evolved from mathematical calculations that could be solved by the computer, and not from traditional sketching activity. The survey results show low availability and usage of facilities for production of quantities, heatloss calculations and structural calculations suggesting that the mathematical problem solving approach to design has largely been rejected.

One of the most optimistic views of CAD in the 1970's was that it would enable architects to regain some of the responsibilities that they had contracted out to other professions over the past 150 years. Again, the survey showed low availability and usage of facilities for production of quantities, heatloss calculations and structural calculations, suggesting that the potential of CAD as a means for architects to dispense with the need for consultants has not been realised.

CONCLUSION

In the early 1970's it was thought that development of software would in time lead to an architectural process in which non-skilled operators would evolve design solutions by pressing the right buttons. It did not take very long to discover that, to develop sophisticated software to cope with the complexities of the early stages of the architectural design process would be an expensive and incredibly difficult task. The results of the survey show that across all the drawing stages of the design process the least available and lowest usage of drawing facilities still occurs at the early stages of design.

In the early 1980's an absence of programs at the sketch design stage was identified as a reluctance of architects to develop such systems. A report by the University of Bath in 1985 stated that no cases were found where computers were used in the early (creative design) work. The results of the survey clearly demonstrate that this has changed dramatically over the past five years.

Although conceptual design software still requires a lot of development, it is available and it is used with some degree of success. A major limitation on the successful use of CAD for design purposes is lack of operating experience. The fact that operating experience is so essential would indicate that the design software that is available is far from intuitive or totally appropriate to the task. The difficulties of developing suitable architectural design software were identified back in the 1970's and the conclusions drawn from this thesis would seem to indicate that there is still some way to go.

CONCLUSION

One of the factors that initially slowed the development of architectural software was identified as the large gap between those developing the programs and those who used them. The importance of suitable software has always been a key factor to the success of its use. In the 1970's high development costs slowed its advance, attempts by architectural practices to develop their own software products in the 1980's were also largely restricted by lack of funds. General purpose draughting software developed by computer biased companies has on the other hand benefited from mass sales, and whilst much of the software is adequate, it is not specifically architect orientated. The lack of functionality of commercially available software is most pronounced in the early stages of design, where the role of an architect is most specialised, but as the demand increases, market forces will prevail and more intuitive design software will emerge.

Early fears that the architectural process would become disintegrated and develop into a factory process in which the designer would become deskilled have largely disappeared. The realisation that any tool is only as good as the person using it and the decline of the bureau have ensured that CAD has become an integral part of the architectural team. The arrival of desktop computing has enabled computers to be located wherever they are required within the office, and distribution of computer facilities amongst projects teams is now the norm.

Despite the introduction of CAD into the heart of the design studio, the results of the survey confirm that the highest usage of computers still occurs in the post design stages. This would seem to indicate that the design process is fragmented, because "design" information is not generated on computer and must therefore be copied into the computer at some stage.

CONCLUSION

Technology has provided the majority of the tools required for the post-design phases of the architectural process and other factors such as appropriate staff, training and management have become the limiting factors to its successful application.

Over the past 25 years there have been incredible advances in the performance of software and hardware. Despite this, the mechanics of today's pen plotters are remarkably similar to those available in the 1970's. Alternatives are available, but to obtain high quality output is significantly more expensive, and well beyond the reach of a small practice. Whilst pen plotters are adequate for production information, they are not well suited to the needs of the designer. Utilising hand drawn methods a designer can choose to use a variety of media, to obtain a quality of graphics suited to the purpose of the drawing, until output devices (and software) allow the same flexibility they will continue to be a limitation to design on computer.

As more designers continue to use computer systems, the chance of technology coming closer to their ideals increases. At present designers will have to adapt their skills to work less than perfect tools and a certain amount of frustration is inevitable. CAD is a unique medium, able to mimic other media, infinitely expandible and highly complex. There is no short cut to gaining experience of using any medium, especially CAD. As CAD develops and design facilities become more suited to the needs of the architect, its success will continue to be limited by the competence and imagination of the user.

FURTHER RESEARCH

The survey confirms that computers are being used for design and that some degree of success is being achieved, it would be useful to know what enables some designers to achieve success and what prevents others. This thesis intentionally does not compare specific software and hardware, however it would be of interest to discover what bearing this has on the improvements in CAD skills that can be realised. Which areas of the software are deficient, the extent to which hardware is a limitation and what improvements would be most beneficial are all worthwhile topics for investigation.

The results of the survey show that 3D modelling was available to the vast proportion of the respondents, yet not all of them use the facility. The factors that prevent designers using 3D would be interesting. Of those who do make use of a 3D facility; what do they use it for; how it is integrated into the overall design process; what are its limitations and strengths.

Whilst CAD is used across all stages of design, the results of the survey do not investigate the continuity of the design process. It may be that design activity is carried out totally independently from the construction stages. The initial development of CAD saw two distinct but related streams of development: The limited program designed to solve a particular task and the more ambitious attempts to link all phases from brief to completion. It may be that some practices utilise the same piece of software across all phases from brief to completion and others use different software (and hardware) as and when it is required. The reasons for this may be many and varied, it would be an interesting topic for research, and may help to shed some light on the deficiencies/success of CAD systems.

THE ROLE OF CAD FOR DESIGN IN THE FUTURE

For computers to become widely recognised as a tool for design they must do more than mimic what can already be done in the brain or by pencil on paper. A medium cannot improve a designer; when using a CAD system we do not learn 'how' to design, but rather how to manipulate a medium to achieve and perhaps improve what we have already 'designed' in our brain. The difference between computer and many other media is that computers have the potential for knowledge input. When using other media, we can attend classes or read books to improve our skills. With CAD, we can do all of the above as well as draw on the knowledge that could be contained within the computer. The knowledge could not only teach us how to use the media, but also teach us about design. How to deliver this knowledge to the designer is the problem.

