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A Survey and Evaluation of Microbased Computer Aided Design Systems for design education and practice in Scotland primarily in the area of Product Design: their application, problems and potential solutions.

Volume One

Roderick P Carter

This thesis is presented for the Master of Philosophy Degree in the Faculty of Applied Arts in Napier University in collaboration with Middlesex University

December 1992
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A Survey and Evaluation of Microbased Computer Aided Design Systems for design education and practice in Scotland primarily in the area of Product Design: their application, problems and potential solutions.

By Roderick P Carter

The initial premise of the research centred around the relatively new adoption by the Product Design sector of Computer Aided Design technology. Problems were expected to occur in applying the hardware and understanding the terminology of the software by this sector which prides itself in its artisan skills.

The aim of the work was to determine the extent of the adoption of Computer Aided Design and to clarify the problem areas. The research determined, by study of more experienced but similar Computer Aided Design users, that the expected problems were not insurmountable and were being overcome by the constant improvements of computer hardware and software. However, the problems that were pinpointed actually involved the human issues encountered in working with a Computer Aided Design system and involved issues such as the management skills required, working conditions and understanding of the advantages and disadvantages of Computer Aided Design.

The research focused on what had to be considered and what should be known about Computer Aided Design so that it could be effectively used in Product Design. The research was undertaken to establish general solutions to the introduction of Computer Aided Design into companies. These solutions are intended to provide a guide to potential and current users on how to improve the effectiveness of the use of Computer Aided Design systems in Product Design. The research has identified the themes and topics that should be covered in training staff on the use and potential of Computer Aided Design systems.
I should like to acknowledge the support and help given to me by my Supervisors, Mr S Boyd-Davis of Middlesex University and Professor A R Young, Napier University.

I should also like to thank all the companies which assisted me in my research by returning the questionnaires and allowing me to visit them to discuss their CAD systems. Their help gave me the source material necessary for the research.

I should also like to thank those members of the Design Department who gave me their co-operation and assistance to my research.
1.1 Purpose of the research

Computer Aided Design only became a financially viable prospect for the average design company with the advent of the Micro Computer and with the development of relevant design software. This combined with the computer industry's approach to sales which is to target sectors of industry and initiate sales drives within them until the selected sector has become established with computer technology has offered an alternative working environment. The design industry has become comparatively recently one of these targeted sectors with the result that CAD usage is now growing. This is illustrated in an article by Lloyd\textsuperscript{1} where he claims:-

"Design, in all its forms has been targeted by the computer image manipulators as the 'next' growth area. That dream has already come true in areas such as industrial (i.e. product) design and in specialist sectors.".

The pressures to adopt CAD and the subsequent changes in working practices are currently not strong enough to make it a necessity for those working in the Product Design sector and companies still consider it as a 'luxury' item. The other factor is that product design has a composite nature which has found the computer systems of the past to be inadequate for their purposes or too expensive. This is illustrated in the articles written by Pipes\textsuperscript{2} and the latter by Stokdyk\textsuperscript{3}:-

"Product design has always been a difficult market to target for the CAD suppliers - designers do a little of everything, demand the highest possible functional requirements from a system and, because design consultancies tend to be small, have the least amount of money to spend on kit."

"Industrial designers have been the most resistant to CAD. Even the most sophisticated computer system will struggle when called upon to meet the demands for intuitive conceptualising and realistic visualisations. Over the past year or so a number of CAD vendors have turned their attention to this potentially lucrative market and their products are being taken increasingly seriously by the design community."

This failing of the computer systems has been changing due to improvements in both hardware and software. This change was recognized by the computer industry and was the theme of the November 1990 Computer Graphics Show held in the Alexandra Palace. An article in the preview magazine for this show written by Langler\textsuperscript{4} illustrates this biased point of view:-

"However, in the past year, there has been a significant shift in attitude caused in the part by improvements to products but also an acceptance of the inevitability of computers in design."
Designers are now much more likely to get what they want from a computer."

Early research work suggested that instead of the 'luxury' label perceived by companies that perhaps CAD was becoming a working necessity and a required skill for designers. This is supported by the article written by Eckersley:

"The designer without computer skills is becoming obsolete: the point where a spokeswoman for the Recruitment Media agency was only able to recall three jobs in the last three years that didn't require computer skills! Designers with an eye to the future in any field must have those skills."

To many companies, the introduction of the new technology is a cause of many problems and the growth of CAD has been the subject of some reports. However, little original research has been conducted concerning the problems related to the selection, purchasing and training associated with Computer Aided Design at the Micro level specifically for the product design industry.

Past research work has been more suitable for the way the engineering and electrical industries work, which historically were the main users of computers. The implications and the effects of CAD on the working design environment are only now being considered but no known work has been carried out to provide cohesive assistance to the user market with regard to:

1 Cost of starting up and selection in Microbased CAD.
2 Cost of continuation and maintenance in Microbased CAD.
3 The provision of information and/or training packages to assist users of Microbased CAD.
4 The management of Microbased CAD systems.
5 The establishment of guidelines for the selection, implementation and training for CAD, specially related to designers' needs.

So in summary the research set out to investigate the needs of designers and design groups in industry and whether or not the changes mentioned earlier are affecting the product design sector in Scotland and if they are, how the product design sector is altered and to what degree. The next step was then to identify the problems that were being encountered and to suggest solutions to the problems that could be applied by companies working in the design field. It also set out to study the current trends in the educational sector of product design and to identify the problems of this area and how it might interact with the industrial sector more efficiently.

1.2 Definition of terms

To avoid any ambiguity of interpretation in the reading of this thesis it is advantageous to define the terms used in the way in which I understand them and used them in the writing of this thesis.
1.2.1 Microbased

There are three distinctive types of computer that can be used within a CAD system; Mainframe, Mini and Microcomputer. The amount of computer power available (processing speed and memory) is the most important limitation on a system's abilities. This does not mean that a great deal of computer power ensures a good CAD system. However, the development of CAD has not simply been a matter of providing more computer power at lower cost. CAD developed in two distinct but progressive ways.

1) Developments in the manufacture of computer technology prompted the first significant change by offering an alternative to using a giant Mainframe computer. This was the Mini Computer. The CAD user was not forced to queue up for a limited share of computer power. This was achieved by not having to "plug in" to the shared resources of a Mainframe, users could afford the services of a "dedicated minicomputer".

2) The second development resulted from the introduction of the microprocessor allowing the decentralisation of computer power within a CAD system, i.e. CAD systems could consist of several separate computers. The power of Microcomputers increased and made possible the self contained "stand-alone" workstation with its own built-in source of computer power. Microbased technology increased and allowed these systems to be linked to form a ring network. The Microprocessor at negligible cost became both economical and made it possible to provide a large number of subsidiary, decentralised, 'intelligence's' within a single system. The advantage of doing this lay in overcoming the CPU 'bottle-neck' appearing on Mini computers due to the increasing sophistication of evolving CAD software.

Today, Microcomputer technology is as powerful as lower-end Mini computers and there is a grey area between these once separate computer technologies. So, for the purposes of the research I have derived a rule of thumb guide-line based on their operating systems. I have classed those systems using DOS or Apple Macintosh computers as being Microbased and those using Unix as being Mini computers. This crude method was adopted to process information collected in the early stages of the research. However, due to the nature and demands of the Product Design sector it is necessary to be aware of developments occurring in the lower end of the Mini market.

1.2.2 Computer Aided Design

At one time, CAD stood for Computer Aided Draughting and some people still regard CAD as nothing
more than an enhanced draughting system. It is certainly a major part of the CAD industry but it is not the whole part. Sometimes to cover this, the term CADD which stands for Computer Aided Design & Draughting, is used. CAD was conventionally grouped into four main functional categories:- Geometric Modelling, Engineering analysis, Kinematics and Automated Draughting.

Computer Aided Design can be defined as being the use of computer systems to facilitate in the creation, modification, analysis or optimisation of a design. This definition describes CAD in a way that is in essence applicable to the diversity of areas utilising CAD.

These areas can be listed as:-

<table>
<thead>
<tr>
<th>Industrial Design</th>
<th>2D Draughting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3D Solid modelling</td>
</tr>
<tr>
<td>Engineering</td>
<td>Electrical-</td>
</tr>
<tr>
<td></td>
<td>Circuit layering 4 approaches</td>
</tr>
<tr>
<td></td>
<td>Geometric</td>
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<td></td>
<td>Symbolic</td>
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<td></td>
<td>Cell based</td>
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<td></td>
<td>Procedural</td>
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<tr>
<td>Mechanical-</td>
<td>Draughting</td>
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<td></td>
<td>Machine Tool Design</td>
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<td></td>
<td>Synthesis of Mechanisms</td>
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<td></td>
<td>Tool Design</td>
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<td></td>
<td>N.C. Programming and cutter path analysis</td>
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<td></td>
<td>Batch assembly</td>
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<td></td>
<td>Definition of a model</td>
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<tr>
<td></td>
<td>Finite Element Analysis</td>
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<td></td>
<td>Determination of Mass and section properties Volume, 2nd moments of Inertia</td>
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<tr>
<td></td>
<td>Plastics Moulding</td>
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<tr>
<td></td>
<td>Simulation</td>
</tr>
<tr>
<td>Interior Design</td>
<td>2D Draughting</td>
</tr>
<tr>
<td>Architecture</td>
<td>3D Presentations &amp; Modelling</td>
</tr>
<tr>
<td></td>
<td>Process plant/site layouts</td>
</tr>
<tr>
<td></td>
<td>Bidding</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>Plant layout</td>
</tr>
<tr>
<td></td>
<td>Bidding</td>
</tr>
<tr>
<td>Business Graphics</td>
<td>Marketing - Advertising, Graphics, Interactive Video</td>
</tr>
<tr>
<td></td>
<td>Finance</td>
</tr>
<tr>
<td></td>
<td>Manufacturing and Resource allocations</td>
</tr>
</tbody>
</table>
Publishing  
Medicine  
Geophysics and Cartography  
Entertainment  

Documentation  
3D images  
(relates to Pharmaceutical and Chemical Industries)  
Map making  
Animation

This shows the scope which is potentially affected by any CAD developments.

1.2.3 Product Design

The activity of product design can be understood to be the preparation of solutions to problems concerning the creating, producing and marketing products. For example the design of a telephone, a car or a television. It would not involve the design of telephone systems, car engines or the circuitry within a television.

Product design requires specific skills and, through discussion with Design Lecturers at Napier University, I have derived the following list:-

- Ability to understand the users' needs, wants, tastes and priorities.
- Ability to create products whose features satisfy aesthetic, ergonomic, quality and economic expectations simultaneously and adequately.
- Ability to produce drawings or other means of transferring information so that the final solution can be communicated to others working in the enterprise.

1.3.1 The Design Process

To help try to understand why the design sector has been slow to adopt Computer Aided Design, I found it useful to define the design process. I believe the following best describes it.

- Identification of a need
- Problem Analysis
- Design Evolution
- Submission of Final Design
- Production/Construction of Design

I am aware that other Designers would vary this interpretation. Other models are described in the
following works:-

Developments in Design Methodology, N Cross, Open University, 1984.

These references have different approaches to the Design Process but in general terms they are essentially similar in the achievement of the end result.

To appreciate how Microbased CAD is being used and how its use can change, it is beneficial to consider the design process described earlier in more detail. I believe it will also explain my own reasoning about the assumptions made in the thesis. How CAD can be integrated with this is described further on in this chapter. Basically it follows the process:-

<table>
<thead>
<tr>
<th>First stage</th>
<th>Identification of a need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second stage</td>
<td>Problem Analysis</td>
</tr>
<tr>
<td>Third stage</td>
<td>Design Evolution</td>
</tr>
<tr>
<td>Fourth stage</td>
<td>Submission of Final Design</td>
</tr>
<tr>
<td>Final stage</td>
<td>Production/Construction of Design</td>
</tr>
</tbody>
</table>

Of course it is not as clear as this in reality and there are feedback loops and second attempts to match changing criteria. However, in essence, this forward process is true for all of the design backgrounds being considered in this research. A more detailed example to clarify this description of the design process can be shown by using the stages which are carried out in the Product Design background.

The first stage is the **Identification of a need**. This is the initial stage, whatever the input. The source could come from the marketing department, or a client, or some other originator. The next stage can be described as the **problem analysis**. In this stage, operations such as formulating the problem into smaller elements and/or identifying the problems associated with the need occur. Investigation, Definition and a Problem Specification are also carried out at this stage. The Problem Specification is not for the final design but it is a formalised statement about the need.

The **design evolution** is where ideas are generated, processes selected, refinement and prototype development are carried out.

**Step One**  Generation of ideas through the study of the functions necessary for the product to work.

This produces a basic structure for further development while no decisions have been made
regarding quantities, dimensions, volumes or relative arrangement.

**Step Two** Optimisation of the important parameters and any specified and relative arrangements of the elements are carried out.

This results in a measure for selection, not necessarily for "the" solution.

**Step Three** Product's form in its entirety has to be considered and requirements for criteria such as the aesthetics, technical and economic constraints need to be considered on how they affect the overall form.

This study of the form is produced towards the detailed design stage of the design evolution. Various considerations of the form of the functional areas make a good starting point for this stage. The important criteria are determined by the function, strength and manufacturing methods necessary. The nature of the work carried out at this stage is freehand sketching and then as form is settled, the sketches are replaced by layouts. 3D mock-ups would be carried out at this stage as well.

**Step Four** Detailed drawings emerge.

Scale drawings of the final design are prepared for the final decisions on materials, dimensions, surface, tolerance and production techniques. The working drawings created at this stage also supply further information for decisions on quantities to be produced, possible manufacturing processes and details on the drawings such as number, date and scale. The final fundamental property is the structure. This is specified in assembly drawings which show the component elements to be assembled. The prototype would be built at this stage.

It can be seen that the Design evolution stage could also be titled "Product Synthesis Stage". The work evolves into a final idea. This goes for evaluation to ensure that it matches the need and if everyone involved is satisfied it will go off for conversion into manufacturing information, enabling it to be produced and marketed. As the work progresses, the developments can be shown to the "client" and feedback can be incorporated into the development changes and thus become part of the design evolution. The final stage can now be implemented.

It is important to remember that while I have described this phase in detailed stages in reality this is not the case. It is sometimes possible to bypass stages. Human inspiration, together with creativity, reduces the organised crystalline structure I have just described into a more amorphous fluid process.

Remembering this design scenario it is now important to view what Computer Aided Design can do
for the design process. The analytical abilities of computers are very useful but for some areas they have a minimal immediate application or benefit. Throughout my research I have deduced that computers give little or no assistance in the stages of conceptualisation. There is work being carried out in the field of Artificial Intelligence that might one day produce a computer that will give this assistance but it is not in a very practical level of operation at present in my opinion. During the conceptual phase the requirement is heavily weighted towards creative and innovative thought. This is illustrated in the Industrial Design methodology scenario. Generally, as aids to design, they are still at an elementary stage of their development. However, while CAD systems are unable to work in the grey areas of conceptualisation they are well suited for the creation, manipulation and storage of graphical information. It is this type of information which designers rely on to perform their principal function - which is the transmission and translation of a product concept from initially vague, ill-defined, and possibly confused beginnings, to a precise, clearly defined product design. So currently the main application of CAD is in the later stages of the design process where details are more defined and dimensions clearly stated. It can be seen that to classify design problems, they fall within one of the following classes:-

1 Configuration Design
   e.g. Electronic circuits, networks of pipelines, mechanical power transmission lines, control systems, thermal circuits and transportation systems.
   Experimental configurations are checked for compatibility of component interfaces, for transient and/or equilibrium behaviour, sensitivity, stability and reliability.

2 Layout Design
   e.g. Layouts of pipes, houses, process plants, manufacturing workshops, printed circuit boards and integrated circuits.
   Experimental layouts are checked for distances between lines and components, for lengths of component packing, flow of data, energy or materials.

3 Shape Design of
   e.g. Car bodies, cams, houses, bathroom fittings, mechanical support structures and magnetic circuits.
   Experimental shapes are checked for aerodynamic behaviour, strength, safety, aesthetics and ergonomics.

It can be seen from the above descriptions and from my earlier description of Product Design that the research is concerned with the third option the design of shapes.

There are two methods which can be used to generate experimental solutions.
Type One
The first method is single starting point strategy. Single starting point strategy consists of selecting an experimental solution and then by the process of error elimination, modifying it until a correct solution emerges.

Type Two
The second method is a multiple starting point strategy. Multiple starting point strategy consists of generating as many radically different experimental solutions as practical and then by process of elimination with each one or at least with as many as possible. The selection of the best solution takes place at the end of the sequence.

The second method is the more effective because it is most likely to lead to an original solution. To generate solutions of this type, the designer needs large quantities of information such as:

1. Specified performance criteria for the product
2. Catalogues of available parts and materials
3. Various standards, rules, guidelines and recommendations
4. Constraints imposed by production, testing, maintenance
5. Descriptions of similar successful and unsuccessful displays
6. State of the art methods and "know-how"

To generate this range of information, the designer needs the following:

1. Effective techniques of searching for the relevant information.
2. Before a solution can be created it is necessary to select a medium and a language for its description.

My own working design experience has shown me that for every design problem there is, in principle, an infinite number of solutions. However, the designer eliminates some and selects some, but it is not understood by any calculable method, the mechanism by which means the designer arrives at a single, or group of, experimental solutions. It is a qualitative judgement rather than a quantitative assessment. There does, however, appear to be several distinctly different approaches which a designer employs, depending on that person's own capabilities and on the way in which he understands the problem. They can be listed like this.

1. Creative approach - by a leap of imagination
2. Pattern recognition - by analogy with previously encountered problem solutions
3. Random search - by guessing
4. Expert approach - by following a set of rules based on experience
5. Systematic search-by reducing the solution space to a finite number of possibilities and exploring each one in turn
6 Mathematical approach - by transforming the design problem into a mathematical problem and obtaining its solution
7 By a combination of all, or some, of the above approaches.

(This whole process is similar to another way of approaching design problems to the method laid out in the book written by Tjalve\textsuperscript{6} Chapter 1.)

Now, before the process of error elimination can begin it is necessary to:

1 Select a medium and language for constructing experimental solutions
2 Select a means by which the behaviour of experimental solutions will be assessed
3 Select a means by which the actual and specified behaviours will be compared
4 Create a set of possible modifications
5 Select decision making mechanism which will be used to decide upon the relevant modifications as a function of error.

Once that is done, the process of error elimination can begin and the essential requirements of this are:

1 Rational critique
2 Experimental
3 Mathematical and/or simulation techniques

(Tjalve\textsuperscript{6}, Chapter 2)

1.4 Description of the subject area

As illustrated earlier the extent of activities that could be classified as CAD related activities is very broad but the research deals specifically with Product Design so the following area is where CAD and Product Design interact:

Two and Three Dimensional Design-

2D Draughting
3D Solid modelling
3D Representation
Presentation Graphics

These are relevant to the following work groups:

Industrial Design
Mechanical Engineering
Interior Design
Architecture
Graphic Design

However the areas relevant to the research are Industrial Design and Mechanical Engineering.
1.4.1 Defining the subject area

The destination companies for graduating students from Napier University was used as an approximate guide to the company types that are involved in the product design activity. Employment has been found in a wide range of companies which can be seen in Appendix I.

This gives a wide range of possible users of product design CAD systems since the graduates were employed by companies working in Design consultancy, Engineering and Architectural roles. This range of variety indicated the types of company which would benefit from the findings of the research and aided in initially identifying the subject area involved in the research.

1.4.2 Structure of the subject area

The design sector is primarily composed of small design units which are either independent groups that service the design needs of many companies or are small units in a company such as an engineering company. Currently, in industrial Scotland, there are very few large companies. Resources are limited and manpower is kept to a minimum, so the training of staff is seen as a low priority.

1.5 Interaction with other working roles

Product design is not an isolated activity and it interacts with various working roles. However in terms of CAD, it is mainly involved with the manufacturing processes. In some aspects of the work there is very little to distinguish it from roles such as engineering design, since for the following aspects they would use the same type of software.

- 2D Draughting
- 3D Solid modelling
- 3D Representation
- Presentation Graphics

In short, the end product of a design consultancy would be used in some form in a manufacturing company for injection moulding, machining or assembling. Historically this information has been passed on to the companies in the form of engineering drawings and 3-dimensional models. This would then be translated into the format required by the various stages involved in the manufacturing activity; process planning materials requirement and machining stages.
The other important aspect is that design is not an isolated activity because it works in conjunction with other areas. These areas have influence on how the product design sector will progress. Since the manufacturing industry is rapidly becoming an automated industry with a heavy commitment to the use of computer technology this will exert demands that the product design sector supplies design information in an electronic format. This is becoming apparent in the car industry which offers favourable conditions to sub-contractors who use compatible computer technology to their own.

1.5.1 Commonality with other users of CAD

At the start of the research it was expected that the activity of Product Design would have some commonality with other groups working in CAD. These were seen to be:-

- Draughting packages.
- Computer Hardware such as plotters, printers CPU's and screens.
- Work related aspects such as working environment, ergonomic features and management aspects.

Compared to other working functions that use CAD, product design is still a comparatively recent user so it was considered that where it had commonality with these more mature users then the problems and solutions adopted could be usefully adapted to product design. This meant the research had to confirm areas of commonality, establish whether or not they were as expected at the start of the research, and whether or not they could provide valuable insights.
The first part of the research required an evaluation of usage within the area covered by the title of this thesis. To achieve this the most efficient method of analysis had to be first decided.

2.1 The Possible Methods of Analysis

The first stage of the research was to perform an analysis of the subject area, this could have been carried out by any of the following methods:-

- Personally visiting each company.
- Telephoning each company.
- Sending a questionnaire to each company.

2.1.1 The Selected Method

The intention at this stage of the research was to get as broad a coverage as possible and as soon as possible. This meant that the most feasible method was the questionnaire.

This was carried out by sending a questionnaire to one thousand companies. The addresses were obtained from the SDA listing held at Napier University, The Design Council, and a listing of Architects in Scotland.

The large coverage was planned and expected to give an accurate general representation of design education and practice in Scotland. It was also expected to give a picture of usage and potential usage of CAD within Scotland. Finally it was expected to provide initial indications of whether the problems were generally widespread.

2.1.2 Questionnaire Review

The exact methodology used in constructing the questionnaire can be reviewed in Appendix II. It discusses the questionnaire format, content, application of the questionnaire, the processing of the returns, how the companies were expected to answer the questionnaire and an analysis of the non-returns.

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2.1.3 Similarity

Careful comparison of the results show that my assumption that there is quite a large area of commonality between different design activities using CAD systems is well founded. This allowed me to use the experiences of companies well versed in CAD work to be used for those companies in Product Design which are new to its implications.

2.2 Questionnaire Results

A detailed set of results to the first questionnaire can be found in Appendix II but the overall findings are now described. It is important to remember that the companies contacted were seen to have some design content in their working activity and would, therefore, have some requirement for having a CAD system. Whether they possessed CAD or not was one of the main points to be established. The other point to remember is that when the questionnaire was sent out to the companies the exact nature of their business was not known.

2.2.1 Points brought out by the First Questionnaire

It showed that CAD is increasingly being used with 51% saying that they use it and a further 21% expressed an interest in its uses with only 28% having absolutely no interest in CAD. Therefore 72% had some positive interest in CAD. This is a very high figure. Although it would be wrong to say that 72% of all companies in Scotland had an interest in CAD, it would, however, be reasonable to assume that the trend was positively in favour of moving towards a computer aided design process.

Of those companies which expressed they had no CAD system, 12% said they did have a DTP system. The largest contribution to this had expressed they had no interest in a CAD system at all which suggests that it was not the thought of introducing new technology which puts them off.

The general trend in Scottish companies showed that size was a determining factor whether CAD was used or not. Most of the companies which had CAD did not have DTP and where they did, most of them did not operate it in conjunction with their CAD system. This suggests that most of them regarded CAD as an electronic drawing board and not as a source of shared information. Of those companies which used CAD, by far the largest percentage used a Microbased system. Most of the systems in use are not networked.

The reasons that companies chose to use CAD were varied but the main themes were 'efficiency of
work', 'only possible way,' and 'maintaining staff levels'.

The companies chose their particular system primarily for its ability to upgrade the software to match any change of the company's requirements. The main secondary reason was the software's ease of use.

The decision to buy a particular system in companies was mainly made by senior management in consultation with their Design Department although in almost as many companies, the choice was made purely by their senior management.

The software/hardware chosen was that which matched the company's requirements as close as possible.

Companies preferred to train current staff rather than employ someone specially for the task. When companies employed an "outsider", their first choice was for someone who was in the same field and who had general CAD experience but not necessarily the system used by the company. The next level was equally for an expert on the system or someone with CAD experience but who did not have experience in the company's field of work.

Long-term instruction was usually by a third party but there were very few that chose this option of training. Very few commented that CAD training was ongoing. The method of training preferred by companies was for a short training session given by the vendor. This was the only training method carried out by some companies while equally other companies backed this short period by a period where the operator taught him or herself or by a third party training concern. 53% said that the price of training was included in the overall price of the system. Those companies using CAD only had some of their staff trained to use the system.

2.3 Analysis

2.3.1 Reasons for not having CAD

The questionnaire results suggest that for those who have no current CAD system but have an interest in CAD there are two reasons why they have no CAD system at present and these are:-

a) The company does not consider CAD necessary to its operational needs, and (to a lesser extent.)

b) Companies were dissuaded by the costs involved with CAD.
These two reasons were applicable to those companies which stated they did not have a CAD system and did not intend to own a CAD system. Companies were not any more forthcoming as to their reasoning for this but possibly those which had an interest in CAD thought that their operational needs would/might change in the future and it would be necessary for them to use CAD. However, until then, they are going to carry on with their tried and tested manual methods. One clue towards this assumption is shown in the responses to question 3b) and that is that the reasons were governed mainly by financial constraints. Perhaps they can see no way of ever having the initial capital to invest in CAD and its running costs but recognize that their future situation might change with increases in workload or the reduction in costs to start up in CAD.

Some companies which returned the questionnaire were further contacted and asked about their reasons for not having a CAD system but had expressed an interest in CAD. Twenty five companies were contacted and the percentages expressed in the following statements are representative of that total. The companies usually had more than one reason for their decisions.

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>32%</td>
<td>said they were too busy to get a CAD system and then learn how to use it</td>
</tr>
<tr>
<td>28%</td>
<td>said they expected that if workload increased then it would be worthwhile in getting CAD</td>
</tr>
<tr>
<td>24%</td>
<td>said they could not see that they had enough input of work to justify costs</td>
</tr>
<tr>
<td>20%</td>
<td>said at present they could not afford to buy in new equipment</td>
</tr>
<tr>
<td>16%</td>
<td>said the thought of using CAD for the draughting is good but they can not find the time to properly assess it</td>
</tr>
<tr>
<td>12%</td>
<td>said they know that other companies in their field use CAD but they are unsure as to how to start as nobody in the company has any computer experience</td>
</tr>
<tr>
<td>8%</td>
<td>said the work carried out by the company tended to be 'one-offs' and they felt on assessment that CAD was too expensive for work being carried out at present</td>
</tr>
<tr>
<td>8%</td>
<td>said management is not prepared to make the investment but those in the drawing office think that they could use it</td>
</tr>
<tr>
<td>4%</td>
<td>said they considered that while CAD would be useful, they felt they (the partners) would lose control of the design project and it would go to their employees</td>
</tr>
</tbody>
</table>

Some of these reasons would support the assumptions I have made about the other companies which did not respond further. The leading reason supports my belief that training, with all its implications, is a perceived barrier to companies. The second highest reason supports my belief that it is necessary for companies to adopt a management awareness programme.
When the work types were assessed it was seen that, on the one hand, some work types were exclusively in the "no CAD no interest" category and that on the other hand some work group types occurred in all four categories. Company size was another factor that was considered and it was found that the smaller companies tended not to have CAD. Where size was not the case then the actual work carried out by the company tended not to need the CAD input.

The company responses given to question 14a) can be listed as below. However, whatever the nature of the work being carried out by the companies, the responses suggest that the companies involved adopted a realistic attitude to CAD when they carried out their appraisal for purchasing a CAD system. The benefits mentioned by the companies usually matched their own particular needs.

A compilation of the benefits are listed below:

1) Shorter lead times
2) Design modifications are easier to make
3) Faster response to requests for quotations
4) Minimize transcription errors
5) In analysis, easier recognition of component interactions
6) Improved accuracy of design
7) Assistance in preparation of documentation
8) Better designs provided
9) Better knowledge of costs provided
10) Makes the management of design personnel on projects more effective
11) Better communication interfaces
12) Greater understanding among those involved in the work.
13) Better drawing precision
14) Design process is speeded up
15) Retrieval of design information easier
16) Marketing opportunity for user company, to impress clients
17) Design quality improved
18) Job enrichment
19) Opportunity to improve working procedures
20) Designs have more standardisation
21) Provides the potential for using more existing parts and tooling
22) Assistance in inspection of complicated parts.

2.3.2 Job Security

Like the advent of computer technology in other working environments, the computer was seen as a threat to job security. Others felt that computers were inappropriate in the context of design. However the results from my survey show that most companies are prepared to keep their Design teams and to train them to use computer technology. Research by others (Boyd Davis\(^1\) and Arnold \& Senker\(^2\)) has shown that for those who become involved in Information Technology, it has only
Improved their position. These researches have shown that the tendency is for work to increase, with Designers carrying out more work and not less; a tendency which would be a beneficial factor for those companies wanting to increase the effectiveness of their current staff levels.

2.3.3 Training

The respondents tended to adopt the tactic of using the cheapest methods of training which were either a short training period of a few days or self training. The self training option is perceived to be the cheapest option by the companies because there are no apparent direct costs. The hidden costs such as the fact that the company will have a person who is learning the system is not working at their real potential is not apparently taken into account. AutoCAD is an example of the type of software which people try to teach themselves and it is stated by AutoCAD themselves, that with proper training it takes three months to become fully functional in operating the standard command sequences properly.

The other factor is that the company is paying for the computer system and staff are learning to use the system whereas often the training given by the vendor or third party trainer is started before the system has been installed on the premises. While it is essential to obtain hands-on training it should be in a structured programme as supported by Garratt³.

One company which opted for this self teaching method answered in the questionnaire that they eventually had to resort to outside training after their own attempts did not prove very successful. It could therefore be argued that this method was the more expensive option, especially if you consider all the hidden costs of non-productive time of staff learning to use the system, the non-productive time of the computer system, and the eventual costs of the training.

Many software houses are becoming more involved with training partly because local dealers of the software are not big enough to justify dedicated training staff or have training site facilities. However, those software companies which are offering their own training do have the facilities - Autodesk for example, is the first to offer training centres that on completion can give a City and Guilds certificate in the use of the AutoCAD draughting package. It is also felt that because some dealers do not have the facilities for training that no dealers should, therefore, be allowed to be authorised training centres as it is seen that they will have an unfair advantage to sell over their smaller competitors, as discussed by Hannington⁴. Due to this fact it is more cost effective to have a centralised body to organise training. There are at present arguments for and against this and dealers should be given the chance for training packages. Should dealers be allowed to offer training services then minimum
standards might be set by the software companies themselves so they have a proper network of people giving a standard training package. This is beginning to happen through the moves of Autodesk but this is only one company whose motives are commercial.

One other point is that, at present, companies are stressing their ease of use and no training is needed and novice CAD companies are believing this. In the article by Hannington there is a comment made by John Beckett of Datacad which states that, in his opinion, there must be plenty of CAD systems being operated by badly trained people. This gives some credence to reports of CAD being ineffective and not worth the money. Properly trained, there would be a lot more cost effective CAD systems on the market. Money is always the primary governing factor and when companies are given the offer of a CAD package that requires no training then most companies would consider this aspect very important in their decision making. In the article by Hannington, Beckett states that an effective level of investment in training is a minimum twenty per cent of the total system investment. This level of investment is based on his experience but there is no supporting evidence given in the article. The standard of training is also varied. Some trainers follow the manual strictly to the letter, whereas other trainers work in close association with the learning company. There are a lot of issues concerning training but the training aspect is dealt with in more detail later on in the thesis.

The fundamental aspect to be remembered especially in relation to some of the responses is that just because someone knows a CAD system, this does not qualify him as the best person to impart those skills to other people. This is supported by work from Boyd Davis and Arnold and Senker.

The questionnaire showed that the most favoured training option was for a "short training period given by the seller". This seems to reflect similar research carried out on this subject by Senker and Simmonds and Boyd Davis.

The most popular alternate option was "the operator was allowed to teach himself/herself". Certainly if only Microbased CAD responses were to be used this option was a very close second.

The important aspect about companies choosing this option is that they want increased working efficiency within the company but they are reluctant to allow time to learn how to work efficiently on the system. So when companies choose the option of self-training, they opt for a method that is not very effective and thereby wastes costly time on the computer. This factor is supported in the article by Edwards.
"Today AutoCAD is an immensely capable and powerful product. Release 11 promises even more capability, although the trade off is always against simplicity. The more it can do, the more you have to know to use it to its limits. ..... The need for formal and structured training is now greater than before. It is impossible to justify investment in Release 11 AutoCAD if, by skimping on training you are restricting its use to levels attainable with Autosketch".

(Autosketch is a much simplified version of AutoCAD.)

The companies participating in the questionnaire had the option to state the training method they carried out if it was different to the options supplied and they ranged from 'on the job' training, training by vendor, training by third party consultant and training from an educational establishment. The educational establishment types varied from the local skill centre to University level. The packages taught by these different establishments were often the same or an equivalent package. Some of the educational establishments gave training in the evenings, some were acting in conjunction with the SDA and some were acting in conjunction with the relevant software house.

The training of CAD software is becoming a growing industry with many third party companies offering their services for particular packages. College training for CAD packages has come under criticism from people such as reported by Hannington\textsuperscript{4}, with the tutor knowing less than the students about the package and sometimes the training is not job specific enough for those attending. However, the work which I have conducted does not give credence to this comment. The companies in the questionnaire who attended college training courses were generally very satisfied.

2.3.4 CAD usage within the company

The questionnaire respondents showed that not all their employees knew how to use the CAD system while in design consultancies everyone could use it but not all of the time. What has to be remembered is the part that design plays in a company. In design consultancies, design is the 'end product' while in engineering companies 'design' is just a component part. However what should be considered is that while not every employee within a company actually uses CAD they should be aware of the capabilities of CAD just as they are aware of the wants and capabilities of process planning and accounts. So in terms of CAD there are different levels of operational knowledge to be remembered. This view is supported by Port\textsuperscript{7} and Bramer\textsuperscript{8}. These different levels can be illustrated by the following:

Level one Should a manager need to show clients work at the level so far reached, then he should have the minimum ability to turn on the system, get into the CAD package, call up the required drawings and move about the drawing to show it to the client.
Level two  This is the ability to carry out the drawing work in conjunction with the software.

Level three  This is the ability to solve problems in the computer system so the operator needs to know more about the operating system and more about the technical workings of the hardware.

2.3.5 Usage in relation to company size

The sizes of the companies participating in the questionnaire varied and even those which were smaller, tended still to have "specialists" rather than everyone being familiar with the system. This can be put down to factors such as workload and divisions of work. Most of the companies appreciated that computer time is expensive but did not appreciate the fact that if everyone in the Design department could operate the system then the computer would be in constant use. There are some exceptions to this - in those companies where only some staff know how to operate the system then, when they are absent or engaged in other tasks, the computer is idle which, in financial terms is a wasting asset and not the working asset which it should be.

2.3.6 Deciding factors for working on CAD

Due to the initial and ongoing costs of a CAD system, it could be considered that those implementing CAD would want it to be at its most productive and to gain the maximum benefits they could to the advantage of the company. The responses of the companies in the questionnaire would suggest that the management of the system was not a prime concern with some of the companies and this would suggest to me that all the other aspects involved in CAD management are also being ignored. This can only be to the detriment of the company in the long term. Some examples of inadequate management are discussed further on in this chapter and aspects of CAD management are discussed in Chapter 6.

It is even more important for small companies to become properly organised if they are to successfully implement CAD. It is more than just an electronic drawing board but even if it was just that, then drawings still need to be filed for reference. A conventional drawing office has filing systems and practices and so must a CAD equipped drawing office. The answers to this question show that only some companies have really understood the complexities. Even though companies are quite small the different tasks can be shared out so that the CAD manager can also be the CAD operator. The responsibilities need not be so strenuous that they cannot be properly carried out. This is supported by the article written by Bartho10.
2.3.7 Problems found in current usage

Hardware Problems

Most of the faults appear due to mechanical failure. However, the other problems are related to poorly considered requirement specifications and under estimating what they would need after only a short period of operation which would appear to be due mainly to inexperience.

The points that need further discussion are those in this section which were due to inexperience. Those points are:

1. Minor learning problems for hardware set up configuration
2. Compatibility problems between processor and hardware set up
3. Non expert supplier
4. Too slow under full load
5. Slow CPU need to upgrade
6. Had to upgrade sooner than expected with level of operators skill
7. Obtaining equipment quick enough when needing to expand, replace disk drives, intelligence modules.

Points 1 & 2 would be typical for a company installing a CAD system for the first time and they also show that they did not include the set up of equipment in the contract with the dealer or that the dealer failed in his job.

Point 3 seems to suggest that some dealers are not doing all that they should and that companies should learn for themselves and find out their own information and not to rely too heavily upon the dealers.

The aspects brought out by points 4-7 show that companies are not implementing the correct approach in their preliminaries to purchasing/leasing a CAD system.

Point 4 shows that the company had not fully appreciated its own requirements nor matched them to the computer's performance which they needed. They set their levels too low and now they will have to upgrade the system causing them more expense.

Points 5 & 6 are related again to not carrying out a proper implementation plan at the beginning. They either underestimated their requirements or their abilities or they did not check a similar system already in operation before making their purchase. It is difficult, especially when costs of machinery are high, and naturally no one wants to pay for a high powered system when all they need is a

22
medium powered system. In the long run however, it is advisable that an upgrade coincides with the time to replace the existing system. This reduces costs and time spent evaluating. If the time is well spent at the beginning they could have set the process for the following upgrade.

Point 7 is related to forward planning and expectation of growth and this can only be relieved/cured by good management practices.

Two comments that were brought out in the questionnaire which required more discussion and were seen as symptomatic of a company just starting up in CAD were "Minor learning problems for hardware set up configuration" and "Compatibility problems between processor and hardware set up". There are currently a lot of dealers who are purely concerned with sales and not about any after-sales service. These dealers are regarded by other more responsible dealers as 'box shifters'. These 'box shifters' offer cheaper rates which, at first glance, look the better deal. Whereas the reputable dealer would have shown the purchasing company concerned how to install the system or to have installed the system as part of the sales service.

The second point is due to somebody either not knowing or not checking the hardware specifications and requirements for the hardware concerned. The dealer, if he was concerned with the whole deal, having read the specification, should have noticed any inconsistencies and at least pointed these out. Should there have been more than one dealer then the specification should have indicated what other equipment was to be involved so that each selling company could ensure that their product would work as an integral part of the proposed final system by being able to check what their equipment was being linked to. This suggests to me that a more informed management would solve these matters.

Software Problems

By companies using "off the peg" packages which have a wide market they have avoided most of the problems which can occur. These packages are usually well serviced by the software houses which send out any necessary amendments. Occasionally in upgrades some bugs do occur but by relying on customers, the software houses find and sort them out. It might suggest though that some packages are rushed out in the knowledge that there is a possibility that bugs may exist but trust that these will be discovered by the customers for the software houses. A point verbally indicated by some companies who have experienced problems in upgraded software but it should be noted that releasing 'problem software' is not in the best interests of the software house. Probably those companies which consider that is what the software houses are doing are really blaming the software for their own problems which are possibly due to insufficient training.
The number of companies that expressed difficulties in working with the software and which gave
eexamples were few. One company criticized the speed of operation which could be due to poor
choice of system or to poor management of the system. It was not possible to ascertain which.
Another company criticized the operation of the package with the operating system which might
suggest this company bought the software and the hardware separately.

Training Problems
The respondents who did express their problems showed them to be symptomatic of problems found
by others as illustrated by the article by Hannington. On one hand, they considered their training
too short or inadequate and on the other hand some found the time too long before they became
operationally effective. The times stated at one end did seem very short and certainly it could have
only been superficial and the operator would need familiarisation time afterwards. This is highlighted
in the works by Port and the reports by the Institute of Mechanical Engineers which although
aimed at the construction industry make points which are applicable to all CAD systems. Research
suggests that experience will be gained after a training period and initial practice should change into
serious project work later. Actual build-up in operator's speed will take from several weeks to months
depending on the operator's learning ability and the complexity of the software chosen.

Two factors are either forgotten or not known:

1. Periods of time by designers away from the CAD system erodes their working speed
   and efficiency;
2. Due to the constant updates in software, learning will be an ongoing process - a fact
   which came through from some of the replies expressed in other parts of the
   questionnaire.

One comment from someone who claimed to be self-taught shows the weaknesses which probably
exist in all self-taught CAD operators. He claimed he was unaware of the proper efficient work,
functions. The quality and method of training were also issues that were raised by the questionnaire
and this must have an influence on the usefulness of the system at a later date. A factor which must
also put a question of doubt in some peoples' minds about training when considering whether or not
to go to the expense of implementing it. This might explain the high response rate to the self-taught
option. A further point which shows the weaknesses that probably exist in all those self-taught CAD
operators which was made by an operator who proclaimed to be self-taught was that he was unaware
of the proper efficient working functions. While this one comment prohibits drawing any significant
conclusions about self-taught personnel it must surely be a clue as to the possible 'state of being' for
the other self-taught personnel. Should this be the case then this point must surely be justification for training if you are going to run an efficient system, especially if you want to carry out a close scrutiny for financial arguments in the cost effectiveness of a system.

Problems in keeping to the time allowed to choose the system
While some companies expressed that there were problems, only one company elaborated further. This company made the comment "Planning CAD management as everybody wants stuff now". This shows that this company seemed to give very little importance to managing the system but wanted work from it immediately. This company, which is similar to many others in its attitude, probably does not really consider CAD management as a productive exercise. There are many references to the CAD manager's role in books and articles being published on the matter, suggesting a recognised need for this new role. Technology changes in the past have always negated some roles and created new ones; CAD is no exception.

Problems with System's Performance
One response which is typical of the most common mistake is: -
"The need for computer power was underestimated."
This is a problem that is often discussed in publications on CAD. The problem is also seen as a sign of a lack of efficient preplanning/forward thinking by the companies.

2.4 The Second Questionnaire

2.4.1 Purpose of the Questionnaire

The purpose of the second questionnaire was to find out, in more detail, how those companies chose the system, their reason for using CAD, and how they managed the system with regard to their staff.

2.4.2 Structure of the Second Questionnaire

The structure of the second questionnaire and the questionnaire details, are more accurately described in Appendix III. The questionnaire asked the companies to answer briefly to each of the questions. Regrettably some of the questions allowed companies to respond with a simple 'Yes' or 'No'. The companies chose this way of responding and gave no further reasons to back the statement up in each of the questions. This unfortunately limits the information returned. However, some of the questions were worded in such a way that the companies had to answer in more detail. Some companies still responded with a 'Yes' or 'No' to these questions as well. So while this flaw in
the questionnaire could be subscribed to poor construction of some of the questions, it cannot be applied to all the questions.

Some of the questions were similar to those in the first questionnaire as it was intended to compare the companies' individual responses in each of the questionnaires when examining the information in more detail. This was to be applied in some, but not all the cases.

2.4.3 Responses to the Second Questionnaire

The detailed responses can be seen in Appendix III.

2.5 Discussion of the success and failure of the questionnaires

Generally, the response rate of the questionnaires was successful and the companies did not have much difficulty in answering the questions. The information gained was very enlightening and provided a substantial amount on which to base my conclusions. In many cases this was further substantiated by articles on the subject and also by carried out by other researchers. However, some questions were not always answered by companies but this was in a random manner which suggests that it was their choice and not because they could not answer the question. Question twenty three in the first questionnaire was badly answered so it was rephrased and included in the second questionnaire with a more successful result. This suggests that the question was poorly constructed in the first instance. The other criticism that should be made of the first questionnaire is about the layout. There were some questions where companies wanted to give more than a "Yes" or "No" response. Usually they included a more wordy response at these questions. These were often very illuminating about the issues which were really in need of further work.
3.1 Industry in Scotland

Industry in Scotland tends to be in the category of the small to medium company size, with a bias on the small size. The bigger companies are almost exclusively part of International conglomerates but work independently, producing specific parts of a range of goods or particular services specific to that branch. Where the companies have "design" as their output they tend to be in the small category and carry out design roles such as Architects, Interior Designers or Industrial Designers. The only possible exception to this is where the design company has a secondary manufacturing capability producing some of its own designs. So with all these factors having an affect, CAD is not at present a prerequisite for everyone.

The respondents who were not using CAD could be slotted into one of the following categories:-

**Type of work**
- Low design input that would justify the CAD related costs.
- Due to company size and structure it is still quicker/more cost effective to carry on with manual methods.
- The current working role does not require a CAD input.

**Working Practices**
- Design input is taken from outside the company either from an independent source, clients' own designs, or from another company in the corporation.
- The company has established an efficient working format which they cannot implement on an affordable CAD system.
- The company is poorly organised and introducing a computer system would only compound the problems because the company is unable/ not willing to organise itself.

**Money**
- The company does not have the annual income to afford a CAD system.

**Control**
- Some companies worked without CAD as they felt they would lose control of the work being carried out and that islands of activity would arise with the management of the work becoming
impossible.

This assessment was derived from:

- The questionnaire responses
- Meetings with the SDA and the Design Council.

Some companies stated that should conditions change this would alter their assessments about CAD suitability. However, some with CAD have had problems with it, attributable to inadequate emphasis on the planning and selecting stages.

3.1.1 CAD and the Company Size

When it could be seen that a company’s working activity was not conclusive to determining whether a company used CAD the results were evaluated to see if there was any correlation with CAD usage and company size.

The following listing gives an illustration of the maximum and minimum sizes of company types in their work types to be found in Scotland that are using microbased CAD and examples of companies in other categories for comparison. A listing of the range of company size participating in the questionnaire can be seen in Appendix IV.

**ACTIVITY**

**Design Consultancy**

The work types under this heading are varied and could be consultants in Industrial/Product Design, Interior Design and Graphic Design. There were no Mainframe/Mini system users in this work type group.

<table>
<thead>
<tr>
<th>Maximum</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Consultants (Industrial)</td>
<td>22</td>
</tr>
<tr>
<td><em>(AutoCAD, OrCAD)</em></td>
<td></td>
</tr>
<tr>
<td>Design Consultants (Interior)</td>
<td>16</td>
</tr>
<tr>
<td><em>(DrafixCAD, DrafixCAD 3D Modular)</em></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Minimum</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphic Design Consultancy</td>
<td>5</td>
</tr>
<tr>
<td><em>(Adobe Illustrator, Streamline, Pagemaker, Microsoft Word, Hiscan, Visionscan)</em></td>
<td></td>
</tr>
</tbody>
</table>
No CAD but Interested

<table>
<thead>
<tr>
<th>Maximum</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Consultants (Interior)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Minimum</th>
<th>1-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Consultants (Industrial)</td>
<td></td>
</tr>
</tbody>
</table>

No CAD no Interest

<table>
<thead>
<tr>
<th>Maximum</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphic Design and Interior Design Consultants</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Minimum</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphic Design and Interior Design Consultants</td>
<td></td>
</tr>
</tbody>
</table>

Regarding the group as a whole, then size is no determining factor for deciding who has CAD and who has not. However, when viewing them as individual work types, that factor changes:

- Industrial/Product Design - size is a governing factor, with the smaller companies not having CAD.
- Interior Design does not show that size is a factor. In this case the results suggest that the usage of CAD is determined by the work speciality carried out and/or by personal choice as to working preferences.

Engineering

Microbased

<table>
<thead>
<tr>
<th>Maximum</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacture of Tyres</td>
<td>1200</td>
</tr>
<tr>
<td>(Harvard Graphics, Logotec (Mechanical), Eplan (Electrical))</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Minimum</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigeration Consultant and Block Ice Manufacturer</td>
<td>3</td>
</tr>
<tr>
<td>(Model Universe Design CAD)</td>
<td></td>
</tr>
<tr>
<td>Comparison Companies</td>
<td></td>
</tr>
<tr>
<td>1 Designers, Manufacturers, Suppliers of Packaging Products</td>
<td>240</td>
</tr>
<tr>
<td>(Generic CADD)</td>
<td></td>
</tr>
<tr>
<td>2 Industrial Refrigeration Plant Design Manufacturer and Installation</td>
<td>100</td>
</tr>
<tr>
<td>(AutoCAD)</td>
<td></td>
</tr>
<tr>
<td>3 Mould Makers for the Plastics Industry</td>
<td>20</td>
</tr>
<tr>
<td>(AutoCAD, Tool Designer)</td>
<td></td>
</tr>
<tr>
<td>4 Manufacture Plastic Injection Mould Tools</td>
<td>15</td>
</tr>
<tr>
<td>(ACAD, PEPS CNC)</td>
<td></td>
</tr>
</tbody>
</table>
Mainframe/Mini

Maximum
- Design, Manufacture of Avionics Equipment (CAMX, AutoCAD, Scicards, Mentor) 6000

Minimum
- Underwater Equipment Design and Manufacture (DOGS) 4

No CAD but Interested

Maximum
- Manufacture Precision sheet metal components 150

Minimum
- Design and Manufacturer Moulds for Injection Moulding 22
  - Comparison Companies
- 5 Vacuum Forming and Toolmaking 15

No CAD no Interest

Maximum
- Roll and Finish Aluminium Coil & Sheet/Cut to Length 350

Minimum
- Sales and Service Pneumatic Controls 3
  - Comparison Companies
- 6 Precision Sheet Metal Work 33
- 7 Specialist (CNC Precision Machinery and Welding and Fabrication) 24

This work type group had the most varied range of working activities which made exact comparison difficult and sometimes even impossible. I therefore compared the closest comparable company.

Interesting features of this section are:

1. A Refrigeration Consultant with only three employees was using an American 3D package not commonly found in the UK while a larger similar company with one hundred employees was using AutoCAD which is also 3D. AutoCAD would have been more readily obtainable and the acquisition of information about it would have been more easily obtained.

2. Two companies without CAD and which worked in sheet metal were interested in CAD because some CAD packages offer add-ons that convert drawing information to usable cutting instructions for highly accurate cutting equipment. This would really affect working practices and possibly reduce the size of the workforce.

3. One company using CNC equipment for specialist welding and fabrication work had no interest.
in CAD equipment as their instructions for the operations are carried out by a part programmer. Another company which used CNC equipment, albeit for a different process, had its drawing information converted into a part program using computer software. So presumably the specialist obtains his part information from drawings supplied from the outside and it is not convenient to translate drawings from a computer source except through printed sheet. Comparison could only be made between comparison companies 3, 4 and 5. This showed that company size was not a determining factor as a company of size 22 employees did not have CAD and two companies, one of size 15 and one of size 20 did have CAD. Since the nature of their work was similar the reasons for using/not using CAD must be due to other factors such as financial/expertise.

There are variables which are not covered by the information obtained from the questionnaire and no one variable can be seen as being mutually exclusive of any other variables. However, using company size does give a rough rule of thumb guide for making assumptions about companies which were not involved in the survey and whether or not they use CAD.

Another factor concerning companies which do not use CAD might consider that their company is too small to contemplate using CAD and therefore go no further in assessing whether or not it would be advantageous to them. In this case, size just might be a deciding factor. This is quite possible, considering that the government has been pushing for the growth of small businesses and Scotland is one of the areas where small businesses predominate within its industrial manufacturing category.

The first questionnaire established that the various industries could be classified into three categories:

1. Computer Illiterate
2. Computer Beginner
3. Computer Expert

Category One would describe a company which is currently not using computers and has no idea what this technology offers them.

Category Two would describe a company which has just purchased a system or is in the process of purchasing one.

Category Three would describe a company that has been running a system for a period of years.
CAD is not the solution to every company’s problems nor is it necessary for some companies to have a design facility but some engineering companies which always manufacture other peoples’ designs do have a CAD facility as a service to its clients.

My research shows that CAD is fast influencing those areas of work which currently are not directly associated with design activities. Since CAD is increasingly becoming the source material for ‘Bill of Materials’, Production Processes and is itself becoming reliant on the input of computerised information. The cone of influence of CAD is fast resembling all the areas of interaction and influence which "Manual Design" influences currently.

While CAD does not merely mean Computer Aided Draughting the responses from the companies to the two questionnaires showed that it was this feature they thought about when purchasing a CAD system.

Microbased CAD outside of Engineering circles is only recently becoming usefully employed interactively with aspects of design other than draughting. So CAD will eventually affect companies which in the first questionnaire stated 'No CAD no interest'.

3.1.2 Employment Trends

In conjunction with earlier studies for Britain and the results of the questionnaire, it is shown that the trend for CAD usage is on the increase. Even excluding the financial depression and subsequent slumps in industry growth, it is apparent that CAD will be increasingly used. One aspect which needed to be evaluated was employment trends. This was achieved by contacting Employment agencies in Central Scotland to see what demand there was for personnel with CAD experience in Scotland.

The overall response was that for those agencies dealing with recruiting technical staff, CAD experience was certainly an asset. The agencies as a whole declared that the demand for personnel with this experience was certainly increasing. In some regions of Scotland, the demand was higher and salary levels tended to reflect this. The highest paid were in and around Aberdeen. The Central belt was showing an increase in activity and the salary levels for this area were on the increase, particularly around Glasgow and Edinburgh. The most sought after skill is draughting with little demand for any other skills such as macro programming or CAD Management. Areas such as these tend to develop as computer systems grow.
The agencies tended to specialise in particular work areas such as Building and Services Engineering, Electrical Engineering or Mechanical Engineering. It was apparent that certain work types had different rates of change, some were even on the decline. One agency saw Scotland's industrial sector as something of a "branch plant economy" and that most CAE skills led to positions south of the border or to North America. The rebirth of the Oil industry in Scotland has caused the increase in demand for CAD experienced personnel to supply the Oil producing companies and their major contractors.

The agencies all said that most medium and large high technology companies now utilise CAD and CAE tools and that they operate a mix of Mainframe and PC based systems. The questionnaire showed that even small companies were becoming involved with the requirement for CAD and CAE skills as well.

The most used draughting package was AutoCAD and the signs were this was still increasing. This follows the overall pattern in Britain and reflects on Autodesk's marketing skills and tactics. This continual increase in AutoCAD usage also shows how it is being regarded as an industry standard by companies throughout the whole range of Design activities. Other packages mentioned by the agencies were Computervision, Mentor, D.O.G.S. and PDMS. These being used for applications in the Electronics, Petrochemical and Mechanical Engineering sectors.

What this information shows is that in those industries where CAD is being used as a draughting aid there is a growth in usage. The employment agencies could not give any information about employment trends in Design consultancies as they had little dealings with this line of work. There is very little sign of trends through job advertisements in the Scottish region as there were next to no relevant advertisements in the newspapers. The few vacancies there were, apparently being filled by word of mouth. The economic climate at the time this review was carried out was very bad and talks of an ever deepening recession were plain to see and job losses were more the trend than job vacancies. A more country wide review showed very little difference to vacancies of this type. There were some advertisements but not nearly enough to make any differing conclusions than that made from trends highlighted by the employment agencies. Other sources show that Industrial Designers were getting work in Mechanical Engineering and manufacturing companies. Regarding the usage of CAD this study of the Employment agencies shows that it mirrors the fact that 90% of the CAD industry is still geared up for draughting aids as opposed to other CAD applications.

The reasons why CAD is being used are market pressures and working practices with the inevitable outcome that CAD usage is increasing. Also because of industrial changes there are more smaller
companies which is particularly true for the Scottish sector. Combined with the cost of more powerful computers, most of the companies are opting for Microbased computer technology. Performance aspects of the micros was always promising to be better and at the time of writing there is a grey area where micro technology ends and mini technology begins.

Responses in the questionnaire showed that companies were purchasing a system to prevent an increase in staff rather than to reduce staff and these results are backed by work from people, such as Arnold and Senker1 and Boyd Davis2. At that time CAD was seen as a way of overcoming a shortage of Draughtsmen/Designers, although there was some concern that it could eventually lead to a reduction in staff numbers. Now the trend is that CAD allows people to do more work, which in turn allows them to be more productive so rather than decreasing staff it generates more work, thus maintaining staff levels. However, with the recession this means no new work for others wanting to work in this area.

The other tendency is that the designer spends more time working on more alternatives to any one design thereby improving the final quality of the design. Therefore, the project is handled in the same amount of time as if done manually but its content will be better, rather than the designer handling more projects. However figures do show there is a reduction in job opportunities at the bottom of the drawing office hierarchy3. One article concerning an Architectural practice illustrates this point very well4.

When companies have introduced CAD, employees have not suffered job losses; quite the reverse, they have enjoyed greater job security, better pay and improvement of their position in the company5. At the time of writing the industry is going through a difficult financial period and what traditionally happens in British industry is that Design work is reduced or stopped and Design staff are laid off. Companies might find it difficult to compete and become bankrupt. It is not evident from the questionnaire that this is happening but the signs are that Industry is maintaining staff levels rather than reducing them and that other figures show there is only a reduction of new graduate employment.

3.1.3 CAD Usage

Once CAD was regarded as the answer to all problems but this attitude has changed, almost in line with the growth of CAD usage. This is due to an increasing awareness in the implications of using CAD which has given realistic figures of performance and benefits that can be obtained and not the theoretical benefits that were once advocated. There is an appreciation that CAD is not the correct
solution to every company’s needs, especially under current conditions. To some it would be a recipe for disaster.

Those starting up in CAD for reasons such as "everybody else is getting one" or "it would be nice if" also tended to give less thought to the planning and selection stages. While companies can perform their work function competitively with others who have CAD then the former reason is not a very good reason if balanced against financial costs. The latter reason just does not make economical sense at all. Conversely those with more practical and business-like attitudes spent more time in these early stages as seen by the responses in the questionnaire.

The level of use of Microbased CAD within industry is limited, partly due to the relatively recent advent of suitable powerful equipment and partly the limitations of current software. Based on my research, through magazine reviews of CAD software, and the publication by Richens6, I have come to the conclusion that currently software has been able to handle the draughting levels of the design process but it has not managed to meet the demands for intuitive conceptualising and realistic visualisations. This is indicated by the fact that dedicated workstations were used only for that purpose. Software for micros came a poor second. The increase in power for micros means it is becoming more viable for the conceptualising stage as indicated by the drive of the computer industry to fill this gap in the Design Industry. The conceptualising stage is still the hardest to those practicing the programming arts to answer, in the form of a rigid computer program.

The questionnaire went out to basically two types of industry; Manufacturing and Construction. The work carried out under these headings could vary quite considerably as could the design content and the level that the work type entered the design process. The companies which would like the ability to carry out the conceptual work on the computer were those who could be classified as Architects, Interior Designers and Industrial Designers. Building and Services Engineers and Engineering draughtsmen tend to start at a more finished level. This level is currently the mainstay of CAD packages.

The difference between the two industries is that the Manufacturing Industry can use CAD Information directly into the manufacturing phase where for the Construction Industry this passing of Information can only go so far down the computer aided ladder. So in the Construction Industry it is an isolated activity.
3.1.4 Current Patterns of Application

The market research company 'Dataquest' carried out a survey concerning the CADCAM/CAE industry world-wide\(^7\). It found that despite the economic state of the financial world that:

- CADCAM/CAE industry has grown by 16% in 1990
- It predicted the market will enjoy a 13% compound annual growth rate for the period between 1989 and 1994.

The company believes that there is a strong demand for all applications in established international markets and that with the approach of 1992 this is affecting investments made in CAD and manufacturing technology. "CAD/CAE software revenues are expected to grow faster than hardware." Dataquest expects that software will account for 34% of the market in 1994, where in 1989 it comprised 27% of total revenues. The survey showed that host-based systems are declining as users move increasingly towards workstations and servers. Dataquest forecast that the mechanical sector would have the following growth rate:

<table>
<thead>
<tr>
<th>Mechanical</th>
<th>MCAD - 9%</th>
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This growth rate is from 1989 to 1994

Penetration levels approaching 30% overall, closer to 50% for draughting applications. These are seen to have some significant prospects to exist in upgrading/replacing the fast growing population of systems of more than three years old. Major end-user industries are expected to experience modest growth in the next few years.

To outline possible patterns of application of Microbased CAD for end users in the educational, private, and public sectors, I have based them around current trends and possibilities.

**Financial Influences**

At the time of writing, the country is going through a period of recession and with high interest rates there is very little extra money for development schemes for either the purchase of goods or for training. This has slowed down the growth of any potential CAD usage outlined by institutes such as the Engineering Industry Training Board. However, while it has slowed generally, for those companies with the financial resources, it has allowed them to buy more complex systems than they first anticipated. Actual prices of hardware have dropped quite remarkably making high-end
performance machines to be within the grasp of some companies. Developments in technology and changing configurations of computers have also brought prices down for lower end computers. Overall, I expect these lower prices to become the norm and that prices will not increase once the recession is over.

Software prices have also lowered and competition for customers has been high. This I believe is reason to think that within the next few years, some of the software houses will cease working and some form of market-inflicted rationalisation will be brought about. So, with fewer packages to choose from, the surviving packages will be used by a wider range of industry types. If the user-base broadens, then there might be a need for more specialised add-ons to the packages.