Traditional drawing methods restrict the use of the third and fourth (time) dimension. Computer technology has the potential to work in all four dimensions and one of the keys to its success as a design tool lies in how this ability can be made available to designers. The results of the survey show that even to work effectively in two dimensions on computer may take several years, so it is important that systems are developed that facilitate ease of learning.

The approach to the problem of working in a 2 dimensional representation of 3 dimensional space are many and varied. Very often it is not the initial creation of three dimensional objects that is difficult, but the subsequent alteration and manipulation of the model.

THE ROLE OF CAD FOR DESIGN IN THE FUTURE

Input of 3-Dimensional information in to many computer systems is fairly complex, and it may be that the gap between thought and transfer to machine is too long. At present the operation of most computer modelling software is controlled by one hand. Data entry using both hands, feet, eyes and voice and may go some way towards speeding up this process.

One of the greatest difficulties of working in 3D is actually seeing what has been drawn. Systems need to be developed where fully rendered models can be edited in real-time. This makes tremendous demands on the processing power of any computer and a quantum leap in chip technology may be required before this can be a realistic proposition.

The ability to perform calculations on buildings is sadly lacking from many present day architectural CAD systems. Daylight calculations, thermal calculations and structural calculations should be a part of every architectural designers tool kit. Computers have the potential to make this provision.

Certainly computers have a lot to offer for architectural designers and in time they will begin to make a more significant contribution to the early stages of the design process. The possibilities of reviewing the quality of light produced by windows in different positions or testing colour and lighting schemes, are areas in which computers could start to provide architectural designers with a tool that would make a significant contribution to the quality of design.

THE ROLE OF CAD FOR DESIGN IN THE FUTURE

Many designers still feel a barrier to computer use because the process is so fundamentally different to drawing on paper. The development of pen-based computer systems may well encourage more designers to use computers. A technology utilising a flat surface onto which a designer could draw directly at full scale, with an overlay system, similar to sheets of tracing paper laid over earlier sketches are the kind of facilities designers require. The ability to draw lines of different density, thickness and quality in an interactive manner. Tools for adding tones and colour, in short a computerised equivalent to sketching, enhanced by the ability of the computer to store, retrieve and change information.

One of the best opportunities for explaining a design both from the point of view of the designer and the client is virtual reality. This holds the potential to explore a design as it will be when it is built. Architectural designers can look forward to this technology, it is available now, but it is likely to be many years before it is commonplace within the architects office.

The link between the design activity and the post-design phases of the architectural process, may well become the key to greater usage of computers for early design work. At present, any drawn design must be manually input into computer before production information can begin. If designers relied on CAD at the start of the design process, the continuity of data from design to production would maybe require a new breed of software. Perhaps a tool that could convert approximate lengths to accurate dimensions, e.g. sketched parking bays to real parking bays.

THE ROLE OF CAD FOR DESIGN IN THE FUTURE

The evolution of architectural computer technology has progressed fairly steadily over the past twenty years, punctuated by the odd leap forward. Some dreams have turned into reality and others are still dreams. Market forces and technological breakthroughs have tended to steer the course of computer development. Given time technology has no limitations.

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CHAPTER 1
CHAPTER 2
CHAPTER 3
CHAPTER 4
CHAPTER 5
CHAPTER 6

APPENDIX I
APPENDIX II
APPENDIX III
APPENDIX IV
APPENDIX V

LUTCHI Research Centre

Executive Director:
Professor E.A. Edmonds, B.Sc., M.Sc., Ph.D., F.B.C.S., C.Eng.
Directors:
Professor J. L. Alty, B.Sc., Ph.D., F.B.C.S., C.Eng.
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8/8/92

Dear Sir

Over the years there have been many predictions as to the role CAD will play in Architectural Design. The enclosed questionnaire has been designed to assess the level at which CAD is currently most effective:

1. Please ensure the questionnaire is completed by someone who regularly operates the CAD facilities, preferably a "designer".

2. Please return the completed questionnaire in the envelope provided.

3. If you wish to receive a summary of the results please state your Name and Company at the end of the questionnaire.

Your co-operation is requested; it should only take a few minutes of your time and it will be of great value to an on-going research project.

Yours faithfully

J.R.B. Wells-Cole

Please tick B

1. **How many years full-time computer operating experience have you?**

More than 10 years	☐
6-9 years	☐
3-5 years	☐
1-2 years	☐
Less than 1 year	☐

Please tick B

2. **Which best describes your status?**

Computer Management	☐
Other Management	☐
Architect	☐
Technician	☐
Operator	☐
Other (please specify)	

Please tick B

3. **How many years Achitectural experience have you? (including college)**

More than 15 years	☐
10-14 years	☐
5-9 years	☐
3-5 years	☐
Less than 2 years	☐

4. **Do you consider yourself to be a designer?** Yes ☐ No ☐

5. **In which areas do you utilise CAD ?**

Production of 3D building Model	☐
Design conceptualisation	☐
Design development	☐
Design of details	☐
Design visualisation	☐
Design presentation	☐
Production of GA drawings	☐
Production of detail drawings	☐
Production of schedules	☐
Production of quantities	☐
Coordination of services	☐
Heatloss calculations	☐
Structural calculations	☐
Other (please specify)	

In which areas is a CAD facility available ?