There are still indications in sectors such as Architecture, that staff with relevant CAD skills are being rewarded with higher wages to attract them. This means for companies starting up in CAD they should consider increasing their relevant staffs' salaries which is another cost influence needing to be balanced by companies assessing if they want a CAD system. The implications for the future is that design time on a product will be effectively more costly even without considering other factors such as inflation.

**Computer Systems Developments**

The computer market in general is an ever changing environment concerning both new hardware technology or new software techniques. This is also true for CAD operations and the choice of CAD computer systems. Irrespective of the final system which a company has just bought, if it were to carry out another review, then it would see something even better than its first choice.

**Trends based on System Developments**

In the 1970's, CAD was exclusive to time shared Minicomputers and this was primarily due to its processor power and graphics capabilities. Minis developed in terms of networking applications and the promotion of open systems which introduced the Unix based system. These factors, combined with the attraction of multi-tasking in CAD applications, have been why CAD has maintained a feature in Mini based systems. One final factor is that all leading suppliers in workstations all utilise Reduced Instruction Set Computer (RISC) technology. This lends itself to techniques for speeding up processing. The weakness in Unix systems is the difficulty of attracting applications and has a limiting choice. This limiting factor is a pitfall to those opting for CAD in this area. However, there are indications that software is developing which will open up the Mini market. The Software House
which highlights this is Autodesk's move to have a Unix operating version of AutoCAD. This is a leading DOS based package which has numerous additions to the basic package and interfacing applications which makes it an attractive choice for a wide range of CAD users. Should this all be channelled through, then there may be signs that Mini systems might compete heavily with Microbased systems in the future.

Currently, there are still a few CAD options which are better suited to Mini based systems such as high-end graphics and animation options. So Minis are competing in the same market area which is currently opting for Microbased systems.

One of the strengths of the Microbased systems has been the wide choice of applications and the software portability across hardware from many different vendors. Initially Microbased CAD appealed to the lower end of the market where price over performance was the leading criterion. P.C. development through the 1980's started to acquire the traits of the traditional workstations. The graphics cards became of such a quality that they could satisfy CAD demands. P.C. networking developed sufficiently so that they could compete on the same level as workstations. Finally the processing power became level to that of workstations. So with the development by Intel of the i486 processor, utilising CISC technology meant a Microbased system could compete on equal terms with any SPARC station. It is reported that there is now no longer an order of magnitude between workstations based around RISC technologyB. This article by HemmingsB further stated that the benefits obtained by using RISC are reduced to zero. However, P.C.'s cannot compete with SPARC servers. These are quoted as offering in excess of 20 mips. The article goes on to say that with the development of Symmetrical Multi Processing (SMP) technology, the combination of two i486 processors can offer 25-30mips. So, for future implications, it can be seen that even current Microbased technology can compete with Mini based technology. It could possibly allow the introduction of high end graphics and animation into its capabilities within the foreseeable future.

The article by HemmingsB quotes a survey carried out by RM technology which showed that more than 50% of CAD users utilise P.C.s as their exclusive platform. It also states that over 70% of P.C. based CAD applications are performed on i386s which HemmingsB suggests the relentless pursuit of more processing power is becoming a less significant factor. He also states that P.C. applications address an audience 100 times greater than that of Unix.

The above has some implications.

1 First there is a much wider scope of software available.
2 The competitive nature of the P.C. applications market produces a wider range of products which are often of higher quality than their workstation counterparts. This is beginning to be emulated by P.C. CAD software. They have extraordinary functionality at a highly competitive price.

3 The P.C. application development driven by a larger potential market ensures that the marginal performance benefits offered by some workstations are more than balanced by the superior quality and wider range of software on P.C.s.

4 If the increase in networking within offices carries on, then P.C. CAD machines will be used increasingly for office productivity. This, Hemmings\(^8\) says is an area in which workstations cannot compete favourably.

Hemmings\(^8\) article goes on to say that from his research, he thinks that the CAD user is no longer in search of more processing power and that the P.C. can compete favourably with work stations. What it means is that the CAD user can choose the machine which is capable of doing what he wants now. Undoubtedly, Microbased technology will develop further and its capabilities will be further enhanced allowing the users to make their own decisions as to what system to opt for.

Hemmings\(^8\) predicts that the 1486 machines will take over as the major product supplied in the CAD market place, with no pre-determined place for the workstation, except in high end applications. Even these areas might become seriously contested by the Microbased machine if its development continues at the rate it has been developed in the past 20 years.

**Areas of Application**

The research I am conducting is primarily involved in Microbased CAD for the Product design orientated companies. However, from the work I have carried out so far, and from responses from the questionnaires, I have seen that there are other users of CAD whose prime function is not design but rather the manufacture of goods. There are indications that there is growth in this area of CAD usage which will have spin-off effects to design orientated companies. The obvious one would be that if the growth continues then these companies will act as further market forces to those companies which do not at present use CAD in their primary role.

This secondary role needs a little more explanation. Companies which see themselves as subcontracting manufacturers, or mould makers, have said that they are using CAD information as an input to their own manufacturing processes. This information is supplied to them by their clients and installed onto their own machines and down-loaded to the shop floor. These companies then went on
to state that they do not run a design office as such but they do require a system for CAD work as an initial step of their production ladder. Should this trend increase, then as it spreads, there will be an increase in demand for CAD information. The only people who will be able to use this facility will be companies with their own Computer Aided Design System. This would increase turn around times to a client's specification for a product and increase the client's own expectation for faster turn around times. So for those design consultancies and design offices without CAD facilities there will be an increase of market pressures for them to obtain such facilities.

One article that highlighted this opinion suggesting the usefulness of an integrated system was in the publication Computer Aided Draughting and Design. In this article by Terry Dawson\textsuperscript{9} he examines the effects of integrating CAD with related activities currently not using CAD.

Dawson\textsuperscript{9} goes on to discuss how beneficial an integrated system would be and shows how it would link departments of a multi-disciplinary practice.

There was one company which came under the 'No CAD No Interest' category which manufactured and installed Double Glazed Replacement Windows, Doors and Patios. The company used standard parts and fittings matching them to the individual needs of each customer. The work required some drawing tasks to derive sizes so that the window units could be manufactured in the factory and then fitted on site. Here is one case where a company could use CAD. They could derive a library of standard parts and then rapidly draw up the drawings as required. Alternatively, using functions of current draughting packages they could now have standard drawings held in memory which they could call up and modify quite rapidly. Initially it would be slower than manual methods but eventually it would be quicker even for one-off designs, simply because they use standard fittings. Combine this with Computer Aided Manufacturing equipment and this company could easily be improved by the use of computer technology. This is just one example of how a company could change its working methods to improve its output.

**Combination Systems**

Currently there are companies which, through the advantages of networking, combine computer systems linking Mainframes to Micros, Mainframes to Minis, Minis to Micros. This allows them to utilise the current advantages within each system into their working practice.

While Mini computers still have advantages over Microbased computers, I believe there will be more combined systems to allow the wide range of CAD packages to provide initial design work. The
information is then translated and down-loaded to a Mini so that high-end CAD applications can be carried out. For example, Finite Element Analysis, Animated walk-throughs of buildings or high-end Graphic representation of products, interiors or buildings. There are signs that Architecture is going in this direction and certainly this combination of packages could be used for Industrial Designers on high profile contracts. So one future trend would be for more mixed systems being used by companies already involved in CAD particularly those using only Microbased systems.

The result of the questionnaire showed that most companies regard CAD as nothing more than a 2-Dimensional Draughting Tool. This is still the largest aspect which the CAD industry caters for.

There were companies which used 3-Dimensional CAD for its analytical properties. However, few used it for any other reason which is apparent by the returns to the question asking what software packages they used. Very few used it for the final presentation of ideas.

The current patterns of application of Microbased CAD can be shown by examination of responses to the questionnaire. This can be summarized by the following:-

1 CAD is increasingly being used by Industry.
2 The CAD systems are mainly unconnected to a DTP package.
3 Most companies using CAD used a Microbased system.
4 Most companies used their computers as a stand-alone system.
5 The software used was generally "off the peg".
6 The reasons that companies chose to use CAD were based around staffing levels, Work output/Control, "Only way possible" and "Regarded it as the next logical step in the office's way of working".
7 A company's main reason for their particular system was its ability to be upgraded in terms of new software to match changing company needs.
8 Companies wanted existing staff to learn how to use the system and staff were trained for a short period by the seller.

3.1.5 Just what is being used in terms of software and hardware?

For the uses to which most of the Scottish companies are applying CAD, it is more cost effective to use microcomputers. I will only be comparing the areas grouped under the headings of Design Consultancy and Engineering.
**Design Consultancy**

All the companies coming under this title used solely Microbased computer systems, four of the companies were purely graphic design studios, one other studio carried out graphics and exhibition design, one of the four also acted as an advertising consultancy. There was only one Interior Design Consultancy and one Industrial/Product Design Consultancy. The Interior Design company packages were from Drafix and the Industrial Design Consultancy used AutoCAD for draughting and OrCAD for its electronics side of the business.

**Engineering**

This work group used the widest range of software (as can be seen in Appendix V) under the heading of draughting. This is entirely due to the wide range of specialities covered by this general heading of Engineering. Twelve out of twenty three companies were using AutoCAD. Surprisingly there were no Finite Element Analysis packages and the only software I grouped under Analytical was for an electrical package used by one of the companies and a package for CNC. Only one company gave a name for a Desk Top Publishing package although two companies said they used such a system. The same company also used a word processor. There was more variety under the heading Organisational Tools, some were packages for the Computer Aided Manufacturing side of their work and some for disk/file utilities. There were more Engineering companies which used more powerful computers but again they were used for Draughting and although some were of the 3D variety there was still no FEA. Five companies used a DTP package, two companies used a GNC package for the production side of their work.

### 3.1.6 Areas where problems were encountered

**Problems Encountered**

One of the problems that the companies reported was finding the time to learn the CAD system. Trying to learn the system in an *adhoc* basis would mean the actual time on the computer system would need to be very effective as time is a valuable commodity to businesses. This is one argument for separate college departments offering CAD training on the same package so that examples used are more closely linked to the people attending unlike the present situation where, for example, AutoCAD is given to Engineers, Architects and Designers all in the one lesson. A more simple solution would be for the tutor to be more responsive to the classes’ needs and working the instructions to suit each particular class.
Mistaken Fears

Concerns had been expressed about what the introduction of the new technology could mean to their company, such as project control and others such as job security and deskillling. This shows that CAD does have other issues other than simply what computer program to purchase.

Some people claim that deskillling happens with the introduction of computer technology to the design office. They also claim that the "Expert systems" which are being introduced mean that designers will need to know less. It cannot be argued that computers will not bring changes to working practices and it obviates the requirement of skills such as technical draughtsmanship. However it can be argued that it necessitates the increase of other skills such as numeracy, analysis and creativity.

Technology has altered the roles of the designer in the past and since a computer is no more than a technological change, it is no different to other past technological breakthroughs. The loss of skills which is happening are in craft skills which in the past have been used by the designer to communicate to others what his idea will look like. So computers are only really changing the media within which this communication takes place. For example, instead of working on paper or with wooden models, the designer will be working with "electronic representations" on screen and only producing hard copy work nearer the end of the design stage. The media he takes to his client in the future will be the floppy disk or its future equivalent and not a set of prints and renderings or bulky models. In the article by Stewart Bickel it shows that companies have concerns about what CAD can do to peoples' jobs.

This article also shows concern about the output of CAD and the quality of drawings.

"We'd been horrified by some of the demonstrations of so-called architectural drawings some of the manufacturers come up with, and we didn't want to produce drawings that looked as if they'd been done on a computer."

In an article by Eckersley Benedict Austin of the UK Design Council is quoted as saying:

"The computer is becoming an alternative to the pencil. Its used for drawing, perspective, renderings and presentation sheets, and has permeated all areas of design. ...It's vital for the future of CAD that designers learn to produce such designer-friendly software, rather than relying on boffins to do it for them!"

The design content will be the same or even better because the speed of operation will allow the designer to evaluate more variations, thereby improving the quality of the design. The end product will be the same i.e. whether it is a hairdryer designed from manual methods or from computer aided
systems. The one aspect that is not possible by computer (at the time of writing) is the appreciation of the tactile qualities of any given product.

**Selection Process**

Mistakes which can occur when people are assessing a CAD system are:-

1) When the output of drawings is seen as the final objective and not the completion of the design solution, so they opt for the cheapest software solution that concentrates on drawing production. This tends to give the least benefits from CAD by realising their systems true value.

2) The use of traditional costing systems is a mistake. Traditional cost accounting systems based on utilisation and cost per part are outmoded concepts and are not suited to the justification for, and the assessment of, CAD systems. New systems which reflect the real world have to be used. The benefits which are hard to quantify in precise monetary terms when assessing the merit of a system should not be forgotten.

3) Assessments on a CAD system's performance can also occur too early on when the drawing office is still in the learning period and is not up to full working speed. This occurs when a company's funding is tight and it wants quick evidence that its investment is proving itself. The sales pitch given by salesmen when selling their system often state that after their included training programme the operators will be fully conversant with the system. This training period, as is shown later on, is subject to varying interpretation and standards. This early assessment gives a false impression. Often they exclude the time that operators need to acquaint themselves with the system after the training period to get up to full operating speed. It is one thing knowing what the commands do and another being able to work with them efficiently. It has been shown that during the early stages, productivity of work will be slower than traditional methods and if the assessment occurs then, it will be an inaccurate appraisal of the system.

4) Companies do not always associate the system's performance with the quality of their management. If the management is poor then this will also affect the system's performance, irrespective of computer power and software performance. The management would be comprised of the following:

1. Practice management - the organisation
2. Project management - the design process
3. System management - hardware/software/data handling, operators, support and maintenance.
System
The problems mainly consisted of mechanical faults with the hardware, software, bugs and inadequate training sessions.

The software chosen did not completely satisfy the software requirements of most of the companies.

Financial Problems
"Design is difficult to quantify and to justify". This attitude is on the decrease but it still persists. This reaction to new untried designs lingers in British Industry so when asked to justify new equipment for CAD, performance figures raise their heads and reduction factors are often quoted. This, to the people in the decision making sectors in the industry, means less staff and anything that keeps staff levels down is a very valuable asset. New equipment is expensive but it is viewed as a one-off bill whereas staff require wages and are therefore a financial burden. This is why job losses really occur and not simply because the company has introduced computers. They disregard the fact that more design work could produce more and better designs, increasing their ability to compete in a tightening market instead of current level of activity. However, the rising demand for CAD skills is on the increase as illustrated by Carroll\textsuperscript{15}.

Problems with the training
The questionnaire established that most training consisted of a "short training period by the seller" with the operator backing this up with a period of self teaching. Alternatively it was backed up by a third party teaching concern. The tendency however was not aimed at anything further than the short term learning period.

The exchange of computer generated drawings between companies is also on the increase and when companies are using \textit{de facto} standards such as DXF files, they are finding that what is presentable on their screen is not being converted correctly into DXF format when it is introduced into another system due to people not operating the necessary drawing practices in CAD to get a suitable translation, as a result of inadequate or no training on the system. The systems used allow people many options to carry out a drawing but some ways are more efficient. This again comes back to proper training. It would seem from the results of the questionnaire that it is doubtful that this is being achieved.

One of the problems with CAD is that software is consistently being upgraded/improved and if industry is to keep abreast it has to realise that CAD training does not just happen at the beginning of its introduction but that it is an ongoing or at least a recurring necessity. Industry cannot therefore
expect places of education to supply them with fully trained people and that industry itself is going to have to implement a training strategy within each company to keep its employees up to date.

A summary of the problems highlighted by the research can be shown by the following:

- Length of time before becoming productive.\(^{16}\)
- The time for getting experience between courses was too long.\(^{16}\)
- Cost of courses was too high.
- The content of the courses was too much for the short time allowed for them.
- Companies experienced difficulties in organising staff to get time away from their main working tasks within the company.
- Organising time to practice with the system.\(^{16}\)
- Companies found that they had to change their working methods to comply with the chosen software.
- Difficulty in understanding the manual.
- Training given was not effective on user techniques.\(^{16}\)
- Short training times made familiarisation with the various commands difficult.
- Some who were self taught doubted if they were working and using the system efficiently.\(^{18}\)
- The training did not take account of the range of CAD experience of the trainees.\(^{16}\)\(^{19}\)

In answer to the above, training sessions should be:

- Relatively brief.
- Interspersed with periods of practice to consolidate skills.
- The time and duration of the training should be carefully considered to avoid any loss from the usual gains from training. For example:
  - Little benefit will be derived from intensive one-and-a-half or two-day training courses such as typically offered by suppliers.
  - New skills may rapidly decay if there is no opportunity to use them. This should be remembered if a delay occurs between training and installation.
3.2 Training

3.2.1 Education or training

"Training" is the imparting of specific skills to handle a specific task i.e. Learning to use AutoCAD. To "educate" means the overall explanation and understanding of how a topic is presented and given. These two issues are the starting point for other points of discussion which I intend to cover in detail later on. Currently industry's use of CAD is increasing and in the article by Carroll15, he states that this is causing a skills shortage which is bringing about problems:-

1. The short term effect of the skills shortage is to push salaries higher as companies compete to get the staff they need.
2. Due to the potential for inflated earnings, Computer Sales departments can poach qualified people from user companies.
3. To correct the skills shortage, Colleges are responding with increased course coverage in CADCAM and this in turn creates a need for teachers of this technology.

Levels of training

There are two basic questions which have to be asked in relation to training when preparing to use a CAD system.

1. Is there a need for training?
2. Who needs to know what within the company?

Question one is concerned with personnel who are familiar with CAD systems and in particular with the one being chosen. The second question is concerned with just what do people need to know in order to carry out their new roles.

In answering the second question you have to consider the following aspects:-

- How to choose who to train for what role and why?
- Selection of personnel for training.
- Decisions necessary to start up in CAD/ make operational
- Level of training necessary for staff.
This level of training has been shown necessary and potentially beneficial through the questionnaire responses and other research. This is supported by Garratt. He goes on to say that some employees only really require an awareness course. He sees that typical trainees would be engineering directors, production engineers and possibly marketing people. This is slightly different to Design Consultancies as the top level management will be Designers whose working role will still have some design input. The comparison is similar when it is a design department in a manufacturing company. The article sees that there are three levels of CAD user - beginners, intermediate and advanced.

What are the training levels?

- Awareness training - for the whole company
- Package User Training - operators
- Systems User Training - operators & CAD manager
- Management training - Managers of company

The article by Browning describes what "most reputable training establishments" would offer specifically for AutoCAD and it can be shown by the following:

Basic training for new starters.
3-5 days intensive training concentrating on package drawing and editing commands, blocks, elementary knowledge of file management.

An improver's course
Based on the operators increased efficiency.
Covers: symbol libraries, attribute extraction, menu customising, scripts and AutoLISP routines. A two day course after the operator has had three to six months working with AutoCAD.

Using Add-ons
Course offers productivity improvements in the relevant sphere of work. Most add-ons have a tutorial booklet in some form. However, some instruction from an experienced user is very effective.

This type of training overcomes situations found in the course of my research and is supported by Browning

Specialised trainingS Such as 3D surface modelling and AutoLISP programming and
New release update training

It would be extremely useful to have an in-house expert who can do this sort of work because it can save countless hours by automating tedious procedures. This includes new releases of the basic package. AutoCAD has a policy to release a new version of its basic package every eighteen months. Therefore, it is effective to have existing users receive up-to-date instruction on new releases away from the everyday pressures of the job.

Management appreciation courses

To overcome common complaints from operators such as lack of management understanding, inappropriate purchasing of hardware and peripherals and no comprehension of the total capabilities of the software. Awareness training for managers would help reduce and even eliminate these complaints.

What level of staff to train

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<tr>
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<th>Computer Appreciation Skills</th>
<th>Computer Operation Skills</th>
<th>System Knowledge</th>
<th>Software Package Operation</th>
<th>Use of Computer Information</th>
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<td>CAD manager</td>
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3.2.2 Company Opinions on Training

Research in this area already shows that training is a neglected aspect on the introduction of CAD systems to the working environment. Research which I have carried out also tends to show this. Companies seem to be prepared to spend money on purchasing the equipment but then drag their heels when paying for training. This is illustrated by Garratt:

"While nearly 80 per cent of the surveyed companies have a formal overall computing strategy, only half include training as a part of that scheme."

In my work, I found the following:-
88% of the companies expected to have to train any new staff with the required necessary CAD skills. However, only half of those companies had a training programme. These were to keep staff abreast of new developments. There was no mention of a training programme for beginners. Other companies tended to consider training as a one-off event and hence a one-off cost.

The article by Garratt\textsuperscript{17} supports my understanding that under current financial circumstances it is hard for companies to justify expenditure on training. Companies do not appear to justify their need for training and spending authority is given without any formal definition of why and what training is needed and how it contributes to the overall objectives of the business. When companies were able to measure the training benefits they were seen as:-

- Improved Productivity
- Improved Quality of Work
- Retention of key staff with the improvement of their skills

From my own research, I found that the only type of training carried out was the short training period given by the seller which accounted for 53% of the companies. However, 42% stated they allowed the operator to teach himself from the manual. A method generally regarded by others as being inefficient in application and wasteful of training time when considering that the main reasons for companies with CAD for having CAD were:-

- Increased Efficiency
- Increased Quality

Their considerations to training do not readily suggest they could have achieved these aims.

The preferred method of training was ‘in-house’ provided either internally or by external specialists, reportedly being preferable to public training. Considering the ad-hoc nature of these arrangements it is important that the supplier is both responsive and flexible. The problem with in-house training is that it may comprise of anything from written timetabled courses to reading from the manual.

Although in some respects the software is fast becoming more user friendly, the contents are becoming more complex and so training of some level will be needed to operate it. For example, sitting behind the driver’s wheel of a car, everything is laid out and is quite friendly but no one learns to drive straight from a manual. So development trends in training could be along the following lines:-
1 Software houses might supply purchasers with a companion training package which introduces the functions and the function procedures for carrying out drawing features.

2 Packages might be supplied with greater user friendliness and a step by step, interactive, help guide. This enables users to work from day one with a package, asking it how to carry out functions as the operator needs to know about them. Effectively it supplies a training routine for users as and when needed, giving working hands on experience.

3 Training packages written to match programs from training institutions/education centres. This would require educational establishments to work in conjunction with software houses as the programs are developed. Alternatively educational establishments could work out training routines to act as guidelines for software houses to write their own training programs.

4 Educational Establishments obtaining contracts with software companies to act as training centres and being supplied with the necessary backup, free of charge, while the Educational Establishments pay for the outlay in hardware. These courses would service local industry and the systems would benefit the Educational Establishments ability to enhance CAD education to its full-time courses as well.

There are indications that all four options are currently happening but developments will probably favour one method over another. Depending on who takes the initiative first will decide in which direction it goes.

Sources of Training

The obvious first step in developing a strategy is to consider what the possible options are to the training. Boyd Davis\(^2\) in his paper derived the following reasons for not carrying out training in-house.

a  Inefficient use of trained designer's time if they are used to teach the others in the company, and training ties up company workstations.

b  Most packages require time after completion of training before operators achieve complete mastery of the system implying that newly trained designers would not be sufficiently skilled to train others.

c  Just because someone is an expert in their field it does not mean they have the required skills
to train others.

It is more productive to use other peoples facilities and skills to train operators.

Generally the training most vendors carry out is no more than an introduction to the commands and they are not prepared, or capable, to organise comprehensive courses to suit any particular company; hence you may need to consider other sources of training such as consultants, educational establishments and computer manufacturers.20

This is where the purchase of one of the leading packages is an advantage as you may be able to get first-class training at a local college by professional educators, or at a bureau. However, some people have their doubts about this statement.

The opinions about other types of training are:

- College courses are not job specific and the tutors rarely have experience in applying the package.20
- Specialised training is on the increase but there is a shortage of sufficient people of the right calibre.17
- Computer based training is likely to become more popular as multimedia technology increases.18

Cost of Training

"Quality training is not cheap, Frequently, its intangible nature isn't appreciated by those who control the purse strings."19

Training costs are only acceptable because few packages have functions which are readily obvious to the novice user, so, without training, the package remains largely unused. The simple fact that packages are meant to be used by a wide range of users means that any one user will only use about 20 per cent of the features of any standard application. Another point is that often the functions that are used are being used inefficiently because the operator has never been taught the best way of doing them.18

1. One point worth considering when evaluating the cost of training is the cost of not carrying out training.18
2. Awareness training may cost very little except for the price of some journals, videos and seminar fees. The cost of time lost by not giving training may be considerable.
3. Training costs contain a component directly related to the cost of training and a component due to the loss of production during training time.
4. Costs of training may appear high but they should be compared to the cost of investment of
the system purchased.
5 Costs of trainers can be very high and variable. The amount of training relates to the complexity of the system, the cost of the trainer will depend on the contents of the course.
6 Ways of keeping costs down would be to use cheaper lower grade machines for training purposes whenever possible.
7 The cost of training over several years will exceed the cost of the CAD system.

Quality of Training
When considering the quality of training it involves the following:-

There are many excellent training companies in this country, but there are also as many questionable ones offering apparently comparable courses.

The reasons for this are:-

The personal computer market development has meant that demand for training has began to outstrip supply.
The downward spiral of hardware prices has meant shrinking margins for many dealers who began to consider the training market. They are lured on by the promise of low overheads and instant cash (most training companies insist on payment in advance) many with little expertise in the field set up their own training companies. Training is viewed by many as an easy way of making money.21

My research showed that companies wanted to improve working efficiencies by introducing CAD. Training was seen as less of a concern as supported by Gibbs22.

Companies are occasionally reluctant to give intensive training as they suspect that the staff, once trained, will move to another company. It would appear they would rather have an inefficient workforce which stays than an efficient one which may move. Improvements to working conditions and improved salaries might be more of an incentive to retain staff and consolidate the investment in training.

3.3 Putting Training into Practice

It is particularly difficult when the overall level of the system knowledge is low, to apply the new skills to everyday work. So unless suitable work is available, the trainees will rapidly forget what they have learnt. Even if suitable work is available, they will quickly find themselves unable to solve relatively
simple problems that are outside the scope of the training source. This suggests that there is a need for a transition phase between training and unsupported everyday use of the system. This is backed by my own experience of training degree students at Napier University who, after going through an intensive block training period under close supervision, tend to require support when working on their first drawing. Often there is a time period between training and carrying out their first unassisted drawing caused by other commitments.

Progression starts with a theoretical introduction to system use, followed by hands-on training. Then the user must be able to practice with examples that are drawn from typical use but are not part of the current workload. Ideally during this period support should be available on call. The next phase starting to work on "real" tasks, support should be at hand if a problem arises, so the users are able to find assistance rapidly. Saving time preventing mistakes and despondency setting in. So the role of a CAD manager here is to see that at the end of the training period, there are sufficient resources and suitable work available for the trainees. There is no point in training large numbers of users when the facilities are insufficient for them to consolidate it.

What is Involved in Training
Dealer training is little more than a run through the command terminology and location in the command structure of the package. Companies in the questionnaire stated that it was usually insufficient in length of time. The other method of training stated by the companies comprised no more than reading the manual as they carried out drawings for the company, "on the job".

There appears to be no training involving the actual hardware and how it functions or how to maintain it. There is also no sign of training on how to implement the system to use the information to its most efficient, the running of the system, security aspects of the system and personnel matters such as ergonomic requirements.

What are the issues necessary in a training programme?
Training staff for the operation and use of a new computer system involves providing them with the required knowledge, competence and confidence at many levels. It varies according to what part each individual has to play in ensuring a smooth operation of the system within the business. Suitable awareness training increases the efficiency of the managers and shows them the importance of their company CAD system.22

Starting with a company that is about to introduce a CAD system the content of an awareness training course would be:-
What is CAD?

What are its advantages?

Who in the company has any knowledge of CAD?

Do they know enough to purchase a system?

How do the other members of the company feel about CAD?

What are the costs?

Training needs to be justified, qualified, evaluated and its value calculated.

Can the company afford it?

How long will it take to introduce it and become productive?

The evaluation phase will have established the extent to which training is necessary but will include the following aspects:

Staff need to be trained in what the system is meant to achieve:

- How it operates.
- How to collect data for the system.
- Where the information is best used.
- Changes in procedures are inevitable and staff need to be both aware of and competent with the new procedures.

By deciding:

- What skills are required.
- Who is to be trained.
- When is this training to be scheduled to be most effective.

3.2.3 Which area has the greatest need for training?

The two categories which the research has highlighted 'Beginner and Expert' that are present in the Scottish industrial environment have different sets of needs for levels of training packages. However they also have some areas of similarity such as in system security and system maintenance. The 'experts' would have found out the necessities for these aspects themselves if they did not know about it when they started. The beginner category would probably not be aware of anything other than the purchase of the system and initial training on the package.

The research has shown that training is a neglected aspect and that companies were prepared to spend money on the purchase of the system but then tended to skimp on the costs for training. Some of the smaller companies tend to regard training as a way perceived by the employee as a way
to enhance their own career prospects and/or improve their financial remuneration.

Early work showed that there were two groups:

The largest group were those companies already using CAD.
The next largest was those interested in purchasing a system. These two groups can be outlined by the following:

1. This group is quite experienced in CAD and progressing to its second or third generation CAD system.
2. The second group covers those who have just bought and who are in the early stages of operating a CAD system or who are in the process of choosing a CAD system.

The work has shown that the first group is quite self-sufficient and its training needs are quite amply satisfied by themselves or by their local educational establishments for those companies with a well known system were able to get good specific training.

Those companies who purchased less well used packages were not so well catered for and training was for a short period of time from the seller or 'on-the-job' training which, if they were new to CAD, would then be very limited as I have already commented on. This group has also shown that the first group has progressed already through more than one generation of CAD system.

The second group is still by far the largest group, in fact, and it has the most need for assistance. Companies with a system illustrated a wide range of strategies for purchasing a system which varied from a painstaking approach to a hit or miss method of selection. There is a limited source of assistance for this area to get advice but it is very often biased or piecemeal in its content. There is some advice from institutes such as the Design Council, but not from the Chartered Society of Designers, (at the time of writing) - an area where professional Designers turn to when they are looking for information and guidance. There is occasional advice in computer magazines and at exhibitions where computer organisations offer their assistance and of course some dealers give their advice. However the advice is dependent on companies knowing where to ask the correct initial questions. The people here are on the whole computer orientated with backgrounds in computer technology. So there is little help for designers from design minded people.

So for the newcomer, the standard of assistance and depth to their enquiries depends on them asking the right questions at the right time from the right people. The flaw being, if they do not know
much about CAD they will not know what questions to ask or where to ask them, which means they will get an inaccurate or incomplete picture.

Companies are short of money and time so they want to prevent overspending or buying the wrong system. They also do not want to spend too much time in becoming familiar with the system although they do want to be able to produce working drawings as soon as possible. There is a distinct lack of guidance to companies about ways that they should/could implement their system and use it to get the most out of its information.

It is, therefore, this category that is seen as having the most need. It has a requirement for an educational package covering aspects of CAD that is not currently readily at hand.
4.1 Purpose of the exercise

The purpose of this chapter is to:

- Present attitudes found in 'real' companies.
- Highlight situations and the reasons for/against CAD usage.
- Portray the problems identified in the previous chapter.

The areas involved are Design and Engineering.

The chapter is divided into two main sections. The first covers the description of the mock companies and the second outlines the desired software capabilities.

4.1.1 Exercise Methodology

The simulated company structures will be based on the responses of the questionnaires; in some cases only the 'differing' factors will be mentioned.

I have not included a section for those companies using wholly based Mainframe or Mini technology because they are not relevant in this case. However there will be some reference to a mix of Mini and Microbased systems.

There will be five company illustrations given. They will be used to illustrate the problems and issues raised by the research and to help discuss the possible solutions to these typical problems in Chapter 6 of this thesis.

Companies' sizes are based on responses to the questionnaire but are wholly representative of companies within Scotland. These sizes can be seen in Appendix IV.
Design Consultancies

Regardless of the CAD package used, Design companies have some commonality between them. The similarities are:-

- The final output is the realisation of a concept in a physical format a product.
- Quality, aesthetics and functionality are the essence of the design service.

The handling and control of the information in the CAD systems is common to all and so is the decision making and running of the system. So this is what the stereotype company will be based on. The design consultancies in Scotland tend to be small concerns in terms of staff numbers and the large ones are very rare.

The following are packages that could be used by the consultancies:- DesignCAD 3D, AutoCAD, ClarisCAD, Microstation, RoboCAD, RoboSOLID, VersaCAD, Personnal Designer, DrafixCAD Ultra, DrafixCAD 3D Modeller, DOGS, Macsurf, Anvil 5000, Cadkey, Cadmax 3D, Cadvance, Aldus Freehand, Illustrator, Streamline, Persuasion.

Engineering

The Engineering companies are primarily using AutoCAD. All their other Microbased Draughting packages are on IBM compatible hardware. Other packages that could be used are:- Personnal Designer, Microstation, RoboCAD, Versacad, Macsurf, Anvil 5000, Cadkey, Cadmax 3D, DOGS, FastCAD, Tooldesigner, Generic CADD, Medusa 3D, DesignCAD, DaxCAD, P.C. Draft, Micro Cadam, Eplan, Racal Redboard, Logotech. Extra add-on packages include Turbopipe, SMP 81, PEPS, GNC, P.C. Tools are packages used by companies in the questionnaire. The list is to show some potentially suitable packages and to illustrate the range that is available. The type of software can be seen in Appendix V.

However if the argument is simplified to basics then all engineering companies using CAD will be using it as a part of the manufacturing process. The companies will be using it in their drawing office environment or as in a few cases as a service for their customers drawings. The commonality between the engineering companies in this simplified argument allows the use of a mock company for illustration purposes.
Company One

Company Description
This company has a staff level of 6. The company consists of two partners, one secretarial member of staff and the others being designers. The company would have grown from the two designer partners with approximately 15 years experience before starting up their own business. The company has a turnover capable of installing one CAD seat but at present they know that their closest rivals are not using CAD so they feel they do not need it. Most of their work comes from regular clients and the work is usually for small 'low-tech' products with short run production numbers.

Working Practice
The business has no input of computer origin from clients and it has no need to supply the clients with electronic data. Intermediary work is given to manufacturers by paper drawing leaving it to them should they require it to be entered onto a computer system.

The company has not lost any work as a result of not having a CAD system. Currently the company works on the usual procedure of sketching development work, then presentation drawings for early talks with the client, then development work for the chosen option which means engineering drawings and 3D models for prototyping purposes. Each designer concentrates on his/her own particular projects with little involvement from the others although they do work together as the deadline approaches to complete the detailed work.

Attitudes towards CAD
One owner appreciates that computers can be helpful but he has no practical experience of what the full range of applications, advantages, disadvantages, costings, organisation and training requirements are required by CAD. However, when asked, the company would say they do not have the financial resources to install a CAD system and have decided it is not necessary to their working requirements. The partners lack of familiarity with the technology suggests to them that they are too busy to obtain the information. The partners are also unconvinced that the human production of work which has a quality of finish cannot be surpassed by what can be achieved on the computer. They agree that technically, the computer is more accurate in presentation but the final image lacks the flair that manual presentation work has. They use the comparison of the difference between paintings and photographs. For example, the painted landscape can portray more than just the physical view since it can portray depth of feeling, and other emotions, where the photograph is just the physical view. The partners, if pressed, might agree that their judgement of the computer is slightly tainted with the fact that they are a little afraid of the unknown and this is, therefore, something which they
could not control. The other reason is that one partner is less inclined to want to get involved in what he perceives to be an expensive pastime.

Company Two

Company Description
This would be a one-man organisation with about 5 years experience as a designer and would have built up a reliable name for good quality design. Financially they are breaking even and are looking for ways to improve and compete with other bigger companies and also to alleviate the work load without having to employ someone with all the implied administration. They will probably be registered with the Design Council although this is not necessary. They would be working from either small rented offices or from their home so space is at a premium.

Working Practice
Concepts are sketched out and promising options developed on paper. These are presented to the client before proceeding to the final design. At this stage of the development the designer then carries out the engineering drawing work finalising the dimensions used for model making and for manufacturing the design.

Simple model work can be carried out by themselves but presentation models and prototypes are subcontracted out to professional model-makers.

Attitudes towards CAD
The designer considers there is not the working space to install a CAD system and certainly not the time to train on the system. However, the use of a CAD system would be worth further consideration as the designer believes that CAD would be helpful in improving the turn around time of the engineering drawing work required in the design jobs. Particularly since the clients often ask for alterations or developments require a change of specification of internal parts to be incorporated.

Further to a system which carried out the engineering drawing work, should the company's financial resources allow it, the designer would contemplate getting some graphical enhancement packages to add on to the system so that it could be used on presentation work. 3D work would still be carried out manually but like the bigger concerns the designer would like to utilise the 3D capabilities on the more prestigious jobs to produce presentation work.
Company Three

Company Description
The company has a staff size of 19. The company would be involved with the design of high end 'high technology' equipment. The company is made up of two partners, three designers, four model makers, eight technical staff and the rest carrying out administrative duties such as secretarial and accounts.

Working Practice
The company uses AutoCAD and DrafixCAD for its draughting requirements working 3 operators to a CAD seat. If work was steady and reliable a ratio of 3:2 would be more desirable.

The reason for getting a CAD system was based on increasing the working efficiency of staff within the company thereby negating the need to increase staffing levels. The system would be used to produce the 2D content of a job, the presentation work being carried out manually. Experimentation with 3D capabilities within their systems is now probably beginning to be used as a source of a stencil for some presentation work. Cost is the deciding factor in when and how to use CAD. CAD is used for the production of accurate draughting. Ideally the company would want more work to be carried out on the system but on some jobs there is simply not the justification to use it.

Conceptual work is still being carried out manually. The 3D capabilities of the package would be used in the production of exploded views and as underlays for some presentation renderings or even for some presentation renderings themselves.

AutoCAD or Drafix 3D modeller and DrafixCAD Ultra 386 are used. CAD is used only on large jobs where repetitive drafting is needed for example, General Arrangement drawing development. DrafixCAD can handle the 2D requirements and the Modeller to create 3D drawings in full perspective and view them from any position and along any track to demonstrate to clients. The 3D information is transferred to the DrafixCAD Ultra as a 3D view or as any 2D projection for further enhancement for presentation work to show to the client. The 2D package is very easy to use. Commands are selected from a menu with a mouse and pull down submenus can be displayed. It has all the usual features of draughting packages and with pan and zoom it allows redraws between the operation of other commands. Text can be imported from Word and WordPerfect. The package allows the import or export of entire drawings in the standard DXF file format. Along with the draughting utilities and capabilities it is possible to generate a bill of materials, cost estimates and other reports automatically as it allows you to add attributes such as price, part number and vendor.

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Drawings cannot be transferred from the 2D package into the 3D, only from 3D down to 2D. However, the closest to this requires hardware of the level at top range mini/workstation level and the cost of this technology and the software costs are just too high.

All drawing information is backed up at the end of the week at each operator's discretion. The back-ups are stored within the office but not in a fire proof container.

When the system was purchased the office layout was not considered for the proper installation of the CAD hardware.

**Attitudes towards CAD**

The company is contemplating getting some more extras that can be used to enhance the 3D graphical output.

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**Company Four**

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**Company Description**

This has a staff size of 70. Only three personnel are involved in the design tasks of the company, the rest are involved in the manufacture, software writing and administrative tasks of the company.

**Working Practice**

The company is involved in the design and manufacture of its own products which are heavy duty weighing instruments. The CAD system is the source of information to its manufacturing departments through paper output and, because some of the products have an electrical content, it has CAD software for development of any required electronic circuit boards. Each department is making demands of the company's resources.

CAD was initially bought in for the drawing of the circuit boards used in the weighing products. It was decided by one of the company directors to transfer all standard drawings onto the CAD system so that they could be used for sales and marketing purposes. This work led on to developing the use of the CAD system within the design office and all later work was carried out on the system. The design staff were sent out to train on the system at evening classes as the initial operator was self taught and too heavily committed in development work of the circuit boards to train staff internally.

The design department finds that the CAD system has speeded up the production of their engineering drawing work for both new models and editing current drawings. However it does not use the CAD
system on sketch work or early conceptualisation. Neither does it use the system's 3D capabilities as the design staff do not have the time to maintain familiarity with the system and find it quite complex to work with.

The manufacturing side uses the drawings from paper format. The work is not suited to automated equipment as the work is usually one-off modifications of the company's standard products.

Attitudes towards CAD
The aim is to become more organised in the use of the computer information and it is intending to become networked as an initial stage towards this aim. The network would be with the production processing department within the company and not the actual manufacturing processes of the company. Money is tight and they must clearly establish a need for further system development to justify further expenditure. The design office is all for the development but they require a bigger budget for drawing office capital equipment and the manufacturing side is demanding new equipment as well.

Company Five

Company Description
Small company size of 8. There is only one designer within the company structure.

Working Practice
The work is carried out by one draughtsman and the in-flow of work is such that he can handle it on the drawing board. The company regards its main function as being manufacturing and that the draughting design content is only approximately 15% of the company’s function. Currently, finances are not high and there is no spare time to start a review for new equipment. Since the work is primarily for other companies, production information is often supplied by the contract company and so the company only needs limited drawing facilities. All work is given to them in the format of paper drawings and they have not lost any work through not having CAD. However the manufacturing side of the company uses CNC equipment.

Attitudes towards CAD
The company is quite small but one of the partners realises that CAD could be very useful to its needs and wants to go about selecting a suitable system. The company has its own design requirements for the work that it carries out and therefore would select a software package that suited its own specific requirements. Money is an aspect and that would be why the company prefers a
microbased system as it had suitable software, capabilities and was affordable.

4.2 Commonality between the stereotype companies getting started in Microbased CAD

It is recognised that the actual design work carried out by these companies is different. However, they all share identical problems which are:-

- The identification of whether CAD is necessary or not.
- How to choose a system.
- How it is to be implemented
- Organise training.
- Maintenance.

Should there be an identified need for CAD at present, it is helpful to incorporate a plan for the next system requirements as well.

The differences are:-

- The actual work content.
- The CAD solutions available to meet their needs.

4.3 Commonality between the stereotype companies working in Microbased CAD

These similarities are:-

- The identification of whether CAD is necessary to the company and/or to continue in CAD or not.
- How to choose the next system.
- Is it necessary to replace the system or can it be upgraded?
- Justification for an upgrade/new system.
- How can it be implemented more efficiently?
- Organise the transfer of necessary work.
- Organise training.
- Maintenance.

The differences are:-

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• The actual work content.
• The CAD solutions available to meet their needs.

I have mentioned one of the differences as being the CAD solutions to meet their needs. This is really only applicable for 3D programs and not the basic 2D draughting packages. The difference is that some types of work group will simply require add-ons to the basic packages, so even here there are some similarities. These similarities in computer usage within the different design professions can be grouped together for deriving a common strategy for purchasing a computer for the first/next time.

There are numerous software packages in the market place which can be used to answer the needs of a design facility. The difference in price between them is usually a guide to their suitability and the range, type and complexity of the programs. The questionnaire has shown that companies had a variety of reasons for choosing a system; some of them practical, some less so. The reasons given show that some companies had thought out their requirements and others had not.

One aim of this research is to "Identify specific and/or common software/hardware system types suitable for integration in appropriate design environments which can be supported wholly by Microbased CAD." It is not the intention to extol the virtues of operating system D over operating system A or even package R over package A. The purpose is to identify features that allow designers to use software without encountering a mass of problems and complications. I believe by the identification of these features and commenting on their use this would help derive the training methodology for choosing a package. The reasoning behind doing this is based on the following points:

1) Time - An analysis carried out in early 1991 would be redundant by the time the thesis is finally written up in late 1992. Primarily, because software can change commands, its content of commands, and resolve any problems within itself at least twice a year.

The work involved in independently analysing the multitude of packages constitutes a research programme all of its own.

2) Other work - There is work already being carried out comparing the different packages sometimes even evaluating one package against another.
There is work of this nature being carried out at the time of writing by Coventry Polytechnic researching the various packages with the intention of recommending certain packages for Industrial Design usage. The difference is that they are not exclusive to Microbased CAD.

So what is to be the work involved? There are three sources. The work carried out in the first questionnaire gives an indication of what named packages are being used by the differing design professions within Scotland. The Computer Aided Design Press also gives a review of what the different professions are doing nationally and even, occasionally, internationally. Finally, utilising other peoples' reviews of specific packages, I can establish how they operate. These three sources of information can be combined to derive an evaluation of what software type is suitable for what profession.

It is the way in which the software handles the information that I consider to be important. The Command structure and its handling can classify one draughting package in one group and another similar one, by another company, into a different group. Communication between packages is another useful device to sort packages. The ability to share information might make package B more suitable. It is these differences or similarities which I will be studying. My judgements will be based on what types of packages are being used currently by the product design profession. The reasoning I have outlined for the analysis of the software will be similar to the analysis for the hardware. It is my opinion that currently the type of work carried out by an individual company determines the most appropriate software and this determines the hardware and probably this will be the case until a true open systems policy is adopted by the computer/software manufacturers.

To answer the problem of 'Which package?' there are two steps which have to be carried out.

1. What work do we want to do?
2. What do the different packages do?

An analysis of the different packages can show some basic commonality and differences which can be used to compare work to be carried out with software functions and the difference between the package types. This can be accomplished by reviewing appraisals of the major packages carried out by magazines and Professional Institutes. This will give the basics of what constitutes a draughting package or a graphics package and this will be used in the same manner.
4.4 What are the companies currently using?

The Design Consultancies reasons for choosing their current CAD system were:-

1. "Proven track record in the area in question."
   "Ability to upgrade system in terms of new software to match changing company needs."
   "Ease of Use."

2. "Reliable after sales support."
   "Ability to develop system i.e. adding workstations without throwing away existing equipment.

The leading software chosen for the Industrial Design area was AutoCAD.

AutoCAD has already been established as suitable for such reasons albeit in other areas of design. However, within the limitations of microbased design, AutoCAD is sufficiently suited to the Industrial design area. It has extra packages that can be used in conjunction to develop the system for 3D work if required so this allows for company development and/or expansion of working practices. It certainly seems a viable concern for the smaller company which, through DXF files, can communicate with others if the need arises and achieve a good working CAD tool.

The Engineers' reasons for choosing their current CAD system were:-

1. "Ease of use."

2. "Value for money."

3. "Ability to upgrade system in terms of new software to match changing company needs."

4. "Proven track record."
   "Ability to develop system i.e. adding workstations without throwing away existing equipment."

The leading software was AutoCAD. The only companies not using AutoCAD were companies in more specialised areas that found other more suitable packages. There is the tendency for some to pick AutoCAD because it is the most well known and, therefore, it does not require much hunting and evaluation. It is the easy way out. However, in saying that, it does have the 'bolt on' extras that most of the companies in this sector were looking for in.

4.5 What were the companies looking for in their chosen CAD system?

The most favoured response from the first questionnaire in terms of Microbased users was "ease of
4.5.1 What constitutes "ease of use" in a package?

Basically it must be easy to interact with the software to achieve the aim of creating a drawing. This means it should require either none, or as little as necessary, instruction to operate it. It should be like riding a bike, once learnt it should be easy to remember how to do it. This is achieved through its structure and clarity of commands. It needs some more superficial aspects such as a comprehensive Help System, idiot-proofed to allow for errors that will not cause the computer to crash. This requires an all encompassing recover command or, as the packages phrase it, 'Undo'. The more varied the package the more complex it becomes. All packages will require some learning, so it must have documentation in the form of manuals and aided by a tutorial to help you learn it in the early stages. This appears to be a common weakness in most software. Their manuals are not very well written or structured. They are more orientated to the structure of its commands rather than the sequencing of commands necessary to perform a drawing function.

When reading software sales literature the terms "User friendly" and "Easy to use" appear quite liberally. The companies I have visited and/or contacted with the questionnaire certainly used these terms. It was a theme which came through in the answers to the second questionnaire and in the meetings with companies.

The companies cannot afford to choose CAD systems that are difficult to learn which require a lengthy training period and months to become productive. The timescales vary but the trend is that the smaller the company the less time they have to 'learn'.

Software houses have been known to say that the systems that are easy to use when learning are not easy and efficient to use once learnt. Reviews of software have commented on this fact and they elaborate by saying that because a system is complex and difficult to learn it is no guarantee that it is competent. This is an area that is being recognised as a problem for some software houses and they are revamping or developing the front end of their programs in an attempt to make them more acceptable. This is a problem that is more related to the older programs on the market and while they are now still being highly competitive I suspect they will have to go through a period of metamorphosis to emerge as viable competitors for the future markets. The newer programs are generally friendlier but lack the strength of widespread usage.

"Ease of use" breaks down into three subgroups:
• User Interface Features.
• Ease of Learning.
• Ease of Running.

The ideal package would amply satisfy these three requirements but unfortunately it is not that easy and each package is written differently and therefore has its own advantages and disadvantages. The three categories are broken down even further which is helpful when evaluating a selection procedure for software which is carried out further on in this thesis.

The first criterion is as entitled earlier "User Interface Features". Primarily, this is based on how the program interacts and this is a product of the manner in which the package was written.

4.6 How the packages operate

The operating system which demands the most commonality between packages is that based for the Apple Macintosh computers. This commonality allows a user of one package to have approximately 60% familiarity with just about any other Apple Macintosh package. It works on the premise that the screen of the computer acts as an interactive device covered in 'items' that in conjunction with a mouse you can point to, click or drag. It becomes more a control panel and does not require an operating language with an encompassing phrase book. Some Apple Macintosh software producers are not followers of this system (e.g. AutoCADMac). Similar methods can also be seen outside the Apple Macintosh environment and one draughting package like this is RoboCAD. The most obvious one being Microsoft Windows.

The other way in which packages operate is more historical in its origins and is similar to early CAD methods. The package operates through user keyboard inputs based on an instructional language. For example the user types in "Draw Line", the computer would then prompt "Start point, length, direction". This goes on in this mode until the line is drawn. The weakness of this system is the operator needs to be fluent in the language which could be quite extensive. It is very much akin to a high level computer programming language. Progress made the key words short and cryptic in an attempt to optimise this language barrier. Sequences would be grouped into logical areas of similarity. While this sounds clear, the operator still has to declare what parameters are relevant to the task. Similar to declaring the parameters at the start of a 'C' program. The cryptic commands developed into a hierarchical menu system. This was based on multiple questions, responded to by keyboard entry to gradually pinpoint the required operation. The hierarchical method is very much a standard for commercial systems, although as software becomes more complex in command
functions it produces more complex menu schemes. To overcome this, the software houses have tried adding screen or tablet menus to alleviate the necessity of typing. The key words are still there because the menus need them. However, the operator can use them, although with care, as it needs the computer to prompt for them. This approach appears to allow more choice but is not as tidy as a pure hierarchical arrangement simply because in the menu scheme a lot of the choices are actually invalid. To utilise and operate in this mode you still need to know the instructional language.

Computer manuals for software of this type will generally describe the instructional language and not the menu structure as the menus are more of an afterthought. The instructions need to be carefully thought out or it will not be possible to derive a respectable menu structure. The menus are soft and allow for user customisation. Packages like this are primarily found on the DOS operating system and are typified by AutoCAD and Microstation.

Of the two basic types, the systems that work on the principle of direct manipulation are easier to learn and to use without error than their counterparts in the instructional or command language area.

4.6.1 User Interface Features

Style of Interface

This is the means of interaction between operator and system e.g. keyboard entry, mouse or combination.

Menus

Menus can be either classified as soft menus, in which case they are easily altered by the user, or permanent. The latter is usually the better thought out and documented. Menus have some basic characteristics and appearances.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop/pull down</td>
<td>Activated by pointing to a menu bar at top of screen, once used it disappears. This type is easier to memorise than below.</td>
</tr>
<tr>
<td>Nested</td>
<td>Lower level menus overwrite the previous master menu in a hierarchical procedure. This format can be lengthy in their working therefore tedious in use. Harder to learn than above.</td>
</tr>
<tr>
<td>Overlayed</td>
<td>Found on a fixed part of the screen and operates differently to nested type but is switched by a master menu elsewhere on the screen.</td>
</tr>
<tr>
<td>Palette</td>
<td>Remains on screen for some time and it is possible to reposition it at will.</td>
</tr>
</tbody>
</table>
This is a quick way of getting in a few commands.

Static
Found on a fixed position on the screen and permanently there.

Tablet
Separate piece of equipment not on screen but can overwrite command sequences.

Appearances
Type.

Ionic
Commands identified by use of little pictures instead of text.

List
Vertically arranged series of commands.

Matrix
Portrayed in a grid and commands grouped and identified by name.

Another type of menu is a Data Menu. This indicates whether items of data such as linestyles, layer names, and file titles have to be either typed in or selected from a menu.

Dialogue Box
This is a method of collecting data and selecting options by completing a list like form filling. It is argued by Richens¹ that this is "consistently clearer and more flexible than the alternative of typing responses to prompts or using parameter setting commands".

Mouse Buttons
The mouse is usually the device for interacting with any screen menu or icon commands. The two button mouse caters for the simplest protocols. When the mouse or puck has 3 buttons it requires more concentration and co-ordination to be worked properly. The Apple Macintosh system of a one-button mouse relies on a keyboard entry to compensate in some command sequences which is a more complicated way of operating than it could be.

Typed Co-ordinates
Any package allows relative co-ordinates (i.e. measured from last entry) and absolute co-ordinates (i.e. measured from a fixed origin). Other types of co-ordinate which can be catered for and used by packages are polar co-ordinates and/or where they relate to an origin where the absolute co-ordinates can be offset and the axes can be rotated.

Snapping
This is a technique used by all packages to some degree but they are not all used in all packages. The technique allows to input co-ordinates precisely by reference to items already drawn. The more ways in which a package can snap onto a point the more usable is the package. While all the packages have snapping features, they do not all allow the user a method of switch from one mode to another. Where the packages do allow switching, the methods of selection are:

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Keyboard

Seen as an alternative to other methods, the tendency is that experienced users will use the keyboard as it is the faster method in experienced hands.

Nested Menus

For example, contained in a side bar menu which is different from the one containing the command the operator is executing. Not very efficient.

Pop up Menu

Works in conjunction with mouse and the menu appears near to where operator is drawing, less movement is needed to access it than if the menu is a static variety. The disadvantage is that it requires a dedicated mouse button.

Pull-down Menu

This requires using the mouse and is seen as a more complex method of selection than the one above.

Static Menu

This is a text or iconic menu which is permanently on the screen.

Two stage snapping

Sometimes called tentative snapping. First stage is the identification of the item then the second stage is either confirmation or retry. Efficient for very complex situations such as 3D work but on the whole clumsy.

The ideal package would have all the following snap modes but generally in reality it is some combination of them:- End point, Nearest point, Midpoint, Intersecting point and Arc centre. Other snap options are:-

Tangent/Normal

For drawing geometry this is useful when the operator wants to construct lines tangent to circles or in some cases circles to lines or other circles.

Perpendicular or normal snap aid construction of lines at right angles to something that exists already.

Offset from Snap

This is a feature that allows the operator to specify a point that is offset from a snapped point by relative Cartesian or polar co-ordinates.

Retry a Snap

This is a feature that is useful when working on a busy drawing and it is hard to pick up the correct snap point. The useful aspect is that it allows the operator to try again or an alternative snap.

Feedback

When working with a new or unfamiliar system it is reassuring to know what is happening and even possibly what will happen if operation X is pressed. The packages can supply the operator this perception through the following ways:-
Co-ordinate Readout
The cursors position is continuously referenced by co-ordinates by eye and snapping routines are easier than by keyboard entry alone.

Edit Selection Highlight
Some editing operations can be on more than one entity at a time and the highlighting option visually tells the operator if it is correct or not.

Position Marker
This marks out a blip on the screen at every entered position. This is helpful for commands which require several co-ordinates before anything happens.

Rubberband
Aids line construction by portraying a rubberband line from last line/point input to the current cursor position. This technique can be altered for other operations such as circles, rectangles and dimensions.

Undo
This is a feature that is ideal for learning to use a package by trial and error methods and relies on the fact that even experts can make mistakes. The packages vary in the limits of this command but it is advantageous to get as flexible an Undo command as possible. An effective Undo will reverse the action of any command that alters the database. A truly effective one will even 'undo' an Undo! Usually the Undo just deletes the last operation. In packages that allow the operator to run macro commands it would be desirable that the Undo sees the macro as a single command and not as a series of operations otherwise the operator could be faced with a lot of manual editing.

Help
Almost as useful as the Undo command, a good help command will allow you to interrogate the system to allow you to find out where you are, what you are doing and what you can do next. The first stage help would give the operator a list of commands names, so the operator has freedom to choose what he is wanting to know. Once a command has been selected it should describe what the command does and how it relates to other commands. A rarity in the packages is a set of illustrations which includes diagrams of constructions or user interface devices. Hypertext is another rare command that can be useful. This command allows cross references or further information to be accessed simply by pointing to items on the help screen.
This is unlike the others as it is external to the system, it reverts back to the book form. It is as it suggests a working list of what and how the software operates. When the system is new and operators are still learning how to use it, desk space will be needed so that aid is not too far away from the operator. The more compact the manual the greater the convenience. The disadvantages are they have little correlation to the power of the software, they can require effectively quite a lot of space and depending on their style do not fit tidily away. The binding of manuals can be ring, wire and hard bound. They all have good and bad points. The more important aspect of the manuals is the content. They are often more an afterthought to the software and can suffer accordingly. Commands are sometimes referenced alphabetically so that when an operation has to be carried out the operator can find himself flipping back and forward as he proceeds through it. Often they are referenced to the master menus in a hierarchical form which in terms of operation sequencing still requires flipping between sections. One part of the manual that would help illustrate features of the software and proper operational sequencing of commands would be a good accompanying tutorial. Not all packages contain tutorials and even these which do range from the good to indifferent. The good are based around clearly thought out examples that illustrate the points. The bad are full of sequencing mistakes and/or refer to older outmoded versions of the software. The manuals are often written with people operating and managing the system in mind (computer specialists) rather than people just using the system to produce drawings (designers). Even although these operators are computer literate the manuals are not very helpful.

4.6.2 The second criteria is Ease of Learning.

It is regarded that the key features that make a system approachable to a new or casual user are Simplicity and Friendliness.

Basic requirements for Simplicity

- The elementary concepts of the system are straight forward.
- The commands should be well designed.
- The commands should not be too numerous.
- The commands should be organised into meaningful groups.
- The commands should be consistent in their behaviour.
- Individual commands should not have too many options or alternate methods of doing things.
- Menus kept neat and simple.

Excessive use of Modal Parameters decreases the ease of learning, more prone to mistakes
occurring. The use of modal behaviour where a single command can be several very different actions dependant on the current 'mode' in operation certainly makes a system harder to understand and to operate error free.

Basic requirements for Friendliness
This covers a wide range of topics which contribute to make a system friendly and easier to learn. They free the operator from frustration and unproductive time pouring through the manuals.

What is seen as the most helpful user interface is the option of only giving valid options. This is where older style programs that are command language/menu systems do badly, e.g. AutoCAD and Microstation. Their menus are basically independent of commands and do nothing to guarantee correct operation. That is why direct manipulation systems are friendlier as they are based on this fundamental method.

When it is required to choose an action the direct manipulation systems produce a list of possible alternatives for the operator to choose. They do not expect the operator to remember the name and type it in. Easiest method is a display list and a means of scrolling, selection by pointing. Seeing and pointing is better than remembering and typing. So, should a predefined order of events be required by the system, then this should be clear and a set of prompts be supplied by the system. In terms of command language systems, AutoCAD is helpful in its use of prompts and Microstation is poor. Macintosh systems tend not to use prompts and systems such as ClarisCAD suffer accordingly.

Error detection is a relation to the Undo command and the way a system deals with errors which can make it friendly or hostile. The more helpful systems on detection of an error gives notification to the user that an error is about to happen. Unfriendly systems tend to do some combination of the following:-

- Do not detect errors thereby carrying out incorrect operations and consequent harm to the current drawing.
- Do not notify errors and then doing nothing, provide obscure/misleading notification, insisting that whole complex operations be abandoned if an error is made.

One last point, where a system puts up an error notification on a stick up panel which has to be explicitly acknowledged before going on with the drawing is considered to be a minor irritant.

Dynamic feedback (as outlined earlier), where the screen image is continuously modified with the
movement of the mouse is very helpful. This information to the operator reduces the chances of mistakes and allows the operator to feel at ease with the system. Some feedback can negate the requirement for screen prompts as it gives the operator a visual indication of what is about to happen and whether it is right or not.

Feedback such as highlighting is useful to show what elements have been selected for purposes such as editing. This avoids errors. The operator can carry on as errors that do occur are obvious and are easy to correct. Highlighting features in order of usefulness are:- overdraw with a reserved colour, drawing handles (title dots at extremities of an object), overdrawing with a dashed line.

How the packages 'screen image' is perceived is important; it should be legible and logical. This can be achieved by the use of judicious character and icon sizes, plain backgrounds, restraining the use of colour and avoidance of obscure abbreviations and iconography. By achieving a logical grouping it helps to reinforce relationships by making them visible. For example, submenus appear below or to one side of the master menu. Clutter should be avoided. There has to be a balance between drawing area and operating features clarity.

The command language software such as AutoCAD fail to exploit screen layout to clarify the structure and operation of the software. This is another area where the direct manipulators do much better, particularly RoboCAD.