Production of 3D building Model	☐
Design conceptualisation	☐
Design development	☐
Design of details	☐
Design visualisation	☐
Design presentation	☐
Production of GA drawings	☐
Production of detail drawings	☐
Production of schedules	☐
Production of quantities	☐
Coordination of services	☐
Heatloss calculations	☐
Structural calculations	☐
Other (please specify)	

Please tick B

6. How has CAD affected your design skills?

Vast improvement	☐
Good improvement	☐
Slight improvement	☐
No change	☐
Diminished	☐

Please tick B

7. How has CAD affected your ability to co-ordinate plans, sections, and elevations?

Vast improvement	☐
Good improvement	☐
Slight improvement	☐
No change	☐
Diminished	☐

Please tick B

8. How has CAD affected your presentation skills?

Vast improvement	☐
Good improvement	☐
Slight improvement	☐
No change	☐
Diminished	☐

9. Has the software restricted the way you would like to work? Yes ☐ No ☐

10. Has the software changed the way you visualise design? Yes ☐ No ☐

11. Which of the following apply to the organisation of CAD staff within the office?

Please tick B

A. Within project teams alongside drawing board staff	☐
B. As a draughting service for designers/job runners	☐
C. As complete project teams (as an alternative to the drawing board)	☐

12. Has computerisation given the designers more or less control over the design process?

More ☐ Less ☐

13. **Who uses CAD in your office?**

	Full Time	Part Time
Partners	☐	☐
Associates	☐	☐
Architects	☐	☐
Technicians	☐	☐
Operators	☐	☐

14. **How has CAD affected the communication of project data within the office?**

Please tick B

Vast improvement	☐
Slight improvement	☐
No change	☐
Slightly worse	☐
Much Worse	☐

15. **How has CAD affected the communication of project data within the building team?**

Please tick B

Vast improvement	☐
Slight improvement	☐
No change	☐
Slightly worse	☐
Much Worse	☐

16. **How many years has your office had a CAD capability?** ☐

17. **What CAD hardware are you running?**

	How Many
Mini-computers	☐
Workstations	☐
PC's	☐
Macintosh	☐
Other (please specify)	☐

18. **Do you utilise a network?** Yes ☐ No ☐

19. **To the nearest £10,000 what is the total value of CAD hardware?** £

20. **To the nearest £10,000 what is the total value of CAD software?** £

Please tick B

21. **Which of the following input/output devices do you utilise?**

Pen plotter	☐
Electrostatic plotter	☐
Thermal plotter	☐
Laser writer	☐
Dot matrix	☐
Ink jet	☐
Scanner	☐
Digitiser	☐
....	☐
....	☐

22. **Do you feel that the output devices match the capabilities of the software?** Yes ☐ No ☐

23. **How effective are computers as an Aid to Design?**

24. **Would you be willing to be interviewed in person?** Yes ☐ No ☐

ALL INFORMATION GIVEN WILL BE HELD IN STRICTEST CONFIDENCE AND NO PRACTICE WILL BE MENTIONED INDIVIDUALLY

Thankyou for your assistance

SPREADSHEET DATA EXPLANATION

Question 1

Number of years operating experience

A = >10 B = 6-9 C = 3-5 D = 1-2 E = <1

Question 2

Status of respondents

A = Computer Management C = Architect D =Technician E = Operator

Question 3

Number of years architectural experience

A = >15 B = 10-14 C = 5-9 D = 3-5 E = <2

Question 5

In which areas do you utilise CAD/in which areas is a CAD facility available

Blank = No facility available 1 = Facility available but not used

2 = Facility available and used

5a = Production of 3D building Model 5b = Design conceptualisation

5c = Design development 5d = Design of details

5e = Design visualisation 5f = Design presentation

5g = Production of GA drawings 5h = Production of detail drawings

5i = Production of schedules 5j = Production of quantities

5k = Coordination of services 5l = Heatloss calculations

5m= Structural calculations 5n = Other

SPREADSHEET DATA EXPLANATION

Question 6

The effect of CAD on design skills

A = Vast improvement B = Good improvement C = Slight improvement

D = No change E = Diminished

Question 7

The effect of CAD on ability to co-ordinate plans, sections, and elevations

A = Vast improvement B = Good improvement C = Slight improvement

D = No change E = Diminished

Question 8

The effect of CAD on design skills

A = Vast improvement B = Good improvement C = Slight improvement

D = No change E = Diminished

Question 13

Who uses CAD within the office on a full time basis

A = Partners B = Associates C = Architects

D = Technicians E = Operators

Who uses CAD within the office on a part time basis

A = Partners B = Associates C = Architects

D = Technicians E = Operators

Question 14

The effect of CAD on communication of project data within the office

A = Vast improvement   B = Slight improvement   C = No change

D = Slightly worse   E = Much worse

Question 15

The effect of CAD on communication of project data within the the building team

A = Vast improvement   B = Slight improvement   C = No change

D = Slightly worse   E = Much worse

Spreadsheet data

No.	Q1	Q2	Q3	Q4	5a	5b	5c	5d	5e	5f	5g	5h	5i	5j	5k	5l	5m	5n
3	A	A	A	Y	2	1	2	2	1	2	2	2			2			2
4	D	D	C	Y	2	2	2	1	2	2	2	1	1		2			
6	D	C	D	Y	2				2		2	1	1		1			
7	C	C	A	Y	2	1	1	1	1	1	2	2	2					
13	E	C	D	Y	2	1	1	2	2	2	1	2	2	2	1			
14	C	A	E	N	2	1	2	1	2	2	2	2	1	1				
17	B	A	A	Y	2	2			2	2	1	1			2		2	
19	B	C	C	Y	2	1	2	1	2	2	2	2	2	1	1	2		2
22	E	E	C	Y	2		2		1		1	2	2					
32	D	C	B	Y			2	2	1	2	2	2	2		1			
33	C	A	A	N	2	2			2	2	2	2	2					
34	C	A	A	Y	1	2	2	2	1	1	2	2	2					
37	B	A	C	Y	2	2	2	1	2	2	2	2	2	2	2			
38	B	A	A	Y	2	1	2	1	2	2	2	2			2			
39	D	C	A	Y		1	1	1	2	2	2	2	2					
41	C	C	C	Y	1	1	2	1	1	2	2	1	2		2			2
46	B	A	C	N	2	2	2	2	2	2	2	2	2	1	2			
48	B	A	B	N	2		2		2	2	2	1					1	
50	E	C	B	Y	1	2	2	2	1	2	2	2	2		2			
60	D	D	B	Y				2		2	2	2						
63	C	C	B	Y	2	1	1	1	1	1	2	2	2	1	1			
72	E	C	A	Y	2	1	1	1	1	1	1	1	2					
76	D	C	B	Y	2		1	2			2	2	1	1	1			
77	E	C	A	Y	2	1	2	2	2		2	2						
81	E	C	A	Y	2	2	2	2	2	2	2	2	2					
84	D	C	A	Y	2	2	2	2	2	2	2	2	1		1	1		
92	D	C	C	Y	2	2	2	2	2	2	2	2	2					
93	B	A	D	Y	2	2	2	2	2	2	2	1	2					
105	C	D	B	Y	2		2	2	2	2	2	2	2	2				
107	C	A	B	Y	2	2	2	1	2	2	2	1			2			
108	D	D	B	Y	1						2	2	2	1				
109	D	C	B	Y	2	1	1	1	2	2	2	1	2					2
111	C	C	A	Y			2	1	2	2	2	1	2		1	2		
118	E	C	C	Y	2	1	1	1	2	1		2	2			2		
119	C	A	A	Y	2	2	2		2	2	2				2			2
132	D	C	A	Y	1			1	1	1	2	1	2					
133	B	C	A	Y	2	2	2	2	2	2	2	2	1		1			
136	B	C	A	Y	2		2	1	2	2	2	2	2	1				
143	C	A	C	Y		2	2	1	2	2	2	2	2	2	2			
145	C	D	D	Y	2	1	1	2	2	2	1	2	1					
148	B	C	B	Y	2	2	2	2	2	2	2	2	2	2	2	2		
152	D	C	C	N	2	2	2	2	2	2	2	2	2				1	
156	C	C	B	Y	2	2	2	2	2	2	2	2	2		2			
157	C	C	B	N	1	1		2	1	2	2	2						
158	D	C	A	Y	1		2	2	2	2	2	2	2	1				
166	E	C	C	Y	2		2	1	2	2	2	2		2				
167	D	C	A	Y	1	2	2	1	1	2	2	2	2	1	2			
172	B	C	A	Y	2	1	1	1	1	1	2	2	2	1	1			
175	E	C	A	Y	2	1	2	2	2	2	2	2	1					
176	C	C	A	Y	2	1	2	1			2	2	2					
180	E	E	B	Y	1	1	2	2	1	1	2	2	2					
182	D	C	A	Y	2	2	2	2	2	2	2	2	2					
185	B	C	B	Y	2	2	2	2	2	2	2	2	2	1				
186	A	C	A	Y	2	2	2	2	2	2	2	2	2		2	2	2	
187	E	C	B	Y						2	2	2						
188	A	C	A	Y	2	2	2	1	2	2	2	1	2	1	2			
189	B	A	B	Y	1	2	1	1	2	1	2	2			2			
190	C	C	A	Y	1	2	2	2	2	2		2	2	1				
192	D	C	B	Y	2	2	2	2	2	2	2	2	2					
204	D	A	C	Y	2	2	2	2	2	2	2	2	2	2	2	2	2	1
205	A	A	A	Y	2	2	2	2	2	2	2	2	2		2		2	
209	C	D	B	Y	2	2	2	2	2	2	2	2			2			
211	A	C	A	Y	2		2		2	2	2		1					
213	E	C	C	Y	2			1	1	2	2	1	1	1	1			
214	C	A	A	Y	2	2	2	2	2	2	2	2	2	1		1		
218	A	A	D	N	2	2	2	2	2	2	2	2	2	2				
221	C	A	D	Y	2	2	1	1	1	1	2	2	1	1	1	1	1	
223	D	C	C	Y	2	2	2	2	2	2	2	2	1		1			
224	B	C	B	Y	2	1	2	1	2	2	2	1	2					
226	B	D	A	N	1	2	2		2	2	1	1	2					
227	C	C	C	Y	1	1	2	2	1	2	2	2	2					
229	D	A	D	N	2	2	2		2	2	2	2						
232	B	C	B	Y	2			1	2	2	2	1	2	1	2			
233	D	C	A	Y	1				1	2	2	2	2					
234	E	D	C	Y	2	2	2	2	2	2		2	2		2			
235	C	A	A	N			2	1		2	2	2	2		2			
237	C	C	B	Y	2			2	2	2	2	2	1					
240	E	D	A	Y	1	1	1	1	1	1	2	1	2					