In conjunction with ease of use there is the requirement for an Undo command. The nature of which should be as I described earlier. There are some further points that I consider worth elaborating on. It is worthwhile to check the extents of a packages 'Undo' command as they all vary in effectiveness. The worst is no more than an 'Oops' command, where only the last thing constructed is deleted. The best 'Undo' command will encompass any delete command or edit functions no matter how complex. This gives the operator peace of mind and facilitates the learning of the software. Therefore it is important to establish what the extents of the Undo command are and hence what it is capable of doing.

The help command is another one which eases the operator's burden and aids the learning of the software. I have already covered what could/should constitute a help command.

Manuals are a necessity. It does not matter what the seller of the software system says, no system is so clear and intuitive that you can effectively employ it efficiently without some reference to the manual. The sooner the manual can be shelved, the easier the package is. The primary factor in the
manual should be the tutorial which should contain a collection of practical exercises to introduce the basic concepts and techniques, which will leave the operator with the feeling of confidence to carry on to the next step on their own. It should be possible to start on the tutorial without any advance reading.

The second factor is that the manual has a reference section explaining in plain English everything about the software's functions keeping the manual free from jargon unless previously explained or it is impossible to avoid. The index should contain more than just the names of the commands. Microstation has a manual that is complete but voluminous and poorly structured resulting in it being hard to use. However, manuals are usually organised around the menu structure. AutoCAD and Microstation are not.

RoboCAD, Cadadvance & VersaCAD are particularly easy and best suited for intermittent or casual users. Microstation & Cadbuild are difficult packages with unfriendly interfaces and a poor manual. A training course would/should be essential prior to using this program. AutoCAD requires a lot of study and would be hard to learn thoroughly without the benefit of a training course.

The third and final criteria is ease of running. This criteria is the application of the software once the learning curve is nearly finished. The operator would clearly understand the menus and commands. This criteria is looking at the user interface features which will assist the experienced operator to be more productive.

The system is controlled by selecting commands and entering the data or options they need. AutoCAD and Microstation use clumsy menus and are more effectively controlled by the keyboard entry of the command language.

Direct manipulation packages such as ClarisCAD, RoboCAD and VersaCAD have faster methods of control. Data entry is generally faster and easier in those systems using 'pointing' alternatives to typing. Co-ordinate input is functional to nearly all construction and editing operations. Typing is the most tedious method but often unavoidable. Some software packages need a specific menu action as a preliminary, to allow keyboard entry. Some packages are limited to the type of input that is allowed and do not allow the use of polar or user defined axis, origin or rotation. AutoCAD has no such restrictions. RoboCAD is the least flexible. Another method of inputting co-ordinates is the use of grids, its use can be fast, switching on and off as required, it is facilitated as the cursor leaps from grid point to grid point. This is further aided if there is a readout that continually displays the relative distance to the gridded point. If the grid point is flexible and allows it to be positioned easily and
allows grid size and rotation to be altered. AutoCAD (ClarisCAD) handles gridded input very well and has a very flexible grid format. The last way of providing co-ordinates is by snapping to lines that have already been drawn. The important feature for this to happen is the snapping facility. The snap features of interest for this are Snap selection, Intersection snap, Midpoint snap, and Snap & offset. AutoCAD allows most of these very well except Snap & Offset and average snap selection capability. Microstation does not allow for any of these modes very well except Snap & Offset. RoboCAD does not show favourably for this mode of co-ordinate input at all.

Productivity depends on doing things fast and correctly. Dynamic techniques such as rubberbanding, dragging and highlighting help to avoid mistakes and a good Undo command corrects those that are made during the drawing process. These two friendly features allow for a fast, less cautious way of working.

RoboCAD, Cadvance & VersaCAD are only moderately easy to run, which means that experienced operators might find their choice of software package rather cumbersome. AutoCAD favours better in this classification and is likely to be more appreciated by experienced operators.

4.7 Overview of Chapter

The fact is that most companies in Scotland could be classified as small and they are also typical of the companies which took part in the questionnaire, it is my opinion therefore, that these comments are true for companies not involved in my survey.

I have discussed the mock companies as it is my intention to use these company profiles when outlining potential solutions in Chapter 6. It is also a form of summary of the results obtained in my research todate.

The software features are discussed in detail to show that the comments made in Chapter 6 are based on a sound foundation of knowledge. It is also my belief that through understanding what is required to overcome the problems highlighted by my research it helps to identify methods that could be used to train people in package selection. However, package selection is only really only one facet of the overall problem which I now believe to be one of management. This is the major aspect which constitutes Chapter 6.
5.1 Education or Training

One part of the thesis was the evaluation of CAD systems suitable for the Educational sector within Scotland and discuss its interaction with the Industrial sector. This required distinguishing between the roles of training and educating so that I could appraise the different tertiary education establishments that were to be found.

The dictionary meaning for "training" is:-

- To bring to the desired standard of efficiency by instruction and practice.

The dictionary meaning for "educate" is:-

- To train or instruct mentally.

Initially this would suggest to me that there is a similarity of purpose behind both these actions. However there is usually a distinction between the aims of the two deeds. Basically, when the courses are educational they cover the broader aspects of the subject and when the courses are 'training' courses they deal with the specifics - which in the case of CAD it is for a particular CAD package.

The questionnaire showed that the skills gap in the current workforce was being answered by training and this was being implemented by all levels of tertiary education. The trend of the educational establishments is to choose the software package market leader which is seen to be a standard for industry, when in reality there are no real set standards. The problem with this is that it is not necessarily the best software to be learnt for the first time when learning about CAD. In relation to CAD systems the problems for the educational establishments are:-

1. Funding for the implementation of CAD.
2. Selection of appropriate systems (software and hardware).
3. Training of staff to teach these systems.
4. The constant requirement of keeping staff up to date with upgrades.
5. Keeping staff with relevant expertise as the allure of high rewards in other CAD sectors.
may be more tempting.

The problems for Industry

1. Finding the required staff now.
2. Keeping staff from moving to other companies.
3. Carrying out training for staff.

5.2 Current Patterns of use in Education

CAD training occurs in the following level of educational institutes:-

- University
- Polytechnic
- Further Education College
- Skills Training Centre

They, as a group, share some common problems. One problem is funding the implementation and running of CAD equipment which is a considerable drain on their resources. This is because if they are to keep their students abreast of current technology then they have to keep upgrading their equipment. It is not just the matter of buying the latest hardware which does things faster/better or buying software "brand x". The problem is that industry uses a wide range of packages for any given purpose e.g. draughting, stress analysis or DTP. This can be seen from the questionnaire results. Generally, educational establishments do not have the resources to provide training in a wide range of specific packages used by industry.

5.2.1 Education

Irrespective of the type of educational establishment i.e. whether it is a College of Further Education or a University, the question of funding affects the way in which the establishment handles the implementation of CAD. It is also dependant on the role of the establishment i.e. if it is a place of training or a place of education. Training establishments want their students to be trained in the current software and hardware being utilised by Industry. Places of education want their students to be aware of and to understand the potentials in state of the art CAD equipment.

Keeping in line with CAD technology is very expensive but Microbased systems are not as costly as
Mainframe or Mini systems. The CAD industry gives discounts to the educational market although even with this it is still a major outlay of funds.

To an extent the role of the establishment governs how the funding is allocated. Those establishments which give specific training can use all their equipment funds towards the problem, as that is their primary role. Those which have CAD as just one part of a syllabus, have to decide how to split the funding between CAD equipment and the demands of their other requirements.

The questionnaire and visits to educational establishments showed that specific training was being carried out by all levels of the educational structure in Scotland. In the hierarchy of education, at one level were the skills centres, ITEC and similar, which provided specific training in Computer Skills. These bodies train people on specific software packages to meet the demands of their local industries. The people on these courses varied from Youth Training Scheme candidates attending full-time courses to evening classes for local company representatives who were starting in CAD. There were no institutions in this category which used anything other than Microbased Computers, at least according to the results of the questionnaire. Many had started this line of training in response to the Scottish Development Agency Initiative Schemes.

The next level were the Colleges of Further Education. These establishments again run courses in response to the need of the local industry for software specific courses and again they only used Microbased Computers.

The next level of Higher Education which encompasses Colleges to Universities also act as training establishments. This was again to satisfy the requirements of local industries. This sometimes meant they only provided the rooms and equipment and the "trainer" was from outside the staff of the institute. However, these institutions of Higher Education also run full-time courses which contain a "design element" to them. These courses cover CAD as a general subject and introduce packages to their students as examples of their type. To meet the academic demands, the students need to be aware of how to operate the system within the institute to produce examples of their own work. They are not necessarily trained on a specific package to meet the demands of industry. However, the packages chosen are usually ones which it is known are in popular use in industry.

The questionnaire highlighted that a wide variety of software packages are in use but it also showed there are a few market leaders. This variety is due to the differing demands of industry and the requirements of the operators. It is not possible for Educational Establishments to give a broad specific coverage of all the packages. There is not the money or the time for students to learn them.
It has to be remembered that CAD is only one aspect of these courses and not the prime concern.

The most recent review of Design Education in Scotland was carried out by the Design Council, whose findings were first published in 1987⁴. This report briefly discusses CAD as a subset of CAE and states that it helps improve product quality and improves engineering productivity and reduces costs in manufacture. It discusses how these factors have implications for the tertiary sector. It sees that these qualities depend on continuing availability of designers which in turn depends on continual recruitment from schools. It also states that these designers should be highly qualified and trained in relevant skills and their effective deployment in product development. It goes on to say that for Engineering Design and Industrial Design, greater concentration on factors relating to the introduction of Computer Integrated Manufacturing and Advanced Manufacturing Technology are required.

One part of this research was to visit different centres and study how they handled the different factors. I found that the educational institutes are aware of the strategies of funding and the factor of the skills shortages and are carrying out strategies towards overcoming the problems.

The Design Council report went on to make some recommendations. However, since then, there have been changes towards the curriculum in line with their recommendations. There were also changes for training staff to carry out more elementary design education at secondary level and student teachers are leaving teacher training colleges trained to answer the demands which current curriculum changes have made and for those about to be made.

These changes are due to the realisation of the importance of design in the manufacturing industry. The importance of design awareness to the appreciation of any finished item, whether it is a new ball-point pen or an office complex, is also becoming a recognisable factor.

5.3 Industrial Influences on Education

One of the roles of the educational establishments is to supply the demands of industry with a source for a well educated workforce. To meet this task it is necessary for educational establishments to interact with industry and comply with its requirements as much as possible.

5.3.1 Industry

Industry's expectations

It is commonly recognised that in Scotland, the manufacturing industry has gone through quite a
period of change. Where before there were many companies producing their own products, now the majority of large companies produce items which are designed elsewhere. The Manufacturing Industry in small companies has fallen quite considerably and now very little design work is actually being carried out in Scotland. The Design Council describes these companies as being of a nature and scale which is difficult to interface with design resources in the colleges.

However, small-scale manufacturing enterprises are being encouraged and the design content of their items is becoming increasingly important, so that they can compete with their European counterparts. This growth area could bring about a growth of designer employment and the increase of self employment; a similar situation to the Textiles Industry. In the Engineering Industry, computerisation is on the increase and the ultimate aims of CAE require a CAD input to the workings of the system. Even the current level of CAE in Scotland is benefited by CAD input. Companies are using or asking for information to be passed in electronic format. The larger companies tend to use Mainframe computers but they find it economical and in many ways effective to use Microcomputers networked in their system.

The smaller industries also find the Microcomputer an effective medium for CAD input. In these contexts CAD refers to drafting packages. In the Construction Industry there are indications of a growth of shared computer information and in the way that this industry works, it finds that drawings are now more and more being transferred electronically instead of on paper. Drawing files are being shared between Civil Engineers, Architects and Interior Designers. So Microbased CAD usage is on the increase and the demands for people leaving educational establishments to be trained in CAD is also increasing.

In the Microbased industry, there is not an industry standard for information exchange but there is an unofficial one emerging. This is DXF and is due to the widespread use of AutoCAD and software designed to be compatible with AutoCAD. Industry as a whole is showing signs of adopting this as a standard. This is probably due to the changing practice of exchanging information electronically rather than the inked drawing. The reasons of choice for a software package may vary but industry shows signs of moving towards a "one-system-solution" which by its nature has a growing momentum.

Education's ability to respond

Education is tending to follow industry's lead in choice of software. These are the packages being presented to students and the ones that they are learning to use. So to that effect they are training students on systems currently being used in Industry and learning about the more general aspects of
CAD as well. The learning of packages used by the majority of industries is an asset for a student when entering the job market. In terms of Hardware, colleges have a growing use of Microbased equipment and the choice of Apple Macintosh or IBM compatible is reflected in the major decision of the software packages required. Partly due to the level and manner of funds, decisions are made by individual departments.

The increases in computer power are proving that Microbased systems are even more suitable for CAD usage even though CAD is very demanding on computer resources. This increased adaptability is useful for the more demanding of CAD tasks in 3D design work and this competition with lower-end Mini systems could prove convenient for the Educational Establishments. That is it allows institutes with limited funds to be potentially able to show their students a wider range of packages on the same machinery. Thus freeing them of the need to have different hardware types. However, some graphics packages and solids modelling packages still require the power of mini computer technology.

The dilemma with using industry standard software is a factor of time. The software is usually more complex in its sophistication and operators gain efficiency in its use through hands-on experience and time on the system. Students do not usually get sufficient time to learn these packages and do not have the same day-to-day contact with the system allowing them to achieve familiarity with the system. In cases such as this it would be better for the educational establishment to opt for a package that works in a similar way but is more intuitive in its working and easier to learn. The leading software manufacturer Autodesk has recognised this by launching Autosketch which is an elementary version of AutoCAD but this is only one example of this happening.

Carrying out training for staff is discussed in an article by Winton\(^1\) where he describes the situation for the Computer Graphics Industry. He sees that educational establishments are not supplying industry with enough students and those who are coming out, are being enticed abroad. He sees that this shortfall is due to the industry's explosive growth and fragmentation.

Winton\(^1\) takes the industrialist's common viewpoint of small companies to whom the training of a single person represents a significant investment in "down time" and, being non-productive, believes that companies should not or do not see this training as an investment for the future. It is thought that because the Graphics industry consists of small companies they do not have the resources to train their own staff. He comments that Educational Establishments should fulfill industry's expectations and requirements by ensuring its staff are equally informed in all relevant fields of the industry and that they have more experience of business. If industry has these expectations mentioned by Winton\(^1\) they should do more to co-operate with the educational establishments, so
staff and students have a clearer idea. Industry gives the impression it is too busy for this sort of interaction but expects establishments to get the experience elsewhere and to get on with supplying the students which industry needs.

The short term answer really lies in those establishments which are set up for passing on skills, such as Further Education Colleges and Skills Centres, to carry out the necessary training for current workers to meet local industry's requirements. This would leave the establishments set up for higher education free to carry on a more general education about CAD on those courses which require it, so that their students are prepared to cope with the technology of the future. This would be the educational content rather than the vocational training element which is required by industry now. The students passing out from the educational establishments would be the required "commodity" of industry's needs in the future. To some extent this is already happening but some universities are still running training specific package themselves and there are no clear demarcation lines at present.

In an article by Simon\textsuperscript{2} which highlights the problems with introducing Computers in Design Teaching, he states that the danger of introducing any technological equipment into a course is that it tends to be self justifying and its very presence dominates the planning and execution of the syllabus. So when a large investment has been made he considers that the staff responsible should be required to justify their decisions. Justification should be based around learning quality and not measured in terms of use such as quantity of hours.

I share the opinion also made by Simon\textsuperscript{2} that the emphasis for full-time students should be on education rather than training but that as more educational establishments offer training courses in CAD to local industry the distinction is becoming blurred. Due to high costs of equipment this training to industry is seen as a good way to recuperate funds. Simon\textsuperscript{2} considers that the broadest educational aims are met by a syllabus which prepares students to cope with the technology of the future and not just the current. He also compares this with the comment:

"whereas a narrow vocational training in today's technology is not a good preparation for a rewarding career".\textsuperscript{2}

It is considered that to understand and appreciate the area of work that is being carried out by an individual it is useful for that individual to be aware of the overview of the processes concerned. This is true for all computer processes. The starting point for a broad educational approach is to look at the teaching of design as a "unifying theme within engineering and to ask where do we need to use computers?".\textsuperscript{2}
This would be achieved by the following aims:-

1. To give all students an appreciation of the technology both available and under development in their field of study.

So for computers the view needs to be more than a superficial understanding of the function of current computer systems by allowing students to handle a CAD system. A deeper study of systems used in design so that students can appreciate general similarities between systems rather than their obvious differences.

2. To give students experience of using a variety of computer systems. This raises problems such as :-

   a. Amount of time needed to learn to use each design software before it can be fully appreciated and assessed and the resulting pressure on the syllabus.
   b. The resources needed to ensure that every student has reasonable access to facilities.
   c. To generate an understanding of the roles to which computers can be put. To recognise their strengths and weaknesses.
   d. The variety of technologies have to be placed within the context of current industrial and commercial setting, so that students can appreciate and be prepared for the variety of different stages of computerisation in industry.

To carry out these aims it is therefore not necessary for educational establishments to cover the range of software used by industry but only to cover examples of different types of software. The classes of software would probably include2:-

1. True modelling systems, 2D or 3D, for mechanisms, solids, surfaces and which can be used at the earliest possible stage.
2. Calculation aids, for solving a specific problem/ type of problem for the evaluation of a design.
3. Simulations, usually specific to one process, which involve the construction of a mathematical model of the design.
4. Drawing and Painting systems for 2D design presentation.
5. Design Presentation Aids such as Desk Top Publishing or Word Processing.
An earlier study on CAD in the Design world, which coincides with my own views, showed that in certain areas, employers had an altogether different attitude to Winton\(^1\). This found that employers involved in I.T. still looked for the traditional criteria when considering employing a designer, with the view that they could train the person in any specific skills whenever it was needed\(^3\). In this study the employers thought the colleges should continue to teach the traditional aspects and skills of design and disregard Computer Aided Art and Design skills. The work went on to outline that possibly the employers were mistaking the teaching of specific knowledge of one package to students as CAAD training and forgetting the education of students in CAAD in general. This led on to the argument that this relieved the financial drain to colleges in purchasing CAD systems and allowed them time on other subjects.

However, the report went on to agree with Simon\(^2\) in making the conclusion that "Facility in the use of computers seems of far less importance than a breadth and depth of understanding of their significance". The report still thought it desirable for students to get some experience on Computers so that their overall education would benefit from personal experience. It then argued that in the educational world, to place less importance on trying to mimic, at great expense, and with a shortage of time to its complexity, the industrial implication of computer based applications and a move to a more general, broader, understanding of the issues. This could be brought into perspective by looking at the working life of a student leaving college now and comparing it to the functional life of a software package. Approximately 40 years working life for the operator against 8 years for the effectiveness of a software package. Arguably its life span is shorter if compared against new software coming out during its working life but it is viable software for most of those 8 years. After this time it would find it difficult to compete against more recent software. Computers would appear to become more of an essential to design rather than an option. The areas under study are more vocational than some of the areas that this report covered. Of those vocational areas it is becoming obvious that they have their differences in the usage and requirements of CAD.

5.4 Current Teaching Methods of CAD in Educational Establishments

One part of the research required the study of teaching methods of CAD in educational establishments. The places visited covered Engineering, Graphics, Architecture and Design sectors. This was to see if there were any similarities/differences and approaches in CAD so that comparisons and evaluations could be made to enable a set of proposals to be made.

It was found that the period of CAD teaching duration ranged from hourly sessions to morning/afternoon blocks to weekly blocks. One engineering establishment used hourly sessions and
in these they carried out programming lessons and training in specific packages. The college involved claimed that this method was found to suit their time-tabling and certainly it suited instruction in programming languages. Another engineering establishment preferred longer periods of a block morning or afternoon. Both places found it useful to teach a programming language as they were not just interested in the software capabilities but they considered it necessary to get the computer to interface with other peripherals. An Architectural school initially taught in hourly sessions with programming included in the CAD syllabus but found, for them, programming was not necessary and that one hour on the computer each week was insufficient to learn much since the first fifteen minutes were spent recapping on what was taught the previous week. This school now only introduces Computer Aided Architectural Design as an option for a few students and they get intensive tuition and time to acquaint themselves with the equipment. The stress is not on a specific system but it is taught as an example of CAAD but there are other types of systems. An art college which had a range of disciplines, found that initial training in weekly blocks to acquaint the students was satisfactory. They were then given top-ups throughout the rest of their time at college. Another art college also favours this period of weekly blocks. The students then choose whether to develop their skills or not, or only if their course requires it. One college which is more a graphics type establishment, mainly 2D, also favoured weekly blocks and then as the students work required it.

Strategies for computer implementation were of two types:

1 Centralised CAD unit
2 Departmental CAD units.

An art college initially tried having a centralised CAD unit but found that with all the disciplines in the college it was causing problems. The problems consisted of staff getting to know all the packages so they could teach them and the time involved in this. Time-tabling also proved a problem when trying to allocate each department its own time in the computer room. This college decided to meet all the demands which were necessary for each department to purchase its own specialised systems and to use them as they required. At present, they share initial training with the computer unit but it is foreseen that this will have to go as it now does not have the internal budget it once had. Financially, the centralised theme sounds the best with a unified budget giving greater spending power but if there is more than one department requiring CAD then the main budget has to be divided by the number of interested parties as they will all have their own demands. (Typified by the art college example.) The 2D graphics establishment on the other hand had less divisions and they were not divided in their interests so they found that they were moving towards a centralised unit with staff specialising in CAD and away from their initial craft specialities. The arts based college tended to
have relevant computer systems spread throughout the college and open access systems for the rest. One college which had an Industrial Design department had shared computer facilities within the college so it was open for all departments but the graphics were divided from word processors and computer performance reflected the requirements of the software. They tended to opt for the initial block training and then only as the students' work required it or if a better result would be achieved on the computer. The students were advised about this.

Those colleges which had shared facilities found that networking allowed better access to packages throughout the establishment.

5.5 Trends in Education

1 The CAD content in any one course is proportional to the level of importance placed on it in relation to the level of importance to the overall course content and nature of the course.

2 The CAD facilities reflect more the budget of the department than the requirements of the courses using the facilities.

3 The selection of software is usually to mimic industry and so benefit its students, with a proviso of cost being of equal importance when selecting the system. Another concern would be the time necessary to learn the system.

4 The Educational establishments which I visited are concerned that students need not spend a disproportionate time in learning to use the system before they can produce work from it in relation to the other work demands on the students.

5 Availability of computer facilities to students varied from place to place. For example, the opening hours of one establishment was 09.00hrs to 17.00hrs working on a first come first served basis working on a machine the whole time and in another it was 07.30hrs to 21.00hrs but students had to book time on any given machine for hourly slots. This was usually based on internal policy on access and security within the establishment.

6 The manner in which CAD principles and practices are taught varied between the establishments. Some required that all their students should have at least the basics whilst others gave instruction if and when the students' work would benefit from it.
7 There are developments which are aiming at setting up of standards in CAD Microbased software which would be beneficial for all concerned who have to use the software.

5.5.1 Development trends which could influence the Education sector

1 Harder areas to predict on their influence on educational establishments are the developments and financial implications of computer technology as a whole. It is not only Microbased technology which needs to be considered here but the whole spectrum of computer technology. Developments in these areas might influence financial aspects of micros or they might have spin-off effects that would enhance Microbased technology. It is probably safe to assume that they will become even more powerful and capable of handling CAD topics. Software will probably change in relation to these advancements and it will become even more efficient in its use of current technological constraints.

2 The overall effect of this is that it will become even more desirable to industry and it will be even more essential that there are people able to use it to carry the design functions. Some software developments such as proper industry standards and shared terminology in CAD commands might eventually make training a lessening requirement as well.

3 The educational establishments could offer services to local industry such as crises printing. This would be used by local companies when their own print facilities have broken down or are being extensively used in busy periods.

4 More specialised training in areas such as intensive awareness courses and CAD management courses for the differing design activities in the local area could be carried out.

These services would be advantageous to the establishment as they will:

- Give extra funding to them.
- Acquaint the establishment's staff with current Industrial Practice.
- Allow the establishment to be running software used by industry.
- Give increased and improved connections between the establishment and local industry.
5.6 General Problems of CAD education as opposed to training

1. Time needed to learn to use the design software before it can be fully appreciated and assessed with the resulting pressure on the syllabus.

2. Resources needed to ensure that every student has reasonable access to facilities and the time-tabling complications that limited resources can produce.

3. Nature of the software and its suitability for the educational aims. Much commercial software is designed for regular, well-trained, users.

4. CAD education should reflect the various technologies that will prepare students for employment in organisations at differing stages of computerisation ranging from complete manual design offices to integrated CAD/CAM set-ups to be found in the aeronautical and motor industries.

5. Some expressed that the look of the drawings was impersonal.

6. One establishment thought there was a danger that people would design according to the system constraints and not the "physical" constraints of the would-be design.

7. The same establishment found that the people who used CAD with the best results were not necessarily the ones who could be termed "computer buffs".

8. It was apparent from interviews and opinions expressed from people covered in the questionnaire that there would be a lot of interest in self-learning packages.

5.6.1 Problems with Current Practice

These can be listed in the following way:-

- Allowing students access time out of the normal working hours for "college" staff.

- The number of students wanting to use computers to the number of computers available.

- Finding the time to be proficient in the use of the necessary software.
• Academics have difficulty finding the time to become, and maintain, the efficiency in relevant software. Some do not even know how it works. This suggests that even for those who do not use CAD in the Design Department, there should be a series of awareness lectures so they can appreciate the value and potential of CAD in the students design projects. This is closely paralleled by the company situation of awareness training for upper management levels.

• Academics do not have the time to stand around the computer facilities on the 'off' chance a student might need them.

• Finding the academic staff to ask questions about problems with the software. This causes a dependency on the Technicians who are not necessarily the 'right' people to ask. This is because they are often not experts in the field of design although they are skilled users of the software.

• Increasingly there are instances that students encounter problems that are a mixture of design matters and software limitations. Traditionally the technicians are not employed to teach the students in design matters. Therefore, with the increasing use of CAD in Design courses, this suggests that there will be a need for a change in the job description to encompass a new hybrid role to facilitate the new requirements brought about by the introduction of computers. Thus, this would result in a role where the person would be half technician and half academic in the relevant subject. This could have difficulties in establishing a pay scale for this new category and even one of finding the proper staff. It is not considered satisfactory for students of one design activity to be taught by an expert in an unrelated field. This has been the cause of some complaint by people when they have gone to general package training courses. When the person is skilled in the proper activity it ensures that the computer application is directly relevant and the students gain a perception of the computer usage as an integral part of their design work. This does not happen when the CAD training is given by a non-relevant user where students see that CAD is a disjointed part and tend to understand its use in a negative fashion.

• Educational Establishments have the problem of how much the software and the equipment have to resemble those used in Industry for the education of their full-time students. On the one hand, industry standard machines make for an easy transition for students from classroom to drawing office situations. On the otherhand, the packages might need a heavy time commitment - initially away from studies for the students to become proficient. The dilemma is that educational establishments are more concerned in passing an understanding of the broader issues involved. The impression gained from industry is that they require students to be 'trained' in specific
packages. The problem with this is that not all industry uses the same package. Only in the cases of evening class students or day-release students do they really require specific training which can be easily identified. This is not a variable option for an external training course.

- Specialist CAD units within departments overcome the problems of general service units as it is easier to match the required software to the hardware. This failing in general service units arises as they have widely differing needs.
6.1 Overview of the Chapter

To illustrate the potential solutions the Chapter is divided into two sections. The first section explains the nature of a self-teaching option and how it can be useful. This first section also explains the structure of the package that would be useful. The second section uses the company profiles illustrated in Chapter 4 to illustrate potential solutions for ‘Product Design Companies’.

6.2 Self-teaching option

The research to date has shown that one solution to those companies wishing to start up in CAD and/or develop their CAD system would be a self-training package. The layout of the training package would have to recognise that each reader would have differing amounts of knowledge and requirements. The package would therefore need to be written in a manner such that it is not necessary to start from the beginning of the text and that each section of the package is readily accessed.

My proposal for a training package of this type would be based around the three main phases in purchasing a CAD system thus dividing the package into three sections entitled:-

- Justification
- Selection
- Implementation

The package would start with a flowchart illustrating the contents and acting as a contents section. Then it would be divided into the three sections. Within each of the above sections there would be chapters covering the recommended procedures to fulfil each section. The chapters would themselves comprise of paragraphs necessary to achieve the chapter heading. The package would have to be as free from jargon as possible but, where impossible to avoid, the term used would be explained. The terms explained will be as the operator needs to know them and not in any ordered list such as in alphabetical order. However, a reference section of the terms used would also be provided and this would be in alphabetical order. To help the user of the package work their way through and around the package there would be cross-referencing to related sections. This would facilitate the differences in background knowledge and experience of potential users and prevent the
user having to waste time reading the parts which they are already familiar with.

So to illustrate the necessary contents and to help me answer the problems of the five mock companies, I have constructed the framework of the proposed training package. The contents of this package are based on my research notes made during the earlier stage of the project. There are sections in the example training package with only a title as it is unnecessary to write about them since they were not an essential part of the research. However, the title is mentioned as it helps in the illustration of a training package. The supporting reference sources can be seen in the reference section relevant to this chapter but not mentioned in the 'training package' as I considered that it would spoil the illustration of how the package would look. The contents can be seen in Volume Two. I would expect that in a 'real' package, the layout would be more finished visually and some of the contents expressed differently making it easier to read. Volume Two therefore represents what I consider to be the necessary contents for a training package for the proper management of a CAD system. It includes a wide range of aspects which the research showed were being neglected at present. Some of the aspects were based around comments made by companies participating in the two questionnaires.

6.2.1 Summary of the contents

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The Justification Phase would involve the following:-

Stage One

Analyse current working practices and description of the work carried out.

How the work is broken down such as how much of it is:-

- Conceptualising.
- Detailing.
- Prototyping.
- Production drawings.

Who wants the work?

Who might want the work?

How the work might change.

Review of the company's financial capabilities.

- At present.
- In the foreseeable future.
Stage Two

Familiarise oneself with what CAD offers

- Learn about the terms and jargon involved.
- CAD's capabilities.
- What others are using.
- What could be used.

Stage Three

Review of how all the above information interacts/could interact with each other.

**Selection**

The Selection Phase would involve the process of matching the following:-

- Preferred working practices.
- Desired working benefits/needs.
- Financial capabilities.
- Proposed development plans.
- Recognition of the needs of the work place.
- Recognition of the needs of the staff.

With the software available on the market at the time of selection.

**Implementation**

The Implementation Phase of the system is a successful process of combining the following:-

- Working with the system.
- Learning (fully) the system.
- Developing working methods with the system.
- Evaluating the system.
- Recognising the strengths and weaknesses of the system.
- Developing the staff.
- Installing the system to gain its maximum efficiency.
- Ensuring staff comfort.
1 Physical
2 Mental

- Developing a working drawing database.
- Recognising any future requirements.

I would suggest that the contents of Volume Two should be used in one of the following ways:-

1 The manual would be given to a company to decide the relevant sections it needs to meet the individual requirements of that particular company.
2 The manual would be divided into relevant sections to match each individual company’s needs. This would be carried out by an outside consultant.

The CAD operatives would then use the manual initially by reading through the appropriate sections and then as a reference book as and when they required to use it.

6.3 Solutions for the Mock Companies

The very nature of the work involved in Product Design provides all five companies with some common attributes. The differences usually being a matter of scale. By scale, I mean size of the company and/or financial strengths. Should they be in a position where they all had the same starting point, level of knowledge, experience and capital, then they could quite easily follow the same plan of campaign when proceeding through the process of deciding to purchase a CAD system.

6.3.1 Solutions relevant to Company One

Company One has attributes typical of Product Design companies in Scotland, which are liable not to change until the competitive related pressures force them to change.

Company One’s situation and the problems that it can be expected to encounter can be summarised as follows:-

The lack of practical experience and computer awareness will make it difficult to overcome the company’s reticence and the imposed barriers that have been established through the following considerations:-

- The company does not have sufficient financial resources for developments.
• CAD is not really necessary to working requirements.
• That work produced by humans has a higher aesthetic quality of finish.
• The company lacks familiarity with the new technology.
• It is too busy to obtain the information.

The difficulty will be assessing the advantages, disadvantages, costings, organisation and training needs of the company.

However, the person who has the interest in using CAD is one of the company's partners which gives him sufficient power within the company to maintain the drive through the difficult phases of considering the merits of a CAD system. The company does positively consider that computers are more accurate in draughting precision.

The relevant aspects of the three phases of acquisition for a company such as Company One can now be discussed.

When a company is busy and considers that it does not have the time to carry out an evaluation then there are only two reasons why change would occur. The first would be if external pressures would initiate a change. These pressures would be:-

• Increasing complexity of modern design.
• Design of completely new kinds of products.
• Need to work in multi-disciplinary products.
• High risks and costs of modern design.
• Reduction in design lead times.
• Economies in design and draughting lead times.
• Economies in material usage.
• Combination of CAD with production automation to obtain benefits of integration (CAM).
• Major customer insists on design work being carried out on package X.
• Market pressures forcing company to use CAD just to stay competitive.
• Contracts lost due to lack of CAD.

The other reason would be for someone within the company to champion the cause of CAD.

In the current economic climate and in Company One's case this latter reason would be the reason
why change would be considered. In Scotland at least, I expect the external pressures will not really become strong enough to impose on Design Consultancies to change for approximately the next 5 years. This is partly due to the recessionary burdens currently working on industrial development.

So, assuming that change is initiated by the internal factor, before trying to increase computer awareness it would be advisable for the CAD Champion to carry out a detailed evaluation of the company including any possible plans it might have for the future growth.

- Analyse current working practices.
- Who would want the services of the company?
- Who might want the services of the company?
- How the work might change.
- Review of the company's financial capabilities.

This can be seen in more detail in Volume Two - Justification Phase 1.1.1 - 1.1.6. This evaluation would help show any flaws in the current working practices and initiate a study on how to remedy them. One potential solution would be the adoption of a CAD system. There are many reasons for purchasing a CAD system but the reasons that are usually given are displayed as a panacea to all companies regardless of activity. This is not the case and each company's situation is different. The company has to evaluate its own current situation and pinpoint just which benefits are applicable to them. The following list is, therefore, seen as possible ways in which Company One could benefit from CAD.

- The use of computers can help the way in which a design company operates and allows people to be more in control of their working time.
- CAD allows the company to take a democratic and decentralised approach to management, where everybody does their own administrative duties on them.
- The investment is in the people who operate the system.
- Computerisation is seen as a way to prevent further staff growth rather than staff decline. The ability to alter salaries might be seen as one way to encourage staff to remain with the company. However, it is still a viable option if the staff are handling an increased workload.
- The following are ways that CAD is seen to be quicker:
  - You can get plans, sections and elevations from a single database, revise them a lot faster and provide information selectively for different people on a computer than you can manually.
• It enables you to communicate better. Today's world requires more information than in the past, much more quickly and more precisely targeted. CAD allows you to keep pace. The CAD system provides a common database from which useful information can be calculated. Database information can be passed to other computer programs, for example, CNC programs.

• The repetitive work is now much easier to do than when it was done manually.

• The system allows us to make corrections and alterations far easier than before preventing the need to have to do the whole drawing again if the changes were drastic. Now anyone can alter anyone else's drawing and you can not see the joins.

A more detailed explanation can be seen in Volume Two - Justification Phase 1.2.11.1.

To increase computer awareness within the company, the CAD champion could carry out the following procedures:

• Read CAD magazines.

• Visit CAD exhibitions.

• Visit Educational Establishments which teach in the relevant field.

The champion would be advised to carry out at least two of the above steps so that a realistic perspective of CAD's capabilities is achieved.

So far the CAD champion has only made people within the company aware of CAD's capabilities at a general level. The champion must now carry out the process of justification to 'sell' the idea to the company 'doubters'.

The process of justification has essentially two major constituents; financial and technical. These are described more fully in Volume Two - Justification Phase 1.3.1 - 1.3.2.10. In Company One's case, the champion would have to concentrate on the eventual financial advantages and the technical merits which CAD offers the company. These advantages would be:

• The saving in time on complex development projects that often require many modifications throughout the projects gestation period.

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The saving in 'design' time which the above gives, allows the designer to carry out more qualitative work and/or design time on other projects.

The champion could illustrate the case by showing the costing of a design job carried out previously, compared to what it would approximately cost when carried out on a CAD system. This method could show the company what the cost of not obtaining a CAD system would be.

The areas to study are in lower inventory, faster response times and better quality as these areas are seen to lead to higher profits rather than studies in utilisation, labour efficiencies and cost per part.

The technical advantages are:-

By selection, a package which allows the operator to choose features such as line style, text style and others, the operator can create a drawing that is dimensionally more precise and not clinical in appearance. The level of sophistication of the final drawing would be dependant on the complexity of the package. Should a less complex package be used there would be nothing to stop the company enhancing the work in any way it liked. In fact numerous prints could be made allowing the company to illustrate to the client different aspects of the design.

To comments such as, 'the company is too busy', then the process could be carried out initially in periods of relative inactivity, or, if the champion is one of the partners, then he may be prepared to carry out the early work in his own time.

The selection process needs to be carried out as relatively quickly as possible so that information obtained during the process is still valid. It would be also necessary, as Company One considers, it is too busy 'doing paid work' rather than planning for the future.

Company One would have to carry out a selection process as described in Volume Two - Selection Phase.

Provided Company One has decided to purchase a CAD system, and that it is still very busy, then it must work on a successful implementation scheme.

The system set-up should be planned such that:-

- Standards and defaults are set to ensure consistency of work.
- Data structure based on research that studied the needs of all affected
departments.

- Back-up and recovery procedures i.e. fireproof safe for copies, back-up routines established, possibly daily back-up.
- Plotting procedures for mundane tasks such as who cleans out the pens or cuts off the plots?
- Establish access controls/passwords/user's directories.
- Monitor a system usage and performance.
- Produce a company system handbook which contains all the standards and procedures for everyone to refer to.

A work plan should be organised to facilitate the implementation. The following is one method after initial training has been carried out for example:-

- Select modest work first.
- Set achievable and measurable goals for first 6 months.
- Identify symbols/parts for capture.

It is also helpful to create a standard demonstration for visitors to minimise the impact on production and present the best image whenever required. It is essential to prove the short term success of the investment to the senior management e.g. the senior partners and any other affected departments.

The introduction of the system will have an effect on current work and this should be allowed for, such as:-

- Current projects being handled manually.
- Throughput to/from other departments.
- Acceptance of new style output by other departments such as plots or prints.
- Time-scale for CAD based work
  - allow for learning curve of new users.
  - casual users produce casual results.
  - no database in the early days which is the equivalent of the worst case situation in a job.
  - there will be the inevitable snags.

The implementation scheme can be seen in more detail in Volume Two - Implementation Phase.
6.3.2 Solutions relevant to Company Two

Company Two's position is typical of most small product design concerns in Scotland without CAD. So for the purposes of this exercise the designer sets out to consider the merits of the acquisition of a CAD system. So for a company in this position it is worth considering the three phases. These being Justification, Selection and Implementation.

Company Two's position and the problems it can expect to encounter can be summarised as follows:

This is a one-man organisation which does not have to develop the arguments for CAD to persuade anybody else as in larger companies. In some respects, this makes the justification and selection stages easier and less formal. However he probably has to develop them sufficiently to persuade a bank manager to provide him with the funding. His problems are that he considers that he has not the following:

- The working space for a system.
- The time to train on a CAD system.

However, he is prepared to consider CAD as it would speed up the time to produce engineering drawings especially as the development work often require changes. He would want the system to be capable of more than just 2D draughting material.

The relevant aspects of the three stages of acquisition for a company such as Company Two can now be discussed.

The justification process in this sort of example will be based primarily or winning agreement for financial assistance from a bank so it should be a more detailed study on the cost aspects of a CAD system, both in the costs incurred and financial advantages to the company purchasing the system. In Company Two's case, he will have to establish if there will be sufficient space and that the learning period will not be too demanding of his time.

Costs Involved
The important point to remember is that when you invest in a CAD system, getting it right first time is imperative. The cost of failure is high. Investing in a CAD system is a serious and costly decision which can bring enormous benefits if the company makes the effort to examine the whole business and to consider the potential strategic impact of CAD.
There are different types of cost involved in the purchase of a CAD system and they have their own aspects associated to them. The different types of cost are:

- Justification
- System Purchase
  Justification of costs for:
  - Starting up
  - Continuation
  - Maintenance
- Service Contracts
- Training
- Office Adjustment
- Maintenance: what is required
  - Continuation/maintenance:
    - Service contracts
    - Parts breakdown
    - Levels of maintenance:
      - In-house repairs
      - Skilled

In the planning stages for CAD the issue of cost is a very important factor. It is often the main deciding criteria for either the continuance with the purchase of the system or the level and type of the system finally purchased. The type of cost first encountered when purchasing a system is connected with the justification of the system. This is an area where potentially, mistakes can be made, especially if using traditional costing procedures.

Any cost justification exercise needs to start from a clear definition of what it is that we are trying to do; that is, the establishment of a set of objectives against which the project can be measured.

A Design Consultancy has to be a viable business concern just like any business today, and it, more than ever, is about continuously improving the "competitive edge".

Cost justification is essentially about comparison but it is becoming increasingly obvious that present day Costing and Accounting Systems do not always provide useful benchmarks against which to measure the potential of new ideas. Current systems often base all costs on Direct Labour hours,
regardless of the fact that these have shrunk to only 10% - 20% of total costs by the application of JIT and other techniques. The division or allocation of large overhead costs to these small amounts leads to difficulties. It is also not entirely satisfactory to use Machine Hour rates. This is a situation not so applicable to a small Design Consultancy where there are not so many indirect labour costs and all labour is more closely connected to related working costs. It is not the case, therefore, that justification can be based around comparison with staffing costs. The single most important factor in successful personnel selection for a CAD system is enthusiasm for its implementation.

Financial appraisal is, of course, only one of the tools used in the justification of investment. It is the most difficult to use but often the first to be applied. It is important that the accountancy and financial sectors of a company are both fully aware and fully committed early on, as questions of justification may need considerable effort. It is also important to agree early upon the financial appraisal methodology, the contents of any financial model, and the basis of all the forecasts used in the process. The financial appraisal is basically the prediction of the financial results which will be produced by a project over a period of its own lifetime, the comparison of these results with general go/no go criteria target guidelines, and finally the integration of these predicted results within the wider framework of company forward planning to assess the effect on the Profit and Loss Account and Balance Sheet, which is where the translation of one accounting conversion to another becomes difficult. So what is basically meant by Financial Appraisal or Financial Justification is that it is a simple calculation of savings against costs carried out to justify the purchase of an item to produce a pay-back period.

Financial appraisal should be considered as being a three stage process.

1. Construct a set of predicted financial results for a new project on a stand-alone basis.
2. Comparison of the results of stage one with those factors representing existing arrangement.
3. On successful results of the previous two steps, the integration of such predictions into the more comprehensive accounts maintained by the company particularly into the forward financial projections which should be prepared as part of the full effect of the project, on the "bottom-line" can be assessed.

The appraisal needs to be made in a form which takes account of all revenue and cost generation activities - whether these be direct costs, indirect costs, or any other form of cost term which is being used by the company. This facilitates later integration into the predictions of Profit and Loss Accounts.
and Balance Sheets.

The object of financial appraisal is financial justification and justification aims at overcoming doubts and disbeliefs. It also covers "lack of conviction" rather than an outright rejection of proposals.

Project Time Scale is an important element in Financial Appraisal. Investment in a CAD system can be over a period of time and the factors involved need to be carefully considered. The economic life expectancy of a new piece of equipment may differ from its effective technical life expectancy. By technical life expectancy, I mean by its technical obsolescence. This is a factor which is changing drastically in the rapidly moving world of CAD. To assess this, companies use typical criteria such as setting targets for Simple Pay Back, or for Return on Investment, Internal Rates of Return and Net Present Values. This requires the use of analysis techniques.

The most common method is Simple Pay Back - that is the time taken for savings to recover the investment. It is the most simple to understand and to calculate. The drawback here is that no account is taken of the time value of money or the actual technical or economic life of the system.

Another form of simple analysis used is to assess the Return on the Funds Invested (ROFI) which is calculated in a similar way to Pay Back although it is expressed in the opposite way. The time value of money and the life of a project can be taken into account by using discounting methods. Both Internal Rates of Return (IRR) and Net Present Value (NPV) techniques have their advantages and disadvantages. They are reportedly becoming more commonly used and are relatively easy to perform on small computers using the widening range of analysis software currently available. The problem with this is that it is unlikely that Design Consultancies would have this kind of support readily at hand. The first two methods of analysis are therefore the most suitable to be carried out by a Design Consultancy.

To carry out the evaluation of the quantifiable elements in a Financial Appraisal you first need to start by establishing a "Bench Mark" or "Reference" against which to measure the predicted results (savings) of the project. This is taken to be the "Status Quo" situation but to incorporate the time element, the "Status Quo" situation needs to be projected forward. This is difficult as no company can stand absolutely stationary and isolated from the outside world e.g. labour rates change, material costs change and the market changes. The "Status Quo" case for a Design Consultancy would be the case of doing nothing and carrying on as before. However, the cost of doing nothing is not as easy to establish e.g. how do you predict what not having the system will cost in terms of work contracts?
In the justification phase for CAD the issue of cost is a very important factor. It is often the main deciding criteria for either the continuance with the purchase of the system or the level and the type of system finally purchased.

Competition with other companies is likely to be intense and rival companies will no doubt be equipping themselves with the latest technology as well. Marketing issues are also likely to be more intense. The alternative aspect to be considered is what happens if the company does not get the work increase as predicted? This has to be considered for the obvious reason of getting a complete overall picture for the appraisal.

Non-CAD companies often state that their working area is not suitable for CAD as they are in an area of one-off designs. This shows the ignorance about the potentials of CAD. It should be shown that even one-off designs have geometry or contain standard parts that CAD can handle more quickly and that some parts of a design can be used at a later date - all of which leads to better performance times than manual work.

When evaluating systems it should be remembered that the CAD system is not only as a solution for replacing the drafting board but it has a potential impact throughout the engineering, manufacturing process and modify how that process is organised to maximise the returns on the investment. This type of analysis should consider whether the system be used with dedicated operators or as a shared resource among a number of part-time users. What is the impact where manufacturing is involved in the design process during the concept stage, rather than once the drawings have been completed? What information can be passed to materials planning and finance systems during the design process so that cost optimisation can be considered?

Ultimately, the real value of the system is not the hardware nor software, but rather the value of the design and documentation databases and 'experience' stored within.

The system must be treated as a profit centre for which the only goal is to make money as fast as possible. If you measure volume you get output. If you measure efficiency you get activity, if you measure throughput you get profit: lower inventory, faster response, better quality, leading to higher profits - rather than outmoded concepts such as utilisation, labour efficiency, cost per part.

Accounting in modern manufacturing is currently in a state of transition, accompanied by some uncertainty. Ideas such as JIT have won almost unquestioned support, but the accounting systems
to complement them are lagging behind. It is possible, however, to see common threads running through the new ideas. These include the trend towards overall performance measured rather than departmental costing, the use of several different accounting yardsticks rather than one, and the need to involve production staff in accounting processes.

The accounting methods discussed here show that the costing of CAD equipment is still in its infancy and it is understandable that companies are not using a truly practicable method for the cost justification for the purchase of CAD systems. It also suggests why, potentially, other feasibility studies carried out by companies have not been continued into system purchase and explain why some companies consider CAD too expensive for their company.

The justification has to be well balanced and any areas of objection should have responses clearly explaining how these can be overcome. It helps identify the cost areas and prevents the mistake of only acquiring the prices for the software and basic hardware then later finding out about the extras such as Computer Installation, training, computer consumables, colour graphics cards, maths coprocessor, mouse or graphics tablet, output devices, maintenance contracts, software updates.

**Hidden Costs**

These are illustrated by examples such as software, training, commissioning, maintenance and relevant costs.

These are principally caused by grossly underestimating the fundamental nature of the changes which are required. These span all facets of the organisation but especially attitudes, functional roles, resources and time.

One hidden cost is the cost of an incorrect decision caused by factors such as skimping on expenditure or incorrectly identifying the real needs of the company.

Unsuccessful CAD installations are often due to the wrong system being chosen good benchmarking can avoid this, as can the system.

Identification of your cost areas, prevents falling into the trap of asking only for the cost of CAD software and computer, only to find a complete installation demands more: colour graphics, maths coprocessor, mouse/graphics tablet, a plotter/printer, training, (post and pre purchase) maintenance agreement(s). Cost allocations might be withdrawn if hidden extras comes to light.
Cultural dislocation can cause productivity and losses can persist until fully operational.

Cost Prediction

When predicting cost benefits it is prudent not to predict grossly inflated cost savings and to use realistic assumptions and payback periods when carrying out a financial appraisal. There are difficulties when carrying out this work. The real problem is that it is notoriously difficult to get real information on the savings that can be achieved.

The use of payback to CAD expenditure in terms of staff reductions is not a good policy for either staff motivation reasons or what is now being recognised as suitable cost financial practices. A more palatable way would be to argue in terms of ways to maintain staff levels or prevention of further growth. This could be argued in terms of savings against the costs of company growth such as increased staff salary bills, greater space costs, more equipment and material costs.

Company Two should use current work to derive a working budget and determine an approximate investment for software, including specialised application modules and libraries. The same methodology should be used for hardware, including peripherals such as a plotter. This would be achieved by adding 10 to 30 per cent to cover training and start-up consultancy, also another 10 - 30 per cent for furniture and facilities.

Lower cost systems may require a higher percentage of extras. This is the total investment required. While it may seem that some of the non system costs are high, remember the first six months are the most critical. Skimping at the outset in training and support will cost much more later and delay the effective return on investment. At the end of the justification process the company will be able to decide if it should proceed with the purchase or discontinue with it.

Quantifying the costs

The direct costs of a CAD system are fairly straightforward to establish and assess. The direct savings from the CAD system are harder to establish and are partly dependent upon the individual company's particular situation. Pitfalls can arise on the cost side of the calculations such as estimates of the investment required - how many times does the initial cost estimate advanced by a supplier bear little relation to the final quotation?
How can these be quantified?

Some benefits are more easily quantifiable than others, the following are some of the more easily assessed benefits:

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Productivity</td>
<td>Work involving projects that require a great deal of repetitive work; modification or updating are real beneficiaries.</td>
</tr>
<tr>
<td>Shorter lead-times</td>
<td>CAD speeds up and concentrates the design-to-manufacture cycle, getting better products out to market faster, giving companies a competitive edge. Take the opportunity to open up new markets and produce more diversified and targeted products.</td>
</tr>
<tr>
<td>Improved Accuracy</td>
<td>Clarity and precision provided by CAD has all sorts of positive benefits. Eliminates ambiguity and gives designers confidence that their concepts will not be compromised. Better communications between engineers, designers, management, sales and clerical staff.</td>
</tr>
<tr>
<td>Better quality designs</td>
<td>CAD allows designer time to try out “what if” solutions. Analysis, simulations and evaluation programs mean that ‘no-hopers’ are caught on the screen rather than later. Reduces the need for many prototypes to be made.</td>
</tr>
<tr>
<td>More accurate cost control</td>
<td>Easier to work out exactly how much a product will cost to make. Reducing stock and work in progress. Hard copy drawings take up a great deal of physical space - storing this information in a computer database makes it more accessible and more likely to be consulted and liberate valuable office space.</td>
</tr>
<tr>
<td>More and better Information</td>
<td>Availability of DTP and related presentation technologies can be used to provide more and better information, easing communication making it easier to sell their ideas.</td>
</tr>
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</table>

The next stage is the quantification of Indirect Costs and Savings. These are often not so easy to quantify. Indirect personnel savings start with items like reductions in indirect personnel e.g. less intermediate supervision. It is also necessary to include the potential cost savings from other personnel reductions such as fewer inspectors and quality control checks.
Cultural dislocation can cause productivity and losses can persist until fully operational.

**Cost Prediction**

When predicting cost benefits it is prudent not to predict grossly inflated cost savings and to use realistic assumptions and payback periods when carrying out a financial appraisal. There are difficulties when carrying out this work. The real problem is that it is notoriously difficult to get real information on the savings that can be achieved.

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**Quantifying the costs**

The direct costs of a CAD system are fairly straightforward to establish and assess. The direct savings from the CAD system are harder to establish and are partly dependent upon the individual company's particular situation. Pitfalls can arise on the cost side of the calculations such as estimates of the investment required - how many times does the initial cost estimate advanced by a supplier bear little relation to the final quotation?
One aspect of appraisal is the consideration of the unquantifiables. The analysis, quantification and summarisation of the above direct and indirect savings may or may not justify the investment when all costs, direct and indirect, are included. Therefore, the next stage is trying to find "other" savings and this involves estimating figures for the items termed as "unquantifiables". The type of "unquantifiable" benefits that can occur are:

<table>
<thead>
<tr>
<th>Flexibility</th>
<th>The ability to respond more rapidly to changes in products, enquiries and to be able to offer shorter lead-times.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved Image</td>
<td>The ability to react faster to clients' requests will encourage them to return with future work and possibly even to give favourable advertising to other potential clients.</td>
</tr>
<tr>
<td>Improved Management Control</td>
<td>Information can be more easily checked and copies of work/alterations can be conducted more easily.</td>
</tr>
</tbody>
</table>

One approach to deal with the benefit of improved flexibility is to demonstrate the effect on costs by comparison to previous work and relating to where it would have been advantageous.

The benefits gained from CAD lead to higher quality and service level, improved flexibility and ultimately higher productivity. Justification is made more difficult by the intangible nature of many of the benefits which are harder to assess and by their nature are intangible. Such as:

- Competition with other companies is likely to be intense and rival companies will no doubt be equipping themselves with the latest technology as well.
- Marketing issues are likely to be more intense also.

An alternative aspect to be considered is what happens if the company does not get the work increase as predicted? This has to be considered for the obvious reason of getting a complete overall picture for the appraisal.

How much is the ability to carry out changes worth? Cost justification is essentially about comparison. For example a simple approach to justify a CAD station in a three year period would be:

If a PC system cost £5000 that would work out at £6.67 a day. So productivity per day would have to be increased by at least £6.67 to make it worthwhile.

Assuming that there were 250 working days to a year.

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There is an understandable preoccupation with the purchase cost of the hardware and software without considering the full cost in use over a typical five-year write-off period. The tendency is for smaller partnerships, unused to making large capital investments, to limit their choice to low-cost solutions which may not give them all the facilities they need, or take the drastic step of floating their companies on the stock-market to raise enough cash to implement mainstream CAD throughout the office.

The cost factors can be seen in more detail in *Volume Two - Justification Phase 1.3.1 - 1.3.3.1.*

The other factors which Company Two has to establish are whether or not it has the space and how long is necessary to train on the package. These are more involved with the technical side of the justification process.

The aspect of space is a factor dependant on the physical space the company has and the recommended sizes laid out in the EC directive. For the purposes of the argument let us assume that company two has established that with a little reorganisation of the office he has found sufficient space. The sizes can be seen in more detail in *Volume Two - Implementation Section 3.1.6 - 3.3.3.*

If time is a real problem then Company Two should put a high value on ease of learning when it comes to evaluate the package. It is a question of matching their requirements and setting values to the attributes that are important to the company. It is a matter of the selection process which is covered in more general detail in *Volume Two section on Selection,* specifically sections 2.2.1, 2.4.1.1 - 2.4.2 and 2.8.6.1.

Company Two’s selection criteria are:-

- A system that is capable of the work required of it.
  
  Which is 2D and 3D capable and rendering enhancement an advantage.

- Has a high ease of use factor.

The first aspect would be restricted by financial restrictions and the hardware necessary to produce hard copy of the rendered work. Company Two might be advised to leave the rendering capability for a future development stage.
The important aspects in the implementation stage for Company Two are to establish a suitable training programme to become proficient with the system and the organisation of the office to provide the necessary working environment for the system.

Identification of Training Needs

1. Before looking at any form of training, make sure you have a firm idea of future strategies as well as present use of software and applications. It is pointless initiating training if the hardware or software it covers is to be changed in the near future, so plan ahead.

2. If you are looking to get more value from current hardware and software, make an honest evaluation of the current level of knowledge among users (and system administrators, where appropriate). Assign someone to that task or set a simple test for a sample group. If you are considering training while planning investment in new systems, check that your existing ones do not offer the functions you need: you could find all you need to spend is the cost of training.

3. Assess who really needs training. Could a few trained personnel carry it out internally, and if they did, how would the costs of allocating them to a training role compare with investing in outside training for everyone?

4. Ask about training options from your direct supplier, preferably when you buy in the first place, but be aware that the situation may change at any time. Although many are identifying training as an extra source of revenue, they are first and foremost, suppliers of hardware or software. If the supplier is not the original manufacturer, particularly in the case of networks and applications, try to get advice from the original manufacturer too, as they may run an authorisation scheme covering training.

5. Find out more about the company offering the training: what qualifications do the trainers have, how big is the company, and how long has it been going? Try to obtain some references.

6. Look carefully at the proposed costs: once you have paid for accommodation and travel, does it really save money to send staff away to a training centre, or would it be cheaper to keep it on-site? Be particularly careful to establish all the costs, particularly for bespoke courses where there are no listed prices, checking that they include possible travel, equipment transportation and accommodation charges.
7 Find out about cancellation charges and be realistic about their implications.

8 If it is a course being run just for your organisation, are there limits on numbers? What happens if the number of attendees drops below your stated estimate, or you wish to increase the number?

9 What happens if the company offering the training cancels? Get a written guarantee of the minimum notice it will give if this happens.

10 Be prepared to shop around. With the increased interest in training from all sides, the market could become very competitive very soon.

Training should not cover just how the system works, but also ergonomic factors such as: correct posture; any keyboard shortcuts available; how to adjust furniture; screen brightness and contrast; when to take rest breaks and how to use them; what the early symptoms of computer related diseases are and the importance of seeking medical advice early.

When organising the office Company Two should consider the following:

Office Planning
Thought should be given to the source of the power supplies because great care should be taken to avoid cables from crossing or in any way being near to where people move about the office.

One aspect of positioning the equipment is its location of equipment. Hardware such as plotters and printers should be ideally be separate in another room or area to subdue the associated noise with these devices.

Man-machine factors
There are a number of dimensions or clearances which may need to be adjusted in a given workstation to suit the size and shapes of the potential users. There are three main areas in which to check the fit between the user and the VDU workstation.

Can the user reach and operate the controls?

The different controls which a user may need to operate at various points in an interaction should all be easily accessible. The major controls which may need to be operated are keyboard, special
functions key, power or other VDU controls (e.g. brightness), modems. There are also likely to be a number of controls on other office equipment which the user may have to operate in conjunction with computer equipment, e.g. lighting, telephones, calculators, photocopiers and heating.

Can the user see and read the displays?

The different displays which the user may need to read or use during the interaction should be at a suitable distance and not, for example, concealed by other objects if the user sits down.

Can the user work in a comfortable position and get in and out easily?

There are a number of basic clearances which are necessary to prevent the user having to adopt an uncomfortable or damaging posture either when using the workstation or when getting in or out. Thus, for example, short operators may need a footrest, but adequate knee clearance is required between table or desk and seat top. The screen should be at a comfortable viewing distance.

Suitably sized equipment and seating is necessary not just for comfort, essential though this is for efficient work, it is also a matter of health and safety. Back problems account for a substantial proportion of industrial ill health, and bad work station design is a major contribution to poor posture and backstrain.

Workspace factors

If more than one user, or group of users, are to share the VDU, then there may be difficulties in locating the terminal in a mutually convenient place. If it is located in one user's office, there may be interference to the normal work of the office caused by other users either interacting with the system or queuing up for their turn. To overcome these difficulties it may be appropriate to place the VDU in a separate room altogether. If this room is open to a wide range of people then various security devices may be necessary to prevent unauthorised use or to limit access to specific facilities. Such devices may include badge readers, passwords or a locking power supply; they can all be effective in limiting or preventing unauthorised access but are inconvenient to authorised users.

Terminal workstations require a considerable quantity of equipment and materials to be accessible to the user and unless adequate provision is made for rubbish, such as scrap printouts from Teletypes or associated printers, wires from VDUs, modems and the telephone will result in clutter, which is not only aesthetically unpleasant but can also present a real hazard.
Access will be required to even the best equipment (or perhaps especially the best equipment) for routine servicing and maintenance. It is worthwhile also considering when designing the work station what access might be needed for non-routine repairs and servicing. Maintenance access should not be regarded as the main consideration as it should be only infrequent or at least less frequent than normal usage.

Environmental Factors
There are a number of different physical environments to consider, in each of which the VDU can create a problem or be threatened. Its location should take account of these and should result in a suitable environment being created.

There are a number of features of VDUs which lead to potential safety problems for users. In addition to the electrical hazards common to other office equipment, VDUs have high voltages at various places within them and although these should be well protected under normal circumstances, it is important that all metallic objects should not be able to fall into sensitive areas through grilles or slots.

The VDU itself is vulnerable to a number of hazards ranging from vibrations or knocks to fluctuations in the power supply which can cause screens to clear and data to be corrupted. Even if these effects are temporary they can be extremely disruptive to users. Hot coffee spilt down the back of a VDU can be considered a chemical hazard, but more typical chemical hazards are that the plastic components may be attacked by cleaning solvents and inflammable liquids may be ignited by sparking contacts.