Q6	Q7	Q8	Q9	Q10	Q11	Q12	QA	QB	QC	QD	QE	QA	QB	QC	QD	QE
B	B	B	N	Y	A/B	M				D		A		C		
E	E	C	Y	Y	A	M										
D	B	D	Y	N	A	M								C		
D	C	B	N	N	A	N						A	B	C	D	
D	C	C	N	N	C	M			C							
C	C	A	N	N	A	L								C	D	E
C	B	C	N	N	A	M								C	D	E
D	C	C	N	N	B	M							B	C	D	E
D	D	D	Y	N	A	M						A			D	
C	B	C	N	N	C	L			C	D						
B	B	A	N	N	A/C	M				D	E		B	C		
C	C	C	Y	Y	A	M						A	B	C	D	
B	A	A	N	Y	A/B	L		B	C	D	E			C	D	
D	C	A	N	Y	A	M				D	E		B	C		
D	A	A	N	Y	A	M				D			B	C		
D	B	C	Y	Y	A	L			C				B		D	
D	A	A	N	N	C	M		B	C	D		A				
B	B	A	N	N	A	M					E			C	D	
C	C	B	N	N	A	M	A			D						
D	D	D	N	N	C	N			C	D		A				
C	C	C	N	N	A	M				D				C	D	
D	C	C	N	N	B	M						A		C		
B	A	C	N	Y	A	M			C	D						
D	C	C	N	Y	B	M								C		
D	B	B	N	Y	A	M			C	D			B			
C	C	E	N	N	A	M					E		B	C	D	E
B	B	B	N	Y	C	M		B	C			A				
B	B	A	N	Y	A	M			C	D						
C	D	B	Y	Y	A	M		B		D						
D	D	B	Y	N	A	M							B	C	D	
D	B	A	Y	Y	C	L							B		D	
D	D	C	N	N	A	M	A	B	C	D						
C	B	B	Y	Y	A	M				D			B	C		
D	D	D	Y	N	B	L					E			C		
B	A	B	X	N	A	M				D	E					
D	C	C	Y	N	B	N						A		C	D	
B	B	B	N	Y	A	L		B			E	A		C	D	
C	B	C	Y	Y	A	M						A		C	D	
B	B	B	N	Y	A/B	L				D	E			C		
B	A	A	N	Y	A	M				D	E			C		
D	B	A	N	N	A	M		B	C	D		A				
A	A	B	N	Y	C	M			C	D					D	E
B	A	A	N	Y	C	M	A	B	C	D						
B	B	A	N	N	B	M				D				C		
D	C	C	Y	N	A	N						A	B		D	
D	C	B	Y	Y	A	M					E			C		
D	A	B	N	N	A	M			C	D		A	B			
B	A	A	N	Y	A/B	M		B	C	D	E					
C	B	A	Y	Y	C	M	A									
D	D	B	Y	Y	A	L						A				
B	B	C	N	Y	A	M								C	D	E
B	B	B	N	N	C	M			C				B			
B	B	A	N	Y	A/C	M			C			A	B			
B	B	B	N	N	B	M				D		A	B	C		
D	D	C	Y	N	A	M			C			A		C		
B	A	B	Y	Y	B	M			C	D	E			C		
D	B	B	Y	Y	A	M				D	E			C	D	E
D	D	B	Y	Y	A	M	A			D				C		
D	B	D	N	Y	A	M				D		A		C		
C	B	A	N	Y	C	M			C	D	E	A	B			
B	B	B	N	N	A/C	M						A	B	C	D	E
B	B	B	Y	N	A	M			C	D						
C	C	A	N	Y	A	M			C	D			B			
D	D	C	Y	N	A	M		B	C				B	C	D	
A	B	B	Y	Y	A	M				D			B	C		
D	B	C	Y	Y	A	M				D	E					
D	A	B	Y	Y	A/B	L				D	E					
C	B	B	N	Y	C	M			C							
C	B	B	Y	Y	A	M				D	E			C		
D	B	B	Y	Y	A	M			C	D	E		B	C		
A	A	B	N	Y	B	N			C	D						
B	B	B	N	N	A/C	M					E			C	D	
C	C	B	Y	Y	A	M			C					C		
C	C	A	N	N	A/C	M				D		A	B	C		
D	B	B	N	N	A	M		B	C							
D	B	B	Y	Y	A	L								C	D	E
C	D	C	N	Y	A	L				D	E		B	C		
D	B	D	Y	Y	A	M					E		B	C	D	

Q14	Q15	Q16	Mini	Ws	PC	Mac	Q18	Hard	Soft	Pen	Elec	Ther	Lase	Dot	Ink	Scan	Dig	Q22
B	B	11	1	1	1		N			•		•				•	•	Y
A	A	2		1	1		Y	550	75		•					•	•	N
C	B	2		1			Y	110	20		•							N
B	B	2				1	N	30	10	•				•				Y
B	C	1				1	N	10	4	•			•					Y
C	C	1		1			Y	100	15		•			•				N
B	B	6	1		1		N	500	75	•	•			•	•		•	Y
C	C	1				1	Y	20	1	•			•					N
B	B	1			1		N	70	10	•								Y
B	C	2			1		N			•	•							Y
B	B	3		1	1	1	N	500	175	•			•	•			•	Y
C	C	3			1		N	40	10	•								N
B	A	10		1			Y	140	240		•	•		•				Y
B	B	9		1			Y	220	125		•						•	Y
B	B	3			1		N	60	15	•				•				N
C	B	4					N			•				•			•	Y
A	A	10	1		1		N	150	50	•	•		•				•	Y
B	C	12		1	1	1	Y				•	•	•	•			•	N
B	C	1		1			N	25	7	•				•				Y
B	C	2			1		Y	200	30	•			•	•	•	•	•	Y
C	C	10				1	N	30	10	•			•			•		Y
C	C	1				1	N	12	2					•				N
B	B	1		1			Y	40	20	•					•			N
B	B	1			1		N	14	4	•			•				•	N
B	C	1				1	N	20	10	•			•					N
B	B	1		1	1		Y	150	20	•			•	•	•			N
B	A	1		1			Y	100	20	•					•			N
B	B	2			1	1	N	120	20	•		•	•		•		•	Y
B	B	2			1		N	20	10	•			•			•	•	N
B	B	1		1			N	50	10	•				•			•	N
C	C	2			1		N	20	10	•							•	Y
B	B	2		1			Y	140	15		•							Y
C	B				1		N	70	20	•			•	•	•		•	N
C	C	5		1	1		N	100	20	•			•					N
B	B	2	1	1			Y	250	60	•	•	•						Y
A	A	2				1	Y	75	9	•			•			•	•	N
B	B	5	1	1	1		N	120	30	•				•	•		•	N
C	C	1				1	N	20	10	•			•	•				N
B	B	2			1		N	60	10	•			•	•				N
A	B	1			1		N	10	3	•							•	N
A	A	6		1	1		N	100	50	•		•	•	•			•	Y
B	B	2		1			Y	20	10	•								Y
A	A	5				1	Y	80	10			•	•	•				N
B	B	4			1		N	40	10	•							•	Y
C	B	1			1		N	20	10	•				•			•	N
D	C	1				1	N		5	•							•	N
B	C	2			1		N	15	4	•			•				•	Y
A	B	2			1	1	N	60	12	•			•	•	•		•	N
A	B	2				1	N	13	2				•					N
C	C	2			1		N	20	4	•				•			•	N
B	C	1				1	N	35	15	•								N
A	A	1				1	Y	500	10		•		•	•				N
A	A	2				1	Y	120	10	•			•	•	•	•		N
A	A	2		1			Y	60	125	•				•			•	N
B	B	1			1	1	N	20	2					•				N
A	A	1	1	1	1		Y		125	•	•		•	•			•	N
C	B	1		1	1		Y	100	40	•								N
B	B	3				1	N	20	10	•			•					N
C	B	2			1	1	N	30	10	•					•	•	•	Y
B	A	2			1		Y	150	30	•		•	•	•		•	•	N
B	B	11		1	1		Y	200	70	•	•			•			•	N
B	A	3			1		N	30	10				•	•	•	•	•	N
B	B	10	1	1		1	N	500	120	•	•	•	•			•	•	N
B	B	2		1		1	Y	50	30	•			•	•		•		N
A	A	2	1			1	Y	350	70	•			•	•		•	•	N
C	B	5	1	1			Y			•				•			•	N
X	B	5	1				N	90	30	•								N
B	C	2		1			Y	40	30	•				•				Y
B	X	2		1			Y	200	X		•							N
B	B	5			1		Y	300	40	•	•			•			•	N
B	B	2			1		N	130	20	•		•		•			•	Y
B	B	3			1		N	40	10	•					•		•	N
B	B	4				1	Y	50	20	•			•				•	N
C	B	2			1		N	50	10	•				•			•	N
C	X	<1				1	Y						•					Y
B	B	5	1				Y	250	60	•	•			•				Y
D	C	12		1	1		N	250	60	•	•		•				•	N
B	B	1		1			Y	150	30		•			•				N

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CHAPTER 1

1.1 - 1.2 **Technology**

This section briefly describes the early beginnings of CAD in architecture, and outlines the capabilities of the software and the problems impeding its development. It mentions the first hardware that was available and the likely course of its development. Finally, it outlines the range and operation of the output devices that were available.

1.3- 1.8 **The role of computers in design**

The realisation of the designers that the future of CAD was in the hands of the program writers and that the development of appropriate software was going to be a lengthy and costly process. Concerns over the role that computers would be able to play in design and fears of a forthcoming factory process in which the designer would become "de-skilled".

1 .9 **Managing people, machines and information**

The inadequacies of management in coping with the influx of the new technology.

1.10-1.11 **Software review**

(1) A brief description of the capabilities and cost of a typical program in 1973 used to asses project feasibility.

(2) A brief description of who was using CAD in the early 1970's, the operation and capabilities of a typical CAD installation.

1.12 -1.13 Conclusion

The inadequacies of the technology prevented any significant use of computers for design. Their only use seemed to lie in evaluating solutions and producing drawings more quickly. Problems of utilising the new technology began to occur, in trying to organise the flow of information between the computer operators and the design staff.

2.1 - 2.5 **The development of software**

The range of software that was available, who was developing it, what its capabilities and limitations were, and the developments that were taking place that would have an impact on design.

2.6 - 2.8 **The development of hardware**

The range of hardware that was available, its application in architecture, its capabilities and limitations, its cost and what could be expected from it in the future. The relative importance of hardware to software, and the need to connect hardware.

2.9 - 2.17 **The role of computers in design**

Opposing views as to the pros and cons of using computers for design, from academics and from those in practice. Examples from architectural practices as to how far CAD had penetrated into the design of buildings, its benefits and shortcomings.

2.18 - 2.19 **Staff, training and management**

Raises important issues of who should be using the computers and the role of management in their successful application. Describes new methods of organising the drawing team that had evolved to cope with the technology.

2.20 - 2.23 **Conclusion**

Summarises why the limitations of the software have determined the end users, and the consequent reorganisation of the design process. Discusses the extent to which the introduction of non-architecturally trained operators is likely to limit the development and potential of architectural design on computers. Finally the chapter summarizes the consensus of opinions as to what constituted the main limiting factors to the use of computers in architectural design.

3.1 **Introduction**

3.2 - 3.3 **The development of software**

An overview of what is available, its method of operation, limitations, and the problem of knowing what to purchase.

3.4 - 3.5 **The development of hardware**

Briefly mentions the importance, capabilities and range of hardware available and its relative importance to software.

3.6 **Operating systems**

Briefly outlines their importance and limitations.

3.7 **Data exchange**

Briefly outlines the current standards for the exchange and structuring of computer graphic information. Points towards what can be expected from standards in the future.

3.8 **Networks**

Briefly outlines the importance of networks.

3.9 - 3.17 **The role of computers in design**

The capabilities and shortcoming of available CAD systems for the purpose of design. What to look for in design software and how to ensure it is used effectively. Arguments for and against the use of CAD as a conceptual tool. What to expect from 3D modelling systems, techniques required to utilise them, and their application in the design process.

3.18 **The role of CAD in presentation**

A very brief description of state of the art presentation.

3.1 9 **The role of CAD in production information**

The suitability of CAD systems for this purpose, and where the limitations now lie.

3.20 - 3.21 **Output considerations**

The importance of efficient output, what to look for in a plotter, and how weaknesses in the operation of pen plotters can be minimised.

3.22 - 3.23 **Communication of data in the building team**

Confirms that in 1985 there had been little change in communication between disciplines but that the future looked bright.

3.24 - 3.31 **Staff, training and management**

Stresses the importance of effective management on the successful implementation of a CAD installation. The dangers of employing non-architecturally trained operators and the need for training of all staff. Problems of incorporating the new technology into the architectural process and the general move away from CAD bureaux towards integration into design teams. The need to organise the efficient storage and retrieval of information.

3.32 **Modern bureau**

A brief look at where a new generation of bureaux have found their niche.

3.33 **Health, safety and comfort**

A brief resume of the factors that should be considered in respect of the above.

3.34 - 3.36 **Conclusion**

Opposing arguments as to the merits of using CAD for design work. The new skills required in order to work with CAD systems, the limitations of CAD software, and the issues management should tackle in order to ensure its success.