Solutions to work place
Office Design

- Apart from moving, there is not much that can be done about the basic fabric of a building. However, decoration and layout have significant ergonomic influence.
- Cabling should not trail across the floor, or round people's feet. Should be securely fastened so that they do not represent a hazard. Should follow the guidance given in BS6390.
- It makes a huge difference to workers psychological well-being if people have control over lighting, heating and ventilation.

Position of workstations within a room.

- **Access** - People using the workstation need to be able to gain access to them and the width of
access-ways and the space behind chairs should not restrict this.

- **Maintenance** - The design of the workstation and its position within a room should not hamper service engineers access to all parts of the equipment.

- **Work flow** - objective is to provide a work environment which will facilitate the efficient operation of the VDT and provide the user with comfortable working conditions. In particular, the combined effects of light, noise and heat are important in determining the work environment.

### 6.3.3 Solutions relevant to Company Three

Company Three represents a company that has a CAD system and is looking for ways in which to maximise the returns from their investment. To do this, the company is prepared to further that investment by increased expenditure. This places it in the position where it must reassess the current system, proceed through to the implementation of its plans. There are some differences in this case as opposed to a company new to CAD and it is these points that are discussed in this section.

Company Three's position and the problems it can expect to encounter can be summarised as follows:-

This company already has a CAD system but wants to develop it more efficiently. It originally purchased the CAD system to increase the efficiency of its designers and maintain current staff levels. The current system is used to produce accurate 2D draughting material, 3D work for complex exploded views and underlays for presentation work. Currently the final presentation work is rendered and finished manually. When and how the company uses CAD is decided by cost factors. The company wants the system to work harder. It currently uses two draughting packages. It currently has no clients that require any electronic transfer of data.

The company has to carry out another process of selection and careful consideration of its current implementation of the new system. Prior to these stages it will have to carry out a justification process that is different to a company that has no CAD system.

The relevant aspects of the three stages of acquisition for a company such as Company Three can now be discussed.

The first thing that any company in Company Three's position should do is to carry out an evaluation of the current system. This would facilitate the company in identifying the strengths and weaknesses of the current system which naturally helps them clearly establish how the company can improve on
the system.

System Evaluation
The methods of evaluation of a system will be different as each company will have its own criteria based upon its reasons for selecting the CAD system initially. However, there will be a central basis of topics. Performance indicators for CAD systems will be different for each application, but will fall into one of four categories:-

- Time.
- Quality.
- Product performance.
- Cost.

Assessment areas include design and development lead times and overall part count.

Some companies fail to qualify the benefits gained and/or the efficiency of their systems because many managers believe that because their systems are performing well, there is no need to measure the benefits.

Review of their system with the intention of upgrading/modernising
Problems with companies failing to evaluate their systems properly can cause problems for them when it comes to forming the justification case for the next system. The establishment of a proper evaluation system makes it easier to appraise the current system and deciding if it is necessary for the company to upgrade the system, purchase a new one or leave it until a later date. The evaluation would be able to give better parameters for deciding when this later date will occur. The review would also help establish any communication requirements the company has:-

- Internally, currently, or in the future.
- Externally, present, or future, with clients and/or subcontracting firms.

Review of competition and trends in the market
The review of what is happening out-with the company is a vital and necessary part of the evaluation study of the current system and thereby determining the current effectiveness of it. Part of this review allows the company to:-

- Be aware of what everybody else is using.
• To keep abreast of developments.

This knowledge maintains their appreciation and understanding of the changes and advances in the CAD sector. It will also create a foundation should they wish to proceed with a second generation justification, selection and implementation process.

One possible method that may be identified from the current company profile is that the company could concentrate on just one type of draughting package which reduces the knowledge base of the operators and helps them to keep acquainted with the remaining package. It has been found by myself that after any length of time away from using a package, there is a need to reacquaint yourself which slows you down in productivity terms and I know that other operators experience the same difficulty. That and operating two draughting packages in an IBM compatible environment means that the operators must be not as efficient as those working in only one package.

6.3.4 Solutions relevant to Company Four

Company Four is representative of a small engineering company that has a product design department within its company infrastructure. It has similarities with Company Three’s position but it also has particular aspects relevant particularly to itself. It is these points that are discussed in this section.

Company Four’s situation and the potential problems that it could encounter can be summarised as follows:-

• This is an engineering company which has a CAD system and wishes to use its created computer information more efficiently. The information used for internal use only and apart from marketing purposes it is not going to be used outside the company. It wants to network the system linking the design department and the production planning department.

• Money is restricted and there are various demands on the companies budget. This means that to develop the system, the company will need to develop a sound process for assessing its needs if it is to develop an improved system implementation.

The relevant aspects of the three stages of acquisition for a company such as Company Four can now be discussed.
The first step in increasing the efficiency of a system is to consider how the present one operates and how it is organised.

**Administration**

CAD Management is a complex activity which is made up of various subsections which can now be discussed further. This essentially can be described as the organization involved in running the system which can be broken down into two sections which are:-

- System Organisation
- Company Organisation

**System Organisation**

One aspect of the system that needs to be very well considered is the manner in which the created work is stored. The more work that a company carries out, the more it creates drawing files which accumulate on the hard disk. This means that drawing files for standard components and symbols for current jobs have to be resident on the hard disk as well. This is primarily so they can be accessed daily. The result is that there will not be sufficient memory for the storage of all past work which, therefore, means that these old files will have to be archived onto floppy disks, magnetic tape or optical disks. While not seen as a productive activity it is very worthwhile as each drawing, whether archived or resident on the CAD system, represents a considerable investment in time and resources. For that fact alone it is essential to organise and manage this investment. This holds true for any CAD installation, small or large. The way to control this material is through the use of a drawing management system which will make handling of this data more efficient and eventually increase drawing productivity.

Every company will have its own individual conventions for drawing numbers and for classifying projects, procedures for drawing revisions, checking, approval and for monitoring project costs. They might even change from project to project, as companies are continually developing ways to improve their working practices. A CAD drawing management system must therefore be flexible, so that it can meet individual company needs and adapt to changes in drawing office practices. It must be capable of storing fields of information about each drawing, such as: project, drawing number, DOS directory, drawing title, engineering discipline, draughtsman, revision level, approval status, date created, date last edited, time spent working on the drawing.

The information content requirement will vary from company to company so the required number of fields will also change. The content of the fields will vary. Some will be numeric, some alpha numeric.
and some just text. The information has to be kept consistent between the drawing's title block and the database of the drawing management system. However, some of this information need only be recorded in the database of the drawing management system and will be deliberately excluded from the drawing itself. For example, the time spent working on a drawing. This information is needed by the drawing office for the invoicing of the job but the company would not want to tell the client this sort of information. However, there will be quite a lot of duplication of information as well. The information will be held within the drawing itself, either in its title block or elsewhere on the computer such as the DOS directory structure. A flexible system will also be configurable so information can be automatically copied into, or from, the database. The drawing management system should also be capable of powerful search and report facilities which would help the CAD manager to find the required information to satisfy any queries in a variety of situations ranging from the simple to the complex.

The most common and simplest mistake is the creation of \textit{ad hoc} files. Inevitably it will become impossible to identify the contents of these files contents. This is when, with hindsight, it is appreciated that it would have been better to have been more organised from the beginning. Not only in the creation of files but in the use of a proper layering convention. One way to prevent this is the stricter use of any relevant conventions which would then ensure that the files generated from the work are much more useful and data is properly structured allowing for easier manipulation.

Conventions are essential not only for managing a company's own data but also for exchanging data with others. For example, Interior designers would find reference to BS 1192 Part 5 useful as it is the guide for the structuring of Computer Graphic Information in the Construction Drawing. There is not the same specific type of standard for Industrial Design drawings.

The aim of BS 1192 is to give assist on the production of graphical information needed to provide communication with accuracy, clarity, economy and consistency of presentation, between all concerned with the construction industry. The standard gives some indication of the important future standard for data exchange. This is called STEP, the Standard for Exchange of Product Data. This is currently met by such standards for interim use as IGES, although DXF is the recognised industry standard. Layering currently has no standard nomenclature although a \textit{de facto} standard has been set up for the construction industry.

Information Protection

It is mistakenly understood that computers are the expensive aspect of a CAD system where really it is the information stored within the system that is the really valuable commodity. This is especially
true in these days of manufacturers lowering the prices of hardware. When planning a system it is, therefore, an important consideration of any facilities that can be acquired which can aid the protection of information. An aspect that should be made clear to companies ignorant of computer requirements. The simplest form of protection is the simple matter of backing up the information stored on hard disk. Back-ups help overcome other disk problems such as faulty disks. There are programs that are available which can recover data from a damaged disk, or data that has been 'deleted' from a disk. Prevention is better than the cure. The cost of backing up will be a function of the cost of the back-up software, the cost of the back-up media, and the frequency of the back-up process. The cost of not backing up can be measured by the cost and the time involved of recreating the data, should it be lost.

Data Management

One important aspect of CAD management is Data Management. This generally includes activities such as file naming, layering structures, backing up and any other form of activity that is related to the manipulation of the information stored on the computer.

This aspect of IT systems is the control of the information produced and the fact that this involves a new working activity effectively which is secondary to the actual design role which is often neglected. However, it is one of the activities which actually helps to organise the working environment. They greatly enhance the speed and quality of working with CAD. One cardinal rule should be that individuals are responsible for their own data and should not rely on others to back it up for them. Files should be regularly saved, either manually or using an automatic routine, such as half-hourly intervals and certainly if the machine is left unattended. This way is the easiest method to organise and is just a matter of getting people used to carrying this procedure out as a matter of habit and preferably as an automatic gesture. The CAD manager would do a weekly back-up, using a tape streamer onto alternating tapes, so that there is always a week old and fortnight old store of the files. Daily back-ups are unlikely to be feasible, taking into account the wasted man hours and the extra cost of tapes, unless, of course, there is a central file server.

The problem of this spread of responsibility is keeping track of the work by the drawing office manager. This is a difficult area to police, hence the devolution of responsibility. Keeping a record of this devolved organisation structure is a potential problem area and is one that requires an organised approach if it is to be efficient. The details of all archived projects should be recorded in a database for future reference. Also, a disaster recovery plan has to be devised. This is not just about insurance or a plan of what to do if one of the workstations goes down. The plan must consider where the money should come from.
Product libraries will almost certainly become more essential in the future. Manufacturers are increasingly putting their product details onto CAD and particularly AutoCAD. That is one way that CAD will make drawing work quicker than current manual ways. Another of the ways that CAD work is more efficient and quicker is in the area of alteration and the use of 'standard parts'. Their strength is exactly the opposite of the weakness of manual methods. Manually-produced libraries of standard details have invariably failed, chiefly because no two details are exactly the same and a redraw is usually preferred to make fiddly amendments. In some respects, CAD changes all that, as one of its strengths is the ability to easily change drawings.

Many of the libraries of standard symbols, as covered by BS 1192 Part 3, are available on CAD and are yet another management burden. There are a number of other conventions which can be adopted in the office. For example, text fonts for final detail work.

Standardisation of industry drawings for CAD could be one way that future developments can help the transfer of information. Screen colours are useful for denoting line thicknesses on plots. The CAD layering working party of the construction industry special interest group section of the AutoCAD User Group have proposed that the third field in the layer name could be a number indicating the line colour which in turn would plot to a specific pen thickness, where colour is set by layer and not entity. With good management, a system should also relieve everybody from the burden of managing and securing their own data and programs - a task that, in practice, many standalone users perilously neglect to perform.

A network is one way which can help make a system economical provided of course there are sufficient number of users because expensive peripherals can be shared and with site licences for networked applications software, and PCs on a network need not be as powerful and as expensive as standalone machines.

Contents of a Drawing Management System

Some drawing management systems are designed for more than classifying, reporting, archiving and retrieving drawing files. They will also allow the CAD manager to organise and manage the whole computer resource at his disposal. The systems that are designed to be flexible and meet the very different needs of numerous companies have the flexibility to extend their areas of influence and provide the CAD manager with a very effective management tool.

There are 3 areas in which this can be helpful:
A drawing management system can be used to classify, report, archive and retrieve a variety of file types: drawings, word processor documents, spreadsheets, parts lists and even drawings that have been scanned into the system as raster images.

The drawing management system can be used to invoke any other programs on the system, such as drawing programs, plot management, bills of materials and costing.

The drawing management system can control access of users to files, to programs and to the drawing management system itself either globally record or by information field. This is archived by levels of security using passwords. If the system is used in conjunction with a network, which requires the user to log onto the system with a user name and password, then it is sensible if the software can be set up to use the same user names and passwords, so that these do not have to be typed in repeatedly during the day.

The evaluation of the system will allow the company to identify whether it will need a new system or how the present one can be enhanced. The company already knows that any information will be used internally and this is not likely to change in the foreseeable future. This is partly governed by the nature of the work and the structure of the company. The company wants to network the computers of the design office with the computers used in the process planning department. This could use the drawing information for its own requirements which is one way of utilising the created information. To do this, the evaluation process will have to determine if the package being used by the design department will link to the planning package.

- Are there facilities for extracting data from the database, say into a computer file with a specified format, so that the data is readily available for use by an external application program such as graphic material for a finite element analysis program?
- Are there facilities for the reverse process?
- Is there a need for an interface with a specific applications software?

One of the deciding factors of whether or not the company will get a new system will be the financial limitations being imposed by the company. Provided that the software is compatible then it would be advised to maintain current packages and network the system. This is probably the cheapest option in terms of capital expenditure and the saving in operators not having to learn a new package regardless of which department had to get a new one.
6.3.5 Solutions relevant to Company Five

Company Five represents a small engineering concern with a product design capacity and without CAD. The company has a positive attitude towards CAD even though it has currently a low requirement for it. The aspects of the stages relevant to this company are discussed in this section.

Company Five's situation and the potential problems it is likely to encounter can be summarised as follows:

The company has only a small need for a CAD system as most of the design work is carried out by its client companies. The company uses CNC machinery and does carry out some design work. So it will need to use a system that can communicate with the CNC machinery already in use and possibly with other systems run by its clients companies. Currently all work is given in a paper format. The company is very busy and has no spare time to carry out a review to look into the feasibility of purchasing a CAD system. Money is a deciding factor.

The relevant aspects of the three stages of acquisition for a company such as Company Five can now be discussed.

While the company is busy, the design department has some quiet periods so whenever these occur it is possible for the staff to carry out a feasibility study. The company takes in work and drawings from its clients but it knows that some of its clients have CAD systems and would appreciate the advantages gained by not having to supply paper documents. The company could provide a service for its clients by being able to take in information electronically and then downloading it to the CNC machines. This would increase the turn-around time of work and speed up the company's response rate. This is out-with the advantages that would be gained in the actual drawing office. Often the drawing office work is variations of work already carried out for existing clients so with CAD the drawing work could be carried out faster. There would be some advantages from having the CAD system linked to the CNC machines internally as the company would experience savings in reduced levels of scrap produced.

The company would be interested in expanding and one way it could achieve this is by being able to offer a fast design facility. The CAD system could allow the same number of designers to handle more work to keep the CNC machines in operation without having to increase staffing costs in a department that is not used all the time.
Company Five would still have to undergo a similar Justification, Selection and Implementation process as illustrated by Volume Two.

The criteria Company Five would have to be sure to incorporate in the above would be:

- To ensure that system was compatible with CNC equipment already in use.
- Communicate with other systems at least with current clients systems.
- Allow networking to take place.
- Be relatively inexpensive.
- Be able to carry out current and future drawing requirements. Need not have 3D capability but potential to upgrade would be advantageous.

6.3.6 General Solutions
There are some solutions to problems that are not specific to any one company or activity, they only differ in the scale of application and complexity of the organisation. These solutions are issues of CAD management which cover aspects of computer security, staffing. These aspects, are covered where I see they are relevant throughout Volume Two.

Particularly in the following sections:-

Justification Section
  1.2.11.1 Management
  1.2.12.1
  1.2.13.3

Selection Section
  2.1.1
  2.4.9.1
  2.4.10 - 2.4.10.6
  2.8.1.6 - 2.8.2
  2.8.4 - 2.8.4.4

Implementation Section
  3.1.3.2 - 3.1.5
  3.2.1 - 3.2.1.2
  3.3.4.1 - 3.3.5.3
  3.3.7.3 - 3.3.8.4
  3.3.9.5

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Chapter SEVEN

Conclusions

7.1 Discussion of the work

The purpose of this section is to appraise the work carried out by myself, with the advantage of hindsight. This is broken down into two sections:

- Limitations
- Strengths

7.1.1 Limitations

The research began when another financial recession was just affecting the industrial sector. It was publicly not expected to be very bad or to last any real period of time. Regrettably, however, it has been more severe than expected and has even affected the financial institutions such as banks and building societies which have usually been comparatively safe areas of employment. Like most recessionary periods the work for design orientated companies has been reduced. This has affected design jobs and the proposed growth plans any design company has had. So any plans for purchasing a CAD system have been temporarily shelved or even forgotten. During the course of my research I found that very few design companies were very co-operative which has affected the work I have carried out. While I compensated for this by discussion with establishments such as the Design Council and Scottish Enterprise, and my own contacts within companies, to gain an insight to the state of the industry there may be some missing factor that I have not taken into account.

One small aspect of the work was whether CAD was affecting staff numbers. The research suggested that it was not affecting staff numbers in terms of staff reduction. However, CAD was to negate staff increases. The problem in coming to this decision is hard to establish in all certainty with job losses being incurred due to the recession. If the question was asked now it might have a different response. This might be true for some of the other responses as well. Such as whether a company was considering purchasing a CAD system or not and whether they would persevere through some of the problems some companies put up with in the early stages of their CAD system.

The work started with the assumption that microcomputers were the right choice but perhaps while this has been found to be the case it might have been better to have been more open minded about the matter.

I found that the design consultancies were not as helpful as they might have been but perhaps this
lack of co-operation reflects the fact that most of them are small companies with little time to spare. Quite a large percentage of the people on the Design Council's list of designers are one-man organisations who have employment in other areas such as Education.

The time factor and other pressures of the research project necessitated that the questionnaire was sent out without a thorough testing of the content and layout of the questionnaire. However this proved not to be a problem.

Reference work had to be current which meant using magazine articles by people who sometimes might not be so academically neutral in their standpoint. It was discovered that work found in books was quickly outdated technologically.

Some particular aspects of the overall work would have benefited from more intensive work and could in themselves be research projects.

7.1.2 Strengths

The research project covered a wide area but a general overview of some subject areas was sufficient for the purposes of the work.

Two questionnaires allowed a clear understanding of the problem areas that needed answering. They also helped to overcome some initial preconceptions of the problem areas and highlighted some that had not been initially considered. The questionnaires allowed an overview to be achieved combining industries' needs and education's services.

The initial questionnaire was based around a random sample of industry which brought comments from users and non-users of CAD.

The initial questionnaire also provided the drive for the second questionnaire.

The research work could be seen as the source material for a number of more intensive and specialised studies related to CAD.

CAD has a general commonality which can provide insights to specialised activities from areas not directly related. For example, Architects drawing office practice can be easily modified to Product Design offices. This commonality in CAD offices allows a good source of tried 'remedies'.
Specialisation was found to be in actual software packages used but hardware required was often identical or very similar irrespective of the design activity.

The study evaluated current usage in Scotland and was able to derive some possible solutions applicable to the product design sector which would not date as much as some technological solutions might. This is useful should further work be generated once the recession ends.

7.2 Possible future work areas

During the period of the research there were indications that further work would be beneficial in some areas. This work could be carried out for either academic qualification or for commercial purposes. These areas are briefly discussed in this section.

7.2.1 Development of an accounting strategy

During the course of my research I found that there were weaknesses in current accounting methods when applied to the application of computers in design working practices. While people such as Price Waterhouse have carried out work in this area there was no clear cut and definitive strategy that small companies and non-accountants could apply to computer systems. Articles in this area indicated that the newer methods that were available were not in wide usage or well known about outside the enlightened users. Research on how these more applicable methods of accounting for computer systems and applying them to Design Consultancies would be useful in proving them. This could be achieved through case study methods and trial studies of old and new methods. The end result of this work would establish the most accurate and efficient methods currently being used and perhaps even the development of a new method of accounting computer systems for CADCAM applications.

7.2.2 Computer User Interface

This area was highlighted in my research as being an area that was only comparatively recently being considered. Most areas of current work concentrate around the interaction of the user and the software. This work involves how information is interpreted by both computer and human user and how to maximise the efficient translation of this information.

Other work has been involved in the Ergonomic restrictions and how users can use current computer workstation equipment without any discomfort. There is also a growing concern about Repetitive Strain Injury.
The consensus of opinion is that the most efficient way of treating this potentially crippling disorder is to prevent it happening in the first place. This is where I feel more work could be carried out. Studies into working around current systems are common but studies in how the workstations could be developed now, with state of the art electronics, could produce computer workstations that are much more 'organic' in their design which eases the operator's tasks and hence increases the working efficiency of the overall system. The work could revolve around the human operator and design a computer system both hardware and software from 'scratch' to achieve a system more suited to the user and not how it currently appears to be which is that current system configurations are derived from the development of the hardware. Keyboards are based on a layout that has origins when typewriters were more mechanic in their construction and that dictated the layout of the keys. Screens and Central Processors have developed around the technological development and the assumption that the computer manufacturer just had to supply a unit to be placed on the desk which the operator previously used to carry out the work on paper. The research would be based around designing a 'revolutionary' new workstation layout.

A second area of research could be based around the development of more user friendly software that is more self evident for CAD programs. While there is work being carried out and there is a growing interest in Graphical User Interfaces there is still no real system that allows for people to start working with a CAD system without some training. Apple Macintosh systems appear to be the best since they are concentrated around the one manufacturer. Other GUI systems are on the whole, in my opinion, not as clear as the Apple Macintosh but they are used on more varied manufacturer based systems. The research I am therefore advocating would be in a GUI system that could be used on any micro computer and could front end any CAD software.

7.2.3 Differences between the needs of Industry and Educational Establishments

During my work I detected a difference in opinion between what Industry expects to find from Educational Establishments and what Educational Establishments considered their role to be. Industry expects its graduate employees to be fully trained in the software and hardware that it uses regardless of what it is. Educational Establishments are faced with the dilemma of choosing which software to use. They are also more concerned in preparing the students in the broader aspects of the work involved. In point of fact they are educating the students as opposed to merely training them. This raises the question, 'Is there some way that the two requirements can be suitably met?' There is scope for further study to establish just what these differing requirements are and how they
can be met. The work could involve deriving policies and strategies to obtain the following:-

- Whether or not they really have to.
- How educational establishments can maintain state of the art equipment.
- Match their equipment with local industry requirements or match it on a broader geographical scale.

The work could also be to find out if there are any sources of funding available and how to use the funds to their most efficient application. This work would have to be specially orientated to comply with each separate Educational Establishment as each case would be different.

7.2.4 Determination of the most efficient teaching methods for CAD

There is scope for some studies to be carried out to test and evaluate the different methods there are to teach the required aspects of CAD. The work would help establish what type of method is the most efficient for each aspect related to CAD. For example the advantages of hands-on experience when learning a CAD package, determining whether a manual for learning how to manage a system is the best solution.

7.3 Concluding Comments

Currently, Product Designers are capable of carrying out their working tasks quite satisfactorily without the aid of computers. However, in my opinion, this is not always going to be the case. Industry and the consumer society are continually wanting 'things' produced quicker and this factor will force CAD to become a necessity and not the luxury item it is currently perceived to be by some Product Designers. My research suggests that this is inevitable.

The area that is not quite so clear cut is what is the usefulness of CAD in the Product Design role? Current technology offers Designers a tool that is very powerful in the manipulation and creation of 'drawn' matter. Presently it is limited as to its usefulness in the very early conceptual stages of design but this is, in effect, rapidly diminishing. The advances in software now mean that it can be used effectively and efficiently quite early on in the design stage which indicates it will eventually be used at the conceptual stage. In some respects it is how CAD is currently perceived which prevents it from being used now in the early stages. To do this now would require designers to change their way of solving design problems which some appear reluctant to do. The introduction of the computer into
the design working environment means that some change must happen. The changing working role will mean a change in job roles and job definitions which in my opinion will be the real factor in the speed at which CAD will be introduced to the Product Design sector.

Currently there are small model-making companies that offer this facility to design consultancies who might prefer to put this work out to tender rather than to do it themselves. Possibly, very shortly, these companies will offer a computer model-making facility instead of a physical model to design consultancies thus relieving them of the purchase of different software. What is more likely to happen is that software will be of the capacity that design Consultancies will not need the services of the model-makers resulting in job losses in this industry. CAD really offers the designer more control of the project throughout the project's development life.

Prices of software and the hardware which constitutes the computer are falling quite sharply, the only limiting factor is in the prices of peripherals such as plotters, printers, scanners, and colour copiers which appear so far to have retained their market price. The next stage of CAD development might be initiated should these peripherals have a drop in price just as software and 'computers' have experienced in the last three years. In my opinion it is the price of the quality peripherals that has restricted CAD usage as there is no point in having a high performance CAD system if you cannot produce hard copy of your designs. The immediate future might therefore see a growth in companies offering an output service for companies using CAD. Plotting and printing facilities for any design activity whether it is Architect, Industrial Designer or Interior Designer. This could result in even more of a polarising effect in the software chosen by companies than is already happening.

So regardless of what software is being chosen and what hardware is being used, the human issues of job content, working environment, and managerial matters are going to be more inflexible and it is these that now have to be addressed. This is the aim for the development of work involved in Volume Two of this thesis. In that volume I have tried to illustrate what companies should be aware of and to put this in a layout that could be used to write a training manual to answer this need.
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Merritt, Douglas, Television Graphics (from pencil to pixel), 1987, Trefoil Publication Ltd


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ACW Ltd.
Baxi Heating.
BiB Design Consultants
Bissel Appliances Ltd.
Black and Decker Ltd.
BREL (1988) Ltd.
British Aerospace
Butler International Ltd.
Campbell Hearn Design.
Crombie Anderson Associates.
DEC Limited.
Ebac Ltd.
Gerrard and Medd Designers.
Glaxo Ltd.
Grant Westfield Ltd.
Hewlett Packard.
Honeywell Control Systems, Keyboard Division.
Indes Design Consultants.
Industrial Display Systems (Fife) Ltd.
J & F Johnston & Partners.
J & G Coughtrie Ltd.
Kinnear Dufort Design Ltd.
Liebritz Lann Ltd. Electrical Engineers.
Liverpool Museum & Planetarium.
Lothian Regional Council, Department of Education.
Marconi Instruments Ltd.
Michael Peters Graphic Designers.
National Cash Register Ltd.
Paul Usher Design.
PDD Pankhurst Design and Developments Ltd.
Peugeot Citroen Style Centre.
Planet Design.
Plysu PLC.
Rawlplug Co. Ltd.
Sector Design Ltd.
Sensation Corporation.
Strathclyde Regional Council, Department of Education.
The Boots Co. PLC, Hospital Products Development.
Thorn EMI Domestic Appliances.
Warwick Evans Design.
Wood Group Industrial Controls Ltd.
The first questionnaire.

Since the first stage of the research was to define the current state of Microbased CAD within the area of study, this work needed to cover as many opinions which could be gathered and a questionnaire was considered the most efficient method. The preparation of the questionnaire took some time since there were many aspects which needed to be considered.

First of all it was necessary to establish exactly the type of information I was really looking for at this stage of the project. Once the subject matter was decided, it then had to be put into a question format so that it was unambiguous and would not cause offence to anyone completing it. One well-known factor regarding questionnaires is that a large proportion are not answered; therefore the format had to be clear in order to provide the least inconvenience to recipients. Therefore, the questionnaire was constructed so that the question/response layout required minimum effort whilst maximising information gained. This was tested by asking people concerned with the research to read the questions and pinpoint any areas of ambiguity or weakness in the questions format. This achieved the majority of the questions being answered by a Yes or a No. However, some questions did not fall into this category and did require a little more effort from the “respondent”, and these were kept as few and as brief as possible.

When the first draft was ready, I gave it to people connected with the project so that I could get their opinions of it. This acted as the test for any ambiguity in the question format and any missing depth of subject matter. The questionnaire was then restructured, new questions added, rephrased, and presentation altered, before it was printed. Due to the time factor, it was thought better to just send the form out without actually carrying out a small sample of responses. To try and compensate for the fact that some forms would still be unanswered, it was decided to send out one thousand questionnaires. The addresses were gleaned from information obtained from the Design Council, Scottish Development Agency and professional bodies' publications of members. This information from the above sources did not give a full description of the actual work carried out by the companies, other than the general area that they covered, e.g. Engineering or Construction. One other aspect which was not given was whether or not they used CAD. The companies from the list were not specially selected for any particular reason and excluding those which did not lie within the general area being covered. This helped randomise the nature of the companies to which the questionnaire was sent. A covering letter was sent explaining the questionnaire and notes were put into the questionnaire indicating that it would be helpful if companies without CAD could complete the relevant sections and return it. It was also stressed that any question which the company did not wish to answer could be missed out but it would be very useful if they returned what they had completed. The last factor to optimise the returns was the inclusion of a prepaid envelope.
Questionnaire content

The subject matter of the questionnaire was divided into sections:-

- **Section One:** Company Information
- **Section Two:** System Information
- **Section Three:** System Training

**Section One**

This section asked for the Company's name, address, nature of business and number of employees. To ensure further communication with the company at a later date, this section also asked if they were willing to give further assistance; either with additional written information or an agreement for me to visit. A contact name was also asked for. The further assistance questions were seen as a possibly more reliable base for any future work. The last question in this section asked if the company used CAD. The respondent was then directed to the part of the form which they were then to complete. For example, if they responded with a "No", they were asked for their reasons. The later sections were only for those who said "Yes" in response to the use of CAD.

**Section Two**

This section was concerned with their hardware and software and their reasons for choosing/using CAD and their respective equipment.

**Section Three**

This section was concerned with how CAD was introduced, by way of training to use the chosen systems, how many employees were trained and whether or not the company had experienced any problems with their chosen system.

**Application of the Questionnaire**

The questionnaire went out in two separate mailings of 500 each. This gave the following results:-

- 648 did not answer
- 136 were returned by the GPO
- 210 were answered in time for the analysis
- 6 responded after the cut-off point.

The cut-off point was set at three months after the date of the first mailing, which was March 1990. This was considered long enough to obtain the largest number of returns and not too long before the
information gained could be usefully employed towards the project. The largest return was from the second mailing which was primarily to Architects, who had apparently changed their address.

<table>
<thead>
<tr>
<th>Batch</th>
<th>First 500</th>
<th>Second 500</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Returned by GPO</td>
<td>21</td>
<td>115</td>
<td>136</td>
</tr>
<tr>
<td>No CAD/No Interest</td>
<td>33</td>
<td>25</td>
<td>58</td>
</tr>
<tr>
<td>No CAD/But Interest</td>
<td>28</td>
<td>17</td>
<td>45</td>
</tr>
<tr>
<td>Mainframe/Mini</td>
<td>11</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>Microbased</td>
<td>48</td>
<td>40</td>
<td>88</td>
</tr>
<tr>
<td>Total replies</td>
<td></td>
<td></td>
<td>210</td>
</tr>
<tr>
<td>Accounted for overall total</td>
<td></td>
<td></td>
<td>346</td>
</tr>
</tbody>
</table>

Processing the Returns

To facilitate the processing of the returns of the questionnaire the companies were grouped into work type areas. One section had to be identified as 'Irregular' because some of the companies did not quite fit into the classifications I had used. These groups are as follows:-

A  Architecture
CS Cad Specialists/Computer Manufacturers
CE Building and Services Engineering
D  Design Consultancy
E  Electronic
En Engineering
I  Irregular
Te Textiles
Tr Training

The companies which did respond could further be divided into those primarily with CAD and those without CAD. These two groups could be divided into two further groups each. The companies with CAD could be split into those with Microbased CAD and those with more powerful computers as explained earlier, (Mainframe/Mini/workstation). The companies without CAD could be divided into those without CAD but which were interested in CAD and those without CAD and had no interest in CAD. So from the 210 replies, the following results can be obtained:-
Using Microbased CAD 88 (42%)
Using Mainframe/Mini based CAD 19 (9%)
Not using CAD but Interested 45 (21%)
Not using CAD and no interest 58 (28%)

The percentages given are derived from the completed returns.

The groups will be seen throughout this appendix in the tables showing the results of the questionnaire. For the purposes of some of the tables they will be abbreviated as follows:

- No CAD and No Interest in obtaining CAD
- No CAD but does have an Interest in CAD
- Mainframe/Mini based CAD
- Microbased CAD

These were then the grouping factors used to sort the Questionnaire returns. This can be summarized by the following table where X marks where returns occurred:

<table>
<thead>
<tr>
<th>CAD State</th>
<th>No CAD</th>
<th>No CAD</th>
<th>Mainframe</th>
<th>Microbased</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work Type</td>
<td>No Int.</td>
<td>But Int.</td>
<td>Mini</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CS</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>CE</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>D</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>El</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>En</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>I</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Te</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Tr</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

The above four categories will be used later to organize the results. It is helpful to clarify just what is meant by these four categories.

The category 'No CAD and no Interest' is used when a company obviously has no CAD system and for reasons given/not given in the questionnaire has no intention of getting a system.
The category 'No CAD but Interested' is applied to companies not having CAD but who are either in the process of assessing systems or are interested but who are put off for reasons given/not given in the questionnaire.

The companies, although asked to explain, did not always answer all the questions relevant to them. Occasionally, they chose to omit questions they did not want to answer.

The category 'using Mainframe/Mini based CAD' is given to companies which run a CAD system on more powerful machines. I have included those companies which stated that they use workstations in this category as well, due to the difficulties in clearly defining between micros and minis because of the developments in computer technology. However, I consider that their reasons for using CAD in their working environment is equally applicable to the research as the reasons given by companies with Microbased CAD. Therefore, the results shown later will have these responses included although I have also shown the results without using their responses. These can be seen later on in this appendix.

The category 'Using Microbased CAD' is now more clearly defined as it shows how the information is grouped.

Finally, by way of introducing the results obtained from the questionnaire as part of the analysis of the response, I placed the companies into work related groups. This was to see if there were any similarities/differences between them when responding to the questions. One group is marked as "Irregular". This covers companies whose work I considered at the time of sorting did not fall into the other categories, or which used CAD as a secondary function to the main role of the company.

How the companies were expected to answer the questionnaire

Sometimes companies did not answer questions and the "nil response" is noted in the results at each particular section relating to a question. One final point, while I am discussing the questionnaire results, concerns the manner in which companies answered the questionnaire. Depending upon the response of a company to a question at the start of the form i.e. whether or not they used CAD, the respondent would be guided to what questions they had to answer. The problem arose when companies would omit some questions because to them they would have no significance but with regard to the questionnaire results they should have answered. These omissions can be seen but it is not possible to give an explanation since the companies have not chosen to give their reasons.

The following are examples of possible question sequences that could be given:-

viii
1) A company which has a CAD system and uses "off the peg" software and whose hardware is not networked would respond to questions 1, 2, 3, 3c, 4, 6, 8, 9, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 and 24.

2) A company which does not have CAD would answer questions 1, 2, 3, 3a, 3b and 3c.

3) A company which has a CAD system using specialised software and is networked would answer questions 1, 2, 3, 3c, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 and 24.

Only those companies using a CAD system on anything other than Microbased systems would answer question 5. Their answers could also vary as shown in examples 1) and 3).

Analysis of the Non-returns

Of the 648 companies which did not respond, the question had to be asked, "Was their lack of response due to their lack of interest in CAD?". It was necessary to see if this was true to put my results into some sort of perspective. I obtained the information by checking with my sources of company information, interviews with other people and in some cases by telephoning the companies. This was not done for the whole 648 non-replies as it was not seen as a constructive or worthwhile activity. However, I established the following:

- 11% of the non-replies did actually use a CAD system; whether it was Microbased or more powerful it was not possible to ascertain.
- 7% had a company policy not to answer questionnaires but did say whether or not they used CAD.
- 23% did not use CAD and had no interest in becoming involved with it.
- 9% did not use CAD but were interested.

The reasons for not replying varied from "I don't remember seeing it!" to "We're really too busy to waste our time answering silly questionnaires".

I did not follow up on the remaining 50% as it appeared that the reason for not replying was simply the case of "No interest" so I felt justified that the picture given by those who did actually reply had some significance.

Those companies which answered that they had no CAD are covered here for their responses to
question three. There are two sub groups; those who said they had no CAD and no interest and those who said they had no CAD but were interested.

**Questionnaire Responses to Individual questions**

**Question One**
This question asked for the name and address of the company.

**Question Two**
This question asked for the nature of the business and the number of employees.

**Question Three**
This first of all asked if the company had a CAD system or not. The questionnaire then went on to direct the respondent to the relevant questions dependant on their answers. This direction was described earlier in the thesis. There were two directions in which the respondents could now go, either to those questions relating to companies with a CAD system or to the questions for those without a CAD system.

**Results from Companies not using CAD**

**Question 3a**
This question asked if they had any future interest in CAD.

- 21% (45) said "Yes"
- 26% (55) said "No"
- 2% (3) did not answer

It was assumed that those who did not answer had no interest in CAD.
(Percentages given based on the total number of replies to questionnaire).

**Question 3b**
This question asked respondents to give the reasons for not using CAD. The following are the reasons given:
12% (13) said they were put off by the costs involved
28% (29) said they were not put off by the costs involved
39% (40) said it was not considered necessary to their operational needs
16% (17) said it was not because they did not consider it necessary to their operational needs
3% (4) considered it too time consuming to install
26% (27) did not consider it too time consuming to install
6% (7) said they could not spare the time to train the staff
23% (24) said it was not because they could not spare the time to train the staff.
45% (46) of those who returned the questionnaire and did not have CAD, did not answer the question at all.

(The percentages used here are based on the total replies saying "No CAD").

It was expected that companies would have more than one reason for not having a CAD system and it can be seen that, of those who answered this section, this is true. These figures can be broken down into the companies work type and expressed as percentages of their respective work type totals.

Table 1 REASONS FOR NOT USING CAD

<table>
<thead>
<tr>
<th>Key to table</th>
</tr>
</thead>
<tbody>
<tr>
<td>no CAD but</td>
</tr>
<tr>
<td>no CAD no int</td>
</tr>
<tr>
<td>A Architect</td>
</tr>
<tr>
<td>CE Building and Services Engineers</td>
</tr>
<tr>
<td>D Design/Graphic Design Consultancy</td>
</tr>
<tr>
<td>EI Electronics</td>
</tr>
<tr>
<td>En Engineering</td>
</tr>
<tr>
<td>I Irregular</td>
</tr>
<tr>
<td>Te Textile</td>
</tr>
<tr>
<td>Tr Training</td>
</tr>
</tbody>
</table>

...
Reason I) *Company is put off by the cost*

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>(no CAD interested)</td>
<td>(no CAD no interest)</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>CE</td>
<td>13</td>
</tr>
<tr>
<td>D</td>
<td>11</td>
</tr>
<tr>
<td>El</td>
<td>50</td>
</tr>
<tr>
<td>En</td>
<td>18</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
</tr>
<tr>
<td>Te</td>
<td>20</td>
</tr>
<tr>
<td>Tr</td>
<td>0</td>
</tr>
</tbody>
</table>

Reason II) *Company do not consider it necessary to operational needs*

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>(no CAD but interested)</td>
<td>(no CAD no interest)</td>
</tr>
<tr>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>CE</td>
<td>88</td>
</tr>
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<td>11</td>
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<td>27</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
</tr>
<tr>
<td>Te</td>
<td>20</td>
</tr>
<tr>
<td>Tr</td>
<td>0</td>
</tr>
</tbody>
</table>

Reason III) *Company considers it too time consuming to install*

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>(no CAD interested)</td>
<td>(no CAD no interest)</td>
</tr>
<tr>
<td>A</td>
<td>20</td>
</tr>
<tr>
<td>CE</td>
<td>0</td>
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<td>El</td>
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<td>En</td>
<td>0</td>
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<tr>
<td>Te</td>
<td>20</td>
</tr>
<tr>
<td>Tr</td>
<td>0</td>
</tr>
</tbody>
</table>
Reason iv) *Company can’t spare the time to train the staff*

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th></th>
<th></th>
<th>YES</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(no CAD but interested)</td>
<td>(no CAD no interest)</td>
<td></td>
<td>(no CAD but interested)</td>
<td>(no CAD no interest)</td>
<td></td>
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<tr>
<td>A</td>
<td>20</td>
<td>50</td>
<td></td>
<td>20</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>CE</td>
<td>0</td>
<td>0</td>
<td></td>
<td>50</td>
<td>9</td>
<td></td>
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<tr>
<td>D</td>
<td>0</td>
<td>0</td>
<td></td>
<td>22</td>
<td>0</td>
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<td>50</td>
<td>50</td>
<td></td>
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<td>7</td>
<td></td>
<td>9</td>
<td>38</td>
<td></td>
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<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Te</td>
<td>20</td>
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<tr>
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<td></td>
<td>0</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

The following table shows the numbers and types of companies who did not answer this question:-

<table>
<thead>
<tr>
<th></th>
<th>No response to this question</th>
<th>Work Type Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(no CAD but interested)</td>
<td>(no CAD no interest)</td>
</tr>
<tr>
<td>A</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>CE</td>
<td>13</td>
<td>63</td>
</tr>
<tr>
<td>D</td>
<td>78</td>
<td>0</td>
</tr>
<tr>
<td>El</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>En</td>
<td>45</td>
<td>36</td>
</tr>
<tr>
<td>I</td>
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<td>0</td>
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<td>80</td>
<td>0</td>
</tr>
<tr>
<td>Tr</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>
The final question for them was whether they had a Desk Top Publishing system. These figures can be broken down into the companies work type and expressed as percentages of their respective work type totals.

**Table 2 Do you have a DTP system?**

**Answer i) Which is separate from a CAD system**

<table>
<thead>
<tr>
<th></th>
<th>No CAD But</th>
<th>CAD</th>
<th>No CAD no Int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CE</td>
<td>13</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>El</td>
<td>0</td>
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</tr>
<tr>
<td>En</td>
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<td>7</td>
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</tr>
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<td>I</td>
<td>0</td>
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<td></td>
</tr>
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<td>Te</td>
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<td>0</td>
<td></td>
</tr>
<tr>
<td>Tr</td>
<td>50</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Question 3c ii) was not relevant to this group.

**Answer iii) Nothing at all**

<table>
<thead>
<tr>
<th></th>
<th>No CAD But</th>
<th>No CAD no Int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>CE</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>El</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>En</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
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</tr>
<tr>
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<tr>
<td>Tr</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

12% (13) said they did have a DTP system
54% (55) said they did not have a DTP system
34% (35) did not answer

Interestingly, the largest group which said they had a DTP system fell into the category of "No CAD no Int.". This then would suggest that the companies did not want to dismiss the advantages that could be gained from the use of the new technology, when the situation warranted it.
Results from those using CAD

Those companies which said they did have a CAD system in question 3 were then told to go to question 3c.

Question 3c

Prior to establishing the type of CAD system used, the companies were asked if they had a DTP publishing system. The table has been drawn up using this further information.

Table 3 Do you have a DTP system?

Answer 1) Separate from the CAD system

<table>
<thead>
<tr>
<th></th>
<th>Microbased</th>
<th>Mainframe/Mini based</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>CS</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>CE</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>E1</td>
<td>38</td>
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</tr>
<tr>
<td>En</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>I</td>
<td>43</td>
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<td>0</td>
</tr>
<tr>
<td>Tr</td>
<td>82</td>
<td>0</td>
</tr>
</tbody>
</table>

Answer 2) DTP runs in conjunction with the CAD system

<table>
<thead>
<tr>
<th></th>
<th>Microbased</th>
<th>Mainframe/Mini based</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>CS</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>CE</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>43</td>
<td>0</td>
</tr>
<tr>
<td>E2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>En</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>I</td>
<td>14</td>
<td>33</td>
</tr>
<tr>
<td>Te</td>
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<td>0</td>
</tr>
<tr>
<td>Tr</td>
<td>36</td>
<td>0</td>
</tr>
</tbody>
</table>
Answer iii) Nothing at all

<table>
<thead>
<tr>
<th></th>
<th>Microbased</th>
<th>Mainframe/Mini based</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>52</td>
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</tr>
<tr>
<td>CS</td>
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<td>0</td>
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<tr>
<td>CE</td>
<td>86</td>
<td>100</td>
</tr>
<tr>
<td>D</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>El</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>En</td>
<td>83</td>
<td>38</td>
</tr>
<tr>
<td>I</td>
<td>43</td>
<td>33</td>
</tr>
<tr>
<td>Te</td>
<td>100</td>
<td>0</td>
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<tr>
<td>Tr</td>
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<td>0</td>
</tr>
</tbody>
</table>

No answer to question

<table>
<thead>
<tr>
<th></th>
<th>Microbased</th>
<th>Mainframe/Mini</th>
<th>Microbased</th>
<th>Mainframe/Mini</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<td>21</td>
<td>4</td>
</tr>
<tr>
<td>CS</td>
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<td>1</td>
<td>2</td>
</tr>
<tr>
<td>CE</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>1</td>
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<tr>
<td>D</td>
<td>29</td>
<td>0</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>El</td>
<td>13</td>
<td>0</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>En</td>
<td>8</td>
<td>0</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Te</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
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<tr>
<td>Tr</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>0</td>
</tr>
</tbody>
</table>

Additional Information to tables

Four companies answered both i) & ii)

From the companies that said they had a CAD system the following results were obtained:

3% said they also had a DTP system.
18% said their DTP system worked in conjunction with their CAD system.

The response to those with a DTP system is very similar to the "no cad" group where 40% said they had a DTP system. The overall reply from the tables above is 43%.

The responses of the companies to name the DTP system were as follows:

(decreasing order of importance)

Pagemaker
Ventura
Interleaf
It is recognised that some of these responses are more aptly titled word processor packages but this shows the confusion some of the companies had in distinguishing between a Desk Top Publishing system and a word processor package and these are marked with an asterisk. This confusion is not surprising as these two areas now overlap to a significant degree. In fact this confusion was to appear in other aspects throughout the questionnaire about what the companies had in the way of software and hardware.

The rest of the questions are purely for those with CAD and they have been more closely identified.

**Question Four**

This question was the first question in the section headed "System Information". The companies were asked whether or not the CAD system was a Microbased system:

| 80% (86) of those who used a CAD system used a Microbased system. |
| 18% (20) responded to using a Mainframe or Mini. |

2% did not answer but from their description of other equipment they were established as Microbased CAD users.
Question Five

This question was for those companies which answered "mainframe or mini" in question 4. Companies using a workstation were classified as using a Mini as described at the start of this thesis. This put companies into users of Mainframe technology or Mini computer technology. The numbers given below represent the actual number of companies which responded to the questionnaire.

<table>
<thead>
<tr>
<th></th>
<th>Mainframe</th>
<th>Mini</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>CS</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>CE</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>El</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>En</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Te</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tr</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

One company replied to having both

Question Six

This question asked if the CAD system was networked within the company. Values expressed in this table are representative of their work type totals:

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Micro</td>
<td>M/M</td>
<td>Micro</td>
</tr>
<tr>
<td>A</td>
<td>33</td>
<td>25</td>
<td>67</td>
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<tr>
<td>CS</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>CE</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>D</td>
<td>43</td>
<td>0</td>
<td>43</td>
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<tr>
<td>El</td>
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<td>62</td>
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<tr>
<td>En</td>
<td>29</td>
<td>62</td>
<td>67</td>
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<tr>
<td>I</td>
<td>43</td>
<td>67</td>
<td>57</td>
</tr>
<tr>
<td>Te</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tr</td>
<td>0</td>
<td>0</td>
<td>91</td>
</tr>
</tbody>
</table>

62% (66) responded that they did not have the system networked
32% (34) responded that the system was networked
6% (7) did not answer

Group total 107
Question Seven

This question asked companies to name the manufacturer of their network. These are listed below in descending order of popularity:

**Micro**
- Tops
- Novell
- Token Ring
- Formac
- Siemens
- Nanel
- Amstrad
- Sun OS

**Mainframe/Mini**
- Apollo Domain
- Ethernet
- DEC net
- Sun NFS Ethernet
Question Eight

This question asked the respondent to state the manufacturer of their equipment. These are listed under the hardware type by the companies themselves. The number following each name represents a company response. It has to be stated that not all companies gave this information or were accurate in their statement of type i.e. C.P.U.:

<table>
<thead>
<tr>
<th>MICROBASED</th>
<th>Plotters</th>
<th>Monitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.P.U.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compaq</td>
<td>24</td>
<td>Hewlett Packard</td>
</tr>
<tr>
<td>Apple Macintosh</td>
<td>15</td>
<td>Roland</td>
</tr>
<tr>
<td>Tandon</td>
<td>8</td>
<td>Calcomp</td>
</tr>
<tr>
<td>Amstrad</td>
<td>7</td>
<td>BBC-Goerz</td>
</tr>
<tr>
<td>Sun</td>
<td>6</td>
<td>Benson</td>
</tr>
<tr>
<td>IBM</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Olivetti</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Apricot</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>NEC</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Kaypro</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Data General</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Elonex</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Swift 386</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>RCA 20</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>DEC</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Intel</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>NEL</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Mission</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Zenith</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>PS2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Nimbus</td>
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<td></td>
</tr>
<tr>
<td>Osicom</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Avalon</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lolland</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Unisys</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hitachi</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Mitac</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ness</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Central Electronics</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Tandy</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DigitisersTablets</th>
<th>Printers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherry</td>
<td>3</td>
</tr>
<tr>
<td>Graphtec</td>
<td>1</td>
</tr>
<tr>
<td>Summagraphics</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Summagraphics</td>
</tr>
<tr>
<td></td>
<td>Numonics</td>
</tr>
<tr>
<td></td>
<td>Epson</td>
</tr>
<tr>
<td></td>
<td>Star</td>
</tr>
</tbody>
</table>
Question Nine

This question asked if the software was custom written for their company needs.

<table>
<thead>
<tr>
<th>YES</th>
<th>Micro</th>
<th>M/M</th>
<th>NO</th>
<th>Micro</th>
<th>M/M</th>
<th>Nil Response</th>
<th>Micro</th>
<th>M/M</th>
</tr>
</thead>
<tbody>
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<td>100</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
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<td>CE</td>
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<td>15</td>
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<td></td>
<td></td>
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<tr>
<td>D</td>
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<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Group total 107

Not surprisingly this showed that most companies used software that was "off the peg" and therefore the company would probably have had to change some of its desired working practices.
Questions ten and eleven concerned only those with the specially written software.

Question Ten

This question asked "Was the software written in-house"?

Figures are expressed as percentages of work type totals.

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Micro</td>
<td>M/M</td>
</tr>
<tr>
<td>A</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>CS</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CE</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
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</tr>
<tr>
<td>El</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>En</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Te</td>
<td>0</td>
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</tr>
<tr>
<td>Tr</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Group total 13

The results should correspond to the answers obtained in question 9 but companies did not always answer all the relevant questions.

Question Eleven

This question asked "Was the software written by a software house"?

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Micro</td>
<td>M/M</td>
</tr>
<tr>
<td>A</td>
<td>14</td>
<td>25</td>
</tr>
<tr>
<td>CS</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CE</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>El</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>En</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Te</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Tr</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Group total 13
Question Twelve

This question was for those companies which had responded "Yes" in question eleven which asked if the software was written by a software house.

<table>
<thead>
<tr>
<th>Mainframe/Mini</th>
<th>Micro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pafec</td>
<td>H.C.S.(Europe)Holland</td>
</tr>
<tr>
<td>Tibor Darvas ltd.</td>
<td>L.C. Computers:-&quot;Window Maker&quot;</td>
</tr>
<tr>
<td>Cimlinc</td>
<td>Arcaid</td>
</tr>
<tr>
<td></td>
<td>Claris</td>
</tr>
<tr>
<td></td>
<td>Glimeon</td>
</tr>
<tr>
<td></td>
<td>Computer and Design Services CAPS</td>
</tr>
<tr>
<td></td>
<td>Wiekers &amp; Partner</td>
</tr>
</tbody>
</table>

Question Thirteen

This question asked for the name of the software used by the companies. This information was broken down into software type e.g. Draughting, Spreadsheet. It is also split into the work types. This can be seen in appendix IV.

Question Fourteen

This question asked two things:-

a) What was the reason for the company choosing to use CAD?

b) What was the reason for the company's choice of CAD system?

The question gave some set responses and one where the company could phrase its own response.

Question 14a

The options for part a) were:-

i) To gain the initiative over your rivals

ii) To maintain competitive balance with your rivals

iii) To impress your clients

iv) Other, please state.

It was expected that there would probably be more than one response from each company and this was catered for in the question. Overall the most chosen option was the last one which let the company phrase its reply and these are listed.

If only Microbased responses were used then this would still be the top response.

Now if the reasons given by the companies were analysed with respect to work type, the most
favoured response would be:

<table>
<thead>
<tr>
<th></th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architects</td>
<td>Micro (iv)</td>
</tr>
<tr>
<td></td>
<td>M/M (i)&amp; (iv)</td>
</tr>
<tr>
<td>CAD Specialists</td>
<td>Micro (iv)</td>
</tr>
<tr>
<td></td>
<td>M/M (i)</td>
</tr>
<tr>
<td>Building &amp; Services Engineering</td>
<td>Micro (ii)</td>
</tr>
<tr>
<td></td>
<td>M/M (ii)</td>
</tr>
<tr>
<td>Design</td>
<td>Micro (i)</td>
</tr>
<tr>
<td>Electronic</td>
<td>Micro (iv)</td>
</tr>
<tr>
<td></td>
<td>M/M (i)</td>
</tr>
<tr>
<td>Engineers</td>
<td>Micro (iv)</td>
</tr>
<tr>
<td></td>
<td>M/M (i)</td>
</tr>
<tr>
<td>Irregular</td>
<td>Micro (iv)</td>
</tr>
<tr>
<td></td>
<td>M/M (ii)</td>
</tr>
<tr>
<td>Textile</td>
<td>Micro (ii)</td>
</tr>
<tr>
<td>Training</td>
<td>Micro (iv)</td>
</tr>
</tbody>
</table>

Only one company did not respond to this question.

Part iv) of this question asked those responding to it, to give their own reason. Over all the work types this gave some interesting results. I have grouped the reasons into groups of similarity as this was useful to my use of the information in the main body of the thesis. The reasons are also linked to work type further on in this appendix for individual examination. The reasons are quoted word for word from the questionnaire as the companies gave them.

Staff
"To operate as a small team to produce drawings and design details very quickly without need for a tracer or extra draughtsmen."
"Small number of staff, high productivity."
"Increase quality and productivity without increasing staff."
"To avoid an increase in staff."
"Speed up production of drawings and avoid employing extra people."

Work Output/Control
"Improve efficiency."
"Efficiency of working."
"Improved work procedures."
"Shorten lead-times."
"Speed production of drawings."
"Speed up design processes."
"To produce high quality work fast."
"To speed and improve quality of output."
"Presentation speed."
"Profitability increase."
"Record keeping."
"Error checking."
"To gain competitive costs at a high quality assurance level."
"Increased efficiency, improved quality of presentation, ability to check design options accurately."

**Work Environment**
"Draughting design aid."
"Good quality drawings."
"Improve drawing times."
"Improve productivity."
"Increase productivity and reduce response times."
"To have more control of the complete design project."
"Professional presentation."
"Uniform presentation."
"Improve quality of product"
"Improve capability of project design team."
"Simplify and ease workload."
"3D visualisation."
"Examine options."
"Improve skills and service and become more efficient."
"CAD showed great promise in type of work concerned."

**Only way**
"Not possible to perform simulation manually."
"Improve creation of electronic circuit schemes."
"There is no other way of doing proper 3D."
"Essential for work carried out."
"To save expense of making prototype moulds."
"Help make transformer and wound components more efficient."
"To more easily carry out complex drawing and design tasks."
"Ease of design using many standard parts."

**Up to date thinking**
"State of the art."
"To make use of the technology within our industry."
"To keep up to date with drawing office technology."
"To take graphics into 90's."
"Consider it essential to gain experience in this developing aid and hopefully eventually to increase our efficiency and so impress clients."
"Keep abreast of modern technology."
"To output colour graphics and to use CAD."

**Training**
"SDA initiative."
"To provide an alternative training medium and additional resource."
"Training YTS trainees in using software with aim to them gaining employment."
"Training in Engineering Design and Manufacture."
"Train others."

**Unusual**
"It was already there."
"Deal due to cost reduction."
"Originally to provide part time occupation for daughter whilst rearing her family."
In response to this part, companies were asked why they chose their particular CAD system and the options offered in the question were:-

i) To gain the initiative over your rivals
ii) To maintain competitive balance with your rivals
iii) Reliable after sales support
iv) Proven track record in the area in question
v) Responsiveness to customer’s needs
vi) Value for money
vii) Needs
viii) Ability to upgrade system in terms of new software to match changing company
ix) Ability to develop system i.e. adding workstations without throwing away existing equipment
x) Ease of use
xi) Other, please state

The overall leading option was vii); second was ix).

If it was based on those who responded to Microbased CAD only, then the leader would be ix).

When breaking it down into work types the responses look like this:-

<table>
<thead>
<tr>
<th>Work Type</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architects</td>
<td>Micro vii)</td>
</tr>
<tr>
<td></td>
<td>M/M viii)</td>
</tr>
<tr>
<td>CAD Specialists</td>
<td>Micro xi)</td>
</tr>
<tr>
<td></td>
<td>M/M iii)/iv) equal top</td>
</tr>
<tr>
<td>Building Services</td>
<td>Micro iii)/iv) equal top</td>
</tr>
<tr>
<td>Engineering</td>
<td>M/M ii)/v)/ix) equal top</td>
</tr>
<tr>
<td>Design</td>
<td>Micro ix)/iv)/vii) equal top</td>
</tr>
<tr>
<td>Electronic</td>
<td>Micro ix)</td>
</tr>
<tr>
<td></td>
<td>M/M vii)</td>
</tr>
<tr>
<td>Engineers</td>
<td>Micro ix)</td>
</tr>
<tr>
<td></td>
<td>M/M viii)</td>
</tr>
<tr>
<td>Irregular</td>
<td>Micro ix)</td>
</tr>
<tr>
<td></td>
<td>M/M ii)/viii)/ix) equal top</td>
</tr>
<tr>
<td>Textile</td>
<td>Micro ii)/iii) equal top</td>
</tr>
</tbody>
</table>

Only three companies did not respond to this question.
Responses to Q14b

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</table>

The total responses are as follows:

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<th>MICRO</th>
<th>OVERALL TOTAL</th>
<th>no which were single responses only</th>
<th>MICRO</th>
<th>M/M</th>
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</thead>
<tbody>
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<td></td>
<td></td>
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<tr>
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<tr>
<td>iv</td>
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<td>56</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>v</td>
<td>26</td>
<td>33</td>
<td>3</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>x</td>
<td>27</td>
<td>33</td>
<td>9</td>
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<td></td>
<td>*</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part x) of this question asked those responding to it, to give their own reason. Over all the work types this gave some interesting results. I have grouped the reasons into groups of similarity as this was useful to my use of the information in the main body of the thesis. The reasons are also linked to work type further on in this appendix for individual examination. The reasons are quoted word for word from the questionnaire as the companies gave them.

**Company Act**

"Corporate standard."

"Existing package purchased by section which no longer exists."

"Company policy to use IBM."

"Integration."

"Regarded as industry standard so support seen as guaranteed."
Communication
"No other communicating system."
"Compatibility with another's software."
"Proven CADCAM link."
"File compatibility."
"Compatibility with all European CAD systems and central company directive."

Advice
"World-wide users."
"Track record."
"Recommended."
"No choice decision made by SDA."

Evaluation
"Best on market at time."
"Quality assurance improvement."
"Software chosen was more advanced than its main rivals."
"Consider Multicad best for mechanical Engineering out of 20 tested."
"Only one at time offering suitable package to needs."
"System could be modified to suit our needs."
"Performance."
"Preferred Apple system."
"Only viable low cost 3D PC based system available at time."
"Academy have an extremely "learner friendly" menu system and choice of AutoCAD was to facilitate purchase of add ons."
"Availability of compatible software covering standard components used in 'industries' type of business."
"Impressive software and hardware development, track record and backed by world-wide Multinational computer involvement."
"Local supplier and service Personnel."

Question Fifteen
This question asked who decided on the type of system to be chosen. The options were:-

a) Purely by Senior Management
b) By Management and consultation with the Design Department
c) By Design Department with a maximum price level
d) By Design Department without a maximum price level
e) Other, please state.

One point which needs to be made is that in small firms, where design is the primary function, the people in the role of senior management are also the Design department staff therefore some companies would have chosen option a). It had been predicted that this would have been picked up by the companies and they would have picked c) or d). The point I was trying to find out was whether the system was chosen by people familiar with working practises or by upper management in companies. So the results to this question would give me an indication where these decisions are made.