5.1 - 5.2	**Discussion** A summary of the main points that came out of the survey findings.
5.3 - 5.7	**Figs. 5.1 - 5.3** A demonstration of the relationship of CAD operating experience to improvements in design skills, presentation skills, and the ability to co-ordinate plan, section and elevation.
5.8	**Fig. 5.4** The relative improvements that can be expected in design skills, presentation skills, and the ability to co-ordinate plan, section and elevation.
5.9- 5.10	**Analysis** A general summary of the results of further analysis.
5.11	**The organisation of CAD installations** Confirms that most CAD installations are now integrated within project teams.
5.12 - 5.25	**How effective are computer as an aid to design?** A summary of the comments made by the respondents.

6.1 - 6.4 **Conclusion**

A summary of the complete thesis, this section raises topics that came out of the literature and the light thrown on them by the findings of the survey.

6.5 **Further research**

Outlines areas of research that might be undertaken in the light of the findings presented in this document.

6.6 -6.9 **The role of CAD for design in the future**

A short section that identifies several ways in which CAD technology could develop that would be of particular relevance to the architectural designer.

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The following lists a number of journals, some of which were utilised in the writing of this thesis. It is included to enable anyone interested in computer aided architectural design to easily gain access to a wealth of subject matter. (NB. The dates are in the order YY-MM-DD)

AIA Journal

Date	Vol.	No.	Pages	Subject/title
74-07-00	62	1	38-39	First steps for small firms
74-07-00	62	1	38-40	Basic hardware and software
75-03-00	63	3	46-50	Computers instead of drawings
76-01-00	65	1	48-64	Case study
76-06-00	65	6	60	Case study
80-05-00	69	5	64-65	Biography of a remarkable tool
82-07-00	71	8	64-77	Architecture and the information revolution

Architects' Journal

Date	Vol.	No.	Pages	Subject/title
72-12-06	156	49	1319-24	Where now? York University conference
73-10-03	158	40	815-819	Typical installations
73-10-10	158	41	865-870	Computer development
73-10-24	158	43	1003-11	Applications in practice
73-10-31	158	44	1053-60	The problems of the future
74-01-09	159	2	64	Various comments on CAD
74-05-01	159	18	987-989	Computers in architectural education
76-03-03	163	9	449	Technical review

Architects' Journal

Date	Vol.	No.	Pages	Subject/title
77-01-05	165	1	33	Annual technical review
78-01-04	167	1	37	Annual technical review
79-01-03	169	1	30-31	Annual review
79-12-05	170	49	1227-35	Interbuild themes
80-01-02	171	1	34	Annual review
80-07-30	172	31	229-233	Accessible computing for designers
80-12-17	172	51	1209-13	Choosing a system
81-01-07	173	1	28	Annual computing review 1980
82-01-27	175	4	53-59	Computers simplified
82-02-10	175	6	67-71	Computing for architects
82-02-24	175	8	79-83	Computing for architects
82-03-10	175	10	67-69	Computer kits
82-03-24	175	12	71-74	Case study
82-04-28	175	17	42	Serious computing
82-05-12	175	19	71-83	Guide to hardware
82-05-19	175	20	65-74	Guide to software & systems
82-05-26	175	21	71-74	Case study - Archilab
82-06-23	175	25	81-84	Gable
82-06-30	175	26	53-58	Computer products and services
82-06-30	175	26	59-68	Energy primer
82-08-25	176	34	12-60	The Architect & IT
82-09-29	176	39	75-77	Computer products and services
82-10-13	176	41	89-90	What are the Japs up to in CAD?
83-01-19	177	3	69-75	Draughting & design
83-01-26	177	4	57-65	A strategy for computing
83-02-02	177	5	53-61	Analysing requirements

Architects' Journal

Date	Vol.	No.	Pages	Subject/title
83-02-09	177	6	65-73	Choosing software
83-02-23	177	8	71-83	Choosing hardware
83-03-02	177	9	73-77	Finance
83-03-09	177	10	53-63	Implementation
83-05-04	177	18	79-89	Comparing peripherals
83-05-11	177	19	75-89	Available software
83-06-01	177	22	65-71	Developments
83-06-28	177	23	73-84	Impacts of CAD
83-10-19	178	42	105-106	Architects in AJ computing club
83-10-26	178	43	77-83	Towards the electronic office
83-11-00	178	45	73-81	Choosing a CAD system
83-11-16	178	46	105-109	Installing a CAD system
84-02-08	179	6	55-58	Knowledge for designers
84-02-15	179	7	75-77	Expert systems
84-04-11	179	15	81-84	Networks and communications
84-04-25	179	17	73-75	Managing a draughting system
84-05-02	179	18	71-74	Managing a draughting system
84-12-05	180	49	77-85	Potential uses and limitations
84-12-12	180	50	53-55	Case study
85-01-23	181	4	71-73	Network case studies
85-01-30	181	5	47-54	Low cost computing
85-11-13	182	46	71-76	Types and capabilities
85-11-27	182	42	57-61	Market review
86-09-10	184	37	63-68	Coping with changing systems
86-10-00	184	42	91	New micros and systems
86-11-19	184	47	28	Training students on CAD

Architects' Journal

Date	Vol.	No.	Pages	Subject/title
86-11-26	184	48	73-75	BDP setting standards
87-02-25	185	8	59-63	What's new
87-03-18	185	11	14	Building walk-through
87-04-04	185	9	79-81	Running CAD in a small practice
87-11-25	186	47	4-82	IT supplement
88-04-00	187	16	4-57	IT supplement
88-12-00	187	51	5-57	IT supplement

Architect and Builder

Date	Vol.	No.	Pages	Subject/title
82-03-00	33	3	18-19	Technical or design tool
82-07-00	33	7	18-19	GDS

Architect and Surveyor

Date	Vol.	No.	Pages	Subject/title
83-10-00	58	5	12-15	Installing CAD
87-00-00	61	6	12	Artistic flair

Architecture AIA

Date	Vol.	No.	Pages	Subject/title
83-09-00	72	9	77-78	Some cations on computers
89-02-00	18	2	107-112	Best software
89-05-00	78	5	199-201	Adaptors and monitors
89-07-00	78	7	97-100	Video in restoration

Architectural Design

Date	Vol.	No.	Pages	Subject/title
72-00-00	42	9	538	Smart but not wise
73-05-00	43	5	274	Design participation
73-05-00	43	5	275-278	Techniques for problem solving
74-04-00	44	4	231-240	CAD system & programme development

Architect London

Date	Vol.	No.	Pages	Subject/title
77-06-00	123	6	35-37	The time is ripe
73-01-00	3	1	57-59	CAAD

Architectural Record

Date	Vol.	No.	Pages	Subject/title
80-08-00	168	3	84-91	Case study - SOM
72-10-00	152	4	59-60	computers as automated practice aids
73-09-00	154	3	65-67	Colour graphics for architecture
75-10-00	158	5	65	Analysis to design synthesis
77-08-00	162	3	98-205	Computer graphics in architecture
78-04-00	163	4	65-69	Case study - CRS
82-01-00	170	8	19-25	Evolution over revolution on
82-02-00	170	2	47-51	Computers for the smaller office
82-09-00	170	10	35-39	How do you jump in
82-10-00	170	12	35-37	Software review
83-01-00	171	1	41-43	Where to get software
83-03-00	171	3	41-45	The personal challenge of CAD
83-05-00	177	5	39-53	Round table on computers in architecture
83-07-00	171	8	45-47	Choosing CAD

Architectural Record

Date	Vol.	No.	Pages	Subject/title
83-08-00	171	9	27-31	The single user workstation
83-09-00	171	11	29-31	Using CAD with reprographics
83-10-00	171	12	37-39	Using CAD with reprographics
84-02-00	172	2	23-27	Need for graphic standards
84-06-00	172	7	33-39	A thorough grasp of design
84-09-00	172	10	150-159	Computers as a true design tool
84-10-00	172	12	31-39	What are smaller offices doing
84-10-00	172	12	49-80	A guide to software
85-02-00	173	2	31	Computers can mean efficiency
85-03-00	173	3	43	Switching systems is no fun
85-05-00	173	6	47-49	Where we are now and the future
85-09-00	173	10	35-39	Where we are now and the future
85-10-00	173	12	35-37	Evaluate your options
85-12-00	173	14	23-24	Protecting your decisions
86-01-00	173	1	33	Mini for large practices
86-06-00	173	7	37-41	Record survey results
86-07-00	174	8	35-37	10 clauses in purchase contract
87-06-00	175	7	45-47	The electronic pencil
87-09-00	175	9	51-53	CAD selection and management
87-10-00	175	12	154-158	Software reviews
87-11-00	175	13	163	Software
88-03-00	176	3	141-143	CAD in a small office
89-02-00	177	2	159-161	Future predictions
89-03-00	177	3	130-135	Trends in software
89-04-00	177	4	133-137	Why CAD?

Architectural review

Date	Vol.	No.	Pages	Subject/title
72-09-00	15	3	58-63	Research in Sydney
75-03-00	18	1	14-20	Model for design of offices
76-03-00	19	1	28	Computers in Architecture & engineering
83-03-00	26	1	2-5	CAD past present and future

Architect (RIBA)

Date	Vol.	No.	Pages	Subject/title
86-04-00	93	4	83-84	Would you trust CAD?
86-09-00	93	9	79	User friendly task
87-01-00	94	1	46-47	Computer networks
87-03-00	94	3	9	CAD on view at CICA
87-07-00	94	7	67	Computing
87-09-00	94	9	89	Abacus 3D walk-through
87-10-00	94	9	45-47	CAD in small practices

Architech

Date	Vol.	No.	Pages	Subject/title
85-05-00		73	17-18	Presentation graphics
85-05-00		73	4-6	Inexpensive practice computing
86-01-00		77	10-11	Dynamic CAD
86-01-00		77	6-8	Microcad
86-05-00		79	12-16	CAD and drawing
86-10-00		81	4-8	CAAD today

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Arup Journal

Date	Vol.	No.	Pages	Subject/title
77-03-00	12	1	9-16	Computer aided drawings
80-07-00	15	2	10-12	The development of PC at ARUPS

Building Design

Date	Vol.	No.	Pages	Subject/title
72-09-29		120	15	YORK/RIBA/BCS conference
74-06-14		205	12	Programming for the beginner
75-03-28		243	15	Case study - GMW
75-10-17		270	18-20	Abacus discussion
77-02-04		33	16-17	Look no hands
78-02-24		384	20-21	Drawing an Arabian University with CAD
78-03-31		389	2	Computers in architecture
78-05-05		394	394	Make a jump for computers
79-04-13		441	2	Union fears over introduction of CAD
80-03-07		486	8	By CAD it's the office revolution
80-04-11		491	8	Case study - Cedric Price
80-07-25		506	17	Case study - D'Arcy Race
80-09-12		512	10-11	Production aims - John Lansdown
80-09-19		513	44	Low down On MC scene
80-10-10		516	38-39	The falling cost of computers
81-01-09		527	23-25	An extra dimension to your practice
81-04-24		542	22-23	Welcome to the computer age
81-07-03		552	26-27	CAD in a small firm
81-12-04		573	26	The future of the architect
82-01-15		577	20-21	Graphics hits the screen
82-03-15		584	7	A case for new technology

Building Design

Date	Vol. No.	Pages	Subject/title
82-03-19	586	21	Shopping for systems
82-03-26	582	12-13	CAD chicken shows potential
82-03-26	587	2	Review of CAD '82
82-04-09	589	12	A look at software
82-04-16	590	24	Go on be a CAD
82-04-31	592	12	A cheap system
82-05-07	593	16-17	The plot quickens
82-05-21	595	7	Catching up with CAD
82-06-04	597	18-21	How CAD is used
82-06-04	597	7	Cautionary tales
82-06-25	600	18	Your friendly computer
82-07-02	601	16-17	The sense behind the jargon
82-07-16	603	14	Electronic apprentice
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