The most favoured response was b).
This would have also have been true if using only Microbased responses.
Breaking it down to work types the most favoured response would be:-

<table>
<thead>
<tr>
<th>Architects</th>
<th>Micro</th>
<th>M/M</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAD Specialists</td>
<td>Micro</td>
<td>M/M</td>
<td>a)</td>
</tr>
<tr>
<td>M/M</td>
<td>c)</td>
<td>(b) equal top</td>
<td></td>
</tr>
<tr>
<td>Building &amp; Services Engineers</td>
<td>Micro</td>
<td>M/M</td>
<td>a)</td>
</tr>
<tr>
<td>Design</td>
<td>Micro</td>
<td>M/M</td>
<td>b)</td>
</tr>
<tr>
<td>Electronic</td>
<td>Micro</td>
<td>M/M</td>
<td>a) (b) equal top</td>
</tr>
<tr>
<td>Engineers</td>
<td>Micro</td>
<td>M/M</td>
<td>a)</td>
</tr>
<tr>
<td>Irregular</td>
<td>Micro</td>
<td>M/M</td>
<td>b)</td>
</tr>
<tr>
<td>Textile</td>
<td>Micro</td>
<td>M/M</td>
<td>a) (b) equal top</td>
</tr>
<tr>
<td>Training</td>
<td>Micro</td>
<td>M/M</td>
<td>a) (e) equal top</td>
</tr>
</tbody>
</table>

Those who chose **option e)** gave their own responses and the responses they did give show that some of them could have been answered by option b). The responses are as decided upon by the companies and I have not altered them to b). The replies to **option e)** are listed.

**Responses to Q15**

<table>
<thead>
<tr>
<th>A</th>
<th>CS</th>
<th>CE</th>
<th>D</th>
<th>El</th>
<th>En</th>
<th>I</th>
<th>Te</th>
<th>Tr</th>
</tr>
</thead>
<tbody>
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<td>3</td>
<td>0</td>
</tr>
<tr>
<td>b</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>0</td>
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<tr>
<td>c</td>
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<td>0</td>
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</tr>
</tbody>
</table>

The total responses are as follows:-

<table>
<thead>
<tr>
<th>MICRO</th>
<th>OVERALL TOTAL</th>
<th>no which were single responses only</th>
</tr>
</thead>
<tbody>
<tr>
<td>M/M</td>
<td>M/M</td>
<td></td>
</tr>
<tr>
<td>a</td>
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<tr>
<td>b</td>
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</tr>
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<td>c</td>
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<td>d</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>e</td>
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<td>12</td>
</tr>
<tr>
<td>*</td>
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</tbody>
</table>

**Option e)** asked companies to explain in their own words who made the decision, if it was different...
from the reasons given in the questionnaire. The reasons are first of all grouped together by similar content and then by work type.

**Outside**

"No choice, decision made by SDA."
"By a consultant appointed by SDA."
"SDA and Bell College."

**Big Brother**

"Parent company standard."
"By management with reference to specialist computing section in London Head Office."
"Senior management with a price level."
"Chief Production Engineer."

**Joint**

"Mainly Design department with senior management approval."
"By manager and CAD manager."
"Senior partners and CAD manager's review of old system, changed to a new one."
"Management and consultants."

**Standard**

"Similar users and dealers recommendation."

---

**Question Sixteen**

This question asked what guide-lines were used to choose the software. The options were:

a) The price of the software was within your budget  
b) The software's capabilities match your company's requirements  
c) Ease of use  
d) Ability to develop software, if and when needed  
e) Other, please state.

The overall main response was b).
This would also have been true if only Microbased responses were used.

Divided into work group types the replies are:-

<table>
<thead>
<tr>
<th>Option</th>
<th>Architects</th>
<th>CAD Specialists</th>
<th>Building &amp; Services</th>
<th>Engineers</th>
<th>Design</th>
<th>Electronic</th>
<th>Engineers</th>
<th>Irregular</th>
<th>Textile</th>
<th>Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>M/M b)</td>
<td>M/M b)</td>
<td>M/M b)</td>
<td>M/M a)</td>
<td>M/M b)</td>
<td>M/M b)</td>
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<td>M/M b)</td>
<td>M/M b)</td>
<td>M/M b)</td>
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</tr>
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</table>

The variety of replies to option e) can be seen in the subsequent lists.

Responses to Q16

The total responses are as follows:-

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<tr>
<td>e</td>
<td>17</td>
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<td>e</td>
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</tr>
<tr>
<td>*</td>
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</tbody>
</table>

Option e) allowed the companies to give their own points, in case the ones given, in the xxxii
questionnaire were insufficient.

"System acquired as a package of software and hardware."
"Package fully supported by dealer with good reputation."
"Budget required fixed by system costs."
"Industry standard, good backup, bug free."
"No choice decision made by SDA."
"Company policy to buy IBM."
"Most widely used software CAD."
"Ease of training others to keep up with changing technology."
"Compatibility."
"Technical."
"Suited PC."
"Consistency of design approach required by Apple is supposed to ease learning process."
"Translation of file via various systems and drawings between languages."

Question Seventeen

This question asked what guide-lines were used when the hardware was chosen. The options given were:-

a) The price of the hardware was within your budget
b) The hardware's capabilities matched your company’s requirements
c) Other, please state.

The most popular response was b).

The work type response was:-

<table>
<thead>
<tr>
<th></th>
<th>Option</th>
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<tbody>
<tr>
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<td>b)</td>
</tr>
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<td>Micro</td>
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<td></td>
<td>M/M</td>
</tr>
<tr>
<td></td>
<td>b)/c) equal top</td>
</tr>
<tr>
<td>Building &amp; Services</td>
<td>Micro</td>
</tr>
<tr>
<td>Engineers</td>
<td>Micro</td>
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<td></td>
<td>b)</td>
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<tr>
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<td></td>
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Only two companies did not answer this question at all.
Option c) was the least chosen but the replies it did get are listed.
Responses to Q17

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Option c) allowed the companies to specify their own guidelines.

"it was a complete system."
"Turnkey system."
"Hardware and software all part of one package."
"Software only available on Sun workstation from Prime Computervision."
"Software dependant on hardware."
"Part of package."
"Completely compatible across all "DOS ranges" (MSDOS, UNIX, CP-M)."
"Compatibility."
"To match software with customer compatibility."
"Package allows expansion."
"Versatility."
"Ease of use."
"Industry standard."
"General recommendation by supplier."
"Speed of operation."
"Good VGA."
"Good DOS management (caching CEMM)."
Question Eighteen

This question was the first question in the section headed "System Training". This question asked how the company decided what staff were going to use the computer system. There were four options:

a) Did you employ an expert on the system?
b) Did you employ someone familiar with CAD and the type of work of the company?
c) Did you employ someone familiar with CAD but not the type of work of the company?
d) Internally trained staff

The option that was quite definitely chosen was:

d) 68%

Compared to the other responses:

a) 9%
b) 12%
c) 9%

Only 2% of the companies did not respond at all to this question.

The second factor determined from the questionnaire was that option d) had the highest number of single responses. Out of 94 responses, 67 companies selected only d) with the rest opting for a combination response.

Responses to Q18

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xxxvi
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**Question Nineteen**

This question asked what training was given to introduce the system to the work force. There were five options:-

a) *The operator was allowed to teach himself*
b) *Simple tasks initially then a gradual build up of complexity*
c) *Short training period given by the seller*
d) *Lengthy training period given by the seller*
e) *Other, please state*

The most chosen option was c) followed by a)

When the individual work types were studied they gave:-

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Responses to Q19

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The total responses are as follows:-

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Option e) gave the companies the chance to explain in their own words the training given. The combined response is as follows:

"3 days."
"6 month training programme for everyone in the office, in-house by outside specialist."
"2 days including installing and setting up ; considered inadequate by us the purchaser."
"Training courses 1 week duration."
"Short training by outside consultant after initial period of experimentation."
"Short courses."
"Some outside training involved."
"Training course by local skill centre and vendor training and latterly internal training."
"Night school training on AutoCAD."
"Training courses by seller - AutoCAD and SDA training initiative."
"Additional training at local skill centre."
"Training given by Heriot Watt."
"Training given by Paisley College of Technology."
"Napier Polytechnic CAD courses."
"Attending courses at Bell college Hamilton."
"Course run by local college."
"Training arranged through Cardonald College on all packages, course length as advised by college, some by seller."
"Extra training requires additional cost outwith agreement/software update training programme."
"Training dependant on familiarity of operator."
"CAD still new and still receiving training."
"CAD manager does introduction to DOS and simple AutoCAD, seller gives 1 day reinforcement, later 3 days hands on with CAD manager troubleshooting."
"Night school taught person then he taught others."
"Trained by person self taught on system."

xxviii
"Followed by further in-house training."
"Additional training by in-house training."
"Company expert developed process."
"In-house training."
"Infrequent updates."
"Continual software developments includes update training programmes when implemented."
"More advanced training given by seller as trainees become more proficient."
"Training is ongoing."
"On the job training."
"Purchase of training videos."
"Tutorial manual purchased and worked through."

Question Twenty

This question asked if the training was included in the overall cost of the system. Most of the respondents said:-

"Yes" 71%

as opposed to:-

"No" 29%.

This question had a high no response rate. Out of all those concerned with this part of the questionnaire, 25% did not answer.

Responses to Q20

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xxxix
Question Twenty One

This question dealt with the extent of CAD system use in terms of operator's ability. Four options were given:

a) Only some know how to operate it
b) Everyone can operate it, but not everyone does
c) Everyone can operate it but not all of the time
d) Everyone operates it all of the time

The most favoured response was option a).

The only work type group which did not have this as their option was the Design Consultancy group and their top option was c).

Responses to Q21

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</table>
Question Twenty Two

This was one of the few questions that asked for anything more than a "Yes/No" answer. The subject covered how the company decided what work was carried out on the system and what was done by other means. The actual replies are listed.

Responses to Q22

"All work."
"Policy for all work on CAD."
"All internal work office work."
"All PCB work."
"All work targeted for CAD, only overload done manually."
"Inputting all standard equipment, fabrication drawings but decision for CAD work remains flexible."
"If it can be done on CAD then it must."
"A continual process to utilise systems got and expand on them."
"System dedicated to certain tasks."
"All work has some connection with CAD."
"All work except freehand sketches, produced on CAD as whenever any drawing requiring to be changed or upgraded, it is most efficiently done on CAD."
"Existing old designs altered conventionally."
"Time factors."
"Experience."
"Innovative or one offs better done manually."
"CAD used only on large jobs."
"Complexity of work."
"Complexity, workload, timescales, benefits obtained."
"Time, budget available, complexity of job."
"Combination of repetitive nature of project and integration with other consultants (arbitrary)."
"Amount of alteration and repetitive elements within proposed design."
"Availability and draughting ability for purely CAD."
"Nature of project and volume of work already committed to a single workstation."
"Projects which call for a greater element of repetitiveness are chosen to be prepared for CAD."
"Repetitive work-drafting."
"GA work."
"Used on circuit diagrams for supported designs."
"Standard type drawings on CAD and overall arrangements, non standard details drawn by other means."
"Used as situation arises."
"Work load at any time and type of project."
"Some clients want work done on CAD so as to transfer to their own system."
"Most drawings, sales and GA, foundation drawings, detail drawings, items which require accurate fit ups or geometric checks and standard parts."
"Repetitive and whether staff allotted to it can operate CAD."
"Depends on design team-Architect and client type."
"Judgement of project engineer whether project is suitable in terms of time scale versus complexity."
"Partner decision."
"Evaluation of type of work by senior staff."
"At present decided on a casual basis."
"Evaluation of project goals, programme complexity, operator/system availability."
"Permission gained by project engineer from management based on cost benefit is required to justify use."
"Partner/senior staff joint decision, dependant on type of project and stage needed."
"FE training needs by others."
"Copy existing drawings then onto original work."
"Train people to use systems."

**Question Twenty Three**

This question asked how many people used the system and caused some confusion to the respondents. This was shown by the poor response together with the type of response given. Due to this problem the results were of no use. So I have not recorded any of the results obtained as they have proved to be very misleading.

**Question Twenty Four**

This asked the companies if they had encountered any difficulties. This was broken down into sections dealing with hardware, software, training, choosing a system, timing of training and system performance. While the other replies to questions have been eventually broken down into work groups this question will not be. This is because it is considered that the aspects dealt with in this question are seen to be universal to CAD users, no matter what their area of work.

**Question 24 a) Hardware**

The largest proportion of the companies did not experience any problems with their hardware. The ones that did have problems collectively listed the entire range of equipment necessary for CAD systems as being faulty at one time or another. This list can be seen later on.

Four companies did not respond at all to this section.

**Responses to Q24a**

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<th>Te</th>
<th>Tr</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td>2</td>
<td>0</td>
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</tr>
</tbody>
</table>

xlii
The total responses are as follows:

<table>
<thead>
<tr>
<th></th>
<th>MICRO</th>
<th>OVERALL TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>27</td>
<td>34</td>
</tr>
<tr>
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<td>58</td>
<td>71</td>
</tr>
<tr>
<td>*</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

The problems that were listed are as follows with the most common to the top:

- Faulty printer.
- Faulty VDU.
- Plotter pens.
- Faulty hard disk.
- Graphics tablet faulty.
- Plotter interface.
- Faulty plotter.
- Slow CPU need to upgrade.
- Bad system hard disk replaced.
- Faulty PCB.
- Too slow under full load.
- Non expert supplier.
- Reliability.
- Compatibility problems between processor and hardware set up.
- Floppy disk failure.
- 3 new hard disks required.
- Faulty mother board.
- Cable faults.
- Faulty keyboard.
- Second hand machine had faulty parts.
- Minor learning problems for hardware set up.
- Configuration problems.
- Bad connection between PC/tablet and printer.
- Minor repairs needed.
- Delivery network set up.
- Obtaining equipment quick enough when needing to expand, replace disk drives, intelligence modules.
- Had to upgrade sooner than expected with level of operators skill.
- Supplier became bankrupt without completing installation leading to plotter fault and cable problems.
- Minor problems setting up best caching with respect to CAD performance.
Question 24 b)

Software

This area seems to have given few problems to most of the companies concerned. Although about 38% did experience some problems:

<table>
<thead>
<tr>
<th></th>
<th>Working with the software</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td></td>
<td>29%</td>
</tr>
<tr>
<td>ii)</td>
<td>Bugs in the system</td>
<td>52%</td>
</tr>
<tr>
<td>iii)</td>
<td>Other, please state</td>
<td>20%</td>
</tr>
</tbody>
</table>

The percentages expressed here relate to the 38% that did experience problems.

The companies responses to iii) are listed.

Four companies did not reply to this section.

Responses to Q24b

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>CS</th>
<th>CE</th>
<th>D</th>
<th>El</th>
<th>En</th>
<th>I</th>
<th>Te</th>
<th>Tr</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
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<td>1</td>
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<tr>
<td>ii</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>2</td>
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<td>1</td>
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<td>0</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>*</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>

The total responses are as follows:-

<table>
<thead>
<tr>
<th></th>
<th>MICRO</th>
<th>OVERALL TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>30</td>
<td>42</td>
</tr>
<tr>
<td>i</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>ii</td>
<td>20</td>
<td>31</td>
</tr>
<tr>
<td>iii</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>N</td>
<td>54</td>
<td>62</td>
</tr>
<tr>
<td>*</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

The responses to i) that were stated are as follows:

"Interface to operating system not well enough tested".
"Very slow."
"Minor learning difficulties/experienced only during learning curve but relatively easy to overcome."

xlv
The responses to ii) were as follows :-

"Poor documentation."
"Faults repeating on software update."
"Early versions of AutoCAD, RoboCAD and current versions of Versacad had/have Geometry gaps."
"Some software bugs in Multicad."
"Software bugs ironed out by using reports and suppliers bug trace, software updates/reports."

The responses to iii) are as follows :-

"Enhancements needed as original software specification incorrect."
"Bad documentation."
"Compatibility between software and hardware."
"Upgrades not properly checked out by supplier."
"Software salesman giving inaccurate information."
"Maintaining draughting speed with constant upgrades of software."
"Some systems are better on restricted sections of workload."
"Clarity of documentation and depth of explanation."
"In conjunction with other programs typically the graphics drivers for Cambridge and for Pagemaker on the VGA "trample" on each other leading to crashes."
"Understanding the operating manual."
"Occasional problems with actual program limitations."
"Initial learning/expected learning curve and problems with early versions of software."

Training to use the system

Most of the companies claim to have had no difficulties with training. However 19% did state they experienced problems with training and some went on to state what these were. These are listed.

Responses to Q24c

<table>
<thead>
<tr>
<th>A</th>
<th>CS</th>
<th>CE</th>
<th>D</th>
<th>El</th>
<th>En</th>
<th>I</th>
<th>Te</th>
<th>Tr</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
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</tr>
</tbody>
</table>

12% failed to complete this part of the questionnaire.

The total responses are as follows:-

<table>
<thead>
<tr>
<th>MICRO</th>
<th>OVERALL</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>N</td>
<td>62</td>
<td>74</td>
</tr>
<tr>
<td>*</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>

xlv
The responses that were given are listed below:

"Length of time to be productive."
"Used a consultant to advise so it went smoothly."
"Time scale for experience between courses too long."
"Cost of courses."
"Cramming too much into short training periods."
"Getting staff released from production tasks at a time of overload."
"Teething troubles."
"Learning limitations of software and trying to either improve these with customising or changing your methods of creating designs."
"Understanding the manual."
"Getting familiar with all the commands."
"Most training not effective on user techniques."
"Time allowed."
"Being self taught the use of the proper efficient work functions."
"No problem, no training given."
"Difference between new system and existing Sun system."
"Finding the time for practice applying system other than on new jobs."
"In the more advanced 3D work."

No comment "training still in progress."
"Training run by Cimline did not take account of range of CAD experience of attendees."
"Parts not translated into English."
"Not enough hands on training."

**Question 24 d)**

**Keeping to the time allowed to choose the system**

Very few companies (10%) said they had found difficulties in keeping to the time allowed for choosing the system. Only one company gave any further explanation which was "Planning CAD management as everybody wants stuff now" which is illustrated further on.

27% of the companies decided not to answer this question.

**Responses to Q24d**

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>CS</th>
<th>CE</th>
<th>D</th>
<th>El</th>
<th>En</th>
<th>l</th>
<th>Te</th>
<th>Tr</th>
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</thead>
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</table>

xlvi
The total responses are as follows:

<table>
<thead>
<tr>
<th></th>
<th>MICRO</th>
<th>OVERALL</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
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<td>9</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>54</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>*</td>
<td>25</td>
<td>29</td>
<td></td>
</tr>
</tbody>
</table>

The following was the only response given to this question; the other responses only said "Yes":

"Planning CAD management as everybody wants stuff now."

The above is also illustrated further on.

**Question 24 e)**

Problems in keeping to a pre-set introductory training period

<table>
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<th>OVERALL</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>5</td>
</tr>
<tr>
<td>N</td>
<td>9</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>*</td>
<td>8</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>

20% of the companies decided not to answer this question
64% said they had no problems
16% said they did experience problems but did not give any further information.

The only response that was included with the questionnaire was:

"Planning and research paid off."

When contacted and asked if they would care to elaborate further the following replies were given:

"Some people in the company put up barriers and slowed the process down."
"Did not set a realistic time period as system was quite involved."
"Managing to get people away from their work commitments to train them when the computers were available."
"Tendency to put people trained onto working projects and using up all the computer time so others were unable to get training or time for familiarisation."
"Some required longer time to learn."

Responses to Q24e
The total responses are as follows:

<table>
<thead>
<tr>
<th></th>
<th>MICRO</th>
<th>OVERALL TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
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<td>18</td>
</tr>
<tr>
<td>N</td>
<td>57</td>
<td>68</td>
</tr>
<tr>
<td>*</td>
<td>18</td>
<td>21</td>
</tr>
</tbody>
</table>

The only response given here was:
"Planning and research paid off."

Question 24 f)

Problems with the system giving all you wanted from it.

- 36% said they got all they wanted from their software
- 18% did not respond at all
- 46% they did experience difficulties.

The responses given are listed.

Most of the companies expressed that the systems in use did not give all they wanted from them. They obviously had to adapt their working practices and thereby change their initial needs to purchase a package that was to them affordable. The obvious answer of using a "tailor made" system can increase costs and it could contain many software problems increasing the time before it became operational. This need to get operational quickly was a theme that was present throughout the questionnaire. Some of the responses gave words of advice and wisdom from those who had obviously done it the hard way. Speed of some operating functions appear to be the commonest attribute that had to be dropped. The need for Computer power was also underestimated.

Responses to Q24f

<table>
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<tr>
<th></th>
<th>A</th>
<th>M</th>
<th>M/M</th>
<th>M</th>
<th>M/M</th>
<th>M</th>
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<th>M/M</th>
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</tr>
</thead>
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<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

xlvi
The total responses are as follows:-

<table>
<thead>
<tr>
<th></th>
<th>MICRO</th>
<th>OVERALL TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>29</td>
<td>39</td>
</tr>
<tr>
<td>N</td>
<td>41</td>
<td>48</td>
</tr>
<tr>
<td>*</td>
<td>19</td>
<td>20</td>
</tr>
</tbody>
</table>

The following responses were given to this question:-

"Maximum speed of operation."
"List of parts not as comprehensive as required."
"Company had little idea what the system could/could not do and only established it after one year and received little explanation from salesperson."
"Recommend getting in touch with someone with exact same system for real story and not on sales advice."
"Feature/function availability is a progressive thing."
"Some layout features-Electrical."
"Class contact reduced."
"Inadequate processing power once operators were up to speed."
"Fast generation of 3D models."
"Familiarization difficulties only."
"Some difficulties tailoring in-house menu’s and libraries."
"Output peripherals used are a cost compromise."
Processing the Questionnaire

Due to some of the companies not putting their names to the questionnaire it was not possible to identify which work-group they came under. Hindsight suggests that an identifying number or mark on the forms would have been beneficial. However, this tagging of the forms could have dissuaded some companies from completing the questionnaire. I consider that an unnamed response is better than no response at all. The nature of the questionnaire was more to do with an area which was relevant to all design fields so it was not necessary to be able to pinpoint the responses so accurately. The individual responses in relation to work group types can be seen in this appendix.

Content of the second questionnaire

A second questionnaire was sent out to 65 companies which had responded in the first questionnaire to being agreeable to giving further written assistance. The companies can be broken down into the following groups:-

<table>
<thead>
<tr>
<th></th>
<th>Architecture</th>
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</thead>
<tbody>
<tr>
<td>CS</td>
<td>CAD Specialists/Computer Manufacture</td>
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</tr>
<tr>
<td>CE</td>
<td>Building and Services Engineering</td>
<td>6</td>
</tr>
<tr>
<td>D</td>
<td>Design Consultants/Graphic Design Consultants</td>
<td>6</td>
</tr>
<tr>
<td>El</td>
<td>Electronics</td>
<td>1</td>
</tr>
<tr>
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<td>Engineering</td>
<td>17</td>
</tr>
<tr>
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<td>Irregular</td>
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</tr>
<tr>
<td>Te</td>
<td>Textiles</td>
<td>1</td>
</tr>
<tr>
<td>Tr</td>
<td>Training</td>
<td>9</td>
</tr>
</tbody>
</table>

The next listing shows the individual response rates within the groups to the second questionnaire. There were a further 9 unnamed responses which were not so easy to classify but due to some clues in the answers, some were identified to their work group. They are shown in the second column of the listing below:-

<table>
<thead>
<tr>
<th></th>
<th>Architecture</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS</td>
<td>CAD Specialists/Computer Manufacture</td>
<td>1</td>
</tr>
<tr>
<td>CE</td>
<td>Building and Services Engineering</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>Design Consultants/Graphic Design Consultants</td>
<td>2</td>
</tr>
<tr>
<td>El</td>
<td>Electronics</td>
<td>1</td>
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<td>En</td>
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<td>7</td>
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<td>I</td>
<td>Irregular</td>
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</tr>
<tr>
<td>Te</td>
<td>Textiles</td>
<td>1</td>
</tr>
<tr>
<td>Tr</td>
<td>Training</td>
<td>5</td>
</tr>
</tbody>
</table>

Five responses cannot be grouped any further other than the fact they are not in groups CS, El, Te or
This can be deduced from their replies to the questions and the initial group totals given above. So, out of the 65 companies being asked to complete the form:

<table>
<thead>
<tr>
<th>Number</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>gave named replies</td>
</tr>
<tr>
<td>9</td>
<td>gave unnamed replies</td>
</tr>
</tbody>
</table>

which means that 41 companies replied; approximately a 63% return rate.

The companies will be referred to by numbers and their work type is stated below. Actual names are withheld due to confidentiality.

Company 1 Unnamed Architects
Company 2 Unnamed Engineers
Company 3 Unnamed
Company 4 Unnamed
Company 5 Unnamed
Company 6 Unnamed
Company 7 Unnamed
Company 8 Unnamed Training
Company 9 Irregular
Company 10 Irregular
Company 11 Engineering
Company 12 Engineering
Company 13 Engineering
Company 14 Engineering
Company 15 Engineering
Company 16 Engineering
Company 17 Engineering
Company 18 Design Consultancy
Company 19 Design Consultancy
Company 20 Architects
Company 21 Architects
Company 22 Architects
Company 23 Architects
Company 24 Architects
Company 25 Architects
Company 26 Architects
Company 27 Architects
Company 28 Textile
Company 29 CAD Specialists
Company 30 Building and Services Engineering
Company 31 Building and Services Engineering
Company 32 Building and Services Engineering
Company 33 Training
Company 34 Training
Company 35 Training
Company 36 Training
Company 37 Training

lii
What are the reasons for your company using CAD?

<table>
<thead>
<tr>
<th>Response</th>
<th>Popularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faster presentation/Improved Presentation</td>
<td>12%</td>
</tr>
<tr>
<td>Improve Efficiency</td>
<td>9%</td>
</tr>
<tr>
<td>Overcome potential staffing shortages/Maximise Staffing levels</td>
<td>8%</td>
</tr>
<tr>
<td>Marketing Kudos/Impress clients</td>
<td>6%</td>
</tr>
<tr>
<td>Ease of draughting/Drawing handling/manipulation/change</td>
<td>6%</td>
</tr>
<tr>
<td>Training purposes</td>
<td>6%</td>
</tr>
<tr>
<td>To improve quality/quantity of design output</td>
<td>6%</td>
</tr>
<tr>
<td>Staff aspirations/satisfaction/keep abreast of the current office technology</td>
<td>5%</td>
</tr>
<tr>
<td>Clients requested CAD be used on projects/Client Communication</td>
<td>3%</td>
</tr>
<tr>
<td>Improve Production Process/increase Productivity</td>
<td>3%</td>
</tr>
<tr>
<td>Standardise draughting styles</td>
<td>3%</td>
</tr>
<tr>
<td>Improve cost effectiveness</td>
<td>2%</td>
</tr>
<tr>
<td>Good quality drawings (high accuracy)</td>
<td>2%</td>
</tr>
<tr>
<td>Quality control BS5750 and regard CAD as very important part of drawing office technology</td>
<td>2%</td>
</tr>
<tr>
<td>Design aid</td>
<td>2%</td>
</tr>
<tr>
<td>Communication with other companies/departments</td>
<td>2%</td>
</tr>
<tr>
<td>Cost reduction by not making sample drawings and moulds that are wrong</td>
<td>1%</td>
</tr>
<tr>
<td>Ability to carry out certain tasks requiring accurate profile definitions</td>
<td>1%</td>
</tr>
<tr>
<td>Improved response time</td>
<td>1%</td>
</tr>
<tr>
<td>Elimination of duplicate work</td>
<td>1%</td>
</tr>
<tr>
<td>Education tuition</td>
<td>1%</td>
</tr>
<tr>
<td>To produce graphic display material/standardise forms etc.</td>
<td>1%</td>
</tr>
<tr>
<td>To improve total throughput time from original order, design, manufacture and delivery</td>
<td>1%</td>
</tr>
<tr>
<td>More accurate</td>
<td>1%</td>
</tr>
<tr>
<td>More repeatable design</td>
<td>1%</td>
</tr>
<tr>
<td>Company does not have a design facility but has CAD as an interface to work with customer's design facility and for company's CAM facility</td>
<td>1%</td>
</tr>
<tr>
<td>Quick recall of previously designed/drawn components which can be used in new designs leading to faster designs/drawings useful drawing aids e.g. copy, mirror, rotate, erase etc.</td>
<td>1%</td>
</tr>
<tr>
<td>Concept modelling</td>
<td>1%</td>
</tr>
<tr>
<td>Ability to test options</td>
<td>1%</td>
</tr>
<tr>
<td>Domestic change of family business</td>
<td>1%</td>
</tr>
</tbody>
</table>

Company  | Reason
---|---------------------------------------------------
1 | "Clients requested CAD be used on projects."
2 | "Faster & better presentation to customers, cost reduction by not making sample drawings and moulds that are wrong".
3 | "Improve efficiency & cost effectiveness, overcome potential staffing shortages".
Company | Reason
--- | ---
4 | "Ability to carry out certain tasks requiring accurate profile definitions, staff aspiration satisfaction, Marketing Kudos."
5 | "Improves Production Process, Design Aid, Speed etc."
6 | "Ease of draughting we are not always reinventing the wheel. Drawing is only required once and can be repeated copied arrayed etc, ease of change information is full size so any scale drawing can be created."
7 | "Improved response time, Elimination of duplicate work."
8 | "Education Tuition"
9 | "To improve quality and quality of design output. To standardise drafting styles, to make use of calculation software packages, to produce graphic display material, standardise forms etc."
10 | "To improve total throughput time from original order, design, manufacture and delivery."
11 | "Faster, more accurate, more repeatable design, quicker modification time."
12 | "In answering your questions I should point out that we do not have a design facility as such, we use the CAD purely to interface more easily with our customers design facility and for the CAM facility."
13 | "Quick recall of previously designed/drawn components which can be used in new designs leading to faster designs/drawings, useful drawing aids e.g. copy, mirror image, rotate, erase etc. Good quality drawings (high accuracy), Quality control (BS5750) regard CAD as very important part of drawing office traceability."
14 | "To maximise staff levels and increase efficiency by reducing hours spent manually drafting."
15 | "To give a standard look to all drawings within the design department, easy updating/changes and issue administration, heighten company image, more work less time, more than one person can work on a drawing/s and will not look like a fudged drawing."
16 | Improved drawing quality, increased speed when producing similar types of drawing and a more uniform standard of drawing."
17 | "To improve the scope, speed, quality, efficiency of graphic design work."
18 | "Increase the performance of the individual, enhance presentation, easier to store and transfer documents, project an efficient operation to clients."
19 | "Improve time scale for production drawing."
20 | "To try and improve our manpower efficiency and as a marketing tool to indicate to potential clients that we have such a facility."
21 | "To increase efficiency in the production of drawings."
22 | "Ease of repetitive drawing, changing drawings and production of fast 2D and 3D proposals for clients."
23 | "Efficiency - quicker and easier to prepare information, P.R. - 3D models good for clients - clients expect us to have CAD system, staff morale - good to see office is entering the 20th Century."
24 | "Improved efficiency and standard of service to clients."
25 | "Cost effective draughting, co-ordination with co consultants client service increasingly clients are requiring CAD files as well as drawings, image/marketing, concept modelling."
26 | "Increased Accuracy, Ability to test options, improved presentation, speed, enhance image/marketing tool, efficiency."
Question 2

Do you regard the purchase of the CAD system worthwhile?

<p>| | |</p>
<table>
<thead>
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</thead>
<tbody>
<tr>
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<td>93%</td>
</tr>
<tr>
<td>Marginal</td>
<td>5%</td>
</tr>
<tr>
<td>Unsure</td>
<td>2%</td>
</tr>
<tr>
<td>No</td>
<td>0%</td>
</tr>
</tbody>
</table>

There was one qualifying statement given in this question for the company which said it was uncertain:

"Difficult to produce tangible benefits such as lower engineering costs. However initial objectives have been achieved."

Some companies regarded it worthwhile but gave some qualifying statements:

"... for certain types of work"
"Like most CAD implementations, the benefits have been mixed. As an overall assessment it has been worthwhile."

"... but it is difficult to quantify"

Other companies were more impressed with their system:

"The system was installed 12 months ago and proved itself worthwhile within 6 months."

"... it has widened the workload of the Practice and is constantly introducing new elements to our work."

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
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</thead>
<tbody>
<tr>
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<tr>
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<td>&quot;Very much&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Difficult to produce tangible benefits such as lower engineering costs. However initial objectives have been achieved.&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;Like most CAD implementations, the benefits have been mixed. As an overall assessment it has been worthwhile.&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;Yes&quot;</td>
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<tr>
<td>12</td>
<td>&quot;Yes&quot;</td>
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<tr>
<td>13</td>
<td>&quot;Yes&quot;</td>
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<tr>
<td>14</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>16</td>
<td>&quot;Very much so&quot;</td>
</tr>
<tr>
<td>17</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>18</td>
<td>&quot;Extremely&quot;</td>
</tr>
<tr>
<td>19</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>20</td>
<td>&quot;Only just&quot;</td>
</tr>
<tr>
<td>21</td>
<td>&quot;Yes but it is difficult to quantify&quot;</td>
</tr>
</tbody>
</table>
| 22      | "The system was installed 12 months ago and proved itself worthwhile within 6 months."
| 23      | "Yes it has widened the workload of the Practice and is constantly introducing new elements to our work."
| 24      | "Yes efficient, time saving." |
| 25      | "Yes"  |
| 26      | "Yes"  |
| 27      | "Yes"  |
| 28      | "Yes"  |
| 29      | "Yes"  |
| 30      | "Certainly" |
| 31      | "Yes for reasons in q1" |
| 32      | "Yes"  |
| 33      | "Yes"  |
| 34      | "Absolutely" |
| 35      | "Marginal" |
| 36      | "Yes over 30 systems now purchased" |
| 37      | "Yes"  |
Company | Reason
--- | ---
38 | "Yes"
39 | "Yes for certain types of work"
40 | "Yes"
41 | "Yes"

**Question 3**

Do you think the system has proved successful?

<p>| | |</p>
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<tbody>
<tr>
<td>Yes</td>
<td>88%</td>
</tr>
<tr>
<td>Marginal</td>
<td>12%</td>
</tr>
<tr>
<td>No</td>
<td>0%</td>
</tr>
</tbody>
</table>

Those who considered it marginal gave the following qualifying statements:

"To a limited extent yes"

"After 3 years effort and training and purchasing of improved software it is now good"

"Partially but any deficiency is due probably to our attitude."

"Not entirely. We purchased 'Versacad' at a time when 'AutoCAD' and 'Versacad' were front runners to become the industry standard: 'AutoCAD' won!"

"... for certain types of work."

For some of the companies who said 'Yes' they gave some more qualifying statements:

"... but requires a new approach it cannot be used as a drawing board in the traditional sense and more can be achieved with the same manpower."

"... in a technical sense less obvious now it imparts the 'bottom line'."

"As competition gets harder, we will find there is a strong competitive edge to having CAD."

"Keeping up to date with technology can only help the practice!"

"... clients impressed, staff happy, definite reduction in time spent on projects on CAD."

"... almost all drawing work is now done on CAD."
Company 1
1. "Yes"
2. "Yes"
3. "Very much so customers now rely on these"
4. "Yes"
5. "Yes"
6. "Yes but requires a new approach it cannot be used as a drawing board in the traditional sense and more can be achieved with the same manpower."
7. "Yes in technical sense less obvious now it impacts the 'bottom line'"
8. "Yes"
9. "Yes"
10. "As competition gets harder, we will find there is a strong competitive edge to having CAD."
11. "Yes"
12. "Yes"
13. "Yes"
14. "To a limited extent yes"
15. "Yes"
16. "Yes all in q1 have been met"
17. "Yes"
18. "Yes"
19. "Yes"
20. "After 3 years effort and training and purchaser of improved software it is now good"
21. "Partially but any deficiency is due probably to our attitude."
22. "So far yes"
23. "Yes keeping up to date with technology can only help the practice"
24. "Yes clients impressed, staff happy, definite reduction in time spent on projects on CAD."
25. "Yes"
26. "Yes"
27. "Yes almost all drawing work is now done on CAD."
28. "Yes"
29. "We run 7 different CAD systems - they are all useful in particular applications - 2 most used are Multicad and AutoCAD"
30. "Yes as expected, though it took some time for the expected benefits to appear"
31. "Yes"
32. "Yes"
33. "Yes"
34. "Yes"
35. "Not entirely we purchased 'Versacad' at a time when 'AutoCAD' and 'Versacad' were front runners to become the industry standard: 'Autocad' won I"n
36. "Yes. Training areas are expanding"
37. "Yes as a result of our training we have placed trainees on full time employment"
38. "Yes"
39. "Yes for certain types of work."
40. "Yes"
41. "Yes"
Question 4

Do you think the purchase was really necessary for the company?

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Yes</td>
<td>85%</td>
</tr>
<tr>
<td>Maybe</td>
<td>3%</td>
</tr>
<tr>
<td>Change of attitude</td>
<td>5%</td>
</tr>
<tr>
<td>No</td>
<td>7%</td>
</tr>
</tbody>
</table>

There was one qualifying statement for those who said 'No':
"... not essential but certainly beneficial."

The qualifying statement for the company who said may be:
"In as much as drawing can be produced without the system - No - but when taking into account the need to increase efficiency in a more competitive market - Yes."

The following are the qualifying statements for those who said 'Yes':
"... customers expect it if for no other reason"
"In hindsight, yes."
"... due to overload of work when first purchased did not know if it would help it has sped up completely the production drawing output in a new project - one person doing a two man job."
"... it was essential when a large number of jobs of a similar nature were going through simultaneously."
"I personally think so as an introduction to CAD for the firm."
"... all other consultants have CAD, cost effective."
"If one wants to compete at the highest level with our competitors both retail and contract then these systems are essential."
"For the company to continue to be competitive, Yes."

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;Yes&quot;</td>
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<tr>
<td>3</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Yes customers expect it if for no other reason&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;It was not seen as necessary at the time but would be seen as such now.&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;No not essential but certainly beneficial.&quot;</td>
</tr>
<tr>
<td>12</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>13</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>14</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;In hindsight yes.&quot;</td>
</tr>
<tr>
<td>Company</td>
<td>Reason</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>16</td>
<td>&quot;... due to overload of work when first purchased did not know if it would help it has sped up completely the production drawing output in a new project - one person doing a two man job.&quot;</td>
</tr>
<tr>
<td>17</td>
<td>&quot;... it was essential when a large number of jobs of a similar nature were going through simultaneously.&quot;</td>
</tr>
<tr>
<td>18</td>
<td>&quot;Yes&quot;</td>
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<tr>
<td>19</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>20</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>21</td>
<td>&quot;I personally think so as an introduction to CAD for the firm.&quot;</td>
</tr>
<tr>
<td>22</td>
<td>&quot;In as much as drawing can be produced without the system No, but when taking into account the need to increase efficiency in a more competitive market Yes.&quot;</td>
</tr>
<tr>
<td>23</td>
<td>&quot;Yes basically for the reasons given above&quot; (Q3)</td>
</tr>
<tr>
<td>24</td>
<td>&quot;... all other consultants have CAD, cost effective.&quot;</td>
</tr>
<tr>
<td>25</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>26</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>27</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>28</td>
<td>&quot;If one wants to compete at the highest level with our competitors both retail and contract then these systems are essential.&quot;</td>
</tr>
<tr>
<td>29</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>30</td>
<td>&quot;For the company to continue to be competitive Yes.&quot;</td>
</tr>
<tr>
<td>31</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>32</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>33</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>34</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>35</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>36</td>
<td>&quot;Yes - Policy to extend new technology training&quot;</td>
</tr>
<tr>
<td>37</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>38</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>39</td>
<td>&quot;Yes for reasons given in Q1&quot;</td>
</tr>
<tr>
<td>40</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>41</td>
<td>&quot;Yes&quot;</td>
</tr>
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</table>

### Question 5

**Do you think the purchase is really cost effective?**

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<td>Maybe</td>
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<tr>
<td>Doubtful</td>
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<tr>
<td>Not Certain</td>
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</tr>
<tr>
<td>Not Yet</td>
<td>10%</td>
</tr>
<tr>
<td>No</td>
<td>7%</td>
</tr>
</tbody>
</table>

Comments made by those companies which did not say 'Yes' or 'No':

"Subject to ongoing evaluation."

"Could not identify if it has."
"The payback period was set at three years which has not yet expired."

"Too early to say (18 months) customers have been slow to take advantage of our system and expertise in our own field."

"Probably but needs more analysis to make comparison."

"No to short term Yes to long term."

"Doubtful"

"I really do not know but probably not at this stage."

"Possibly not during initial stages however when a fully integrated system is operational it will be cost effective."

"Not yet."

There was only one qualifying statement for those who said 'No':-

"In our case no as it isn't used in a full production environment."

There were some qualifying statements for those who said 'Yes':-

"... for certain types of work."

"... we have already got our money's worth."

"... in the long run."

"Because of the variety of information which one can acquire from these systems saving on manpower plus speed are obvious examples."

"... we have checked cost/time against similar jobs not on CAD."

"... in a work output to cost ratio it is well within the equivalent staff cost levels."

"There is no doubt that the saving in man-hours on work being done by the computer more than pays for the system."

"... engineering drawings much faster - alterations/mods."

"... over the long term."

"... but it could be better, learning curves are poor."

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;It saved the initial cost of the first PC in the first four weeks&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Yes for certain types of work.&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Subject to ongoing evaluation.&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;... but it could be better, learning curves are poor.&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Could not identify if it has.&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;The payback period was set at three years which has not yet expired.&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>12</td>
<td>&quot;Too early to say (18 months) customers have been slow to take advantage of our system and expertise in our own field.&quot;</td>
</tr>
<tr>
<td>13</td>
<td>&quot;Yes&quot;</td>
</tr>
</tbody>
</table>
Company | Reason
--- | ---
14 | "Yes over the long term."
15 | "Yes"
16 | "Yes (as Q15) engineering drawings much faster - alterations/mods easy, the company has really benefited from this part so far."
17 | "Yes"
18 | "Probably but needs more analysis to make comparison."
19 | "No to short term Yes to long term."
20 | "Doubtful"
21 | "I really do not know but probably not at this stage."
22 | "There is no doubt that the saving in man-hours on work being done by the computer more than pays for the system."
23 | "Yes in a work output to cost ratio it is well within the equivalent staff cost levels."
24 | "... we have checked cost/time against similar jobs not on CAD."
25 | "Possibly not during initial stages however when a fully integrated system is operational it will be cost effective."
26 | "Yes"
27 | "Yes"
28 | "Because of the variety of information which one can acquire from these systems saving on manpower plus speed are obvious examples."
29 | "Yes"
30 | "Yes in the long run."
31 | "Not yet."
32 | "No"
33 | "Yes"
34 | "Yes"
35 | "No"
36 | "Yes"
37 | "... we have already got our money's worth."
38 | "Yes"
39 | "Yes for certain types of work"
40 | "In our case no as it isn't used in a full production environment."
41 | "Yes"

Question 6

Were the people who chose the system familiar with the working practices of the company?

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<td>95%</td>
</tr>
<tr>
<td>No</td>
<td>5%</td>
</tr>
</tbody>
</table>

The only qualifying statements were for those who said 'Yes':-

"Partners and Associates of the firm chose the system."

"... chosen by CAD manager and directors of the company."

"... the first system bought by the firm was a disaster (this was approximately three and a half years ago) from that experience we learnt how to make the right decisions second time around with a
different system.*

These systems were chosen by the Department Design Development Manager and our chief designer plus designers were involved in assessing each system before any decision was made.*

<table>
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<th>Company</th>
<th>Reason</th>
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</tr>
<tr>
<td>2</td>
<td>&quot;Yes it was me&quot;</td>
</tr>
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<td>3</td>
<td>&quot;Yes&quot;</td>
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<td>&quot;Yes&quot;</td>
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<td>&quot;Yes&quot;</td>
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<td>6</td>
<td>&quot;Yes&quot;</td>
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<td>7</td>
<td>&quot;Yes&quot;</td>
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<td>&quot;Yes&quot;</td>
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<td>&quot;Yes&quot;</td>
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<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>14</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>16</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>17</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>18</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>19</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>20</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>21</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>22</td>
<td>&quot;Partners and Associates of the firm chose the system.*&quot;</td>
</tr>
<tr>
<td>23</td>
<td>&quot;Yes chosen by CAD manager and directors of the company.*&quot;</td>
</tr>
<tr>
<td>24</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>25</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>26</td>
<td>&quot;Yes the first system bought by the firm was a disaster (this was approximately three and a half years ago) from that experience we learnt how to make the right decisions second time around with a different system.*&quot;</td>
</tr>
<tr>
<td>27</td>
<td>&quot;Yes partners*&quot;</td>
</tr>
<tr>
<td>28</td>
<td>&quot;These systems were chosen by the Department Design Development Manager and our chief designer plus designers were involved in assessing each system before any decision was made.*&quot;</td>
</tr>
<tr>
<td>29</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>30</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>31</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>32</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>33</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>34</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>35</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>36</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>37</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>38</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>39</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>40</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>41</td>
<td>&quot;Yes&quot;</td>
</tr>
</tbody>
</table>
Question 7

What method of selection was used when purchasing the system?

<table>
<thead>
<tr>
<th>Response</th>
<th>Popularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>By recommendation of peers</td>
<td>8%</td>
</tr>
<tr>
<td>Selected Industry standard</td>
<td>8%</td>
</tr>
<tr>
<td>Working to a budget and selecting an appropriate system</td>
<td>6%</td>
</tr>
<tr>
<td>Testing and review of peers</td>
<td>6%</td>
</tr>
<tr>
<td>Testing of systems, reading trade information, asking computer experience peers</td>
<td>6%</td>
</tr>
<tr>
<td>Review carried out by upper management</td>
<td>6%</td>
</tr>
<tr>
<td>Reading of computer publications &amp; visits to suppliers</td>
<td>2%</td>
</tr>
<tr>
<td>Studying of reports by professional bodies (CICA)</td>
<td>2%</td>
</tr>
<tr>
<td>Evaluation of various systems by trial tasking</td>
<td>2%</td>
</tr>
<tr>
<td>Parent company's choice</td>
<td>2%</td>
</tr>
<tr>
<td>Previous experience and discussion with industry</td>
<td>2%</td>
</tr>
<tr>
<td>Training given, demonstrations of software/hardware, advice for users</td>
<td>2%</td>
</tr>
<tr>
<td>Requirements checklist drawn up then systems tested against this</td>
<td>2%</td>
</tr>
<tr>
<td>Review of customers systems and review of companies requirements</td>
<td>2%</td>
</tr>
<tr>
<td>Availability of software and its ease of customising</td>
<td>2%</td>
</tr>
<tr>
<td>Benchmarking</td>
<td>2%</td>
</tr>
<tr>
<td>Independent consultant</td>
<td>2%</td>
</tr>
<tr>
<td>Economics and number of units in service</td>
<td>2%</td>
</tr>
<tr>
<td>Exhibition visits and discussion</td>
<td>2%</td>
</tr>
<tr>
<td>Review of systems against cost considerations then chosen by ease of learning/use</td>
<td>2%</td>
</tr>
<tr>
<td>Visits to educational establishment, read professional journals and demonstrations on site of short listed systems</td>
<td>2%</td>
</tr>
<tr>
<td>Chosen most widely used system for compatibility and could meet company's requirements</td>
<td>2%</td>
</tr>
<tr>
<td>Select key personnel, select good dealer, commit sufficient funds, chose most widely used system</td>
<td>2%</td>
</tr>
<tr>
<td>Review of market then choice based on cost and market penetration</td>
<td>2%</td>
</tr>
<tr>
<td>Requirements list, software tested against this review of peers for dealer then bought his standard system</td>
<td>2%</td>
</tr>
<tr>
<td>Market Survey Demonstrations</td>
<td>2%</td>
</tr>
<tr>
<td>Dealer demonstrated a system, the dealer had supplied other computer equipment</td>
<td>2%</td>
</tr>
<tr>
<td>Pin the tail on the donkey</td>
<td>2%</td>
</tr>
<tr>
<td>Most widely used and cost effective system</td>
<td>2%</td>
</tr>
<tr>
<td>Compatibility and backup</td>
<td>2%</td>
</tr>
<tr>
<td>Appraisal of requirements, study of market place, benchmarking, requested demonstrations from software companies and hardware companies selected most appropriate combination for companies needs</td>
<td>2%</td>
</tr>
</tbody>
</table>

Company  | Reason                                                                                      |
---------|---------------------------------------------------------------------------------------------|
1        | "By word of mouth from other Architects"                                                    |
2        | "Brief was to find 2D CAD system - Read standard pc magazines and then went to pc suppliers locally" |
"Studied CICA reports and other sources"

"Evaluation of various systems by trial tasking"

"Previous experience from other branch offices"

"5 years of research into the various developing systems within our cost area"

"Parent company in US already had a system and it seemed to work well. The choice was easy"

"Experience and discussion with industry etc."

"Training of operators, demonstration of software/hardware, advice for users"

"A requirements checklist was created and various products were rated against that list"

"Selected industry standard hardware/software"

"We had a look at what our customers had and found we did not have a need for the type of sophistication of their systems, so we then had a look at what was available in the software market for a compatible system"

"Viewpoints and experience of other companies who use CAD to design similar components to ourselves, outside consultant, price"

"Availability of suitable software and ease of customising"

"Benchmark testing of 4 systems compatibility with clients existing systems"

"Trying out various options, research asking those in the 'know'"

"An independent consultant"

"Exploration of computers and programmes available, reading trade magazines asking people with computer experience of the computers"

"Economics and number of units in service in the UK"

"Visit to exhibitions and discussion"

"Two systems were identified within the agreed cost restraints and we felt the purchased system was the simpler to learn and use even although it was not the most best selling product at the time"

"Partners and associates attended computer courses at Heriot Watt geared to the use of CAD in offices, also attended seminars, read professional journals and received demonstrations of two systems in own office"

"Comparison of several systems of varying costs - narrowed down to a cost limit"

"Looked at numerous systems - needed something popular, compatible with others, able to cope with 2D and 3D work"

"General research, reading journals etc. discussion with other practices, viewing installations in other situations"

"Find the right dealer/support team (Academy) commit sufficient funding to ensure a fully workable (rather than half baked) system. Go for something industry standard (i.e. AutoCAD) with a proven track record, good support in terms of software, a good manual etc."

"General research into 'the market' followed by decision based on cost and market penetration"

"as Q6"

"Visiting and testing 20 plus systems"

"Expected uses were established, software packages were investigated, enquired around existing users for recommended dealer, trainer etc. Approached dealer and bought his standard hardware/software."

"Recommendation from Central Committee i.e. in-house appraisal conducted in London Head Office"

"Market Survey Demonstrations"

"The system was demonstrated to us by the suppliers of our CNC machines"

"Need to have 'Standard' software e.g. AutoCAD ? FastCAD and suitable for Computer Graphics syllabus"

"Pin the tail on the Donkey"

"Industrial Standard IBM or compatible"
"Looked at the most widely used and cost effective system"

"We have 4 systems altogether two are large screen systems which were purchased from the market leader in Scotland for reasons of compatibility and backup. The other two are less expensive small screen versions which run the same software"

"Full appraisal of requirements, study of market place and final benchmarking"

"Software companies were invited to furnish us with brochures on their particular CAD system. Likewise with hardware companies. This information was then analysed and the most appropriate combination for our particular needs was chosen"

Question 8

How many used the system when the company first Installed CAD?

<table>
<thead>
<tr>
<th>number of persons in the company</th>
<th>number of companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28%</td>
</tr>
<tr>
<td>2</td>
<td>31%</td>
</tr>
<tr>
<td>3</td>
<td>18%</td>
</tr>
<tr>
<td>4</td>
<td>8%</td>
</tr>
<tr>
<td>5</td>
<td>0%</td>
</tr>
<tr>
<td>6</td>
<td>3%</td>
</tr>
<tr>
<td>7 (4 regularly 3 less frequently)</td>
<td>3%</td>
</tr>
<tr>
<td>8</td>
<td>3%</td>
</tr>
<tr>
<td>9</td>
<td>3%</td>
</tr>
<tr>
<td>18/20</td>
<td>3%</td>
</tr>
</tbody>
</table>

Three companies were not so exact in their response, they answered:

"Several"

"None, all had to learn - then one person became 'office expert"

"All instructional staff and field staff"

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Initially 2 persons&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;2/3 users&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;2&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;4&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;2&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;1&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;All engineer's i.e. 18 - 20 but for a very limited period after initial training as only 2 units were purchased.&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;1&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;4&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;2&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;3&quot;</td>
</tr>
<tr>
<td>12</td>
<td>&quot;1&quot;</td>
</tr>
</tbody>
</table>
Question 9

Has this number of users increased or has it remained constant?

<table>
<thead>
<tr>
<th>Reason</th>
<th>71%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased</td>
<td></td>
</tr>
<tr>
<td>Remained constant</td>
<td>24%</td>
</tr>
<tr>
<td>Decreased</td>
<td>5%</td>
</tr>
</tbody>
</table>

Has this number of users increased or has it remained constant?

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Increased&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;Now 3/4&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Increased&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Increased to 7&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Increased&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;Increased&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Purchase of additional units (12) has extended the period of use of each individual&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;Constant and Tuition&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;Increased&quot;</td>
</tr>
</tbody>
</table>
Question 10

What levels of staff of the company can operate the system?

<table>
<thead>
<tr>
<th>Response</th>
<th>Popularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>All levels (varying degrees of skill)</td>
<td>41%</td>
</tr>
<tr>
<td>Draughting personnel</td>
<td>10%</td>
</tr>
<tr>
<td>Technicians and Engineers</td>
<td>9%</td>
</tr>
<tr>
<td>Intermediate and down</td>
<td>3%</td>
</tr>
<tr>
<td>Supervisory</td>
<td>3%</td>
</tr>
<tr>
<td>Technical staff and some managers</td>
<td>3%</td>
</tr>
<tr>
<td>Designers and 1 Engineer</td>
<td>3%</td>
</tr>
<tr>
<td>Engineering</td>
<td>3%</td>
</tr>
<tr>
<td>Designers and Admin assistant</td>
<td>3%</td>
</tr>
<tr>
<td>Company</td>
<td>Reason</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>1</td>
<td>&quot;All levels*&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;Designers in development department (both managers and assistants)&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Technicians and Engineers&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Draftsmen (OND) Project Engineers (BSc)*&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Intermediate/Down*&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;30&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Draughtsmen and Engineers*&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;Supervisory*&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;Designers Draughtsmen*&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;Technical staff and some managers&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;Designers and 1 Engineer*&quot;</td>
</tr>
<tr>
<td>12</td>
<td>&quot;HND Engineers*&quot;</td>
</tr>
<tr>
<td>13</td>
<td>&quot;2&quot;</td>
</tr>
<tr>
<td>14</td>
<td>&quot;N/A*&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;Only draughting personnel*&quot;</td>
</tr>
<tr>
<td>16</td>
<td>&quot;Design Engineers - 4 off (one subcontract)*&quot;</td>
</tr>
<tr>
<td>17</td>
<td>&quot;?&quot;</td>
</tr>
<tr>
<td>18</td>
<td>&quot;2 designers and 1 admin assistant with computer skills*&quot;</td>
</tr>
<tr>
<td>19</td>
<td>&quot;Skilled*&quot;</td>
</tr>
<tr>
<td>20</td>
<td>&quot;15%*&quot;</td>
</tr>
<tr>
<td>21</td>
<td>&quot;Junior Technician and senior Architect*&quot;</td>
</tr>
<tr>
<td>22</td>
<td>&quot;All levels with a varying degree of efficiency*&quot;</td>
</tr>
<tr>
<td>23</td>
<td>&quot;Trainee, Technician, Manager*&quot;</td>
</tr>
<tr>
<td>24</td>
<td>&quot;Mostly Middle range, only 1 senior member, no partners*&quot;</td>
</tr>
<tr>
<td>25</td>
<td>&quot;A spread between technician and project architect*&quot;</td>
</tr>
<tr>
<td>26</td>
<td>&quot;Architects, Technicians, trainee technicians*&quot;</td>
</tr>
<tr>
<td>27</td>
<td>&quot;All Architectural, Technical staff except one partner*&quot;</td>
</tr>
<tr>
<td>28</td>
<td>&quot;All levels within our Design Studio can work the system. Designers are however the main users and the most skilled as they use them daily*&quot;</td>
</tr>
<tr>
<td>29</td>
<td>&quot;All*&quot;</td>
</tr>
<tr>
<td>30</td>
<td>&quot;Technicians/draughtsmen and Engineers (to a lesser degree)*&quot;</td>
</tr>
<tr>
<td>31</td>
<td>&quot;Junior rather than senior*&quot;</td>
</tr>
<tr>
<td>32</td>
<td>&quot;Only Technicians*&quot;</td>
</tr>
<tr>
<td>33</td>
<td>&quot;All members of staff from Manager to Workshop Instructors*&quot;</td>
</tr>
<tr>
<td>34</td>
<td>&quot;Tutors (+ trainees)*&quot;</td>
</tr>
<tr>
<td>35</td>
<td>&quot;Training Instructors*&quot;</td>
</tr>
<tr>
<td>36</td>
<td>&quot;All levels of staff have access*&quot;</td>
</tr>
<tr>
<td>37</td>
<td>&quot;Supervisors and Trainees*&quot;</td>
</tr>
<tr>
<td>38</td>
<td>&quot;Drawing office staff only*&quot;</td>
</tr>
<tr>
<td>39</td>
<td>&quot;Partners assistant Architects and Technicians*&quot;</td>
</tr>
<tr>
<td>40</td>
<td>&quot;Extractors to section heads*&quot;</td>
</tr>
<tr>
<td>41</td>
<td>&quot;One, me*&quot;</td>
</tr>
</tbody>
</table>
Question 11

What is the ratio in terms of staff to computer e.g. 2 staff : 1 computer

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Number of companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1</td>
<td>31%</td>
</tr>
<tr>
<td>2:1</td>
<td>20%</td>
</tr>
<tr>
<td>3:1</td>
<td>7%</td>
</tr>
<tr>
<td>6:1</td>
<td>7%</td>
</tr>
<tr>
<td>3:2</td>
<td>7%</td>
</tr>
<tr>
<td>4:1</td>
<td>5%</td>
</tr>
<tr>
<td>n/a</td>
<td>5%</td>
</tr>
<tr>
<td>5:1</td>
<td>3%</td>
</tr>
<tr>
<td>25:1</td>
<td>3%</td>
</tr>
<tr>
<td>10:4</td>
<td>3%</td>
</tr>
<tr>
<td>14:9</td>
<td>3%</td>
</tr>
<tr>
<td>11:1</td>
<td>3%</td>
</tr>
<tr>
<td>no answer</td>
<td>3%</td>
</tr>
</tbody>
</table>

One other comment was:-

3 - 5 regularly 3 - 7 other times

One other company responded "More computers than staff."

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;2 staff : 1 computer&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;No answer&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;1:1&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;4:1&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;25:1&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;1.2:1&quot; (6:1)</td>
</tr>
<tr>
<td>7</td>
<td>&quot;12 computers 18 staff&quot; (3:2)</td>
</tr>
<tr>
<td>8</td>
<td>&quot;1:1&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;3 - 5 regular 3 - 7&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;10 staff to 4 CAD screens&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;1:1&quot;</td>
</tr>
<tr>
<td>12</td>
<td>&quot;3:2&quot;</td>
</tr>
<tr>
<td>13</td>
<td>&quot;2:1&quot;</td>
</tr>
<tr>
<td>14</td>
<td>&quot;N/A 1:1&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;1:1&quot;</td>
</tr>
<tr>
<td>16</td>
<td>&quot;3 staff : 2 computers&quot;</td>
</tr>
<tr>
<td>17</td>
<td>&quot;14 staff to 9 stations&quot;</td>
</tr>
<tr>
<td>18</td>
<td>&quot;1 staff to 1 computer&quot;</td>
</tr>
<tr>
<td>19</td>
<td>&quot;1:1&quot;</td>
</tr>
<tr>
<td>20</td>
<td>&quot;5 staff to 1 CAD&quot;</td>
</tr>
<tr>
<td>21</td>
<td>&quot;4 staff to one computer&quot;</td>
</tr>
<tr>
<td>22</td>
<td>&quot;2:1&quot;</td>
</tr>
<tr>
<td>23</td>
<td>&quot;3 staff to 1 computer&quot;</td>
</tr>
<tr>
<td>24</td>
<td>&quot;6:1 approximately)&quot;</td>
</tr>
<tr>
<td>25</td>
<td>&quot;2:1 (approximately)&quot;</td>
</tr>
<tr>
<td>26</td>
<td>&quot;11:1 or if only technical 5 or 6 :1&quot;</td>
</tr>
</tbody>
</table>
Reason
27 "2:1 currently under review"
28 "3:1"
29 "More computers than staff."
30 "2:1"
31 "6:1 Design Engineers 1:1 wp operators, CAD Technicians"
32 "3:1"
33 "2:1"
34 "1:1 as required 1 machine allotted to other training when not in use i.e. accounts/DTP training"
35 "1:1"
36 "1:1 on training 2:1 within admin"
37 "2:1"
38 "1:1"
39 "1:1"
40 "N/A"
41 "1:1"

Question 12

Have you experienced an increase in work quality?

<table>
<thead>
<tr>
<th>Option</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>73%</td>
</tr>
<tr>
<td>Other</td>
<td>5%</td>
</tr>
<tr>
<td>Possibly</td>
<td>2%</td>
</tr>
<tr>
<td>N/A or no ans.</td>
<td>10%</td>
</tr>
<tr>
<td>No</td>
<td>10%</td>
</tr>
</tbody>
</table>

The companies which come under the 'Other' category gave further qualifying statements:

"Some limited benefits here."

"It is only as good as the designer that is using it and therefore is more of a tool with which to create your design with."

There were two qualifying statements for those who answered in the 'No' category:

".. only in visual quality, content quality is not improved."

".. not really as our work quality on the board is of a very high standard any way."

There were some qualifying statements to those who said 'Yes':

"... subject to limitations"

"... definitely in drawing modifications."

"... up to a point."

"Quality improved - neater drawing good 3D presentation."

Company | Reason
--------|-------
1       | "Yes"
2       | No answer
3       | "Yes"
<table>
<thead>
<tr>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
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<tr>
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<td>38</td>
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<tr>
<td>39</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>41</td>
</tr>
</tbody>
</table>

- "No only in visual quality, content quality is not improved."
- "Yes subject to limitations"
- "Yes"
- "Some limited benefits here."
- "Yes"
- "Yes"
- "Yes definitely in drawing modifications."
- "Yes"
- "Yes"
- "Yes up to a point."
- "Yes"
- "Yes"
- "Yes greatly"
- "Yes"
- "Yes"
- "Yes"
- "Yes"
- "Possibly"
- "Yes"
- "Yes"
- "Yes"
- "Quality improved - neater drawings good 3D presentation"
- "Yes"
- "Yes"
- "Yes"
- "Yes"
- "It is only as good as the designer who is using it and therefore is more of a tool with which to create your design with."
- "Yes"
- "Yes"
- "Yes"
- "Yes"
- "N/A"
- "N/A"
- "No"
- "Yes with CAD output & DTP to Laserjet"
- "N/A"
- "No"
- "Yes"
- "Yes"
- "No not really as our work quality on the board is of a very high standard any way."
Question 13

Have you experienced an increase in work output?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>58%</td>
</tr>
<tr>
<td>Moderate</td>
<td>5%</td>
</tr>
<tr>
<td>Can't decide</td>
<td>10%</td>
</tr>
<tr>
<td>N/A or no ans.</td>
<td>12%</td>
</tr>
<tr>
<td>No</td>
<td>15%</td>
</tr>
</tbody>
</table>

Qualifying statements from those who said 'Yes':

"... subject to limitations."

"... in drawing modification."

"... particularly when revising work to incorporate mods."

"... especially in finished production drawings."

"... in certain areas."

"... for the limited projects it has been used on."

"Eventually."

"Database management and spreadsheet survey increase output."

Qualifying statement from those who said 'No':

"... again recession is affecting output dramatically."

Qualifying statements to those in the 'can't decide' category:

"Variable."

"Difficult to say - computer jobs are quicker once changes are called for but not necessarily the initial drawing work."

"Not as yet. CAD is usually only used for GA's and any other plan layout required on a particular job. The rest of the design work is still carried out on the board."

"Hard to judge."

Qualifying statements for those in the moderate category:

"Again - unoriginal i.e. we still have the same number of people."

"Slight."

"Marginal."

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>2</td>
<td>No answer.</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Yes subject to limitations.&quot;</td>
</tr>
<tr>
<td>Company</td>
<td>Reason</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>6</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Again - unoriginal i.e. we still have the same number of people.&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;Slight&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;Yes in drawing modification.&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;Yes particularly when revising work to incorporate mods.&quot;</td>
</tr>
<tr>
<td>12</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>13</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>14</td>
<td>&quot;Hard to judge.&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>16</td>
<td>&quot;Yes especially in finished production drawings.&quot;</td>
</tr>
<tr>
<td>17</td>
<td>&quot;Yes in certain areas.&quot;</td>
</tr>
<tr>
<td>18</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>19</td>
<td>&quot;Marginal.&quot;</td>
</tr>
<tr>
<td>20</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>21</td>
<td>&quot;Yes for the limited projects it has been used on.&quot;</td>
</tr>
<tr>
<td>22</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>23</td>
<td>&quot;Variable.&quot;</td>
</tr>
<tr>
<td>24</td>
<td>&quot;Difficult to say - computer jobs are quicker once changes are called for but not necessarily the initial drawing work.&quot;</td>
</tr>
<tr>
<td>25</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>26</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>27</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>28</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>29</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>30</td>
<td>&quot;Eventually, yes&quot;</td>
</tr>
<tr>
<td>31</td>
<td>&quot;. . . again recession is affecting output dramatically.&quot;</td>
</tr>
<tr>
<td>32</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>33</td>
<td>&quot;N/A&quot;</td>
</tr>
<tr>
<td>34</td>
<td>&quot;N/A&quot;</td>
</tr>
<tr>
<td>35</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>36</td>
<td>&quot;Database management and spreadsheet survey increase output.&quot;</td>
</tr>
<tr>
<td>37</td>
<td>&quot;N/A&quot;</td>
</tr>
<tr>
<td>38</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>39</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>40</td>
<td>&quot;N/A&quot;</td>
</tr>
<tr>
<td>41</td>
<td>&quot;Not as yet CAD is usually only used for GA's and any other plan layout required on a particular job. The rest of the design work is still carried out on the board.&quot;</td>
</tr>
</tbody>
</table>
Question 14

Do you find that your use of CAD increases your chances of winning contracts or has it had no effect at all?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>54%</td>
</tr>
<tr>
<td>Possibly</td>
<td>14%</td>
</tr>
<tr>
<td>Not yet</td>
<td>5%</td>
</tr>
<tr>
<td>N/A or no ans.</td>
<td>17%</td>
</tr>
<tr>
<td>No</td>
<td>10%</td>
</tr>
</tbody>
</table>

Qualifying statements for those who said 'Yes':-

"Marginal increase it is sometimes a prerequisite."

"Strong influence in producing designs that are both good design and presentation."

"Changes contract by contract but overall yes."

"We have had some success in transfer of IGES files from customers via a modem link and this has proved a very useful tool in this age of JIT deliveries."

"It helps win contracts as outline drawings sent with quotation have a good psychological effect."

"... Huge effect we were first graphic design consultancy in Scotland to use CAD."

"... but marginal effect."

"Increases chances if large contract or multi unit contract otherwise very little effect."

"... clients are impressed 3D images good for presentations."

"... particularly in relation to speculative work and free bidding."

"Very much so because of time saved in completing clients request. Plus computer printouts can be supplied to enhance presentations."

"... particularly with addition of FAX and DTP facilities."

"... but only on grounds of technical pre qualification cost is still the overriding factor."

"... AutoCAD and Post Processors has led to new business."

"For certain contracts it is essential."

"... but it depends on who you are pitching your work at. Your average Pub and Night-club owners are not really interested in CAD but large corporations are usually impressed with it.

Qualifying statement for those in the 'No' category:-

"No effect, difficult to judge."

Qualifying statement for those in the 'Possible' category:-

"Not known but I suspect it does due to giving a more technical image."

"Hopefully yes."

"Customer perception is important our customers generally see implementation of CAD as a positive sign."
"It may do in the future. The drawings are only beginning to be supplied to customers - mainly for suppliers in-house."

We believe it has increased our chances of winning contracts, existing customers know the standard of drawing they will require and quotations to new customers all greatly enhanced by the inclusion of CAD drawings.

"No evidence of this as yet but we think it should have an influence."

Qualifying statements for those in the 'Not yet' category:

"Too soon to have an impact yet but likely to allow us to bid more competitively for work, so may indeed increase chances."

"Too early to say."

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>2</td>
<td>No Answer given</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Yes - increases chances&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Not known but I suspect it does due to giving a more technic image&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Hopefully yes...&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;Marginal increase it is sometimes a prerequisite.&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Customer perception is important our customers generally see implementation of CAD as a positive sign.&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;N/A minimal students due to lack of stations available&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;No effect, difficult to judge.&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;Strong influence in producing designs that are both good design and presentation.&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;Changes contract by contract but overall yes.&quot;</td>
</tr>
<tr>
<td>12</td>
<td>&quot;We have had some success in transfer of IGES files from customers via a modem link and this has proved a very useful tool in this age of JIT deliveries.&quot;</td>
</tr>
<tr>
<td>13</td>
<td>&quot;It helps win contracts as outline drawings sent with quotation have a good psychological effect.&quot;</td>
</tr>
<tr>
<td>14</td>
<td>&quot;N/A&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;Increases chances&quot;</td>
</tr>
</tbody>
</table>
| 16      | "It may do in the future. The drawings are only beginning to be supplied to customers - mainly for suppliers in-house."

We believe it has increased our chances of winning contracts, existing customers know the standard of drawing they will require and quotations to new customers all greatly enhanced by the inclusion of CAD drawings.

"Yes huge effect we were the first graphic design consultancy in Scotland to use CAD."

"Yes but marginal effect."

"Yes"

"No evidence of this as yet but we think it should have an influence."

"Too early to say."

"Increases chances if large contract or multi unit contract otherwise very little effect."

"Yes clients are impressed 3D images good for presentations." |
| 25      | "Yes" |
| 26      | "Yes" |
| 27      | "Yes particularly in relation to speculative work and free bidding." |

lxxvi
Question 15

Do you find your staff remain with the company or do they leave for jobs elsewhere for reasons related to their CAD skills?

<table>
<thead>
<tr>
<th>Remain</th>
<th>56%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No change</td>
<td>14%</td>
</tr>
<tr>
<td>Don't know</td>
<td>5%</td>
</tr>
<tr>
<td>N/A</td>
<td>20%</td>
</tr>
<tr>
<td>Leave</td>
<td>5%</td>
</tr>
</tbody>
</table>

Qualifying statements for those whose answers were in the ‘Remain’ category:

“No staff lost yet.”

“Stay not left as yet.”

“No staff trained in CAD have left the company.”

“.... the firm has a very low turnover of staff.”

“No evidence of this at present.”

“They stay.”

“Has not been a problem but we are very much aware of the potential problem hence the importance of Partners having a working knowledge of CAD.”

Qualifying statements for those in the ‘Leave’ category:

“Staff move after training to better wages.”
"We have lost one member perhaps partially for having an introductory skill in CAD. Otherwise there is no evidence that CAD has influenced staff one way or the other.

Qualifying statements for those who answered in the 'No change' category:

"About the same degree of change now as before CAD. Human nature to move job to job."

"We have had varying levels of success in retaining staff approximately 30% turnover in 1 year."

"Staff moves unrelated."

Qualifying statements for those who answered 'Don't know':

"Don't know yet."

"Too soon to tell."

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;No moves yet&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Remain&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;No staff lost yet.&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Remain&quot;</td>
</tr>
</tbody>
</table>
| 6       | "About the same degree of change now as before CAD. Human nature to move job to job."
| 7       | "CAD experience not a factor - low staff turnover anyway" |
| 8       | "N/A" |
| 9       | "Remain" |
| 10      | "No staff left" |
| 11      | "Mainly contract staff who move about" |
| 12      | "Up to now no" |
| 13      | "Have remained so far" |
| 14      | "N/A" |
| 15      | "We have had varying levels of success in retaining staff approximately 30% turnover in 1 year." |
| 16      | "Stay not left as yet." |
| 17      | "No staff trained in CAD have left the company." |
| 18      | "Remain" |
| 19      | Remain |
| 20      | "Staff move after training to better wages." |
| 21      | "We have lost one member perhaps partially for having an introductory skill in CAD. Otherwise there is no evidence that CAD has influenced staff one way or the another."
| 22      | "Remain the firm has a very low turnover of staff." |
| 23      | "Yes" |
| 24      | "Some have left - some stayed" |
| 25      | "No evidence of this at present." |
| 26      | "They stay" |
| 27      | "Don't know yet." |
| 28      | "Yes staff remain" |
| 29      | "Staff moves unrelated." |
| 30      | "Too soon to tell." |
| 31      | "N/A due to small numbers involved" |
| 32      | "Remain currently" |
| 33      | "N/A" |
| 34      | "We hope staff remain (but trainees get employment as a result of training)" |
Company | Reason
---|---
35 | "N/A"
36 | "Staff are generally long-term"
37 | "Trainees find other jobs"
38 | "N/A"
39 | "Has not been a problem but we are very much aware of the potential problem hence the importance of Partners having a working knowledge of CAD."
40 | "Remain"
41 | "N/A"

**Question 16**

Have you or your employees experienced an increase in job satisfaction?

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>69%</td>
</tr>
<tr>
<td>Some</td>
<td>2%</td>
</tr>
<tr>
<td>Maybe</td>
<td>7%</td>
</tr>
<tr>
<td>Don’t Know</td>
<td>2%</td>
</tr>
<tr>
<td>N/A</td>
<td>5%</td>
</tr>
<tr>
<td>No</td>
<td>15%</td>
</tr>
</tbody>
</table>

Qualifying statements for those who said ‘Yes’:-

"... generally, one or so are still uncomfortable about using machines."

"There is a high level of job interest."

"... certain tasks laborious with rotring and paper especially cleaning blocked pens and ink stains in new clothes. The actual drawing by CAD is good for you can look at new ways of doing something with the same drawing."

"... operators show more enthusiasm for work than when they only used manual drawing methods."

"Because it helps to remove most of the laborious tasks that a designer used to do it must be more satisfying."

Qualifying statements for those who said ‘No’:-

"About the same."

"No not really as the CAD is not yet being used in a terribly creative manner and this is where all designers get their job satisfaction."

Qualifying statements for those who said ‘Maybe’:-

"Two way some increase and one industrial designer slightly bored since it does not use all her abilities."

"Debatable."

"Perhaps for the two members who have been using it to date. This may be temporary as there develops a degree of frustration knowing that more sophisticated software is now available and we may not be able to update fast enough to avoid this."
<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;Two way some increase and one industrial designer slightly bored since it does not use all her abilities.&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;Some&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;,... generally, one or so are still uncomfortable about using machines.&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;There is a high level of job interest.&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;About the same&quot;</td>
</tr>
<tr>
<td>12</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>13</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>14</td>
<td>&quot;N/A&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>16</td>
<td>&quot;Yes certain tasks laborious with rotting and paper especially cleaning blocked pens and ink stains in new clothes. The actual drawing by CAD is good for you can look at new ways of doing something with the same drawing.&quot;</td>
</tr>
<tr>
<td>17</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>18</td>
<td>&quot;Debatable.&quot;</td>
</tr>
<tr>
<td>19</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>20</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>21</td>
<td>&quot;Perhaps for the two members who have been using it to date. This may be temporary as there develops a degree of frustration knowing that more sophisticated software is now available and we may not be able to update fast enough to avoid this.&quot;</td>
</tr>
<tr>
<td>22</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>23</td>
<td>..., operators show more enthusiasm for work than when they only used manual drawing methods.&quot;</td>
</tr>
<tr>
<td>24</td>
<td>&quot;Yes also computer games help&quot;</td>
</tr>
<tr>
<td>25</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>26</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>27</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>28</td>
<td>&quot;Because it helps to remove most of the laborious tasks that a designer used to do it must be more satisfying.&quot;</td>
</tr>
<tr>
<td>29</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>30</td>
<td>&quot;Unknown&quot;</td>
</tr>
<tr>
<td>31</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>32</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>33</td>
<td>&quot;Yes&quot;</td>
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</tr>
<tr>
<td>37</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>38</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>39</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>40</td>
<td>&quot;Not really applicable&quot;</td>
</tr>
<tr>
<td>41</td>
<td>&quot;No not really as the CAD is not yet being used in a terribly creative manner and this is where all designers get their job satisfaction&quot;</td>
</tr>
</tbody>
</table>
Do you find staff happier with their work or more discontented because of the installation of the CAD system?

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>61%</td>
</tr>
<tr>
<td>Same</td>
<td>5%</td>
</tr>
<tr>
<td>Don't Know</td>
<td>10%</td>
</tr>
<tr>
<td>N/A</td>
<td>17%</td>
</tr>
<tr>
<td>No</td>
<td>7%</td>
</tr>
</tbody>
</table>

Qualifying statements for those who said 'Yes':

"Some but no real change."

"Probably happier."

"Happier but busier."

"Happier CAD system carries out repetitive work very quickly and easily. Similarly alterations to work is much easier."

"... they are only discontented when they cannot get onto a system. If cost was no object one computer per designer would be perfect."

"Happier - changes are easier to make."

"Less discontented."

"Those who use it are more satisfied."

Qualifying statements for those who said 'No':

"No obvious change"

"On the whole no difference."

"No change however without CAD I am sure we would by now have had an adverse reaction based on the feeling that the individual was being 'left' behind in his profession."

Qualifying statements for those who said 'Don't Know':

"Difficult some definitely happier, some not interested."

"None of current staff were employed prior to introduction of CAD."

"Staff only worked with CAD."

"Not more discontented one draughtsman is happier than the other."

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;Generally happier&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;More contented&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Happier&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Same&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;Some but no real change.&quot;</td>
</tr>
</tbody>
</table>
Reason

"No change however without CAD I am sure we would by now have had an adverse reaction based on the feeling that the individual was being 'left' behind in his profession."

"Happier"

"N/A"

"Unhappy at first during the training/transition but far happier later"

"Same"

"Happier"

"Probably happier."

"N/A"

"Happier"

"Happier"

"Generally happier"

"Happier but busier"

"More content"

"N/A"

"No obvious change"

"Happier CAD system carries out repetitive work very quickly and easily. Similarly alterations to work is much easier."

"On the whole no difference."

"Difficult some definitely happier, some not interested."

"Generally happier"

"Happier"

"None of current staff were employed prior to introduction of CAD."

"... they are only discontented when they cannot get onto a system. (If cost was no object one computer per designer would be perfect.)"

"Staff only worked with CAD."

"Not more discontented one draughtsman is happier than the other."

"Happier - changes are easier to make."

"Less discontented."

"Happier"

"Happier"

"N/A"

"Yes happier"

"N/A"

"Happier"

"Those who use it are more satisfied."

"N/A"

"N/A"

Question 18

Do you find or expect to find it difficult to get new CAD experienced staff?

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
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<td>10%</td>
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<tr>
<td>N/A</td>
<td>15%</td>
</tr>
<tr>
<td>No</td>
<td>29%</td>
</tr>
</tbody>
</table>
Qualifying statements for those who said 'Yes':-

"... but it is improving but good staff in any field are hard to get."

"We find it difficult to get experienced mould designers with or without CAD experience."

"... because even if we obtain new staff who are appointed for their all round expertise the chances are if they have CAD experience it is with different systems."

"... all have CAD experience it is with different systems."

"... all have to be trained on the system."

"Almost impossible to get experienced staff in Dundee area and very difficult even in London, recently recruited technician from London is being trained in-house."

"... due primarily to our geographical position."

Qualifying statements for those who said 'No':-

"CAD experience is not a criteria."

"Can get them but salary expectations are high."

"... but experience maybe on different systems. Also there is a general problem in obtaining suitably qualified people in engineering but where you are able to hire them then it is likely they will have had some CAD experience."

"... it seems to be the intention of most people to gain some experience of CAD. How experienced I don't know."

"Staff are appointed for their engineering skills and trained in CAD when required. We have not attempted to engage experienced CAD staff."

Qualifying statements for those who said 'Something else':-

"Expect to 'home grow' staff as we expand."

"We do not use experienced staff as our policy has been in-house training from scratch up to now."

"Difficult because new experienced staff will have to be adaptable enough to work the system we have adopted in running our CAD system."

Qualifying statement for those who said 'Don't Know':-

"Do not know - would expect not too difficult if salary sufficient."

<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>2</td>
<td>&quot;Expect to 'home grow' staff as we expand.&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Expect to find it difficult&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Trained in-house&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;Yes but it is improving but good staff in any field are hard to get.&quot;</td>
</tr>
<tr>
<td>Company</td>
<td>Reason</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>7</td>
<td>&quot;No but experience maybe on different systems. Also there is a general problem in obtaining suitably qualified people in engineering but where you are able to hire them then it is likely they will have had some CAD experience.&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;Yes it will be&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>12</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>13</td>
<td>&quot;Do not know - would expect not too difficult if salary sufficient.&quot;</td>
</tr>
<tr>
<td>14</td>
<td>&quot;We find it difficult to get experienced mould designers with or without CAD experience.&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;Both&quot;</td>
</tr>
<tr>
<td>16</td>
<td>&quot;No it seems to be the intention of most people to gain some experience of CAD. How experienced I don't know.&quot;</td>
</tr>
<tr>
<td>17</td>
<td>&quot;Staff are appointed for their engineering skills and trained in CAD when required. We have not attempted to engage experienced CAD staff.</td>
</tr>
<tr>
<td>18</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>19</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>20</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>21</td>
<td>&quot;Yes because even if we obtain new staff who are appointed for their all round expertise the chances are if they have CAD experience it is with different systems.&quot;</td>
</tr>
<tr>
<td>22</td>
<td>&quot;Not applicable so far&quot;</td>
</tr>
<tr>
<td>23</td>
<td>&quot;We do not use experienced staff as our policy has been in-house training from scratch up to now.&quot;</td>
</tr>
<tr>
<td>24</td>
<td>&quot;... all have to be trained on the system.&quot;</td>
</tr>
<tr>
<td>25</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>26</td>
<td>&quot;Quite difficult&quot;</td>
</tr>
<tr>
<td>27</td>
<td>&quot;Almost impossible to get experienced staff in Dundee area and very difficult even in London, recently recruited technician from London is being trained in-house.&quot;</td>
</tr>
<tr>
<td>28</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>29</td>
<td>&quot;... due primarily to our geographical position.&quot;</td>
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<tr>
<td>30</td>
<td>&quot;No&quot;</td>
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<td>31</td>
<td>&quot;N/A&quot;</td>
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<tr>
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<td>&quot;Yes&quot;</td>
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<td>34</td>
<td>&quot;N/A&quot;</td>
</tr>
<tr>
<td>35</td>
<td>&quot;CAD experience is not a criteria.&quot;</td>
</tr>
<tr>
<td>36</td>
<td>&quot;No (in-house training available)&quot;</td>
</tr>
<tr>
<td>37</td>
<td>&quot;N/A&quot;</td>
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<td>&quot;No&quot;</td>
</tr>
<tr>
<td>39</td>
<td>&quot;Can get them but salary expectations are high.&quot;</td>
</tr>
<tr>
<td>40</td>
<td>&quot;N/A&quot;</td>
</tr>
<tr>
<td>41</td>
<td>&quot;Difficult because new experienced staff will have to be adaptable enough to work the system we have adopted in running our CAD system.&quot;</td>
</tr>
</tbody>
</table>
**Question 19**

Do you expect to have to train any new staff with the necessary CAD skills that the company might need?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>Maybe</th>
<th>N/A</th>
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<td></td>
<td>88%</td>
<td>5%</td>
<td>2%</td>
<td>5%</td>
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</tbody>
</table>

Qualifying statements for those who said 'Yes':-

"Specific System Training always given as a matter of course."

"... new staff & existing staff."

"... but this is not a problem."

"... ongoing needs to update skills."

"It is anticipated that we will continue to purchase new work-stations and hence we will either train our present staff in the use of CAD or acquire new staff with the skills."

Qualifying statement for one of the companies which came into the 'Maybe' category:-

"Possibly as design department increases."

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<tr>
<th>Company</th>
<th>Reason</th>
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</thead>
<tbody>
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<tr>
<td>2</td>
<td>&quot;see 18&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Yes see 18&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;Yes&quot;</td>
</tr>
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<td>7</td>
<td>&quot;Specific System Training always given as a matter of course.&quot;</td>
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<td>&quot;Yes&quot;</td>
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<tr>
<td>9</td>
<td>&quot;Yes&quot;</td>
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<td>&quot;Yes&quot;</td>
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<td>12</td>
<td>&quot;Yes&quot;</td>
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<td>13</td>
<td>&quot;Yes&quot;</td>
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<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>16</td>
<td>&quot;Possibly as design department increases.&quot;</td>
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<td>&quot;Yes&quot;</td>
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<td>18</td>
<td>&quot;Yes&quot;</td>
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<td>&quot;Yes&quot;</td>
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<tr>
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<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>22</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>23</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>24</td>
<td>&quot;Yes new staff &amp; existing staff.&quot;</td>
</tr>
<tr>
<td>25</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>26</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>27</td>
<td>&quot;Yes&quot;</td>
</tr>
</tbody>
</table>
Company | Reason
--- | ---
28 | "Yes but this is not a problem."
29 | "Yes"
31 | "Yes"
32 | "Yes"
33 | "N/A"
34 | "Yes"
35 | "Unlikely"
36 | "Yes ongoing needs to update skills."
37 | "Yes"
38 | "Yes"
39 | "It is anticipated that we will continue to purchase new work stations and hence we will either train our present staff in the use of CAD or acquire new staff with the skills."
40 | "No"
41 | "Yes"

Question 20

Do you have a training programme to keep your staff abreast of new developments?

<p>| | |</p>
<table>
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<th></th>
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<tbody>
<tr>
<td>Yes</td>
<td>44%</td>
</tr>
<tr>
<td>Other means</td>
<td>7%</td>
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<td>N/A</td>
<td>5%</td>
</tr>
<tr>
<td>No</td>
<td>44%</td>
</tr>
</tbody>
</table>

Qualifying statements for those who said 'Yes':

"Not formalised."
"... staff attend user groups and seminars on new developments of the system."
"Not formally"
"... software upgrades in themselves tend to drive this."
"... staff development plan."

Qualifying statements for those who said 'No':

"Not at present"
".. CAD Manager organises this when felt necessary."
".. Depends on who is interested."
".. not yet."
".. but recognise that this is important."

Qualifying Statements for those who said 'Other means':

"Not except for self motivated reading."
"Send to Napier College etc it seems to benefit."
"Staff attend a dealer run user group which keeps us informed on new developments."
<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
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</thead>
<tbody>
<tr>
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<td>&quot;No&quot;</td>
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<td>3</td>
<td>&quot;No&quot;</td>
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<tr>
<td>4</td>
<td>&quot;Not except for self motivated reading.&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;Yes software upgrades in themselves tend to drive this.&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;Minimal&quot;</td>
</tr>
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<td>9</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;Not formalised.&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;No&quot;</td>
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<td>&quot;Yes&quot;</td>
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<td>&quot;No&quot;</td>
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<tr>
<td>14</td>
<td>&quot;N/A&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>16</td>
<td>&quot;Send to Napier College etc it seems to benefit.&quot;</td>
</tr>
<tr>
<td>17</td>
<td>&quot;Staff attend a dealer run user group which keeps us informed on new developments.&quot;</td>
</tr>
<tr>
<td>18</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>19</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>20</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>21</td>
<td>&quot;Not at present&quot;</td>
</tr>
<tr>
<td>22</td>
<td>&quot;... staff attend user groups and seminars on new developments of the system.&quot;</td>
</tr>
<tr>
<td>23</td>
<td>&quot;No CAD Manager organises this when felt necessary.&quot;</td>
</tr>
<tr>
<td>24</td>
<td>&quot;No Depends on who is interested.&quot;</td>
</tr>
<tr>
<td>25</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>26</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>27</td>
<td>&quot;Not formally&quot;</td>
</tr>
<tr>
<td>28</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>29</td>
<td>&quot;We sell training in CAD&quot;</td>
</tr>
<tr>
<td>30</td>
<td>&quot;No&quot;</td>
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<td>31</td>
<td>&quot;No not yet.&quot;</td>
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<td>32</td>
<td>&quot;No&quot;</td>
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<td>&quot;Yes&quot;</td>
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<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>35</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>36</td>
<td>&quot;Yes staff development plan.&quot;</td>
</tr>
<tr>
<td>37</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>38</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>39</td>
<td>&quot;No but recognise that this is important.&quot;</td>
</tr>
<tr>
<td>40</td>
<td>&quot;N/A&quot;</td>
</tr>
<tr>
<td>41</td>
<td>&quot;No&quot;</td>
</tr>
</tbody>
</table>

lxxxvii
Question 21
Do you have the resources for the implementation of a training programme?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
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<td>Other</td>
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</tr>
<tr>
<td>No</td>
<td>34%</td>
</tr>
</tbody>
</table>

Qualifying statements for those who said 'Yes':-

"Group training department."
"... but only if absolutely necessary."
"... just requires time to be programmed - both teachers and students which is difficult. Tends to tie up computers which limits drawing time."
"... but informally."
"... company is a central resource for 100 member companies."
"Possible."

Qualifying statements for those who said 'No':-

"... all training is on the job."
"No time."
"No real programme but it would be in-house once required, training is on the job starting from my study of program manuals. Once we advance to AutoCAD or whatever we would take advantage of the standard training courses on offer."
"Not really so a voluntary evening compromise training system maybe considered."
"We have training provided by the dealer. All in-house training is 'on-the-job' as the work progresses - so the simple answer is no."

Qualifying statements for those who came under the 'Other' category: -

"Partially."
"A training programme for all the staff has been carried out at Bell College with the assistance of SRC funds."
"Not as much as would be desired but this is constantly monitored in relation to other aspects of the practice."
"Any training programme would most likely be undertaken by in-house staff."

Company | Reason
---------|-------
1        | "Partially"
2        | "No real programme but it would be in-house once required, training is on the job starting from my study of program manuals. Once we advance to AutoCAD or whatever we would take advantage of the standard training courses on offer."
3        | "No"
<table>
<thead>
<tr>
<th>Company</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
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<td>&quot;Yes&quot;</td>
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<td>6</td>
<td>&quot;Yes&quot;</td>
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<tr>
<td>7</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>9</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>10</td>
<td>&quot;Group training department.&quot;</td>
</tr>
<tr>
<td>11</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>12</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>13</td>
<td>&quot;Yes but only if absolutely necessary.&quot;</td>
</tr>
<tr>
<td>14</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>15</td>
<td>&quot;Yes&quot;</td>
</tr>
<tr>
<td>16</td>
<td>&quot;No time.&quot;</td>
</tr>
<tr>
<td>17</td>
<td>&quot;No&quot;</td>
</tr>
<tr>
<td>18</td>
<td>&quot;No all training is on the job.&quot;</td>
</tr>
<tr>
<td>19</td>
<td>&quot;Yes&quot;</td>
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<td>20</td>
<td>&quot;Possible.&quot;</td>
</tr>
<tr>
<td>21</td>
<td>&quot;Not really so a voluntary evening compromise training system may be considered.&quot;</td>
</tr>
<tr>
<td>22</td>
<td>&quot;A training programme for all the staff has been carried out at Bell College with the assistance of SRC funds.&quot;</td>
</tr>
<tr>
<td>23</td>
<td>&quot;Not at present&quot;</td>
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<tr>
<td>24</td>
<td>&quot;Yes just requires time to be programmed - both teachers and students which is difficult. Tends to tie up computers which limits drawing time.&quot;</td>
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<td>25</td>
<td>&quot;Not as much as would be desired but this is constantly monitored in relation to other aspects of the practice.&quot;</td>
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<td>26</td>
<td>&quot;Yes&quot;</td>
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<tr>
<td>27</td>
<td>&quot;Yes but informally.&quot;</td>
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<tr>
<td>28</td>
<td>&quot;Yes&quot;</td>
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<tr>
<td>29</td>
<td>&quot;Yes obviously&quot;</td>
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<tr>
<td>30</td>
<td>&quot;We have training provided by the dealer. All in-house training is 'on-the-job' as the work progresses - so the simple answer is no.&quot;</td>
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<tr>
<td>31</td>
<td>&quot;Yes&quot;</td>
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<td>32</td>
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<td>35</td>
<td>&quot;Yes&quot;</td>
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<tr>
<td>36</td>
<td>&quot;Yes company is a central resource for 100 member companies.&quot;</td>
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<td>37</td>
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<td>38</td>
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<td>39</td>
<td>&quot;Any training programme would most likely be undertaken by in-house staff.&quot;</td>
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## WORK TYPE

### CAD SPECIALISTS/COMPUTER MANUFACTURE

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### CIVIL ENGINEERING

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<tr>
<td>Consulting Civil Engineers (principally water &amp; dam)</td>
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<td>Building Services Consulting Engineers</td>
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<td>Civil, Structural, Transportation</td>
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<td>Subcontractor Electronics</td>
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<td>Local area Networks Communications Products</td>
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<td>Manufacturer Integrated Circuits and Subassemblies</td>
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<td>Transformer and Wound Component Manufacturer</td>
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<td>Control Panel Electrical and Electronic Switch</td>
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<td>Gear Manufacturer</td>
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<td>Printed Circuit Board Manufacturer</td>
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<td>Designers, Manufacturers, Suppliers of Packaging Products</td>
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<td>Design and Manufacturer of High Performance Loudspeaker systems and other Audio Equipment</td>
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<td>Design and Manufacturer of Computerised Weighing Equipment</td>
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<td>Design and Manufacturer Pollution Control Equipment for Effluent treatment systems, Project Management</td>
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<td>Manufacturer and Regrind Special cutting Tools</td>
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<td>Pipework Engineering</td>
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<td>Manufacture of Glassfibre Contour Sheeting and Roof Lights</td>
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</tr>
<tr>
<td>Agricultural Equipment Design and Development/</td>
<td></td>
</tr>
<tr>
<td>Agricultural Engineering Development/Farm and Rural</td>
<td></td>
</tr>
<tr>
<td>Building Design</td>
<td>60</td>
</tr>
<tr>
<td>Text Retrieval Systems</td>
<td>15</td>
</tr>
<tr>
<td>Design for Print</td>
<td>6</td>
</tr>
<tr>
<td>With Mainframe/Mini based CAD</td>
<td></td>
</tr>
<tr>
<td>Conveyor Dryers and Process Machinery for the Food, Chemical and Tobacco Industries</td>
<td>200</td>
</tr>
<tr>
<td>Manufacturers of Food Processing Machinery</td>
<td>76</td>
</tr>
<tr>
<td>Manufacturer of equipment for Bakery and Food Industries</td>
<td>50</td>
</tr>
<tr>
<td>No CAD but Interested</td>
<td></td>
</tr>
<tr>
<td>Scottish Hydro Electric</td>
<td>5000</td>
</tr>
<tr>
<td>Biscuit Manufacturing</td>
<td>1000</td>
</tr>
<tr>
<td>Pottery Manufacturer and Design</td>
<td>3</td>
</tr>
<tr>
<td>No CAD no Interest</td>
<td></td>
</tr>
<tr>
<td>Repair of Hard Disk Units</td>
<td>300</td>
</tr>
<tr>
<td>Computer Bureaux providing Computer Services to Government Departments in Scotland</td>
<td>200</td>
</tr>
<tr>
<td>Computer Dealer</td>
<td>50</td>
</tr>
<tr>
<td>Writing Business Guides etc.</td>
<td>1</td>
</tr>
<tr>
<td>Development and Manufacturing of Housing for the elderly</td>
<td>not given</td>
</tr>
<tr>
<td>Authors and Publishers</td>
<td>not given</td>
</tr>
</tbody>
</table>

### TEXTILES

<p>| With Microbased CAD                    |      |
| Apparel Textile Weaving                | 95   |
| Textile and Carpet Manufacturers       | not given |
| No CAD but Interested                  |      |
| Fastener Manufacturer                  | 150  |
| Manufacturer Fabrics, Industrial and Medical Products | 140  |
| Manufacturer of Rings and Travellers for Yarn Production | 110  |
| Knitwear Design                        | 2    |
| Design/Pattern Service to Clothing Industry | 1    |</p>
<table>
<thead>
<tr>
<th>WORK TYPE</th>
<th>SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>No CAD no Interest</td>
<td></td>
</tr>
<tr>
<td>Commission Dying and Finishing</td>
<td>52</td>
</tr>
<tr>
<td>Marketing Consultancy in the Textile Industry</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>TRAINING</td>
<td></td>
</tr>
<tr>
<td>With Microbased CAD</td>
<td></td>
</tr>
<tr>
<td>Education Further Education</td>
<td>100</td>
</tr>
<tr>
<td>Further Education Engineering and Computer subjects</td>
<td>100</td>
</tr>
<tr>
<td>IT Training</td>
<td>38</td>
</tr>
<tr>
<td>Training</td>
<td>20</td>
</tr>
<tr>
<td>IT Centre</td>
<td>20</td>
</tr>
<tr>
<td>Apprentice First Year Engineering Training</td>
<td>14</td>
</tr>
<tr>
<td>Training</td>
<td>12</td>
</tr>
<tr>
<td>YT Management Training</td>
<td>10</td>
</tr>
<tr>
<td>YTS and ET</td>
<td>4</td>
</tr>
<tr>
<td>Training YTS and Business Organisations</td>
<td>not given</td>
</tr>
<tr>
<td>Training</td>
<td>not given</td>
</tr>
<tr>
<td>No CAD but Interested</td>
<td></td>
</tr>
<tr>
<td>Engineering Training</td>
<td>15</td>
</tr>
<tr>
<td>Training and Software Support</td>
<td>15</td>
</tr>
<tr>
<td>No CAD no Interest</td>
<td></td>
</tr>
<tr>
<td>First Year Engineering Training</td>
<td>4</td>
</tr>
</tbody>
</table>
This is a list of software packages that can be identified with the worktypes identified from the returns of the questionnaire.

**ARCHITECTURE**

| Microbased Drafting | AutoCAD, Powerdraw (Applemac 2D), ArchiCAD (Applemac 3D), Modelshop (Applemac solids modeller), Architrion (Applemac 3D perspective & 2D draughting), Board, Freehand (Applemac), Macdraw (Applemac presentations & draughting), Microstation Mac (Applemac 2D & 3D), Cadvance (2D), Arris (2D, 3D & wireframe).
| Spreadsheet: Supercalc
| Desk Top Publisher: Pagemaker, Ventura.
| Database: Keyscape (Landscape symbol package works with AutoCAD), Ribac (package of standard parts), Dbase, Claris Filemaker (Applemac non relational database).
| Organisational tool: Automanager (basically a drawing register by Academy), Xtree (Applemac sorts contents of hard disk into tree structures for viewing etc.), Smart (Applemac allows user to create small standalone export systems), Excel (Applemac number crunching tool).

**Mainframe/Mini**

| Drafting: G.D.S., Sonata.

**CAD SPECIALISTS/COMPUTER MANUFACTURERS**

| Microbased Drafting | Multicad (2D & 3D parametrics), AutoCAD, RoboCAD, VersaCAD, Cadkey (3D wireframe), TurboCAD, Microsolid (3D interactive solid modeller).

| Mainframe/Mini Drafting | Calma DDM, SDRC’s Geomod (solid modeller), ECAD (Electronic draughting), MCAD (mechanical draughting).
| Desk Top Publisher: Ventura, Interleaf, XY Vision.

xcix
BUILDING AND SERVICES ENGINEERING

**Microbased**
- Draughting: AutoCAD, Windowmaker (specialist draughting system with library of standard parts for windows).
- Analytical: C.A.D.S. Analyse (2D analytical package), Drainage SUITE (Modules for design of surface drainage systems).
- Database: 8110 Detail (reinforced concrete details to BS8110).
- Organisational tool: Albany Data systems (accounts).

**Mainframe/Mini**
- Draughting: Pafec Dogs.

DESIGN CONSULTANCY

**Microbased**
- Draughting: Aldus Freehand (Applemac), DrafixCAD (U.S. 2D with add on symbol library), Drafix 3D Modeller, AutoCAD, Orcad.
- Graphics: Adobe Illustrator (Applemac), Adobe Streamline (Applemac), Aldus Persusion (Applemac), Letraset Image Studio (Applemac copies, simulates photo retouching lab), Adobe Illustrator 88 (Applemac uses templates for precise drawing and detailed artwork), Pixelpaint (Applemac), Cricket Graph (Applemac for creation of graphs), OCR (Applemac optical character recognition:- scanning in text, then allows you to manipulate text in pagemaker as if keyed in), Typemanager (Applemac works in conjunction with adobe typefaces, used on text to smooth out steps in blown up picture image as it would be on print).
- Desk Top Publisher: Pagemaker, Quark Xpress (Applemac).
- Word Processor: Microsoft Word, Words.
- Organisational Tool: Hiscan (Applemac scanner software), Visionscan (scanner software).

**ELECTRONIC**

**Microbased**
- Draughting: Powerdraw (Applemac 2D), AutoCAD, Radraft (2D links to cnc Radpunch), CAADD (mechanical draughting package design package), Gemdraw (icon based drawing package), Autosketch.
- Graphics: Macdraft (Applemac object orientated graphics program).
- Analytical: Orcad (schematic capture), Boardmaker (printed circuit board maker), Spiceage (studies analogue circuit behaviour), Futurenet (Schematic capture), P Spice (simulation software test/analyse circuits).
- Desk Top Publisher: Ventura.
- Organisational Tool: Excel (Applemac number crunching tool), Smart, Pegasus (module based accounting program), Microcache (partition memory to allow two operations, multitasking program).

**Mainframe/Mini**
- Graphics: Tibor Darvas Planmaster (custom written design/manufacture, checks from customer's printed circuits board designs for faults prior to manufacture), EIT Alpha2 (Converts from film scan in to get pixel image then converts to vector file for manufacture and functions in Planmaster).
- Desk Top Publisher: PC Postscript, pagemaker.
ENGINEERING

Microbased
Draughting: Generic CADD, AutoCAD, Medusa (3D), VersaCAD, Turbopipe (specialist draughting), Model Universe Design CAD (U.S. wireframe with infill & without hidden line removal), Daxcad, P.C. Draft, Micro Cadam (Two and half dimensional pc subset of a 3D mainframe package), Eplan (Electrical CAD), Calma DDM (3D with CAM facilities for a CNC program), Racal Redboard (Printed circuit board layout package), SMOP 81 (U.S. special draughting for sheet metal work), Tool Designer (Mould makers CAD package), Intergraph Microstation (2D & 3D), Logotech (Mechanical draughting), Recal Redac (Electronic draughting).

Analytical: Orcad (schematic capture), PEPS (CNC software).

Desk Top Publisher: Harvard Graphics.

Word Processor: Microsoft Word.

Organisational Tool: GNC (System using drawn geometry into tool cutter path for CAM), P.C. Tools (file sorting), Autosave (Utilities insurance against system crashes), Automanager.

Mainframe/Mini
Draughting: CADD 4X (3D draughting), Pafec Dogs, McDonnell Douglas Unigraphics, Ferranti Infocad, Camx, AutoCAD, Scicads (Electronic draughting), Bravo (wireframe solids modeller & 2D).


Desk Top Publisher: Interleaf, Pagemaker

IRREGULAR

Microbased
Draughting: AutoCAD, AutoCAD AEC, Aldus Freehand (Applemac), MLD2 (Montford & Laxon special for catering equipment manufacture).


Analytical: AutoSOLID (Analytical solid modelling), Algor Supersap (F.E.A.), Cosmos M (F.E.A.), Strudir (CAM), Orcad (schematic capture), Microsoft Project (Project planning and analysis package).

Desk Top Publisher: Pagemaker Publisher, Tex.

Database: Dbase 3.


Mainframe/Mini
Draughting: DaxCAD, CimCAD (Specialist CAD).

Desk Top Publisher: On@@ (Intelligent Documentation), Interleaf.

TEXTILES

Microbased
Graphics: AVL (Applemac special for textiles)
<table>
<thead>
<tr>
<th>Microbased</th>
<th>Draughting: AutoCAD, Autosketch, Cadkey, VersaCAD, AutoCADMAC (Applemac), DaxCAD, Macdraft, Txcad <em>(training package comprising of various CAD packages).</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphics:</td>
<td>Freelance, Autoshade.</td>
</tr>
<tr>
<td>Analytical:</td>
<td>Autoboard <em>(add-on schematic capture to AutoCAD)</em>, AutoCAD N.C. <em>(numerical control add-on to Autocad)</em>.</td>
</tr>
<tr>
<td>Desk Top Publisher:</td>
<td>Ventura, Pagemaker, Fleetstreet Editor, Read Set Go <em>(Applemac)</em>, Design Studio <em>(Applemac)</em>.</td>
</tr>
<tr>
<td>Word Processor:</td>
<td>Word Perfect.</td>
</tr>
<tr>
<td>Database:</td>
<td>DbaseIV.</td>
</tr>
<tr>
<td>Spreadsheet:</td>
<td>Lotus 1-2-3, Symphony, Supercalc</td>
</tr>
<tr>
<td>Organisational Tool:</td>
<td>Sage <em>(accounting program)</em>.</td>
</tr>
</tbody>
</table>
ATTENDANCE AT THE 6th INTERNATIONAL FORUM ON CAD

The conference was held on the 11th - 13th September 1991 at the Hilton Hotel, East Midlands Airport.

In the opening talk it stated that the forum's aim was the continued development of existing established systems. The purpose being it would further the benefits gained by the use of CAD technology thereby not only improving its productivity but also maximising the users creativity. The theme of the forum was to address the issues which will increase the awareness of the potential for fully exploiting productive creativity.

This theme, therefore, has some significance to the research being carried out by the author which is in essence connected to the increase of CAD awareness and the increase of its use in the Industrial/Interior Design sectors. This is being carried out through the analysis of Microbased CAD systems for the design education and practice in Scotland: their application, problems and potential solutions.

The research has shown that while CAD has been technically viable for some time now, the design professions have been slow to adopt the use of this powerful technological tool. However, although microbased CAD has been available for some time it is only comparatively recently that it has been anything more than an electronic draughting board. Through advances in hardware and software technologies the "D" in CAD can now stand for Design. In my opinion, this advance is still in its early stages of development, especially where the Industrial and Interior Design sectors are considered.

The electronic drawing board is one reason why the Design professions have been tardy to adopt them in their working environment. The other reason, especially regarding Scotland, is the high cost of these CAD systems which are more than just a draughting tool.

The talks in the forum covered a wide range of design areas from the textile industry to the electrical engineering industry. Within this range there were ten talks that had some significance to my own research area. I will now discuss these related areas under the titles of each talk.

Survey on the current situation in respect of CAD implementation and usage in the East Midlands region of the UK. pp332-346
Author - Keith Jones, EUROTEAM, University of Leicester, UK

This talk covered an area of work which had a similar content of material to my own questionnaire.
work carried out in the early phase of my research programme which it was intended to establish an impression of general CAD usage in Scotland.

The East Midlands work set out "to examine the current situation in respect to CAD implementation and usage across the technology sectors in the region. The aim of the survey was to report on the experiences of companies who were using CAD - system selection methods, transition from conventional design, benefits and drawbacks, economic and staffing issues etc. and the companies who were not using CAD - reasons for not implementing systems, plans for future implementations, economic and staffing issues etc."

The areas of interest for my research were essentially the same as the stated aims of the work by the Euroteam. This survey was based on the regional employment profile for the technological sectors that were users or potential users of CAD. The East Midlands sector comprised of five counties of England. These sectors were manufacturing, textiles, construction, electrical and others (process industries, food production and transport). The survey carried out by myself was a random sample based on subject areas which it was reported (by external establishments such as the Design Council and the Scottish Development Corporation) had a design facility.

The Euroteam survey stages were as follows (Stages marked in italics illustrate where the stages of my survey differed):

Review of Regional Profile
Acquisition of company data for the region
Questionnaire design
Sample selection
Mailshot
Data collection
Analysis of data
Redefinition of sample
Telephone questionnaire data collection

Analysis
Report production

Evaluation of initial subject survey area
Telephone follow-up to query answers or to follow up non-returns
Review of questionnaire material

A procedure which is not too dissimilar to my own. It differs in the early stage of company information sourcing and at the end where I did not conduct a separate telephone questionnaire. I only contacted companies within the mailing list to obtain further information or to query some of their responses. However, I contacted some of the companies which did not respond simply to find out their reasons for not replying and, if they were co-operative, whether or not they used CAD.
The Euroteam questionnaire was divided into three sections. The first section was compulsory to all companies and was to identify the technological sector, company size and whether the company used computers for any organisational processes. The other sections were divided with separate questions for those companies which did or did not use CAD.

The non-users section asked for type of design applications carried out, their reasons for not using computers for design and whether there were any plans to implement a system in the future.

The users section asked about how they implemented their systems, integrated links, plans to develop the system, staffing and training issues.

The questions were asked in the Yes/No, True/False format for ease of processing the information. This again is very similar in content to my own work.

The questionnaire went out on a mailshot to 5000 companies and it returned 746 replies which is a 15% return rate. This was supplemented by a telephone questionnaire asking the same questions as the mailshot. This built up the replies to 20% response rate. In comparison, the results of my own similar questionnaire gave a 21% return rate without the need to back this up with a telephone questionnaire. My own procedures have already been described.

Due to the slight difference of the Euroteam format, the results are not strictly directly related to my own results but they are useful to substantiate some of my results or to justify my opinions expressed throughout the thesis and by way of a comparison work.

The following is a summary of the findings related in one of the ways mentioned above.

- 64% of companies had opted for a PC system. (This was the leading option in my own results.)

The next two results give some correlating information to my own work.

- 78% reported no radical changes in organisational procedures.
- 78% stated that the implementation had a marked effect on the performance of the company.
- 68% stated employment levels had stabilised rather than reduced manning levels.

This substantiates my own findings that CAD was to maintain staffing levels rather than reduce them.

Those companies using CAD gave the following statistics:-

\( cvi \)
68% opted for 2D drawing capability.
11% were only using 3D modelling and (9%) of the total were from the construction sector.

3D was not extensively used by the Scottish companies in the survey although many had the capability.

Methods of selection were listed in order of preference:
- Magazines/Journals/Periodicals
- Exhibitions/trade shows
- Courses/Workshops
- Books
- Other (No examples given to explain this term).

This seems to be a standard pattern of response.

The paper then goes on to describe that, predominantly, CAD was used for 2D drawing and design schemes.
28% were using 3D modelling breaking down to
- 38% manufacturing
- 28% construction

The leading hardware platform was:
- PC 46%
- Workstations 24%
- Mini 14%

The most common system configuration was 1-5 terminals (81%).
21% of respondents were using networks and these were mainly from the manufacturing sector.

56% stated they did not consider CAD quicker than manual processes for the conceptual design processes. This response I consider gives some explanation why CAD is not extensively used by the design professions.

76% reported an altered design methodology by an increase in the number of design iterations.

The main benefits experienced were: Improved Productivity 88%
Improved Design Communication 66%
Reduction in Lead-time 48%

40% of the sample considered the prime benefit to be improved product quality.

Main Drawbacks

<table>
<thead>
<tr>
<th>Drawback</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of the system</td>
<td>57%</td>
</tr>
<tr>
<td>Organisational problems</td>
<td>45%</td>
</tr>
<tr>
<td>Cost of training</td>
<td>34%</td>
</tr>
<tr>
<td>System compatibility</td>
<td>34%</td>
</tr>
<tr>
<td>Shortage of CAD literate staff</td>
<td>26%</td>
</tr>
<tr>
<td>Lack of advice for developing system</td>
<td>23%</td>
</tr>
<tr>
<td>Developing to 3D modelling from 2D draughting</td>
<td>19%</td>
</tr>
<tr>
<td>Personnel with analysis skills/stress analysis</td>
<td>17%</td>
</tr>
<tr>
<td>Managing the system effectively</td>
<td>4%</td>
</tr>
</tbody>
</table>

42% claimed there was a prestige factor in having CAD.
7% stated that having CAD had attracted new work into the company.
95% of designers had experienced a smooth transition from drawing board to CAD system. The transition period for staff to be fully conversant with the system was on average 3 months.
56% had made the transition by working part time on the system.
2% had stated they would prefer to return to drawing on the drawing board.
77% of designers stated they had only slightly changed their design methodology but considered that further change inevitable when they had developed an extensive database or when transferring from 2D draughting to 3D modelling.
9% stated they now had more job management control since their introduction to CAD.

78% of designers stated their job roles had changed in some way. Increased awareness of other processes in their organisation especially in the manufacturing sector where they had to be more conversant in production engineering principles.

List of personal benefits perceived by designers in the poll were:

- Increased quality of work.
- More effective use of time.
- More time for creativity.
- Improved personal marketability.
- Increased interest level.
- Increased earnings.

Drawbacks recorded in the responses were:

<table>
<thead>
<tr>
<th>Drawback</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initially very exhausting using a CAD system</td>
<td>22%</td>
</tr>
<tr>
<td>Experienced eyestrain</td>
<td>7%</td>
</tr>
</tbody>
</table>

Designers reported that they kept up to date by:
Across the range of design sectors the design managers' general comments were CAD systems were a good investment and had an impact on the company in terms of increasing productivity, improving design communication and improving product quality.

Introduction of CAD to workplace

The largest problem reported was organisational when the systems were first installed. 86% of respondents gradually phased in the use of the CAD system by rotating designers between drawing board and CAD system and encouraging each designer to use the system.

25% of the managers felt said they could justify the expense of the purchase and maintenance of the system.

78% of managers were concerned about staffing implications with respect to staff leaving and trying to replace them although only 18% had actually experienced any difficulties with recruitment.

13% of managers expressed a concern that there was little training available for the management of systems. Training and education seemed to be for the user of the system rather than the manager.

The leading responses for not having CAD were :-

1  Cost of Equipment
2  Low Present Priority
3  Problem Identifying Needs

(Similar findings to my own research.)

68% of non-users regarded CAD systems as being slower than manual methods for conceptual work and one-off designs.

15% stated the decision to get a CAD system would be imposed upon them by their main customer.

78% of Design Managers considered the implementation of CAD to be inevitable.

12% had fully investigated the possible implementation of CAD but had deferred due to costs.

These are similar to my own results. The findings of the "No CAD" category are very similar to my own results and therefore substantiate my own work.
"For many years now it has been possible to purchase powerful 2D Computer Aided Design systems on personal computers. These 2D systems have developed over a number of years and enabled companies to make their first move into computer aided draughting with varying degrees of success.

Many of the companies have found that just replacing the drawing board with an electronic alternative has not justified the original expense. They have also found that had a 3D system been available they would have seen much more of a benefit both at the design stage and in the manufacturing stage of a particular project."

Considering that 2D is by far the most favoured way of working in my own results, combined with the fact that not many actually use their 3D capability, this is a very interesting comment for further development work.

The following quotes are useful for the selection aspects in later work.

"It is the personal computer that has brought CADCAM to the forefront of Engineering Technology."

"The important aspect to remember is that it is the ability to design and model in three dimensions that will ensure that your product will reach the market more quickly. The products will be of better quality and they will almost certainly make more profit for your organisation."

"The early personal computer based systems were only used for draughting. The vast business market of facilities planners, architects, engineering draughters, and civil engineers were satisfied with these early systems. Not unexpectedly the disciplines where these two dimensional systems found most success were ones where the majority of tasks were historically performed on the drawing board. Repetitive tasks were minimised and draughting productivity improved but that was all."

"However all that could be done in those early days was the two dimensional work and not the three dimensional design.

It is at this point that we should add a second 'D' to our CAD mnemonic. Computer Aided Draughting and Design. With the design element now added to our computer aided draughting we are able to
perform real design and modelling. This extra ‘D’ can also represent “dimension.” The third dimension.

With three dimensions we can now start to design products. We can build models. We can put together assemblies on screen. We can calculate, analyse and verify. In short three dimensional working allows us to throw off the shackles of flat two dimensional existence. Two dimensional working is for producing paper, a by-product of the design process."

"The important concept now is that availability of 3D systems in within the scope of all users now. Ten years ago a 3D CADCAM system may have cost well over a million pounds to implement. Now it is possible to cut this cost by one or two orders of magnitude. Granted, the sophisticated machine tools are required, but it is possible to install a complex 3D CADCAM system for as little as 70,000 pounds.

For a small company this would seem to represent a considerable outlay if everything was purchased at once. In many cases however, the basic machinery is there already. Even if the machinery is not in place a figure of 70000.00 pounds can be shown to pay back in as little as 6 months if the application of 3D CADCAM is correct."

Considering the Scottish sector, this is a very large outlay for most of the companies.

The following quotes are more relevant to the engineering aspects that would be related to the Industrial Design sector where some companies employ them.

"The development of the machine tool controllers has continued down a route which can be compared to that of pen-plotters.

It is only relatively recently that serious consideration has been given to connecting them up to computer systems."

"As soon as the 3D CADCAM system is installed, the machine tools become computer peripherals, just like plotters or printers."

"It may seem rather controversial to say this, but why have machine controller memories been so small and why have sophisticated canned cycles been introduced to make the programming on line easier? Clearly it is because it makes the machine tool easier to sell as a separate item and not as a
computer peripheral.

Thankfully, there are certain machine tool builders who have finally woken up and fitted their units with large amounts of memory, into which computers can download large programs. A 3D system will generate very large programs and consequently the controller needs a big buffer memory to receive it."

"In order to achieve this integrated approach it is essential to choose a company who understands all aspects of CADCAM. A company who can provide management of the project, not just as the supplier of equipment and software.

"All too often the implementation of a CADCAM System is left to the in-house expert, or worse, a consultant who has little or no knowledge of the job in hand."

The last quote substantiates the reason why most companies opt for microbased systems.

"PC systems are easier to implement, easier to train on and, in the long run, much more flexible."

The status of CAD education in the United States pp408-412
Author - Dr. Paul J Resetarits, Central Connecticut State University, New Britain, Connecticut, USA

The points brought out by this paper are useful when comparing strategies and methodologies employed by colleges/universities covering design subjects.

"Technical drafting is considered a universal graphic language which is used to convey technical information from one individual to another regardless of verbal language spoken. The tools and equipment used by modern day drafters are currently undergoing a tremendous transition. The transition involves changing from the traditional drafting tools such as a drawing board and T-square, to a computer-aided drafting (CAD) system, comprised of a computer, mouse, and plotter as the drafter's standard tools."

"CAD is rapidly being accepted as the industry standard for mechanical drafting/design."

"With the wide use of CAD in industry, should students be learning drafting using a CAD system rather than with a drawing board and T-square?"
There is currently much discussion going on with the emphasis still being on that of manual skills. The talk goes on to say that in America there are also many conflicting opinions on this matter but then expresses the opinion that these varied opinions will "impede the transition from traditional drafting to CAD."

The paper also states that Resetarits is setting out to collect data that "will assist the educators in their choice of which method of drafting should be taught to best meet the needs of students and their future employers."

The problem is seen as being the following:-

"Can students learn the concepts, principles, and practices of drafting utilizing a CAD system equally as well or better than students who use traditional drafting tools? Will there be a significant difference in attitude toward drafting of those students who learned drafting using a CAD system and those student who learned drafting using traditional tools?"

"The problem to be studied is that there are two methods of drafting currently in practice. One method is the use of traditional drafting tools that have been used for hundreds of years and the other method is CAD which has become widely used in recent years. Education is often slow to respond to changes in methodology. Some educators resist change feeling that the old way is the best way."

By way of summary the paper stated the following:-

"The study found that there was not a statistically significant difference in the achievement or attitude of the students in CAD and TRAD classes. This can be explained by the fact that the same content was taught in each of the classes."

"This research supports the theory that there is not a need for students to learn all of the drafting theory on the drawing board first. That in fact they can learn the theory practices and principles of drafting directly on the CAD system."

"...as a result of this and other studies on CAD education many educational institutions in the United States are integrating the use of CAD and traditional drafting into their introductory drafting classes."

What is not mentioned but implied is that it is expected that it will not be necessary to teach manual
methods as these will be redundant. A later paper by Plonski shows that American companies have not completely transferred to CAD. This is an assumption that is not valid for British companies as CAD has not completely established itself here.

The use of Computer Aided Analysis in Design Education pp308-315
Author - Dr. D.K. Wright, Department of Design, Brunel University UK

"This paper describes the application of Computer Aided Analysis within course units which are part of an Industrial Design BSc Course at Brunel University."

I have picked out the following quotations as they have some interest and/or relevance to my own research area.

"In many higher education institutions there is an awareness that the power of current and imminent computer packages will dramatically change courses". Although computer aided analysis, such as finite element techniques, have been available and used for some time there is now a realisation that the computer will be part of the entire design process."

"In order to make best use of computers in a design course we have to take into account the following factors: -

The design process.
The computer aided design process.
Models for the intellectual development of students, especially those which suggest that although many students feel secure with analysis, they are not confident with synthesis until near the end of a traditional course.
The computer should be integrated part of the course and the fundamental nature of the design process must not be forgotten."

"Current packages have very little to say about conceptual design i.e. the designer has already made many vital decisions before approaching the computer. As developments continue in analysis and in assisting in design optimisation, perhaps through artificial intelligence it will be important to incorporate them into design courses. The emphasis on the design process must, however remain."
The work here helps give me a perspective of events and situations happening outwith the Scottish focus of my own work.

"This paper examines the process of the adoption of CAD in engineering firms in Brazil, Canada and the USA, and highlights some of the problems experienced with regard to the interplay between technology and people in the organization. CAD diffusion among these firms has frequently been much slower than expected by their decision-makers, and the degree of acceptance by the professionals is heterogeneous."

"Computer-Aided Design (CAD) has been recognized as a promising revolutionary technology for two main reasons. The first is its potential impact downstream in the production process, enabling significant benefits such as better quality, more quickly marketed and/or cheaper products (consumer goods, machines, plants, buildings, public works, etc). The second reason is the possibility of innovating the traditional ways of engineering and architectural design, which have not changed in their essence for decades and even for a few centuries."

"CAD has been seen as a major source of technological innovation particularly for engineering firms (also called engineering consulting firms, design firms or engineering services firms). And, as the prevailing human resources of these firms are technical-minded high level professionals, it has been taken for granted that CAD would be accepted without any problem, if not enthusiastically. The realities examined, however, show quite another situation. In Brazil

"The surveyed companies that led the introduction of CAD were all frustrated about the results achieved in the first few years. Achievements have been, at maximum, small. The schedule and budget for implementation were unexpected by the firms' top leadership. On the contrary, they expected only enthusiastic reactions, because the users were themselves highly qualified professionals in technology-related fields. The image of CAD within these firms had many negative dimensions."

"An update of this survey is scheduled for the end of 1991, five years after the one summarized above. But it is clear that the current picture has improved,...One is related to the technology itself, in terms of both the empowerment of the lower end of CAD equipment (by the 32 bit workstations)
and user friendliness of the software. But the most important reason seems to be the realization by those responsible for CAD implementation that a more comprehensive strategic-socio-technical approach was needed for planning and implementing the new technology."

In Canada

"80% of the firms did not achieve the expected productivity gains (in terms of labor); it typically takes six months of CAD utilization for a professional to achieve the same level of productivity he had before."

"CAD has been used as a marketing weapon; however, notwithstanding enabling the creation of new business areas for some engineering firms, the new technology did not substantially change the profile of the services provided."

"Because the use of CAD is still in its infancy, there is no clear trend of its effect on labor, both in terms of head count and work content. Nevertheless, there have already been significant impacts on the work organization, for instance as a consequence of working in more than one shift to make more intensive use of the equipment."

In the United States

The survey results below were carried out by PMSJ in 1990:

"...Current CAD use is far from universal, using it on 60% of their projects. While almost all firms use such basic CAD capabilities as drafting of backgrounds, details and schedules, not many use additional CAD capabilities such as 3D perspectives (50%), material quantity estimating (33%) or material specification (48%). These results show CAD prepared items are still only a portion of a firm's total production output. In spite of the obstacles, a majority of the responding firms felt that CAD has been profitable and helped them become significantly more productive."

"Responses on CAD productivity were wide ranging, with a few firms reporting no gains (or negative productivity changes) and some reporting 200% gains. Getting clients to pay for CAD use, especially in government, was a major problem reported by participants."

Results from the Coxe group

"It was found that success in CAD had no correlation either with the size of the firm or its age or with the number or equipment alternatives studied. There was, however, a positive correlation between...
success and the training effort, the involvement of the personnel affected by the innovation, the depth with which the different alternatives have been studied and the degree of understanding of the environment by the new CAD users."

Results from the study carried out by The Center for Integrated Facility Engineering at Stanford University.

"...stress two weak points. One is the lack of a holistic perspective on the potential use of Information Systems in Engineering and Architecture. As a way to overcome this fragmentation, a "clone concept" of what CIM is for manufacturing is being promoted by the Stanford Center: it is the systematic concept of CIC - Computer Integrated Construction, which tries to integrate the whole construction practice. The other weak part of the CAD adoption process is the implementation, which is usually under- or even non-planned. As in Brazil, the firms which successfully climbed the technology ladder are those which decided to reassess the motives for their previous failure and replan the adoption of CAD stressing the broad range of problems which emerge during the implementation phase.

Under the title "The barriers to CAD diffusion", there were the interesting points in this paper which, I believe, are relevant to my own area of interest:-

"Focusing CAD as a "machine system", instead of a "person-machine system". CAD was perceived many times just as computer based equipment with some special hardware features (such as graphic display devices) and software. This machine CAD concept therefore became the framework for all of the reasoning about the new technology. All was done without taking into account the changes in the work process. Thus, unexpected change in required tasks appeared, especially because of the improper superimposition of CAD on the traditional design procedures.

It goes on to say that this emphasis led there to be a negative reaction to what the design staff understood the introduction of the machine to mean to them in terms of job content (deskilling aspects of it), lack of recognition of the new skills in the career plan and the possible aspect of the job loss. The paper goes on to say that these became reasons for resisting the adoption of CAD technology.

"Ambiguity about the concept of CAD. There has been a confusion about the real use of CAD as a drafting tool. In the first case, it is perceived basically as a tactic for enhancing technical labor productivity, measured in terms of drafts per month, which is easily valued in monetary terms. In the second case, it also provides a way of networking the different disciplines involved in the actual
design activities. The benefits of this integration are reflected in quality, development time and cost of the finished product or project, which are frequently difficult to measure in direct monetary terms. The excessive focus on the drafting aspect have led to pressures to use the new "systems" at any price to pay them off rapidly, with heavy overhead charges on the project. These pressures resulted in stress on the technical people, due to the productivity gains, overinflated by CAD vendors. On the other hand there is the difficulty of charging the use of CAD to the design phase, when the commercial relationship between the engineering firm and the client is based on a cost-plus-fee model. This was made worse when most of the benefits of using the technology occurred at the construction, manufacturing and/or operation phases, which are generally outside its formal boundaries.

"Partial understanding of the potential benefits of CAD. When this technological innovation was perceived as contributing mainly to the individual and to the production system of the engineering firm, its benefits were reduced to the notion of productivity and efficiency. However, CAD has a potential for transforming the way engineering firms do business. It is worthwhile mentioning the frustration caused by the difficulty of engineering data communication between different engineering and architecture firms, between the firm and the client, and sometimes even among engineering departments in the same firm, due to the closed proprietary systems policy used by many CAD vendors, which make it very difficult for different machines to "talk" one with the others - a condition for reaping the key benefits".

"Insufficient implementation plans. The feasibility studies for CAD equipment acquisition were, in some cases, very detailed. On the other hand, the planning of the implementation of this major technological innovation was, as a general rule, poorly organized. However, contrary to the common belief of many executives and professionals, investing in sophisticated devices such as CAD did not guarantee successful technological innovation by an engineering firm".

The paper then concludes by stating that "in spite of significant differences in the environment, there are strong similarities in terms of the barriers found and their consequences". The paper's writer continues to point out that "the very name "CAD" is a pitfall, in as much as it enables confusion between "design" and "drafting", stresses the computer over a machine-person system and does not open new "opportunity windows" for the engineering firms to achieve competitive edge with this technological innovation".

The paper proposes that the solution (which could be useful to my own work) to the problems is the concept of "ENGIMATION". This is "the mode of producing, communicating and managing
engineering information by means of an adequately planned person-equipment-technology system, enabling the institutional development of the firm*. The advantages of this concept are seen to be:

"It permits better comprehension, changing the focus from the engineering activity (for instance, "making" designs) to the engineering output (specific types of information). In so doing, all the rich concepts about information, information systems, communication theory, informatics, telematics and other related subjects become explicitly part of the engineering and architecture firms' life. It particularly puts into the organizational culture the idea of "strategic value of the information"*."

"It establishes additional criteria for selecting equipment".

It changes the focus of automation from the equipment to a new production mode, requiring the reconceptualization of the workflow, of the design process and of the job design*.

"It highlights the complex managerial and behavioural dimension of automation, making it easier to negotiate support beforehand rather than trying to eliminate resistance afterward*.

A Case Study Selection and Implementation of Computer Aided Design: The Practical Considerations pp413-418
Author Tony Saunders, Engineering Systems Manager, MAXPAX International

The paper noted that there would be different levels of skill required. "There would be several levels of user even in a small organisation like MAXPAX Engineering.*

This is a factor which my own research has shown to be a concept that companies do not realise when considering in the early stages of the selection phase. The paper detailed the levels within the particular company as being:

- The primary user
- The occasional user
- The casual user
- The clerical user
- Systems manager

The next important aspect for my own research was the concluding paragraph.

"In many companies the responsibility of determining what the large capital sums required for CAD..."
will be spent on is placed in the hands of senior management who, reasonably enough, assess the expenditure on a purely financial basis but, unreasonably, do not place the task of system selection into the hands of those who will use it. All too often this is a recipe for failure. A system is procured which has great things expected of it but, because it may not be suitable for its application, will fail to deliver. It is not the function of senior management to understand the intimate functions of a CAD configuration, much less the requirements demanded of it. The ability to reduce project lead times, reduce product costs, minimise inventory, standardise component usage and control recruitment are certainly of interest and, when achieved as planned, demonstrate the benefits which have been gained. These benefits considered against the initial capital investment will justify the delegation of system selection to "hands on" Engineering management. Under the control of a dedicated systems management function the reduced implementation difficulties, and subsequent improved productivity, is seen to be readily achieved".

Author - Rob Howard, General Manager, Construction Industry Computing Association, and Research Co-ordinator of the Building IT 2000 project. pp207-212

It is the concluding comments that are of interest to my own work.
"There is a great diversity of types of CAD system at present and, although particular systems may increase their share and others will drop out of the race, it is necessary for advancement of the technology to have some diversity. It will therefore be necessary to pass data between them since building design will always involve a variety of types of specialist".

"While the simpler solutions to data exchange, such as DXF, may not always be the most popular since it should be possible to transfer 3D models, the more comprehensive solutions, such as STEP, may be over complex to satisfy the needs of aerospace and motor manufacture and less capable of handling the large quantities of simpler components found in construction".

"Organisation of data is perhaps more vital than the actual transfer mechanism and, apart from standardising layers, there is also the goal of the common building model. This has been a dream for many years and only realised in the context of system building which is currently very popular. It may return, however, with the growth of robotics and international supply of ever larger components".

"When the goal of a common building model is realised, CAD libraries of components exist and data exchange standards of appropriate complexity are available, only then will CAD speed up the process and integrate all the other uses for design such as quantities, costs and building management".

cxx
"The third major area, that of Architecture, Engineering and Construction (AE&C), has been hit especially hard by the recession, and in particularly fickle sector sales have slumped dramatically, particularly in the UK."

"Not only has the volume of business declined, the average seat price has fallen dramatically. This is partially attributed to the fall in hardware costs but is also due to the fact that many purchasers are now happy to buy a PC based system having realised that the functionality of workstation based systems can, in the main, be delivered on a PC. There are obvious exceptions to this such as modelling and visualisation systems. The straight forward drawing production requirement can be satisfactorily served by the PC based system."

"The manipulation of data has never played a major role in the use of CAD, but with the emphasis now being placed by many developers on the links between graphics and data, we can expect to see a consolidation of the CAD systems as part of the corporate computing policy."

"The CAD market does not stand still. We have entered the third phase of the MicroCADD revolution. It's called Workgroup CAD. These are multi-user CAD systems, based on PC technology, that promote the sharing of resources - both information such as drawings and files, and equipment such as printers and plotters. These multi-user systems are based on commercially available technology from vendors such as Novell, Compaq and ISICAD, put together by your friendly local Value Added Reseiler. And these systems are available today."

The paper explains how it perceives the early stages of the microCADD revolution were seen to be spurred on by the opportunity to promote individual productivity which it believes that this aim has been successful. The cause of change it is stated is due the fact that those "who utilise MicroCADD, such as designers, architects, and engineers, rarely work alone. They work in teams; they report to management; they pass drawings to peers on other teams." This then is why the next phase was
brought about. This is described as the second phase where PC software started to be used by these work group types who work as teams.

"This transition was driven more by user's needs than by the availability of technology".

Lerpiniere sees that there were two trends happening to direct this change. "The first was the deeper penetration of PC CAD in corporate America and the second was the increased acceptance of PC CAD in bigger sites where in the past they had been considered unviable before. The third phase is typified by the where the software is designed specifically for PC networks.

The paper sees that the introduction of this new trend in software has its own pitfalls and misunderstandings. The points to look out for are then included in the paper but the subject titles are:

- Explicit certification
- File contention prevention
- Support for direct output to network queues
- Promote shared environment - not lock you out
- Support for client/server technology
- Drawing management/security "hooks"
- Promote communication
- Licensing/pricing

These are factors that will have to be considered when carrying out the "training packages" stage of my own research.

The GUI and Its Impact on CAD and future PC workstations pp190-196

Author - Barrie C.J. Hoban, of Artist Graphics UK.

The paper explains that software vendors are looking at the GUI in an effort to produce more intuitive software.

"... by moving their word processing software Microsoft WORD to a GUI based system has resulted in a 35% increase in productivity".

This increase in a design based environment would mean significant savings.

"The GUI makes a system more effective and easier to use."
"Use of common techniques and principles for controlling applications will reduce training time".

The paper foresees that future systems with GUI will be accompanied by a Graphical User Environment. "The Graphical User Environment will replace the command "shells" and provide the user with a more familiar workspace shell. The user will be able to use the GUE to organise their work and harness the power of the computer".

"The combination of the GUI/GUE will increase the ease of use of applications and operating systems running on the PC of the future".

"Software applications written using GUI's will increase productivity taking advantage of their ease of use, utilizing common icons and techniques to control the input and output to the application. The GUI will reduce the need for indepth knowledge of the operating and the ease of use of lengthy complicated command strings. The net effect is a dramatic reduction in training time and a great increase in efficiency.

As more and more PC based Computer Aided design applications take advantage of the Graphical User Interface the WIMP working environment will become common place for the PC workstation of the future."

"A final point is that graphics is expanding the demand for computer based solutions. It allows applications to process and communicate information more effectively to their operators, and it makes computing accessible to a wider range of users."
1.1.1 What is involved?

The person or persons carrying out the justification for a CAD system require only their own in-depth understanding of their own company to undertake this stage. What is involved with this stage is the following:-

- Analyse current working practices.
- Who would want the services of the company?
- Who might want the services of the company?
- How the work might change.
- Review of the company's financial capabilities.

1.1.2 Analyse current working practices.

This requires reviewing how the company currently operates by determining the following:-

1. The nature of the work carried out.
   - Is the work always from original concepts?
   - Does it ever use standard company details or components?
   - Who does what within the company?
   - Does everybody have their own drawing board or are any shared?
   - How many people actually need to use a drawing board?
   - Could some of the above share a drawing board?

2. How the work is broken down such as:-
   - Conceptualising.
   - Detailing.
   - Prototyping.
   - Production Drawings.

Company records such as time sheets or bills to clients should help establish the times taken for work previously carried out to enable the calculation the above points. This will help determine how much work currently carried out by the company could be carried out on a CAD system in the later stages. Areas of particular interest are times taken for amendments or corrections on current work, if projects
have benefited from use of earlier work, if work has some repetitive nature in their design such as components, symmetrical geometry or are a range of similar models within a client's product range.

1.1.3 Who would want the services of the company?

Examining the past clients of the company will help in the following:

- Illustrating the work that your company has experience in handling.
- Establish a profile of the companies using your company's services.

From the above it can be established if current clients use computer information in their manufacturing process, what systems they use and if they would benefit if your company gave them any future work in a compatible format.

1.1.4 Who might want the services of the company?

You should be able to determine from your current clients, from the expertise within your company and from the senior management just where the company is expecting to seek future work. The company ideally should have a company plan for continuation in the form of a five-year plan, a business plan or something of that nature to help you carry this part of Stage One out.

1.1.5 How the work might change.

This is another feature of the development plan and it should suggest what changes are likely to occur should the company expand its work output, whether or not the increased work will be the same or if it will have any differences and what those differences are. Should a CAD system be purchased, it will be used when these changes are happening and they might benefit from another system's capabilities. In effect, the system you want to choose is the one that best answers the needs of the future and not the needs of the past.

1.1.6 Review of the company's financial capabilities.

Finally in this stage when everything else has been considered the main determining factor to the system chosen will be determined by what the company is in a position to purchase. So it is vital that the financial capabilities of your company are clearly established.
These two time factors will establish whether or not it is viable at present, what in fact is viable at present and what could be viable at a later date. This is useful should you decide to develop a system over a period of time rather than purchasing all the hardware and software at the beginning.

1.2.1 CAD Familiarisation

Familiarise yourself with what CAD offers. This is achieved through an increased awareness about CAD.

- Learn about the terms and jargon involved.
- CAD’s capabilities.
- What others are using.
  1. What are clients using?
  2. What are your company’s rivals using.
- What could be used.

The above work will help in the following:-

- To establish what software your company needs.
- To establish what hardware is necessary for your company’s requirements.
- To establish what costs are involved.

1.2.1.1 Brief review of CAD History

It could be said that CAD started with desk top calculators and, with these, engineering science used them to calculate the stresses and strains in redundant structures, modes and frequencies of vibration, whirl and flutter, aerodynamics and fluid flow velocities and pressures, dynamics and loading actions. In these calculations the shapes concerned were idealised in the form of space frames, boxes and tubes. The application of CAD to real shapes came with geometric loading, using the first mainframe computers. At this time work of this kind was virtually all taking place either in Universities or in large aerospace and automotive firms. Computers were expensive and those early graphics limited in capability.
In the 1960's, computer power was available in the form of mainframes only. Electronic systems were built out of individual components, and the task of assembling them was labour intensive. The result of this was little prospect of a significant fall in computer prices, therefore all computer manufacturers avoided the simple lower level market and concentrated on the prestigious upper level area of more powerful, more versatile and more expensive machines. The idea being that a single machine would handle all the requirements of a large corporation, in computing terms.

Then came electronic circuit design, first for computer listing of complicated cabling, later with a graphic display for the design of printed circuit boards. At the same time the mainframe computer came into the listing and control of engineering drawings and for numerically controlled machine tools.

The driving force behind CAD development, and the people backing it with funds were the space and military. They supported the promotion and development for use in microelectronics which made possible the development of large scale integration circuitry (LSI) in the late 1960's.

At General Motors, the DAC-1 console was installed by IBM on a 7094 computer, it was used to test man/machine interaction for the first time. The use of the computer in this area showed a 1/3 increase in productivity.

In the same year as the DAC-1 console was being installed the Digital Equipment Corporation (DEC) produced its first computer PDP-1. These 2 events marked a major point of departure in solutions to the CAD challenge. The development by DEC led to the PDP-9 in 1966 which offered an optimal storage tube and stroke-vector crt. The PDP-15 laid the groundwork for DEC's reputation in engineering graphics support computers and the PDP-11 opened the door to CAD for DEC. Applicon introduced the 1st system using PDP-11 in the early 70's followed by Intergraph and McAuto a few years later all upgraded to VAX series and joined by Autotrol and Calma as DEC based turnkey suppliers. On another branch of the CAD/CAM tree was the introduction of the IBM 360 in 1964.

In the period of 1968-71, three innovations were made which allowed the widespread diffusion of CAD technology:

1. Relatively cheap minicomputers - this allowed the reduced costs of the enormous computing power required to handle pictures.
2. Storage tube - required less computer power than refresh tubes and provided stable, flicker free images.
3. Structural programming and virtual memory techniques - virtual memory
Techniques allowed large programs to be stored and used in relatively small computers with minimum of penalty in terms of computer response time.

These innovations meant that minicomputers could be made to respond to CAD commands almost as fast as the much more expensive mainframes. This freed CAD from the need to queue up for a limited share of computer power; in short, rather than having to 'plug in' to the shared resources of a mainframe, CAD could afford the services of a dedicated 'minicomputer'.

Early in the 1970's, intense competition arose from various backgrounds:- aerospace, electronics and from academics; began to develop and market general purpose systems based on new technologies. These new systems designed as 'turnkey' systems, i.e. designed in principle, so that customers could buy a system, plug it in, turn the key and produce usable production drawings. Although this is an unattainable objective, some systems have made substantial progress towards the development and marketing of this ideal. However, like most ideals it lays out high standards.

After the dedicated 'mini' a second stage of development resulted from the introduction of the microprocessor and involved the decentralisation or devolution of computer power within a CAD system i.e. CAD systems containing several separate computers. The introduction of the first minis in the early 1970's saw the start of the steady shrinkage of size and cost of computer hardware which continues today. As a result it became possible to provide power to CAD without prohibitive cost. Although not initially as powerful as mainframes, because they were freed from the need to service other users, a mini could service half a dozen workstations by the mid 70's.

Early pioneers in IBM's CAD effort were the Lockheed Corporation, General Motors and McDonnell Douglas. Lockheed's subsidiary CADAM Inc. became a major vendor in software. Computer vision set the pace for turnkey vendors in CAD/CAM during the early 80's, the 32 bit mainframe and the 32 bit microprocessor took their position along with the 32 bit supermini as important factors in turnkey systems. Apollo started in 1979 as suppliers in workstation hardware to Autotrol and Calma and several other computer turnkey electrical vendors:- Data General, Univac, CDC, Prime and Hewlett Packard.

The arrival of the mini heralded the birth of a separate and substantial CAD/CAM industry, because CAD was now envisaged as a general purpose tool. Turnkey suppliers came into being, where systems were built around standard minicomputers. The turnkey suppliers provided software and peripheral hardware. The initial introduction of minis did not at first charge the centralised fashion in which computer power was deployed. Often, a workstation was no more than a console (dumb
terminal) facilitating communications between designer and computer. At least a RASTER DISPLAY might contain the minimal amount of hardware to control its own display screen. The arrival of the microcomputer (processor) at negligible cost it became both economical and possible to provide a large number of subsidiary, decentralised 'intelligences' within a single system. The advantage of doing this lay in overcoming the CPU 'bottlenecks' appearing on minicomputers, due to the increasing sophistication of evolving CAD software.

The manufacturers responded to this problem by producing the first intelligent terminals. By building one or more microprocessors and some memory capacity into each terminal, and providing some back up disc drive units, the terminal could be made sufficiently intelligent to control its own display screen and carry out routine graphics work, e.g. the terminal could handle the transformations involved in zooming and panning across a model, though the mode itself was held in the central computer memory devices. The power of the 'host' computer could also be called upon whenever more elaborate tasks were involved.

In a network of this kind, the host minicomputer is situated at the centre of a number of radiating links, each connecting to one workstation. Due to the fact the minicomputer is spared the task of constant supervision of each workstation, it can react faster when required.

The power of microcomputers increased and made possible a distinct development - the self contained, 'standalone' workstation with its own built in source of computer power. At the most basic level, a standalone system may amount to no more than an off-the-shelf micro such as an Apple or a BBC, equipped with some specialised graphics software. Further up the scale, purpose-built standalone units based around one of the super micro's are available from a number of different suppliers. Often these systems can be linked to form a ring network. The enormous progress in the design and organisation of computer networks which has been made over the past decade allows the individual machines to co-operate in an extremely sophisticated and flexible fashion. Not only can information be exchanged between one terminal and another but resources can be shared, models can be created separately and then assembled. Due to all the developments in computer hardware and in its software, computer aided systems have many applications. These include:-

- Draughting - replacement of rule, protractor, pencil, compass, eraser
- Definition of structural model and finite element calculations
- Pipework layout
- Determination of mass and section properties, volume, second moments of area, principal axis.
• Design of printed circuits and optimisation of layout
• 3D visualisation - "wireframe model"
• Synthesis of mechanisms - (four bar linkages)
• Cutter path visualisation and N.C. programming
• Circuit layering
• Self teaching
• Symbol libraries
• Parts call up and listing
• Evaluated Engineering Science data
• Shape nesting
• Configuration and change management
• Rapid tendering

1.2.2 Areas of CAD

1.2.2.1 Tool Design

If a part has to be machined, formed, welded or assembled, there is a host of jigs, fixtures, welding and assembly fixtures required, designed and tolerances critical on the fixtures. Also the part must be visualised as to what happens when a machining or other activity takes place on the part. Now with the use of computer graphics the fixture can be shown with the part in place and through use of colour, even more can be shown e.g. the clamping action of a fixture on the part and the graphics simplifies the trial and error method that has occurred in companies before the use of CAD. The benefits are:-

1. Tool motions can be checked to see if there is interference between the tool and the fixture.
2. Machining stress on the part can be shown
3. Library of commonality can be developed to eliminate redesign of fixture parts.

1.2.2.2 Plastic Moulding

Not all plastics behave the same way, each part must be custom designed for the plastic used e.g. Mould shrinkage in crystalline plastics is not uniform while it is in amorphous plastics. The use of CAD in this case simplifies the thought behind the design work. Runner designs and gates determine whether mould cavities are completely filled or not. With a proper CAD library many of
these variables can be programmed into the operation and can produce sample parts with N.C. machines directly from a designer's CAD data. Once the part is produced and verified, the mould can then be produced.

1.2.2.3 Plant layout and Design

CAD aids the actual design and layout of the manufacturing facility. It aids co-ordination, such as fire systems, air supply, electrical requirements, plumbing. With the use of colour and overlaying, many of the systems can be shown before construction rather than coming across mistakes during construction.

1.2.2.4 Machine Tool Design

This is similar to Tool Design as all parts in the machine tool business are work intensive, CAD/CAM can eliminate much of the high cost of scrapping, as each part represents a huge investment.

1.2.2.5 Batch Assembly

By tying in the assembly operation into CAD vision sensing robots can assemble a variety of parts.

1.2.2.6 Electronics

CAD tools supporting Integrated Circuit layout are constantly evolving and there are 4 different approaches:-

1 Geometric - Designer creates the exact shape of a specific structure on an IC mask by using a commercially available interactive graphic system.

2 Symbolic - Detail work is hidden from the designer. Designer works with symbols and the CAD system converts them to exact geometrics.

3 Cell based - Individual function cells along with performance data are created by designers and stored in cell libraries.

4 Procedural - Automatic placement of cells into a complete IC layout by using a procedural language that describes the relative placement and interconnection of the cells.
Although automatic design can save production times, one must ensure that the system meets all requirements such as thermal dissipation. High density packaging requires a thermal dissipation. High density packaging also requires a thermal logic program to avoid overheating in the design. There is also a need for CAD equipment to have capabilities of enhancing manufacturing e.g. post routing routines. An advantage of this is of testing the design through simulation on screen, rather than using breadboarding or hardware. For example at each logic gate in an IC, there is a slight delay, because the transistors take a finite time to turn on or off. Gate delays are cumulative and can cause logic errors. In slow circuits small timing errors may be acceptable but in fast circuits they are totally unacceptable. With hardware testing, errors often did not show up until the chip was cast in silicon. Through graphics, timing can be separated from logic testing - corrections can be implemented within the design stage. CAD advantages are numerous for electronics and so are the advantages of CAM.

1.2.2.7 Computer Aided Architectural Design

Development of this central concern is for systems that can afford the designers' insights into cost and performance characteristics of existing building stock and a predictive capability as to cost and performance of future building stock.

Computer based models must be seen as a recent extension of the plan and elevation on the paper. They are dynamic and predictive. The computer can be seen as providing the 'engine' to the 'tool' of design methodology.

- A Tool is a device which allows an amplification of the power which can manually be applied to the task.
- An Engine is a device which provides the power to drive the tool.

So it should be taken that computers are meant to compliment man and not to compete.

CAD offers cost savings e.g. before CAD, the breakdown of costs for any given project would be:

<table>
<thead>
<tr>
<th>Design costs for an industrial plant</th>
<th>20% of final figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical design</td>
<td>15% of final figure</td>
</tr>
</tbody>
</table>

**With CAD**

<table>
<thead>
<tr>
<th>Electrical design there would be</th>
<th>15% savings of the costs before CAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design there would be</td>
<td>15% savings of the costs before CAD</td>
</tr>
</tbody>
</table>
Productivity ratios on repetitive jobs are at least 4 to 1 over pencil and paper sometimes as high as 8 to 1 and with increased output the drawings are more consistent and accurate. They also enjoy all the advantages of manufacturers plus the following:-

1. 3D Presentations - Many clients cannot visualise mechanical drawings and require expensive scale models or artists renditions to visualise the project. With solid modelling on a colour tube, the designer can create renditions and make changes much faster.

2. Process Plants - Many processing plants, such as oil refineries, chemical plants, generation facilities contain thousands of pipes. Often engineering design firms end up with elaborate model making facilities to literally construct the plant in miniature. That model has to be turned into actual drawings then, before the real plant construction can begin. This usually involves taking photographs of the model from every angle to make the drawings, and shipping the model to the field. Piping errors in a project can run high. CAD has not eliminated model making, it is being used for at least 25% of design work for verifying and checking much of the model making.

3. Bidding - CAD allows smaller firms to bid on equal terms with larger firms-
   - Increased accuracy in estimating: one major error in manual estimating is 'omission' which with CAD a company can minimise.
   - Resource Utilisation - information can be captured and libraries developed.
   - Productivity - a lot of bidding is on the eleventh hour and time is a premium.
   - Reliability - built in routines can perform calculations, drawings in a much more reliable manner. Checks are easier to perform.

1.2.2.8 Business Graphics

35mm slide has rapidly become the executives discussion tool and now by having a personal computer, the executive will be generating his own slide. Instead of relying on data processing to generate this data, the executive can create his own data:

1. Marketing - readily shows areas of sales activity and growth. Maps can provide much data, such as market locations to office and sales sites. Market penetration and potential can also be shown.
2. Finance from financial statements to trend and investment analysis, all this information can be shown more vividly through graphics.

3. Manufacturing and resource allocations through maps and charts, new plant locations and reasons for justification become easier to understand. Plant layout will be a major user of CAD.

With the advent of solids modelling in CAD, and with business graphics, presentations to management by marketing, engineering and manufacturing are bound to be much more productive and beneficial to business. Meetings will be more involved and more factual with the bonus of being able to make presentations easier to understand.

1.2.2.9 Medicine

With the advent of the CAT and PET scans, medicine has become a 3D world, coupled with computer generated 3D images of various body organs. Doctors and scientists are finding out more about our body and how it functions. This is important but it also has spill-over effects to other industries which is equally important; these industries are the Pharmaceutical and Chemical industries.

Molecular Modelling allows studies of complex cells and chemicals. Manufacturing of body prostheses with a high degree of accuracy is possible e.g. for speech, sight and hearing are becoming realities. These systems also generate economies.

1.2.2.10 Publishing

Documentation at the time of delivery and in a professional manner is now possible. The benefits are not always obvious to management but to the customer they will become evident immediately as manuals are readily at hand and they need not have to wait to get them. The customer will have an instruction manual that not only looks professional but reflects the product as it was shipped.

1.2.2.11 Geophysics and Cartography

The one sure thing about Geophysics and Cartography is that reams of data will be generated. Interpreting this data and plotting it becomes very time consuming and then in some cases, it still may not be clear what the data shows.
In mapping, the advantages of computer graphics are obvious, instant updates to 3D contours. Computer graphics is almost a must.

In Geophysics large amounts of data generated can be organised into a manageable format. Data can be easily manipulated and with 3D data can be viewed in a manner that previously was not possible.

1.2.2.12 Space and Military

The space program has enthralled millions of viewers with spectacular views of the planets, however many of these views are actually computer generated, where the graphics are simulating the data as gathered on the space probes. Also CAD has been used in many phases of space hardware design and manufacturing.

In the military role there are only two types of missions that are seen to be descriptive of their role; battle or getting ready to battle. The military prefer the latter and regard that battle readiness prevents battle. For example - the U.S. army has four scores to indicate a unit's ability for combat readiness. Although computer printouts of data have been available for some time, interpretation of data was done manually. This meant there was a time lapse before it could be determined that a unit was/was not effective; in a modern military sense this would be too late. Now with graphic software, trouble spots are highlighted immediately. Of course there are more complex graphic uses but the main point is that Computer Graphics are changing the face of the military.

1.2.2.13 Entertainment

Computer Animation is becoming increasingly more used superseding work in advertising, film animation. It allows work that was once done by cartoonists but which was becoming too expensive in man-hours/dollars, to become a viable concern once again.

1.2.3 Design and Information Technology

In today's modern society, lifestyles are changing rapidly and one cause for this rapidity of change is the introduction of computers into our everyday lives. They are becoming a part of our lifestyle with the same speed with which its own technology changes. They are at present enjoying an unprecedented wave of popularity and today the very word "computer" appears to surface in every aspect of our daily lives. For example we receive bills from computing systems, we complete forms
to be processed by computers and we withdraw money from automatic cash dispensers. If you were to ask the average man in the street to describe a computer, he would probably describe it as some super human form of machinery with semi-magical properties. This mysticism is understandable as the whole subject of computer technology has always been shrouded in mystery, generally created by the media and jargon, which is symptomatic of all "specialist" areas as almost a barrier against outsiders. This is gradually becoming torn down as more people come into contact with computers in their everyday lives. Computers have already been used to do all sorts of tasks and are appearing in places where before it was least expected. However, computer jargon excluded, it is necessary to understand the design process and to examine how it can be helped by the use of computers. This then leads to a better understanding of CAD and to appreciate that it is more than just an electronic draughting machine and that it encompasses a wider field. That wider field uses the words "Information Technology" to encircle all related fields. It should be seen that these are not separate entities but are one and the same or at least are so enmeshed with each other that it is virtually impossible to untangle them and to see the differences. So if the aim is to introduce CAD then it is useful to examine the work involved.

It can be seen that to classify design problems, that they fall within one of the following classes:-

1 Configuration Design
   e.g. Electronic circuits, networks of pipelines, mechanical power transmission lines, control systems, thermal circuits and transportation systems. Experimental configurations are checked for compatibility of component interfaces, for transient and/or equilibrium behaviour, sensitivity, stability and reliability.

2 Layout Design
   e.g. Layouts of pipes, houses, process plants, manufacturing workshops, printed circuit boards and integrated circuits. Experimental layouts are checked for distances between lines and components, for lengths of component packing, flow of data, energy or materials.

3 Shape Design
   e.g. Car bodies, cams, houses, bathroom fittings, mechanical support structures and magnetic circuits. Experimental shapes are checked for aerodynamic behaviour, strength, safety, aesthetics and ergonomics.

There are 2 types of strategy that can be used for the generation of Experimental solutions.

1 Single starting point strategy consists of selecting an experimental solution and
then by the process of error elimination modifying it until a correct solution emerges.

2 Multiple starting point strategy consists of generating as many radically different experimental solutions as practical and then by process of elimination with each or at least with a selected few. The selection of the best solution takes place at the end of the sequence.

The second method is generally considered the more effective because it is more likely to lead to an original solution. To be able to generate these solutions, the designer needs large quantities of information. The type of information being as follows:–

1 Specified performance criteria for the product.
2 Catalogues of available parts and materials.
3 Various standards, rules, guidelines and recommendations.
4 Constraints imposed by production, testing, maintenance.
5 Descriptions of similar successful and unsuccessful displays.
6 State of the art methods and "know-how".

To generate the required information, the designer also needs effective techniques of searching for the relevant information. It is also necessary before a solution can be created to select a medium and a language for its description. There is a well known adage for design and that is to every design problem, there is, in principle, an infinite number of solutions. However, the designer eliminates some and selects some, but it is not understood by any calculable method, the means by which the designer arrives at a single or group of tentative solutions. There does, however, appear to be several distinctly different approaches that a designer employs, depending on that person's own capabilities and on the way that they understand the problem.

They can be listed like this.

1 Creative approach - by a leap of imagination.
2 Pattern recognition - by analogy with previously encountered problem solutions.
3 Random search - by guessing.
4 Expert approach - by following a set of rules based on experience.
5 Systematic search - by reducing the solution space to a finite number of possibilities and exploring each one in turn.
6 Mathematical approach - by transforming the design problem into a mathematical
problem and obtaining its solution.

7 By a combination of all or some of the above approaches.

Now, before the process of error elimination can begin, it is necessary to:-

1 Select a medium and language for constructing experimental solutions.
2 Select a means by which the behaviour of experimental solutions will be assessed.
3 Select a means by which the actual and specified behaviours will be compared.
4 Create a set of possible modifications.
5 Select decision making mechanism which will be used to decide upon the relevant modifications as a function of error.

Once that is done the process of error elimination can begin and the essential requirements of this are:-

1 Rational critique
2 Experimental
3 Mathematical and/or simulation techniques

Now that the design methods have been described and broken down into component parts it is possible to discuss how Information Technology can be used in Design.

- Storage and retrieval of design data
- Manual storage and retrieval of design data is a very time consuming and ineffective activity. Data is generally scattered in books, drawings, letters, notes, catalogues, standards, data sheets, contracts, surveys, reports and on microfilm.

It is not possible to cope with such a heterogeneous collection, and the usual practice is, therefore, to limit the range of data sources to be consulted. This may in turn lead to the uniformity of products and to the neglect of new effective components, material, methods, processes or tools.

It is possible, technically, to increase considerably the effectiveness of this activity by storing all design data in a computer database and thereby providing a fast access to every item whenever required and in the format which is the most suitable for the situation at hand. It can be appreciated that for some applications the cost of entering the data and its update of the database content may be unjustifiably high.
Once the error elimination stage has been completed it is now possible to generate some tentative design solutions. In the past those tentative design solutions critical to the design problems are created by senior designers and were displayed when the problem was being discussed in the form of sketches on sheets of paper, diagrams, mathematical expressions and short explanatory notes.

These outlines of solutions, accompanied by generous verbal explanations and elaborations, were then translated by draughtsmen or technicians into formal drawings, full diagrams, product description sheets, prototypes. For the less critical areas this two-stage design process is not normally necessary.

The creation of solutions and preliminary elimination of errors from them follow each other in a rapid succession throughout this creative design stage. The process seems to be efficient and ergonomically well adjusted that some researchers deny any possibility of its improvement is possible. As in any design situation there are always alternatives.

Here are some:-

- The quality of the visual feedback to designers may be considerably improved by the use of interactive colour graphic terminals.
- Modern man/machine interfaces offer rapid editing facilities which designers may use for the preliminary error elimination.
- Machines are very effective at rapid checking of tentative solutions for mutual compatibility and consistency. This further improves preliminary error elimination.
- Voice input facilities offer the designer the possibility of adding verbal comments to his output during the process of creation.
- Half-baked ideas and exploratory thoughts may be entered into the machine and stored in the form of sketches, diagrams or comments for later browsing.
- Rapid retrieval and display of previous designs, relevant guidelines. from the database may stimulate the designer when his inspiration is about to disappear.

Information Technology cannot help the designer to "invent" as it is not clearly understood what creativity and inventiveness are for the purposes of simulating them in the form of software. What exactly constitutes a 'leap of the imagination' is unknown, so the most likely applications of Information Technology will be in other fields. Such as pattern recognition approach which is currently extensively being investigated and in the expert approach which will be the next area of
many practical developments.

The so called "expert systems" are beginning to find applications in CAD. These are computer systems containing a sort of machine intelligence which are trained by experts to solve certain classes of problems by the application of problem solving rules that have evolved often from experience rather than from theory. Considerable potential exists in using 'expert systems' as constituent models of design information systems.

In a small number of well-constrained design sub-problems, it is possible to generate tentative design solutions by a systematic search of the solution space or even by direct mathematical methods. In these cases, machines do perform the task better than designers.

Information Technology could be used for the elimination of errors by using its merits. This could be done by entering a tentative configuration layout and/or shape of a future product into a computer and then using its considerable data processing capabilities for the purpose of:

1. Predicting various aspects of product performance by simulation or mathematical analysis.
2. Comparing predicted performance with the specified one
3. Modifying the product model with a view to eliminating observed errors.
4. Repeating the whole cycle with radically different tentative solutions until the best solution emerges.

This must have considerable appeal when one has the choice of performing the above activities either:

1. Interactively by man and machine or
2. Automatically by machine without any human involvement.

However, the first CAD programs were concerned only with translating a tentative configuration into a set of mathematical equations and predicting certain behaviour of the future system by solving these equations. The comparison of predicted behaviour with the specified one was left to the designer and so was the decision concerning any modifications and improvements. Among the first CAD programs were those developed as an aid to electrical circuit designers. They worked on the following basis: the designer would propose a single tentative circuit configuration. This was then translated into a machine readable language and entered into a computer with instructions indicating which
performance measures were required to be checked. Typically small signal equilibrium response or transient response. After a day or two an answer would arrive from the computer room. It would be scrutinised and a new revised circuit configuration would then be prepared for further checking. Clearly at the beginning of CAD it favoured single starting point strategy and concerned itself exclusively with the problem of checking certain performance factors of proposed design solutions. It is of interest to note that most current CAD programs still operate in a similar fashion. What has changed is the nature of man/machine interaction. The designer is now accustomed to obtaining the desired answers in a matter of a few seconds or minutes instead of days. The medium for interaction is now generally, different. For example, displays and keyboards rather than printers and cards or papertapes. The first design problems that were solved with the aid of a computer were concerned with configurations. A considerable time passed before machines were successfully able to help with design of layouts and only very recently has CAD software, for the design of shapes, come into general use.

Hundreds of powerful CAD programs are currently used by designers for error elimination by means of simulation or analysis. Such as:-

- Stress analysis
- Equilibrium behaviour simulation
- Transient behaviour simulation
- Frequency response analysis
- Reliability analysis
- Sensitivity analysis
- Stability analysis
- Safety analysis

These programs cover a wide range and variety of applications e.g. Architecture, Civil Engineering, Electrical Engineering, Mechanical Engineering.

The complete automation of the error elimination process is feasible but very rarely implemented. Examples include various optimisation programs and a logic circuits CAD program.

Communication links with other functions, as design is but a constituent activity of a complex process of planning, marketing, purchasing, storing, manufacturing, testing, installation and maintenance of products. So for this activity Information Technology has two major tasks and they are:-
Provide aids for collecting, storing, processing, retrieving, distribution and utilising information needed for each constituent activity of this process.

Provide the means for communication of information between the various constituent activities.

Interfaces between these constituent activities appear to be at present major bottlenecks and there should be the major impact of Information Technology.

In the early days of CAD/CAM there were many dream schemes proposed for fully integrated computer systems providing automation for all aspects of a product life cycle. Not a single scheme of this kind is in operation. Current thinking is more along the lines of distributed decentralised systems each aiding a well defined function and interconnected with other systems by means of a local data network.

1.2.4 Design opportunities in Information Technology

There were some key innovations started in the 1980's that have affected Information Technology. The following areas of innovation have been important and show potential in the future.

- Television has become more diverse due to the take off in the use of video cassette machines, the development of cable television and satellite broadcasting. Also the use of video games and home computers are very popular. The development of video discs shows potential.
- Although Automated cash dispensers in the walls of banks are very popular, developments in home banking using a Prestel set show the way for growth in the future.
- Computerised Production has immense scope for the use of computers and telecommunications to improve productivity and quality in manufacture. In addition to robots on the production line, there is scope for computerisation of materials control and quality control. Automated warehouses will become more widely used.
- Computer Aided Design is now becoming more widely used particularly in the design of electronic micro circuits where complexity and number of permutations and speed are necessary. Similar methods will be increasingly applied to the design of products and structures.
- Computer Aided Learning can act as a very valuable complement to human
teachers. The use was held back by high cost through the era of the centralised mainframe computer. The advent of the cheap personal computer has led to an enormous and sudden growth in educational computing, particularly in secondary schools. This helps the acceptance of the use of computers in higher education.

- The use of paper in offices imposes enormous costs of handling, document preparation, filing and retrieval. There is no doubt that electronic screens will steadily take over from paper in offices. The use of computers for internal mail would also cut down in paper usage but only if every employee has a terminal on their desk for their own individual use.

- Early Information retrieval use in the 1960's and 70's was in scientific literature. By computerising titles, authors, keywords and abstracts it became possible to search large databases (of some 20 million documents) to pick out a very small specific subset on a particular combination of topics. The next major application was in Law, with the computerisation of court records. The British Telecom Prestel service (launched in 1979) was the first attempt to bring this technology to the mass of business and residential customers. With a Prestel TV set or a Prestel adapter on an ordinary TV it is possible to call up, via the telephone network, to a central bank of Prestel computers holding some 200,000 pages of information on a wide range of subjects. The information is provided by outside organisations (Information Providers) who may, if they wish, levy an information charge for looking at their pages. These charges are recorded in the Prestel computer and are collected on behalf of the information provider by British Telecom.

- There is a national radio paging service in operation throughout the UK through which anyone carrying a small radio-pager (bleeper) can be contacted via a telephone call. When the individual's assigned telephone number is dialled, some hundreds of radio transmitters are triggered which will cause his radio-pager to bleep. The customer can then go to the nearest telephone to respond. Radio telephones are another development on this subject. Personal hand size telephones offer another possibility.
1.2.5 Scope for Design

The design opportunities in the Information Technology field may be classified into five main areas.

1.2.5.1 Hardware

At the most detailed level, the electronic components and circuits which connect them must be designed, these tasks are for the electronic engineer. To produce a tangible product, the physical object must be designed, in terms of size, weight, shape and finish. Thirdly, there is the very important task of designing the man/machine interface, comprising the controls, displays and other input/output peripherals.

1.2.5.2 Software

Almost every Information Technology product or service contains computing power, this calls for the design of computer programs to drive the devices.

1.2.5.3 Presentation

Many design tasks arise in the presentation of the product to the customer. This includes the design of packaging, of sales and instructional literature and of advertisements.

1.2.5.4 Content

Some Information Technology products, such as Telex are content free with the customer providing his own material to be transmitted. In other cases, the content is manufactured as part of the product, for example:

- Television programmes.
- Electronic Publishing: such as Prestel or Teletext.
- Graphics (explanatory graphics on TV).
- Games.
1.2.5.5 Systems

The most challenging design task in the Information Technology field is perhaps that of designing total systems: assemblies of hardware, software, packaging, literature and content, which together fill some market need in a cost effective way. It is challenging as such systems are usually large and complex, also because they require co-ordinated design effort by many specialists working with differing skills at different levels of detail. Systems design task involves three main steps:-

1 Concepts.
2 Structures.
3 Optimisation and test.

Conceptual stage
This is the stage of dreaming up new products and services, from one's head, market research, or from some technical work in a laboratory.

Structure stage
The alternative ways of providing such a product or service are set out and evaluated. Once a structural approach has been adopted there is a need to optimise by deciding on detailed capacities, distances, and specifications. Finally any large system has to undergo a thorough programme of tests, from which further design changes may spring. Key features of Information Technology as a field for Design.

1 Novelty, the new technology has thrown up "new" devices e.g. Video cassette machines and word processors, which never existed before. Where the designer of a cup or a spade works in a long craft tradition of other people who have designed cups and spades over the years, the designer of one of the new novel Information Technology products has a clean sheet. This is stimulating and risky but, in a way, relaxing. Stimulating as there are no ready-made solutions. Risky as it is possible to make mistakes. Relaxing as there is no pressure to amaze by departing from the style of earlier products.

2 They tend to be a part of a larger system. Their design is therefore akin to that of a building in a city, which must live with its neighbours and the infrastructure of the city as opposed to an isolated and transportable object such as a book or a picture.

3 Technology is changing fast. This means the product may be quickly overtaken
by its successor. It implies that products should either be designed as cheap throw away's or be capable of retrospective enhancement.

4 This is a field which can exercise many different design skills; in hardware, software, presentation, content and systems.

5 It is a field in which Ergonomics - the design of the man/machine interface - is all important. The power of this new electronic technology is amazing, its limit lies in the ability of users to comprehend and command this power. This calls for clear and convenient products which are easy to understand and use, which are easy on the eye and ear, whose processes are logical and predictable and which are well supported by clear and attractive instructional iterative.

Information Technology has its own ways of thinking and problem solving; such as in the field of Graphics which has the problem of representing typefaces. A computer is essentially a mass of switches and these are either on or off. Information in the computer comprises millions of so called 'bits' - numerical abstractions that are distinguished neither by size nor by colour nor by shape. For example :- Bar codes identify the object to the computer - but could you? This difference of thinking led to some quite specific problems in presentation of screen information. An example of this is that screen typefaces are considered ugly and compared to print often difficult to read.

1.2.6 Implications for Practice

A CAD program should help guide the designer by providing explicit measures of predicted cost and performance. This access leads to an increase in search coverage tenfold, allowing the designer to compare quality of solution against quality of previous solutions.

Design team working with access to explicit appraisal techniques means it is possible to check a wide range of criteria simultaneously from the outset of the design activity. Should be entirely practicable for each member of team to have access to and operate on a common design model whether or not they share a design office or not. Therefore the models provide a strong integrating force in design team working.

Design insights:- Programs can be used in a research and development context to provide insights into how design decisions affect cost and performance attributes by comparing existing models to proposed designs.

Objective and Subjective judgements:- Focuses increased attention on subjective value.
judgements rather than lessens attentions. As the measurable attributes of design alternatives are made more explicit the necessary value judgements are forced to the surface of the design activity and thereby themselves become more explicit. Computer models allows more communication between designer and user communities.

Due to the progress in computer technology (microprocessors, rasterscan colour terminals, it is possible to anticipate developments in at least two important directions.

1. Greater involvement in design decision making by those people who are affected by design decisions.
2. A move towards models which allow 'experimental appraisal' of the qualities of the built environment.

Facilities of a design information system (state of the art).

1. A design database where all design information is stored and is easily accessible to designers.
2. Ergonomically designed interface, which enables designers to enter and output all required information and to control effectively all data processing activities. The interfaces enable designers to enter into dialogues with machines using an English like command language or a set of ergonomically designed symbols.
3. A set of programs which generate tentative solutions and/or carry out error elimination
4. Activities under control of designers.
5. Temporary design files where tentative solutions are kept until designers are satisfied that all errors have been eliminated at which point in time they may be transferred into the design database.
6. Communication links with information systems for manufacturing, testing, purchasing, marketing, installation, maintenance, management.

1.2.7 Computer Aids for Designers - state of practice

1. Turnkey, standalone minicomputer systems dedicated mainly to design of shapes and/or layouts. A typical system has, say four interactive graphics terminals and can be bought or leased.
2. CAD software packages each dedicated to a particular application, which can be
installed on a number of mainframe or minicomputers. Packages can be bought or leased.
3 Remote access CAD programs offered by specialist bureaux on an hourly basis, combined with monthly rentals.
4. Small CAD packages for mass produced microcomputers are now beginning to appear and are likely to be very popular.

Only a small number of organisations have a design information system integrated with information system for manufacturing, testing.

1.2.8 Strategy for the introduction of Information Technology into the design process

To obtain maximum benefits of Information Technology and avoid adverse effects, it is necessary to precede purchase, with a thorough analysis of current design practices with a view to establishing:

- Bottlenecks in information processing and flow.
- Major strengths and weaknesses in design planning and control.

As a result of such analysis, it is almost always possible to effect considerable improvement without using any new technology.

The next step is the introduction of the Information Technology devised, including:

1 A statement of what precisely is expected to be improved by the new technology; immediately, in the medium term and in the long term.
2 A specification for a design information system which would be able to meet the stated objectives.
3 A short list of ready made CAD systems which meet, to some degree the proposed specification.
4 A brief proposal for the development of a tailor made information system which would completely meet the proposed specification.
5 Cost benefit analysis followed by a decision on selection.
6 A programme for an evolutionary introduction of design where it is likely that major benefits would be achieved quickly and with the full participation of design staff.
7 An outline of the training programme.
1.2.8.1 Training

1. Full benefits require proper training of designers.
2. Short awareness not sufficient.
3. Need for in depth understanding of decision making.
4. Designers should learn models of design which consider it as a decision making and information handling activity.
5. Should acquire knowledge of systematic design methods that are equally applicable to the design of products and to the design of product information system.

CAD extends from the single user microbased system to the vast industrial networks supported by many remote mainframes. Derived from that fact it is possible to see that CAD has development potential in two directions:

1. Development of ever more complex modelling and graphics machines
2. Looking at more fundamental ways of aiding the designer.

1.2.8.2 Design process

Evaluation of the true parameters affecting the design, be they physical, practical and economic. This is achieved by establishing an approach to the problem then finding out how it works/does not work in the environment. This gives rise to a series of iterations to take place until with a sufficient level of understanding, a satisfactory design is established. Such an approach is one of synthesis rather than analysis. The computer is there to provide design information and give "physical" evidence to "events" in the proposed design.

1.2.8.3 Ideal CAD system

Input of information/instructions not simply to provide graphics generation or display functions but one in which the input request is for engineering information. Output is in terms of graphics, it should be a means to providing answers to status, relationships, functionality.

The program should reflect how designers design. Research in this area has led to the approach that the working pattern has no real parallel in current industrial practices and is more akin to the methods employed by the artisan in his studio - gathering ideas and images on a desired artefact and their
gradual working into reality with the modern craftsman's tool - the computer. The Design process overview is the activity of turning ideas into reality.

Formalised draughting procedures were developed to convey drawn instructions in an accurate and unambiguous way - which is more important as the complexity of an item increases. This has resulted in a more formal design process to be evolved to give a more stable route to the development of ideas.

Originally CAD viewed as having the role predominantly of providing the design paperwork. By that I mean they operated in such a way as either to confirm the proposed design (by acting within the analysis phase) or to generate the engineering information for production (by acting within the scheming phase). This then is the origin of the two distinct types of CAD system which now exist with a third having its origins in the manufacturing phase.

### 1.2.9 CAD Techniques

Development of CAD techniques has been until now on a piecemeal basis following specific needs of the developing group/supporting company:- natural course of development in all engineering situations. This led to a patchwork of techniques and has thus been developed with no common base but all existing under the general umbrella of CAD.

There are three classes:-

- **a** Primary design (conceptual).
- **b** Secondary design (analysis).
- **c** Tertiary design (manufacturing information).

Example topics:- Electrical engineering, Industrial Design, Architecture.

- Electrical engineering would use class b) for circuit analysis/component selection and class c) for LSI and PCB layout.
- Industrial Design would use class b) for Stress (FEM)/Kinematic, mechanism/vibrations, dynamics/pipe runs and class c) for drafting/N.C. tape production.
- Architects would use class b) for Structural analysis/purpose layout analysis and class c) for cartography/plans.
Main aim of normal turnkey CAD/CAM systems is to operate in the tertiary design region. This is not surprising as inputs although numerous, output format is very well defined and falls into two well documented categories of either man readable or machine-readable instructions. There are two types of drawing information within man readable-drawings/schedules as they contain both pictorial and symbolic representations. The Machine readable take the form of N.C. tapes.

1.2.9.1 Analysis-Secondary Design

When people talk or think about CAD they have the secondary stage in mind wherein the seed of the idea is fully investigated and developed. Within this stage lies all the engineering analysis activities normally performed using computers. Many programs have been developed over the years to exploit this ability of the computer to retrieve and/or manipulate large quantities of data. Complex matrix and iterative processes can be employed to resolve or optimise a large number of variables in a complicated iterative model. Therefore to many people design means the application of high level analysis programs such as FEA and automatic circuit analysis programs. Whilst these are perhaps the most complex analysis that need to be performed, these not at present interactive design processes, they are really used for analysis of a specified configuration. However, much analysis and design work can be performed on an existing turnkey computer system by making use of its large graphics capabilities to generate the models but with only a limited amount of 'on board' numerical manipulation. The large 'number crunching' processes are thus performed by linking such systems to a suitable mainframe running the necessary software. Much design work at present is performed in line with company or national codes of practice and standards. Programs can be provided or written which interpret the component design in accordance with these rules. Program output can be in the form of specified data or given as nomograms which can be interpreted by the designer. Many companies have developed a range of these programs to satisfy own needs and requirements. This tends to be solely related to a company and its products and remain unpublished as their content is only of interest to their users and competitors. Therefore this area is where the software houses are most active. Packages are developed in accordance with customer requirements or by recognising that a common need exists within a particular field which can be exploited.

1.2.9.2 Conceptual-Primary design

Little or no work has been published on this conceptual activity whilst desired output and constraints can be specified in both the other two activities it is extremely difficult at times to specify the form of the output required in the primary stage and even more difficult to attend to quantify it. At this stage
many designers are either unaware that they are performing any creative activity or are unable to
describe it rationally. Without an understanding of the logic, weighting and constraints of the design
situation it is impossible to provide the supportive design aids. This is where greatest benefit could
occur but effort necessary to develop the techniques may be enormous. It is also this area where the
greatest fears concerning CAD exist. Paranoiac feeling that machines will take over. Artefacts will be
designed and produced without human control. CAD then can be seen as a threat rather than as an
aid, possibly caused by the lack of clear understanding of the designer's role in this phase. It is here
that a true designing system will be based and will grow from an understanding of the conceptual
activities about how they are developed and controlled. It has to be remembered that even in a
computer driven system the computer assists (but does not supplant), the designer who continues to
take the final responsibility.

One essential phase of computing any activity, irrespective of what it is, is to understand the activity
in terms of its components. The computerisation of a design activity requires a basic understanding
of the concept employed by designers and how they are manipulated before any program can be
formulated. Already during its short existence effective CAD systems are rapidly becoming a natural
part of design studies.

Existing systems arose from the technologies of computation and computer graphics properly used
can lead to better designs and pay for themselves. In draughting, alternative designs can be rapidly
created and examined, and the best one chosen. Using subsidiary programs also give better
confidence in strength, some aspects of function. N.C. programming and parts listing therefore save
time and money in development/production.

1.2.9.3 Computer aided Engineering

Supply of packages dominated by USA and the main users of such systems are USA and Germany
(who dominate supply of CAM systems). In the past, aids were largely confined to programming of
single tasks e.g. stress calculations, surface definition, N.C. tool path generation and these tasks
have been accomplished using largely by self contained programs. For example NASTRAN and APT,
with little regard for the transfer of information between processes. However these programs
established the basic Algorithms which form the building blocks of the more integrated systems
evolving today. More recently turnkey graphics systems which had been developed principally as
draughting aids have been enhanced to perform more analytical and manufacturing functions and the
interfacing of these systems with each other and with the application programs is to be facilitated by
development of communication standards such as IGES (Initial Graphic Exchange Specification).
These developments have led to an increased interest in the turnkey system as the economic advantage of computer aids is seen to be greatly increased when even modest integration of individual subsystems is provided. Turnkey graphic systems have also greatly advanced the communication between man and computer. Technically there is a growing interest and need for research in areas such as database design, design and interfacing of large subsystems and man/machine communication with special reference to the characterisation of the design task and the relevance and structuring of computer aids. Individual processes such as geometric modelling and sculptured surfaces, process planning, advanced numerical control techniques, production planning need to be related to this. Information Technology is speeding up information processes within a department, business, group, while individual programs means specific training. The developments in Information Technology mean there are major organisational changes requiring advanced planning on the part of the technical, administrative and personnel management. Technical processes can be changed relatively quickly whereas organisation skills and particularly attitudes take much longer to adapt. Education establishments therefore have to look far beyond teaching processes upon which CAD and manufacturing depends. Education and training will be needed for all members of an organisation whether they be manual, managerial or involved in areas such as marketing. Indeed the expansion of computer usage in the areas of office communication through the use of word processors and the like, together with developments in computer communications networks, is inevitably leading towards a computer aided industry and a great enrichment of information for design. This means wider awareness must be taught of the interrelationships between different activities in a company, in particular of the ways in which design controls product value and product cost.

To get the best out of CAD the thinking process must be understood, such as for the conceptual stage, where you are thinking in pictures. So the system must operate in this way to be useful otherwise the operator has to alter the way he thinks to match machine and thus, the computer hinders the problem solving. Systems thinkers operate in pictures, graphical aids and flowcharts. For example, maps - information taken in at a glance where if worded it would have taken page after page to get over the same amount of information. Those industries located near to the principle source (USA) of CAD technology or with abundant supplies of highly educated and trained professional engineers are at an advantage in applying CAD effectively e.g. reaction time to market needs are faster due to the benefits of CAD.
1.2.10 Learning to use CAD

Top management of many firms insist that proposed investment be justified in terms of estimated short term financial benefits and this can lead to undue emphasis on achieving savings by reducing draughtsman employment. It should be remembered that the principle benefits offered by CAD are difficult to quantify in financial terms. One crucial advantage though is the reduction in design lead times which is good for firms prosperity and survival. Evidence suggests that firms have neglected CAD and there is the danger of firms using CAD more to economise on design costs rather than to improve the designs.

CAD can be used wherever there is a need for visual presentation of a design e.g. to generate Mathematical representations of designs, co-ordinate data, draw in 2D or 3D, modify drawings and compile drawings using descriptions of standard components stored in databases.

1.2.10.1 Argument for CAD

The progress of technology is such that even although CAD does have some detrimental effects, it is becoming a necessity of a modern working design environment rather than a luxury item. So the reasons for changing the working environment can be listed as such:-

- Increasing complexity of modern design.
- Design of completely new kinds of products.
- Need to work in multi-disciplinary products.
- High risks and costs of modern design.
- Need to improve the efficiency of the design process.

These are typical of the broad set of new demands being made on designers and the adoption of CAD is one response to answering them. There have also been some straightforward commercial pressures.

1.2.10.2 Benefits available from the use of CAD

Use of current generation of CAD facilities has brought to the manufacturing industry some considerable benefits and the following are the major ones:-

- Reduction in design lead times.
• Economies in design and draughting lead times.
• Ability to design products which are too complex to be designed manually.
• Economies in material usage.
• Combination of CAD with production automation to obtain benefits of integration.
• Improved quality of products.
• Reduction of design costs.
• Reduction of manufacturing costs.
• Improved design planning and control.
• Improved job satisfaction.
• Improved company image.

Of course, to gain the full benefits of CAD depends to a large extent on reorganisation of working methods.

These benefits are made possible by the following factors:-

• Better design productivity (1:4).
• More experimental solutions generated.
• More checks performed.
• More rigorous checks performed.
• Checks performed which would be impossible to carry out without the computer.
• Prototyping eliminated or reducing scope due to better accuracy of drawings and diagrams.
• Better communication with managers, manufacturer.
• Wider range of design data consulted.

The greatest benefits are obtained whenever products are complex and/or there is a need for frequent redesign.

There are areas of design where it is now possible to get any success without a considerable use of computer power and aids, e.g. aircraft, cars and computers.

However, the overriding consideration for installing a CAD system has to be, or at least has to appear to be, that it will save money in the design office thus justifying the initial expenditure in the system.

Some more positive reasons for CAD are seen in the two comments made by companies about their systems:-
• "Having the system we feel is warranted in the time saved when the design is being developed."
• "The advantages do not occur in the design department but in the manufacturing stages."

The latter comment shows that in some cases justification for a CAD system is not found when only a departmental attitude is adopted but relevant only when the design department is part of a larger manufacturing concern. It does show that if a consultancy was to use this criteria for justification it would be a cause for disappointment.

1.2.10.3 Possible adverse effects

The introduction of CAD methods into industrial organisations has not always been successful. There is considerable evidence that the reasons for observed adverse effects may be traced to the incompetent management of the change and superficial problem analysis. For example, some organisations opted for CAD systems that are much too expensive than the application warrants. To compensate for unjustifiable costs they have introduced 2-shift design work and imposed a strict control over designers "thinking time" with all the undesirable social consequences which have in most cases backfired and nullified the benefits of the system.

Incorrect design of CAD systems has on some occasions caused deskilling of design work and/or the imposition of unreasonable constraints upon the freedom of design decision making.

Unreliable and unfriendly CAD programs have in some instances alienated designers and reduced their confidence in Information Technology. The most often committed error is the selection of CAD facility which satisfies current company needs but is incapable of extension into a product information system which would significantly improve productivity in the long range.

1.2.10.4 Good "conversational" CAD system

1 Does not ask stupid questions.
2 Does not ask for known data already in the system.
3 Does not surprise the user.
4 Acknowledges entered data.
5 Allows for human error - for example it does not terminate the program but asks for corrections.
Dialogue between user and system can be built with four basic elements:-

1. **Prompt** - an indication of the type of data to be entered. It guides the user and prepares system for input action.
2. **Symbol** - user input.
3. **Echo** - shows interpretation of entered symbol.
4. **Value** - derived from the symbol for further use.

### 1.2.11 CAD's capabilities

No matter what procedure is used, and how detailed the study, it should be remembered that what you ultimately conceive doing with the chosen CAD system, the two important rules are:-

- "Any computer is too small!"
- "Any computer is too slow."

There are two sides to every option; for and against CAD is no exception.

### 2.11.1 Reasons for CAD and for purchasing a CAD system

Computerisation certainly influences your perception of the design but not the design itself.

The saving of labour in the drawing office resulting from the use of CAD is negligible. The main benefits come from using CAD to produce, for example, faster, more accurate and better presented quotations, and quickly translating orders based on these quotations into parts lists and packing lists, thereby improving efficiency and delivery performance. Again, the main benefit is increased sales. The CAD workstation is not perceived as an electronic drawing board; it is a data processing and storage machine which happens to have the ability to produce drawings.

The situation described here is really more applicable for engineering companies with a design department. These advantages are not so applicable to a design consultancy which acts as an outside design department offering its services to a multitude of companies. However, the continuation of the information process is not so convenient to organise or maintain, so some advantages are negated. Where it would not be true is when a consultancy is working in a special relationship with a large company and its system was bought to match that special working situation.
The only other alternative is where the consultancy has bought in a very standard package which offers a wide ranging user environment. The obvious disadvantage here is that it might not be entirely suitable to the consultancy's own requirements list of working criteria. This might mean the need for other software that meets this requirement or adjusting its working practice to comply with any potential weakness in the software. This factor is a potential further cost to a system. The Scottish sector had only one company that had a special working speciality with an industry but it chose software that suited the consultancy first and the industry second.

**Progress** - at some point it will become imperative, although justifications for cost and benefit should be used first. One of the risks for not proceeding with a CAD system is the risk of doing nothing and in an environment such as small design consultancies where finance projects are rationed, there will always be a lobby for a "play it safe" approach.

There is one strong pointer to the way things will develop and that is the fact there are companies who actively seek out partners who can take drawings in CAD format. Currently, this 'preferred supplier status', is being carried out by the larger companies but as in most trends related to computers it is really only a matter of time before this attitude filters down the line.

One 'bonus' point to stress in a justification is that CAD cuts costs and increases efficiency, some users are reportedly stating increases in productivity ratios of 1.5:1 to 3:1 and between 5 and 10:1 on repetitive tasks. Simply at the level of duplication of effort, savings will be made, as a well-maintained database prevents the use of old drawings, cuts storage costs, and saves recreating standard product, design or drawing information. This work cuts the lead time, buying extra time for try-outs of new designs, which feed back into the final quality. By being able to try three designs while your competitors tries one, who is more likely to clinch the contract?

In short this last part simply means that the design staff can make better informed decisions sooner. It would really be dependent upon the type of work and way in which a company works. CAD helps by reducing the duplication of effort that can occur with the advantage of the incurred savings that this allows. By the judicial use of a proper database it will prevent drawing office errors like the use of old outdated drawings, reduce storage costs and relieve the burden of recreating standard product design drawing information. This has the advantage that it eventually builds up drawing speed rates, cutting lead time. This gives more time for creative exploration of further ideas which has the spin-off effect of increased quality.

When some people are unconvinced by the claims of greater speed and they claim it is still faster on
the drawing board. The positive response to this would be that a CAD system can perform operations which are impossible for a drawing board. In the 2D format, objects can be manipulated, copied repeatedly and quickly. Work can be carried out in a 3D format or 3D views can be created and rendered. These features of CAD enhance the overall design for either in-house development to finished presentation work. This is achieved through:

Productivity - to get more out of existing designers because, with CAD, the drawing and design functions can be split to make designers more efficient, particularly when the task involves the modification of existing drawings. For example:-

- Common Parts - Many drawings contain common parts which need only be drawn once using a CAD system and then saved. When required, the part may be called up, scaled as necessary and inserted at any position on the drawing.
- Correction of Drawings - Any line in a CAD drawing that is wrong or any alteration to a design which require altering drawings can be easily carried out.
- Reduction of Lead times - Using CAD significantly reduces the lead-times allowing the production process to be started much earlier.

Management - using a CAD system forces a degree of management on the system so that a haphazard manual process must, by necessity, be organised more efficiently. A CAD system means there is no requirement to store drawings on paper. CAD drawings can be stored on disks or magnetic tape which take up very little storage space.

Quality and standards - CAD drawings will be of a sustainable and high quality; also, several operators can work on a drawing without their varying techniques becoming apparent. What is obtainable using a CAD system is vastly superior to that of manual methods. Printing and Plotting produce very high standards of line quality drawings which do not become marked or smudged due to drawing errors being made. In the case of a paper print being disfigured then they are more easily replaced.

Image - competitors, suppliers, contractors and clients all have CAD - a status point, but not really a strong economic argument for investing in CAD.

Presentation - CAD will produce impressive images for clients, apart from being a dedicated drafting tool. This is achieved through the following:-

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• Colour Drawings - These can be constructed using different line colours or colour shading may be used to highlight drawing details.
• Types of Drawing Models - The power of the computer allows different types of drawings or models to be produced from the same basic information.

Speed of revision - a major factor for designers who produce many changes. One often underrated advantage is the uses which the computer generated data can be put to once it has been created. It does induce changes to working practices which some people regard with suspicion and possibly even a little dread. The application of CAD in Industrial Design reflect the three basic levels of sophistication of the visual design process. The one common to both is “Two dimensional graphics and drafting”. Then the next level could be described as three-dimensional ‘architectural’ work which is typified by mainly using straight lines and flat planes and is more suited to Exhibition design work. The next level is three-dimensional ‘product design’ work typified by using mainly smoothly curved twisted surfaces and is more suited to work carried out by the Industrial Design role.

There are many reasons for purchasing a CAD system but the reasons that are usually given are displayed as a panacea to all companies regardless of activity. This is not the case and each company’s situation is different. The company has to evaluate its own current situation and pinpoint just which benefits are applicable to them. The following list is, therefore, seen as possible ways that companies could benefit from CAD.

• Drawing Accuracy - Each line can be constructed and positioned with great accuracy due to the fact the computer acts as a calculator and each position on a drawing is calculated to at least 6 decimal places. Drawing aids in software allow construction of a drawing to become very accurate.
• The use of computers can help the way in which a design company operates and allows people to be more in control of their working time.
• CAD allows the company to take a democratic and decentralised approach to management, where everybody does their own accounts on them.
• A further implication is that the loss of jobs feared due to computerisation might not necessarily be for designers but in the areas considered as being indirect design jobs, such as clerical jobs.
• The investment is in the people who operate the system.
• You can take on smaller office space and pay one person two or three people’s wages’.
• Computerisation is seen as a way to prevent further staff growth rather than staff
The ability to alter salaries might be seen as one way to encourage staff to remain with the company. However, it is still a viable option if the staff are handling an increased workload.

- The following are ways that CAD is seen to be quicker:-
  - You can get plans, sections and elevations from a single database, revise them a lot faster and provide information selectively for different people on a computer than you can manually.
  - It enables you to communicate better. Today’s world requires more information than in the past, much more quickly and more precisely targeted. CAD allows you to keep pace. The CAD system provides a common database from which useful information can be calculated. Database information can be passed to other computer programs for example C.N.C. programs.
  - The repetitive work is now much easier to do than when it was done manually.
  - The system allows us to make corrections and alterations far easier than before preventing the need to have to do the whole drawing again if the changes were drastic. Now anyone can alter anyone else’s drawing and you can not see the joins.

1.2.11.2 Reasons against CAD

Most of the reasons for having CAD given in any books are more applicable to the areas of Mechanical Engineering, Civil Engineering or Architecture. Regarding the area of Industrial Design when acting as consultancies there are still no strong influences other than the consultancy themselves having decided to invest in this ‘new’ technology. There are signs that this freedom is declining rapidly and soon consultancies will not have the luxury of choice. So designers can still earn their daily bread using markers and pencils to present the ideas. In some situations there are strong indications that some designers could not successfully implement CAD and that they should continue to work without any technological aids. This is based on their turnover of work, type of work they do and their current financial state. Sellers of CAD equipment often say that anybody can start up in CAD but this is not strictly accurate in my opinion. The following list gives examples where it would not be considered a good idea to purchase a CAD system.

- Just because you have heard everyone else has a system, it does not mean you should buy one.
• It should not be bought as a mere status symbol.
• It should not be bought just because you fancy one. A computer system, input device and A3 size plotter will cost between £3000 and £18000 depending on the choice of equipment. The CAD program will cost between £500 and £1500 depending on the software required.

Computer technology is changing at a phenomenal rate and the chosen CAD hardware will be out of date in 2 to 5 years. Similarly, CAD software is continually being improved and updated and the cost of updating at least 3 or 4 times per year must be taken into account.

(The proviso being for these two comments is do not purchase a system unless you can really afford one.)

• Do not buy a CAD system specifically for work that is imminent.

It is a mistake to purchase a system for a contract that the company has just acquired. Apart from the time it takes to acquire the skills, without a proper study of what is required by the company and what systems are available, you might just buy software that is unsuitable for a variety of reasons. For example, the company might purchase a new package on the market and because of its untried nature it could be full of program bugs which will cause learners more trouble as they would probably be unaware that the problem does not lie with themselves. The end result of this is a waste of much precious time and money.

• If the company has purchased a system for a particular impending contract then it is necessary to employ someone who is going to be the company expert. It is very important that this person is not on a temporary contract, as when it expires, the company will be left with a system which nobody knows how to use and with valuable information stored on it that no one can recover.
• The point to remember about the purchase of a system is that it is not picked up without learning the necessary skills. Learning to use the system will take time. During the learning curve, overall productivity will drop but it is essential that staff are fully trained in order to reap the benefits.

During the change of methods the following will happen:-

• A drop in productivity for a period of time.
• Decisions to be made about whether or not the drawing office requires to be re-organised to take full advantage of the CAD
system.

- Decisions on whether or not all the drawings produced using the old method must be redrawn on the CAD system.
- The paradox is that you need time to save time.

Many designers have been/still are suspicious of CAD. They regard the introduction of CAD as being unnecessary. The following comments could be described as being typical of their kind:-

- "Our manual methods are quite successful - why should we spend thousands on a system nobody knows how to operate?"
- "Why should we make ourselves susceptible to the whims and vagaries of inanimate machines?"
- "While I can appreciate the advantages of CAD, the work that I do does not give me the capital to invest in a system."
- "I have neither the money nor the work type that warrants the investment."

CAD is often suspected that it fails to deal adequately with many of the most important aspects of designing and that these aspects will be overlooked in the pressure to increase productivity through computerisation. They have the fear of simply being asked to insert parameters into the computer and then being supplied with the design such that the actual design work is being generated in an essentially synthetic way. The computer then has become an automated design manual, leaving only minor choices to the engineer. While this is a possibility, if current work in artificial intelligence becomes a viable option, then current systems are quite a long way from the expressed fears. However, there is a danger that designers will be influenced and affected by the limitations of current technology and their understanding of any given software package. It could affect the shape, material or texture of a design simply because the operator cannot work around the limitations of the system. This could be due to inadequate software or even training, but whatever the cause it is certainly something that can happen. Arguments of this kind are used against CAD and it is thinking of this nature that gives rise to the following comments about CAD:-

- Deskillling
- Loss of Job Security
- Dehumanise the work environment

There are two ways that this can be seen to be the result:-
1 Management wanting to have people using the system all the time i.e. shift work
2 Work efficiency reduces with time on the system during the working day. An important factor here is one of eye strain and physical discomfort which tires the operator and thus reduces the work output of the operator.

These arguments are due to a low awareness of what CAD can do or alternatively they are examples of poorly introduced systems.

1.2.11.3 What pressures are there to use CAD?

- Increasing complexity of modern design.
- Design of completely new kinds of products.
- Need to work in multi-disciplinary products.
- High risks and costs of modern design.
- Need to improve the efficiency of the design process.

There has been a broad set of new demands being made on designers and the adoption of CAD is one response to these demands. There have also been some straightforward commercial pressures. Such as:-

- Reduction in design lead times.
- Economies in design and draughting lead times.
- Ability to design products which are too complex to be designed manually (the most graphic example of this would be in electronics - large scale integrated circuits).
- Economies in material usage.
- Combination of CAD with production automation to obtain benefits of Integration (CAM).

1.2.11.4 Will these pressures change?

Manufacturing philosophy over the last thirty years has changed dramatically and this change is characterised by the need to manage change and make the best use of scarce time. Radical improvements in performance are required, such as reducing work in progress by 50% or more. Lead times to customers must be reduced by similar margins, and the rate of new product innovation must be increased significantly.
The pressures to use CAD are more dependent on the type of work being carried out such as a product design consultancy that works for a manufacturer on a regular basis. The manufacturer could insist that from a certain date all designs had to be on floppy. So the following list really just typifies examples of pressures:

- Major customer insists on design work being carried out on package X.
- The work is becoming more complex such that it requires computer assistance.
- Market pressures forcing company to use CAD just to stay competitive.
- Contracts lost due to lack of CAD.

The forward drive of computer usage suggests that these pressures will increase and more companies will be forced to use CAD rather than choose to use CAD.

1.2.11.5 What are the worries about using CAD?

- "Most of the work done is conceptual and supply drawings are paper format. Why do we need to get a CAD system?"
- "Hand drawn drawings when executed by a good draughtsman have a quality of line work that is impossible to reproduce by a machine."
- "The company has a style of drawing whose quality is superior to machine drafted images."
- "Machine drawn images are cold and lack the depth that hand drawn images have."
- "I would have to go backwards to achieve a drawing on a machine which I can already do now. What is needed is a computer that does not require the operator to learn how to use it."

1.2.11.6 Inability To Change

Some companies, even with a CAD system, still say that there are some jobs that they can do quicker on the drawing board. To the argument 'Yes but I can still do it faster on the board,' be ready to point out that CAD can do things drawing boards simply can't. Components can be rotated and copied; 3D views created and coloured; and these tools can enhance the broader design, from in-house studies, to client-getting presentations.
Non-CAD companies often state that their working area is not suitable for CAD as they are in an area of one-off designs. In my opinion this shows the ignorance they have about the potentials of CAD. It should be shown that even one-off designs have geometry or contain standard parts that CAD can handle more quickly and that some parts of a design can be used at a later date - all of which leads to better performance times than manual work.

Another common comment is that the design company is mainly concerned with one-off designs and so they do not see any justification for a CAD system. There are a number of common objections to CAD, often based on a lack of understanding about how it will function: 'We only produce one-offs' is a statement which overlooks the fact that often major parts of even a one-off can be used again. Further to this argument would be even though the design is a one-off how often does the design need to be changed before it is acceptable to client and production purposes.

Another reason often given is that they can not justify the system based on the amount of drawing work carried out.

"We can't justify buying a computer for the amount of drawings we do' - but your computer can also be used for word processing, DTP, databasing, spreadsheeting.

One interesting concept for justifying the cost of a system would be to compare it with the purchase of a company car. Few small businesses balk at the thought of acquiring a car - at, say £10,000 plus running costs. A general purpose micro, with a range of business software and a printer need not cost much more than £3000 or £4000. Buying the micro itself, then has become rather like buying a Vauxhall Astra. It is relatively standard, reliable and a vehicle for all sorts of applications.

1.2.12 So what does the new working role require from the workforce in terms of skills and knowledge?

- New problem solving skills are needed by designers such as:-
- Pattern Recognition
- Knowledge of design rules and relationships
- Complex decision making
- The ability to process large amounts of information quickly.

Moreover, the work pace of a job increases with CAD as decision making is now paced by the computer and not the person. This suggests that CAD is likely to lead to information overload. It will change traditionally self-paced jobs into jobs paced by the computer. While such changes to the job
as information overload and reduced control over work pacing are likely to lead to increased stress, studies supporting this claim have, as yet, not been carried out.

1.2.12.1 Computerization of the Working Procedures

One of the biggest changes for the office workers would be the introduction of shift work and all that is entailed in the disrupted personal and social life and unsocial working hours. In management terms, this is a matter of calculating financial returns on capital equipment. Large CAD systems are very expensive and rapidly become obsolete. Therefore, it is necessary to achieve high financial returns in a short time, and this can mean running the machinery 24 hours per day. A situation which has already happened in some design offices. The Technology is usually mainframe based and a strong personnel argument for implementing competent microbased technology which allows companies the freedom of not having to implement shift work.

When deciding about the purchase of a CAD system it is useful to get people to break down their time into work activities to establish the length of time spent on the drawing board and the time spent away. This would help establish working ratios of staff per computer seat and to establish if it is necessary to have one machine per member of staff.

1.2.12.2 Deskilling

There is work being carried out in Artificial Intelligence sectors which is trying to break down design skills into small unskilled subtasks. This kind of research would seem to lend itself to attempts to transform design activities into a highly controlled and tightly timed sequence of discrete, unskilled tasks. It is also an argument being made by some people about current CAD applications. While it may be true for Artificial Intelligence programs, currently it is an incorrect statement about CAD packages.

The reverse argument is also frequently given. CAD frees the designer from low level menial and repetitive tasks and allows the designer's skill to be developed and applied at higher levels. In fact, what often seems to happen in practice is that CAD systems are applied in ways which force further differentiation of skill levels amongst different grades of design staff. Information from various sources have indicated that it has been found that skill requirements of some jobs were increased, with senior designers making almost exclusively "high level" decisions such as conceptualising and problem definition. By contrast, junior designers who typically made "low level" decisions such as detailing had those decisions taken over by CAD, reducing skill requirements even further.
It is not disputed that the introduction of CAD will mean changes - some detrimental - but some to the advantage of the designer. So the new skills that are seen to be necessary now are:

- Fluent use of symbols.
- Ability to work by using information in different dimensions and planes.
- Increased abstraction to manipulate programs and numbers rather than designs.
- Ability to develop personal strategies for problem solving rather than using existing proposals and the ability to change from directly creating alternatives to selecting the best variant of solutions provided.

What can be concluded from this is that CAD inevitably entails some new skills. At higher levels of the office hierarchy these probably create new opportunities as well as imposing new demands. At the lower levels they tend to de-skill or to replace altogether the jobs of junior staff.

1.2.12.3 Job Satisfaction

This could fall depending on how the equipment is implemented. The fall would be due to the adoption of one or more of the following:

- shift working
- formalization
- routinization of activities

There is evidence that suggests there is an increase in job satisfaction with the introduction of CAD systems as:

- Work with CAD is considered more interesting and meaningful.
- Increased job satisfaction was achieved not by CAD but by increased productivity, creativity, quality of work varied tasks and responsibility over work that resulted when some organisations implemented CAD.
- One of the potential effects of CAD is that it can open new career opportunities. This has been found to happen as a result of general office automation with new career paths being opened up. Design engineers and drafters working with CAD have taken on such new jobs as internal CAD consultant, CAD training co-ordinator, systems specialist, marketing of CAD services to other departments in
the organisation. There is the possibility that some organisations might not take this opportunity which could mean CAD operators getting more dead-end careers than before which would breed discontent.

- Job satisfaction in a CAD working environment seems to depend more on job design and office management factors than on the technological change to of CAD.

1.2.12.4 Design Quality

It has been suggested, for example, that CAD systems impose limitations on what kinds of objects can be designed. This has been apparent especially in terms of the limited shapes or range of components that a CAD system can handle. Conversely it has to be recognised that some objects e.g. a microprocessor could not be designed without computer aids.

1.2.13 What are companies looking for in their chosen CAD system?

Companies which are Microbased users want software that is easy to use.

1.2.13.1 What constitutes "ease of use" in a package?

Basically it must be easy to interact with the software to achieve the aim of creating a drawing. This means it should require either none, or as little as necessary, instruction to operate it. It should be like riding a bike, once learnt it should be easy to remember how to do it. This is achieved through its structure and clarity of commands. It needs some more superficial aspects such as a comprehensive Help system, idiot proofed to allow for errors that will not cause the computer to crash. This requires an all encompassing recover command or, as the packages phrase it, 'Undo'. The more varied the package the more complex it becomes. All packages will require some learning, so it must have documentation in the form of manuals and aided by a tutorial to help you learn it in the early stages. This appears to be a common weakness in most software. Their manuals are not very well written or structured. They are more oriented to the structure of its commands rather than the sequencing of commands necessary to perform a drawing function.

The companies cannot afford to choose CAD systems that are difficult to learn which require a lengthy training period and months to become productive. The time scales vary but the trend is the smaller the company the less time they have to ‘learn’.
Software houses have been known to say that the systems that are easy to use when learning are not easy and efficient to use once learnt. Reviews of software have commented on the fact that to an extent this is true but they elaborate and say that because a system is complex and difficult to learn that this is no guarantee that it is competent. This is an area that is being recognised as a problem for some software houses and they are revamping or developing the front end of their programs in an attempt to make them more acceptable. While this is superficially answering the problem it is not really sufficient and eventually this will be realised. This is a problem that is more related to the older programs on the market and while they are now still being highly competitive I suspect they will have to go through a period of metamorphosis to emerge as viable competitors for the future markets. The newer programs are generally friendlier but lack the strength of widespread usage.

So "ease of use" breaks down into three subgroups:

- User Interface Features.
- Ease of Learning.
- Ease of Running.

The ideal package would amply satisfy these three requirements but unfortunately it is not that easy and each package is written differently and therefore has its own advantages and disadvantages. The three categories can be broken down even further which is helpful when evaluating a selection procedure for software.

1.2.13 How the packages operate

The first criteria is "User Interface Features". Primarily this is based on how the program interacts and this is a product of the manner in which the package was written.

Computer Languages

A computer requires to be told exactly what functions to perform. It achieves this through sets of instructions that are very long and understood only by the CPU. However, the computer's advantage is that it can execute these instructions at great speed. These instructions which control the CPU operate as a low level language which is called machine code. Each 0 or 1 is a Bit and 8 Bits equal a Byte or word.

Assembly Language uses Mnemonic Codes as instructions and a program called an Assembler converts the Mnemonics into machine code. Each Mnemonic has an equivalent in Machine code.
from 1 to 4 Bytes in length.

Further improvement to Assembly Code are what are termed high level languages. These include BASIC, FORTRAN and C. These languages are a set of instructions which are similar to the English Language but have to be converted into machine code. This has the effect that all programs written in high level languages tend to run more slowly compared to programs written in assembly language.

CAD programs use a combination of high and low level languages. The main program is written in a high level language while the small most frequently used sub-routines are usually written in assembly code. CAD software do not only consist of programs to create the geometry but they also have the necessary instructions to operate the peripheral devices in the system such as the printers and plotters. To store all these sub-programs in a CAD program makes a hard disk essential. One method used to overcome the problem of using a large CAD package on a computer having a maximum of 640 Kilobytes of RAM is, as follows:-

When the CAD package is loaded into the RAM area ready for use only the main programme which consists of the most frequently used commands is transferred from the hard disk. This leaves an area of RAM called the overlay area is left free. The less frequently used commands or subroutines are left on the hard disk. If during a drawing session a subroutine is requested, the main program calls the subroutine from the hard disk and is copied into the overlay area. This will be overwritten when another subroutine is called or requested.

Each package uses its own method of saving or loading a CAD drawing. Normally a CAD drawing on one package cannot be loaded and used by a different CAD package. The drawing data must be in a format that the other CAD packages can utilise. There are two formats currently in use:-

- DXF Data Exchange Format.

Data Exchange Format

This is normally used between CAD packages which operate on the same type of computer. This format is also used when drawing data is required by other types of engineering software such as C.N.C., 3D modelling.

Initial Graphics Exchange Standard

This is used to transfer drawing data from a microcomputer to a mini or mainframe. It is also used
when data is required by other types of engineering software such as C.N.C., 3D modelling.

1.2.13.3 Special Transfer Conditions

Since computers are increasingly being used in DTP and other applications most computers use Raster graphics formats; these packages may require CAD type drawings to be loaded into them. The majority of CAD packages have a special save routine that saves the CAD drawing data in a suitable format. Often this routine is a function key press, a CTRL plus Key press or a command name. Different DTP or Art type graphic formats are: -

*.PXC, *.PIC, *.PCX, *.IMG, *.TIF or *.EPS files. If the CAD package saves in a different format then it will be necessary to convert the file to the correct format using some third party software.

Each CAD drawing saved as a data file depending on the CAD package, the drawing file will be handled in one of two ways.

- Conventional File - Normally used on package created information and cannot be accessed or extracted easily by other engineering software programs from this sort of file.
- Database File - Stores the drawing data in a structured manner which allows easier access if data is to be shared by other engineering software programs.

A database is a collection of related data made up of files having a predetermined structure and organisation which may be communicated with, interpreted or processed by, any user requiring the information.

A CAD database is a storage area where drawing data may be stored, organised and held ready for use by both the user and other application programs. Typical information held in a drawing file would include line start and end points, line thickness. All this data forms part of the database.

Databases need to be first set up, initial data must be entered and the database must be controlled when in operation. These functions are performed by the Database Management System (DBMS). The DBMS is designed to control all aspects of accessing, modifying, organising and retrieving data for use by the user or by an application program.
1.2.13.4 Parametric Files

This is a special CAD file that allows the user to create a small program file that will automatically construct a drawing from the values entered via the keyboard.

Each part of the component design (diameters) are coded with a name or number. Values are given to each code, via the keyboard, the computer constructs the screen image from these codes. Once constructed the finished drawing can be automatically scaled and fitted into a suitable drawing frame. The file details can be added to the drawing frame. The parametric file can be used to design the next shaft. Any size shaft can be designed. Various items drawn using the same parametric program same number of diameters and lengths, but of different sizes. Any item with the same features can be designed with a parametric program.

1.2.13.5 Operating Systems

The operating system which demands the most commonality between packages is that based for the Apple Macintosh computers. This commonality allows a user of one package to have approximately 60% familiarity with just about any other Apple Macintosh package. It works on the premise that the screen of the computer acts as an interactive device covered in 'items' that, in conjunction with a mouse, you can point to, click or drag. It becomes more a control panel and does not require an operating language with an encompassing phrase book. Some Apple Macintosh software producers are not followers of this system (e.g. AutoCAD Mac). Similar methods can also be seen outside the Apple Macintosh environment and one draughting package like this is RoboCAD.

1.2.13.6 DOS for CAD users

One operating system is the DOS system. It is essentially divided into two types; internal and external. The command files which allow the internal commands to be executed are automatically passed to a directory when the directory is created. External commands can only be executed in the DOS directory itself.

The DOS directory may either be a separate floppy disk or part of the contents of a hard disk.
Two rules to be observed when using a DOS command are:-

- Specify the command.
- Specify any Parameters in the correct order.
Correct use of spaces is very important when using DOS. Most of the commands available in DOS have an in-built flexibility by allowing the user to specify certain Parameters with the command. Some of the Parameters are mandatory, others are optional.

1.2.13.7 DOS Files

A collection of related data, such as a CAD drawing, is kept by DOS in the form of a file. Files are kept track of by DOS by means of a filename and an extension.

1. The filename can be formed from 1 to 8 characters long.
2. The extension is optional but if used it is up to 3 characters long and must be separated from the filename by a period.

1.2.13.8 Wild Cards

Greater flexibility is achieved when using filenames is given by the use of the two wild cards. The wild cards are:

1. The question mark ?
2. The Asterisk *

The ? can be used in the filename or the extension. This means that any character can occupy that specific position.

The * can be used in the filename or the extension. This means that any character can occupy that position or any of the remaining positions in either the filename or extension.

A special use of the asterisk is the designation *.* which refers to all files irrespective of filename or extension.

1.2.13.9 DOS Directories

Files are organised into directories. The directory can be regarded as one drawer in a filing cabinet. The cabinet itself can be regarded as the disk drive. The name of directories are chosen by the user.
In order to locate a file, a pathname is used. A full Pathname consists of:

- Drive
- Directory
- Filename
- Extension

The pathname would look like `C:\CAD\Drawing.XYZ`

The backslash (`\`) is always part of a directory name. The first directory on any disk is known as the root directory and is indicated by the backslash (`\`) alone. All named directories are subdirectories of the root directory. The pathname, consisting of the drive, directory, filename and extension uniquely identifies the file. The directories on a drive are organised into an 'inverted tree'.

**Making Directories**

A new directory is created by using the MKDIR or MD command. MKDIR is an internal command. When the MKDIR command is used two 'hidden' files IO.SYS and MSDOS.SYS are transferred to the new directory. These files hold the internal commands of DOS and set up the path.

The 'working' directory is changed using the CHDIR or CD command. This is an internal command.

The files in a directory may be listed using the DIR command. This is an internal command. The hidden files IO.SYS and MSDOS.SYS are not listed when the DIR command is used.

**Format Command**

A new disk must be formatted before it can be used. Format is an external command.

For example:

```
Format a:\s\1\v
```

/s - copy the operating system to the disk
/1 - Format as a single sided disk.
/v - give the disk a volume name

Never format a hard disk as all the data will be lost.
Copy Command
Files may be copied from one disk or directory to another using this command. This is an internal command.
Copy (source) (destination)

Erase Command
One or more files may be erased from a disk or directory using this command. This is an internal command.

1.2.14 CAD Programs

The other way which packages operate is more historical in its origins and is similar to early CAD methods. The package operates through user keyboard inputs based on an instructional language. For example, user types in "Draw Line"; the computer would then prompt "Start point, length, direction". This goes on in this mode until the line is drawn. The weakness of this system is the operator needs to be fluent in the language which could be quite extensive. It is very much akin to a high level computer programming language. Progress made the key words short and cryptic in an attempt to optimise this language barrier. Sequences would be grouped into logical areas of similarity. While this sounds clear, the operator still has to declare what parameters are relevant to the task. Similar to declaring the parameters at the start of a 'C' program. The cryptic commands developed into a hierarchical menu system. This was based on multiple questions, responded to by keyboard entry to gradually pinpoint the required operation. The hierarchical method is very much a standard for commercial systems, although as software becomes more complex in command functions, it produces more complex menu schemes. To overcome this, the software houses have tried adding screen or tablet menus to alleviate the necessity of typing. The key words are still there because the menus need them. The operator can use them, though with care, as it needs the computer to prompt for them. This approach appears to allow more choice but is not as tidy as a pure hierarchical arrangement simply because in the menu scheme a lot of the choices are actually invalid. To utilise and operate in this mode you still need to know the instructional language.

Computer manuals for software of this type will generally describe the instructional language and not the menu structure as the menus are more an afterthought. The instructions need to be carefully thought out or it will not be possible to derive a respectable menu structure. The menus are soft and allow for user customisation. Packages like this are primarily found on the DOS operating system and are typified by AutoCAD and Microstation.
Of the two basic types, the systems that work on the principle of direct manipulation are easier to learn and to use without error than their counterparts in the instructional or command language area.

1.2.14.1 User Interface Features

Style of Interface
This is the means of interaction between operator and system e.g. keyboard entry, mouse or combination

Menus
Menus can be either classified as soft menus in which case they are easily altered by the user or permanent. The latter is usually the better thought out and documented. Menus have some basic characteristics and appearances.

The position on the screen where they can be found leads to their name such as:-

- Left hand menu
- Right hand menu
- Pull down menu
- Secondary Menu

The menus usually work in a hierarchical way the first screen menu called the root menu then the operator must go down the path to the second menu and then further if the program requires more specific instructions.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop/pull down</td>
<td>Activated by pointing to a menu bar at top of screen, once used it disappears. This type is easier to memorise than below.</td>
</tr>
<tr>
<td>Nested</td>
<td>Lower level menus overwrite the previous master menu in a hierarchical procedure. This format can be lengthy in their working therefore tedious in use. Harder to learn than above.</td>
</tr>
<tr>
<td>Overlaid</td>
<td>Found on a fixed part of the screen and operates differently to nested type but is switched by a master menu elsewhere on the screen.</td>
</tr>
<tr>
<td>Palette</td>
<td>Remains on screen for some time and it is possible to reposition it at will. This is a quick way of getting in a few commands.</td>
</tr>
<tr>
<td>Static</td>
<td>found on a fixed position on the screen and permanently there.</td>
</tr>
</tbody>
</table>
Tablet

Separate piece of equipment not on screen but can overwrite command sequences.

Appearances

<table>
<thead>
<tr>
<th>Type</th>
<th>Ionic</th>
<th>List</th>
<th>Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commands identified by use of little pictures instead of text.</td>
<td>Vertically arranged series of commands</td>
<td>Portrayed in a grid and commands grouped and identified by name.</td>
<td></td>
</tr>
</tbody>
</table>

Another type of menu is a Data Menu this indicates whether items of data such as linestyles, layer names, and file titles have to be either typed in or selected from a menu.

Dialogue Box

This is a method of collecting data and selecting options by completing a list like form filling. It is consistently clearer and more flexible than the alternative of typing responses to prompts or using parameter setting commands.

Mouse Buttons

The mouse is usually the device for interacting with any screen menu or icon commands. The two button mouse caters for the simplest protocols. When the mouse or puck has 3 buttons it requires more concentration and co-ordination to be worked properly. The Apple Macintosh system of a one button mouse relies on a keyboard entry to compensate in some command sequences which is a more complicated way of operating than it could be.

1.2.14.2 Typed Co-ordinates

To be able to enter and display a line, information has to be passed to the CPU to inform it of the position. This is done by entering values called co-ordinates. Any package allows relative co-ordinates (i.e. measured from last entry) and absolute co-ordinates (i.e. measured from a fixed origin). Other types of co-ordinate which can be catered for and used by packages are Polar co-ordinates and/or where they relate to an origin where the absolute co-ordinates can be offset and the axes can be rotated.

Absolute Co-ordinates

All dimensions taken from the Datum point. Any screen point or line position can be located by an X and Y value from the Datum.
Relative Co-ordinates
Line dimensions are taken from the previous line's end point or from the end of a specified point.

Polar Co-ordinates
Drawing line end point is specified by a distance and an angle from the previous line's end point or a selected position. By convention the angle is specified in degrees from the Horizontal in an anticlockwise direction.

Horizontal at 3 O Clock position is 0 degrees.
Vertical at 12 O Clock position is 90 degrees.

1.2.14.3 Snapping
This is a technique used by all packages to some degree but they are not all used in all packages. The technique allows to precisely input co-ordinates by reference to items already drawn. The more ways a package can snap onto a point the more usable is the package. While all the packages have snapping features, they do not all allow the user a method of switch from one mode to another. Where the packages do allow switching, the methods of selection are:-

Keyboard
Seen as an alternative to other methods, the tendency is that experienced users will use the keyboard as it is the faster method in experienced hands.

Nested Menus
For example, contained in a side bar menu which is different from the one containing the command the operator is executing. Not very efficient.

Pop up Menu
Works in conjunction with mouse and the menu appears near to where operator is drawing, less movement is needed to access it than if menu was a static variety. The disadvantage is that it requires a dedicated mouse button.

Pull-down Menu
This require using the mouse and is seen as a more complex method of selection than the one above.

Static Menu
This is a text or iconic menu which is permanently on the screen.

Two stage snapping
Sometimes called tentative snapping. First stage is the identification of the item then the second stage is either confirmation or retry. Efficient for very complex situations such as 3D work but on the whole clumsy.
The ideal package would have all the following snap modes but generally in reality it is some combination of them:- End point, Nearest point, Midpoint, Intersecting point and Arc centre. Other snap options are:-

**Tangent/Normal**
For drawing geometry this is useful when the operator wants to construct lines tangent to circles or in some cases circles to lines or other circles. Perpendicular or Normal snap aid construction of lines at right angles to something that exists already.

**Offset from Snap**
This is a feature that allows an operator to specify a point, that is offset from a snapped point by relative Cartesian or polar co-ordinates.

**Retry a Snap**
This is a feature that is useful when working on a busy drawing and it is hard to pick up the correct snap point. The useful aspect is that it allows the operator to try again or an alternative snap.

### 1.2.14.4 Feedback

When working with a new or unfamiliar system it is reassuring to know what is happening and even possibly what will happen if operation X is pressed. The packages can supply the operator this perception through the following ways:-

**Co-ordinate Readout**
The cursors position is continuously referenced by co-ordinates by eye and snapping routines is easier than by keyboard entry alone.

**Edit Selection Highlight**
Some editing operations can be on more than one entity at a time and the highlighting option visually tells the operator if it is correct or not.

**Position Marker**
This marks out a blip on the screen at every entered position. This is helpful for commands which require several co-ordinates before anything happens.

**Rubberband**
Aids line construction by portraying a rubberband line from last line/point input to the current cursor position. This technique can be altered for other operations such as circles, rectangles and dimensions.
1.2.14.5  Undo

This is a feature that is ideal for mere mortals and relies on the fact that even experts can make mistakes. The packages vary in the limits of this command but it is advantageous to get as flexible an Undo command as possible. An effective Undo will reverse the action of any command that alters the database. A truly effective one will even undo an Undo. Usually the Undo just deletes the last operation. In packages that allow the operator to run macro commands it would be desirable that the Undo sees the macro as a single command and not as a series of operations, otherwise the operator could be faced with a lot of manual editing.

1.2.14.6  Help

Almost as useful as the Undo command, a good help command will allow you to interrogate the system to allow you to find out where you are, what you are doing and what you can do next. The first stage help would give the operator a list of commands names, so the operator has freedom to choose what he is wanting to know. Once a command has been selected it should describe what the command does and how it relates to other commands. A rarity in the packages is a set of illustrations which includes diagrams of constructions or user interface devices. Hypertext is another rare command that can be useful. This command allows cross references or further information to be accessed simply by pointing to items on the help screen.

1.2.14.7  Manuals

This is unlike the others as it is external to the system, it reverts back to the book form. It is as it suggests a working list of what and how the software operates. When the system is new and operators are still learning how to use it, desk space will be needed so that aid is not too far away from the operator. The more compact the manual the greater the convenience. The disadvantages are they have little correlation to the power of the software, they can require effectively quite a lot of space and depending on their style do not fit tidily away. The binding of manuals can be ring, wire and hard bound. They all have good and bad points. The more important aspect of the manuals is the content. They are often more an afterthought to the software and can suffer accordingly. Commands are sometimes referenced alphabetically so when an operation has to be carried out the operator can find himself flipping back and forward as he proceeds through it. Often they are referenced to the master menus in a hierarchical form which in terms of operation sequencing still requires flipping between sections. One part of the manual that would help illustrate features of the software and proper operational sequencing of commands would be a good accompanying tutorial.
Not all packages contain tutorials and even these range from the good to indifferent. The good are based around clearly thought out examples that illustrate the points. The bad are full of sequencing mistakes and/or refer to older outmoded versions of the software. The manuals are often written with people operating and managing the system in mind (Computer specialists) rather than people just using the system to produce drawings (designers). Even though these operators are computer literate the manuals are not very helpful.

1.2.15 Ease of Learning.

It is regarded that the key features that make a system approachable to a new or casual user are Simplicity and Friendliness.

Basic requirements for Simplicity

1. The elementary concepts of the system are straightforward.
2. The commands should be well designed.
3. The commands should not be too numerous.
4. The commands should be organised into meaningful groups.
5. The commands should be consistent in their behaviour.
6. Individual commands should not have too many options or alternate methods of doing things.
7. Menus kept neat and simple.
8. Excessive use of Modal Parameters decreases the ease of learning, more prone to mistakes occurring. The use of modal behaviour where a single command can be several very different actions dependant on the current 'mode' in operation certainly makes a system harder to understand and operate error free.

Basic requirements for Friendliness

1. This covers a wide range of topics, which contribute to make a system friendly and easier to learn. They free the operator from frustration and unproductive time pouring through the manuals.
2. What is seen as the most helpful user interface is the option of only giving valid options. This is where older style programs that are command language/menu systems do badly, e.g. AutoCAD and Microstation. Their menus are basically independent of commands and do nothing to guarantee correct operation. That is
why direct manipulation systems are friendlier as they are based on this fundamental method.

3 When it is required to choose an action the direct manipulation systems produce a list of possible alternatives for the operator to choose. They do not expect the operator to remember the name and type it in. Easiest method is a display list and a means of scrolling, selection by pointing. Seeing and pointing is better than remembering and typing. So should a predefined order of events be required by the system, then this should be clear and a set of prompts be supplied by the system. In terms of command language systems AutoCAD is helpful in its use of prompts and Microstation is poor. Macintosh systems tend not to use prompts and some systems such as ClarisCAD and ArchiCAD suffer accordingly.

4 Error detection is a relation to the Undo command and the way a system deals with errors which can make it friendly or hostile. The more helpful systems on detection of an error gives notification to the user that an error is about to happen. Unfriendly systems tend to do some combination of the following:-

- Do not detect errors thereby carrying out incorrect operations and consequent harm to the current drawing.
- Do not notify errors and then do nothing.
- Provide obscure/misleading notification, insisting that whole complex operations be abandoned if an error is made.

One last point, where a system puts up an error notification on a stick up panel which has to be explicitly acknowledged before going on with the drawing, this is considered to be a minor irritant.

5 Dynamic feedback (as earlier outlined), where the screen image is continuously modified with the movement of the mouse, is very helpful. This information to the operator reduces the chances of mistakes and allows the operator to feel at ease with the system. Some feedback can negate the requirement for screen prompts as it gives the operator a visual indication of what is about to happen and whether it is correct or not.

6 Feedback such as highlighting is useful to show what elements have been selected for purposes such as editing. This avoids errors. The operator can carry on as errors that do occur are obvious and fast to undo. Highlighting features in order of usefulness are:- overdraw with a reserved colour, drawing handles (title dots at extremities of an object), overdrawing with a dashed line.
7 How the packages 'screen image' is perceived is important; it should be legible and logical. This can be achieved by the use of judicious character and icon sizes, plain backgrounds, restraining the use of colour and avoidance of obscure abbreviations and iconography. By achieving a logical grouping it helps to reinforce relationships by making them visible. For example, submenus appear below or to one side of the master menu. Clutter should be avoided. There has to be a balance between, the drawing area and the operating features required clarity.

8 The command language software such as AutoCAD fail to exploit screen layout to clarify the structure and operation of the software. This is another area where the direct manipulators do much better, particularly RoboCAD.

9 In conjunction with ease of use there is the requirement for an Undo command. The nature of which should be as I described earlier. There are some further points that I consider worth elaborating on. It is worthwhile to check the extents of a packages Undo command as they all vary in effectiveness. The worst is no more than an Oops command where only the last thing constructed is deleted. The best Undo command will encompass any inputted delete or edit functions no matter how complex. This gives the operator peace of mind and facilitates the learning of the software. So that it is important to establish where the extents of the Undo command are hence what it is capable of.

10 The help command is another one that eases the operators burden and aids the learning of the software.

1.2.15.1 Manuals

Manuals are a necessity. It does not matter what the seller of the software system says, no system is so clear and intuitive that you can effectively employ it efficiently without some reference to the manual. The sooner the manual can be shelved, the easier the package is. The primary factor in the manual should be the tutorial which should contain a collection of practical exercises to introduce the basic concepts and techniques, which will leave the operator with the feeling of confidence to carry on to the next step on their own. It should be possible to start on the tutorial without any advance reading.

The second factor is that the manual has a reference section, explaining in plain English, everything about the software's functions, keeping free from jargon unless previously explained or impossible to avoid. The index should contain more than just the names of the commands. Microstation has a
manual that is complete but voluminous and poorly structured resulting in it being hard to use. However, manuals are usually organised around the menu structure. AutoCAD and Microstation are not.

RoboCAD (Cadvance & VersaCAD) is particularly easy and best suited for intermittent or casual users. Microstation (& Cadbuild) is a difficult package with unfriendly interfaces and a poor manual. A training course would/should be essential prior to using this program. AutoCAD requires a lot of study and would be hard to learn thoroughly without the benefit of a training course.

1.2.16 Ease of running.

This criteria is the application of the software once the learning curve is nearly finished. The operator would clearly understand the menus and commands. This criteria is looking at the user interface features which will assist the experienced operator to be more productive.

The system is controlled by selecting commands and entering the data or options they need. AutoCAD and Microstation use clumsy menus and are more effectively controlled by the keyboard entry of the command language.

Direct manipulation packages (ArchiCAD & ClarisCAD) such as RoboCAD and VersaCAD have faster methods of control. Data entry is generally faster and easier in those systems using 'pointing' alternatives to typing. Co-ordinate input is functional to nearly all construction and editing operations. Typing is the most tedious method but often unavoidable. Some software packages need a specific menu action as a preliminary, to allow keyboard entry. Some packages are limited to the type of input that is allowed and do not allow the use of polar or user defined axis, origin or rotation. AutoCAD has no such restrictions. RoboCAD is the least flexible. Another method of inputting co-ordinates is the use of grids, its use can be fast, switching on and off as required, it is facilitated as the cursor leaps from grid point to grid point. This is further aided if there is a readout that continually displays the relative distance to the gridded point. If the grid point is flexible and allows it to be positioned easily and allows grid size and rotation to be altered. AutoCAD (ClarisCAD) handles gridded input very well and has a very flexible grid format. The last way of providing co-ordinates is by snapping to lines that have already been drawn. The important feature for this to happen is the snapping facility. The snap features of interest for this are Snap selection, Intersection snap, Midpoint snap, and Snap & Offset. AutoCAD allows most of these very well except Snap & Offset and average snap selection capability. Microstation does not allow for any of these modes very well except Snap & Offset. RoboCAD does not show favourably for this mode of co-ordinate input at all.
Productivity depends on doing things fast and correctly. Dynamic techniques such as rubberbanding, dragging and highlighting help to avoid mistakes and a good Undo command corrects those that are made during the drawing process. These two friendly features allow for a fast, less cautious way of working.

1.2.16.1 Layers

The layer command effectively divides the screen into a number of transparent sheets up to 256.

- Each layer may be drawn on by the user.
- Each layer may be named or numbered.
- Layers may be turned ON or OFF.
- If a layer is turned On the drawing work on that layer will be visible.
- If the layer is turned OFF then the drawing work will be invisible.

The following checklist would be useful when evaluating the software:-

- Ability to meet today's requirements based on real work;
- Ability of current staff to use the system to meet their requirements;
- Availability of support for core software, applications, training and if needed, consultancy;
- Ability to meet the stated future requirements as well as future changes in hardware and software technology.

1.2.17 Hardware

The hardware can be broken down into three sub groups:-

- **Input Devices**
  - Keyboard
  - Mouse
  - Graphics Table
  - Light Pen
  - Scanner

- **Output Devices**
• Monitor
• Printer
• Plotter
• Liquid Crystal Display

• Storage Devices
  • Floppy Disk
  • Hard Disk
  • Tape Streamer
  • Magnetic Disk
  • Magnetic tape

1.2.17.1 Input Devices
  Keyboard
  Mouse
  Graphics Table
  Light Pen
  Scanner

1.2.17.2 Output Devices

Monitors
The monitors suitable for CAD activities range from 12 inch to 20 inch screens measured diagonally. They use a Cathode Ray Tube. Essentially the Visual Display Unit converts electrical signals to a visible image and there are three methods by which this can happen:

Storage Tube Display
Known as the Direct View Storage Tube.

Vector Display
Graphical Information is interpreted by the display processor and converted into analogue voltages which deflect the electron beam. In order to maintain the display, the image must be refreshed a minimum of 30 times per second. The screen image is held as a list so any data within the list can be erased, replaced or edited.

Raster Display
This is the most popular monitor. The viewing screen is made up of a number of Horizontal lines.
Each line made up of small dots which are called Pixels. The resolution of the screen is described as the number of Pixels multiplied by the number of Horizontal Scan lines. The display is allocated an area of RAM which corresponds to the total number of Pixels required to fill the screen. The image information is held as a BITMAP by the display processor. The Pixels operate as an on/off switch, the position of which is dictated by the BITMAP. The main disadvantage of raster displays is that the quality of the displayed line is dependant upon the resolution of the screen. Since all lines are made up of individual pixels, diagonal and circular lines appear jagged. This effect is known as Staircasing. This effect would be seen from a printout from a dot matrix printer but not a plotter.

<table>
<thead>
<tr>
<th>Type</th>
<th>No. of Colours</th>
<th>Typical Resolution</th>
<th>Line Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour Graphics Adapter CGA</td>
<td>2 or 4 Black &amp; White</td>
<td>320 x 200 or 640 x 200 in 2 colour mode</td>
<td>Poor</td>
</tr>
<tr>
<td>Enhanced Graphics Adapter EGA</td>
<td>16</td>
<td>640 x 320</td>
<td>Medium</td>
</tr>
<tr>
<td>Video Graphics Array up to 256</td>
<td>640 x 320</td>
<td>640 x 480 or 800 x 600</td>
<td>Excellent</td>
</tr>
<tr>
<td>Multi Sync. Monitor</td>
<td></td>
<td></td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Colour shading is possible with Raster Display as each pixel can be uniquely addressed by the computer. A special graphics card is required to match the type of monitor in use. The card is usually fitted into one of the expansion slots on the computer Motherboard. The card contains the display processor chip, the display RAM chips and a ROM chip which contains a program to handle screen manipulation of CAD data when using such commands as ZOOM and PAN.

**Controller Architecture. (Raster Graphics Controller)**

The display controller allows the computer to communicate with a cathode ray tube, to whatever visual display terminal is used. This device is also becoming more than just an interface between a terminal and the host computer, it is becoming a computer in its own right. It interprets information generated by a host application program and it separates information into system command codes such as a screen clearing and display data that instructs the controller to draw specific objects e.g.
arcs and vectors, to perform the required operation. Often the controller can be used to provide local control of all workstation peripherals.

The key to a typical Raster Graphics Controller is a supervisor processor which interprets host application program command data, as well as commands from a keyboard, data table or other peripheral. So from the processor, command and associated display data is passed into a hardware or software routine that converts the desired object into Raster format. The algorithm that implements the conversion decides which parts in the display must be set or reset to display the desired object. The rasterized data is written into a refresh memory to continually refresh the displayed image on the screen.

Raster displays are high speed devices in which deflection circuits trace a fixed pattern of parallel lines on the screen. Modulation of one or more electron beams creates the viewed image. Intensity or colour of the image changes at precisely timed intervals corresponding to the individual picture element as the Raster line scans across the screen. Since the image on the face of the screen is volatile it will disappear unless refreshed typically 30 to 60 times per second. Similarly whole characters and symbols can be read out of memory as a block, so as the characters are also mapped in arrays of memory addresses, corresponding to character spaces on the display screen, the systems can employ 2 separate display processors, one for test and one for graphics.

Instead of directly controlling cathode ray tube guns, such as one for each colour (red, green and blue), the combined bit-map map values for a pixel are decoded to select a colour from a video look up table. For example a system with a one colour “bit-plane” produces just 2 colours (black and white), a 2 “bit-plane” generates 4 colours.

Number of colours displayed is 2 to the power n where n = number of bit-planes.

Video data serialised after being read out of memory is then post processed. (Where various colours and intensities are provided for display along with various logic commands.) Video and synchronisation signals are relayed to the monitor to excite the appropriate phosphors on the screen. There are many more features possible in a controller but what is in it is dependant upon the manufacturer.

**Screen Colour**

‘Television screens' translates colour 'perceived' into 3 primary colours Red, Green and Blue. This colour information is encoded electronically and used to stimulate a matrix of Red, Green and Blue
phosphor dots which ultimately form the television's picture. Due to the proximity of the dots, the eye effectively integrates the separate colours to generate different colour sensations. This ability to reduce a colour screen to three colour separations, Red, Green and Blue is exploited within computer Graphic Peripherals e.g. if every pixel on a graphic display screen has 3 bits of memory to store the colour detail RGB, the following binary codes would produce these colours:-

<table>
<thead>
<tr>
<th>COLOUR PRODUCED</th>
<th>R</th>
<th>G</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Blue</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Green</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cyan</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Red</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magenta</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Yellow</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>White</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

If a large variety of colours are required then more memory is to be allocated to each pixel there will be 256 possible codes ranging from 00000000 to 11111111. The specific colours allocated to each code are stored in a system component called a look-up table (which is prepared and selected by the user), e.g. code 00000111 representing 7 - which references the seventh position of the look-up table and identifies the levels of RGB.

To use stores Red = 255, Green = 255 and Blue = 20 this would appear as a slightly desaturated Yellow.

So if the look up table is itself constructed from whole bytes, one for each primary colour, it implies that each table entry is described in terms of one of 256 levels of RGB. Hence any colour is specified in terms of 0 to 255 levels of RGB which in total supplies approximately 16.7 million colours (256*256*256). Due to the fact the byte can only store 256 codes, there are colour display devices capable of displaying 16.7 million colours but only 256 simultaneously.

To extend the range of colours even further requires more memory allocated to a pixel but the memory size and associated electronics often demands for it to be separated from the terminal. The resulting piece of equipment is called a frame store, called thus because it stores one television image a frame, in digital code.
The best way to envisage a true colour frame store is as 3 planes of computer memory which individually hold the 3 colour separations. These planes of memory constructed from bytes are electronically scanned every 1/25th of a second and supply the colour signals eventually interpreted by a colour monitor. The look up table is still used as it provides extra flexibility in changing colours. Normally the look up tables hold values ranging from 000 to 255, so that the values held in the memory planes generate the same number after being indexed by the tables. For example if a memory value had been 36, the 36th position of the look up table would also store 36 thus very little is achieved; but if the look up table entries were altered there would be an instant change in the colours displayed upon the monitor. This technique is called false colouring and is used in the image processing of satellite and medical systems, but also exploited by TV graphics effects. For example flexibility to a designer of textiles whereby a simple interactive command with a frame store could instantly alter colour combinations displayed upon a monitor. So a frame store is nothing more than a block of memory interfacing the computer to a colour monitor.

Colour description for Computer graphics

The use of the RGB colour cube.
Premise that any colour can be composed of different amounts of RGB. (This is not strictly true but it is good enough to get the effect.) A set of 3D Cartesian axes can be constructed along the lines of a 3D axis (no negative values). So any pure colour can only exist on that axis and the further away from its axis the brighter it becomes.

Printers and Plotters

Printers and Plotters are output peripheral devices and therefore must be connected to the computer by the use of cables and a suitable interface. The two most common are:-

- Parallel Interface Connection
- Serial Interface Connection

Parallel Interface Connection
Data is sent from the computer to the buffer along several lines.

Serial Interface Connection
Data is sent from the computer to the buffer along one line.
The ratio at which data is transferred to the buffer using a serial interface is measured in Bits/second often referred to as the BAUD Rate. BAUD Rates used by printers and plotters range from 110 to 9600 BAUD’S. It is essential that both Computer and Peripherals are set to the same Baud rate.

These two devices are the commonest way for the CAD operator to produce Hard copy of his work or more simply paper drawings. Essentially it is the transfer of data from the computer to paper. There are two basic methods:-

**Screen Dumping**
The screen contents are scanned by the program to determine the state of each individual pixel i.e. whether they are on or off. This information is fed to the printer and where a pixel is on a mark is made by the printer on the paper. This type of drawing is not to scale or drawn to any unit of size. It is only really suitable for a visual record of work done and for a cheap means of proof checking.

**Line Plotting**
There are two types:-

- **Vector Line Plotting**
  Program determines X and Y co-ordinates of lines to be plotted and marks the paper with vector lines between appropriate co-ordinates.

- **Raster Line Plotting**
  This method can be regarded as a screen dump using a plotter. Drawing data is sent to the plotter one line at a time. The state of each individual pixel is determined and if a pixel is on, the plotter marks the paper.

It may be necessary to convert screen data to line plotting data dependant upon which type of monitor is used to create the CAD drawing.

<table>
<thead>
<tr>
<th>Type of Monitor</th>
<th>Vector Line</th>
<th>Raster Line</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Tube</td>
<td>No</td>
<td>Convert</td>
</tr>
<tr>
<td>Vector</td>
<td>No</td>
<td>Convert</td>
</tr>
<tr>
<td>Raster</td>
<td>Convert</td>
<td>No</td>
</tr>
</tbody>
</table>
Printers

They are classified by the method employed to actually produce marks upon the paper.

- Impact Printers.
- Imaging Printers.
- Or may also be referred to as either Line Printer or Page Printer.

Line Printers
This type build up the image one line at a time similar to the Raster principle. This type usually have small buffers in the region of 2 KBytes.

Page Printers
This type assembles the complete drawing in the buffer and then produces the complete page in one action. This type therefore has large buffers in the region of 2 MBytes.

Impact Printers
These all mark the paper by impacting through an inked ribbon onto the paper or by shooting a jet of ink directly onto the paper. They all suffer from staircasing of diagonal lines, arcs and circles.

Dot Matrix Printers
This type uses a printing head which traverses the paper. The paper is moved upwards at the completion of each line of printing. The print head has a set of vertical needles which can be individually pressed onto an inked ribbon which produces dots on the paper. The 'resolution' of the dot matrix printer is determined by the number of needles in the print head. Printers with 24 needles give the best results. Capital letters produced using only the top 7 pins, lower case letters are produced using either the top 7 or bottom 7 pins dependant on whether the letter uses an ascender or a descender.

These printers can operate in 2 modes:-

- Draft
- Near Letter Quality NLQ
- In draft mode the head passes across the paper once for each line of text or graphics.
- In NLQ the head has two passes for each line but on the second pass the paper is
moved by a half dot position.

**Daisy Wheel Printers**
These printers employ a wheel of characters which is turned to the correct position. A hammer then strikes the wheel spoke onto an inked ribbon which marks the paper. This type only produces Letter Quality text. Essentially they are electric typewriters without a keyboard.

**Ink jet Printers**
These are worked by pumping out a jet of ink from a nozzle as the printing head passes across the paper. The 'resolution' of this type of printer is dependant upon the number and the spacing of nozzles used in the printing head. If these 4 colours; black, magenta, cyan and yellow are mixed in the printing head it is possible to produce screen dumps with up to 64 different lines colours.

**Thermal Printers**
These are similar to dot matrix printers but the main difference is that the pins in the printing head are heated. The heated pins melt a wax coating on the ribbon and this marks the paper. It is possible to produce colour drawings by using different coloured ribbons. Line quality can be very good if a high density printing head is used. A special heat sensitive paper may be used with this reacts with the paper to produce the marks. Thermal printers can give excellent results but are expensive both to run and purchase.

**Imaging Printers**
These are page printers which work in a similar way to an office photocopier. Screen data is sent to the printer which builds up a bit map in the buffer. The main part of any Imaging Printer is an electrostatically charged drum which is sensitive to light. If light is allowed to hit the drum the charge is reversed. The light source is turned on or off controlled by the contents of the bit map. The sheet of paper is passed under the drum and picks up the electrostatic charge from it. The paper passes a magnetic roller on which toner is deposited. The toner sticks to the charged areas of the paper. The paper is then heated to 'melt' the toner to 'fix' the image onto the paper. The three types of imaging printers that are described differ only in the method used to scan the information dump.

- Laser Printers
- LED Printers
- LCD Printers

**Laser** stands for Light Amplification by the Stimulated Emission Of Radiation. The light source in this
The type of printer is a small laser which is switched on/off by the contents of the bit map.

**LED** stands for Light Emitting Diode. The scanning device of this printer consists of an array of thousands of tiny LED's. Individual LED's are switched on/off dependant upon the state of the bit map.

**LCD** stands for Liquid Crystal Display. This type's scanning device consists of a fluorescent light shining through a long narrow LCD shutter which flickers on/off to selectively block out the light hitting the drum.

**Plotters**

Classified by the method employed to actually produce the marks upon the paper. There are two main types and these are:

- Pen plotters
- Electrostatic Plotters

**Pen Plotters**

These move a pen around in the X and Y axes. When a line is to be drawn the pen is lowered onto the paper. Line thicknesses and colour may be altered by changing the pen.

There are five types of pen plotters in common use and each has a particular use.

<table>
<thead>
<tr>
<th>Pen Type</th>
<th>Line width</th>
<th>Pen Speed</th>
<th>Line Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre Tip</td>
<td>0.3-0.7mm</td>
<td>300mm/s</td>
<td>Excellent</td>
</tr>
<tr>
<td>Ball Point</td>
<td>0.3mm</td>
<td>600mm/s</td>
<td>Average</td>
</tr>
<tr>
<td>Roller Ball</td>
<td>0.3-0.7mm</td>
<td>350mm/s</td>
<td>Good</td>
</tr>
<tr>
<td>Ceramic Tip</td>
<td>0.3-0.7mm</td>
<td>300mm/s</td>
<td>Excellent</td>
</tr>
<tr>
<td>Liquid Ink</td>
<td>0.2-0.7mm</td>
<td>500mm/s</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

The best plotting results must be taken to match the pen type to the paper used.
Flat Bed Plotters
These can be used to produce drawings from A4 to A0 in size. The solenoid unit and Pen Holder is moved to the correct position by the X and Y drive motors which are of the Stepper Motor Type. The solenoid is energised to lower the pen onto the paper to draw the line.

Drum Plotters
The drum is driven backwards and forwards to provide one axis of motion. The pen holder is moved across the paper to provide the second axis of motion. Large drawings may be plotted using a continuous roll of paper.

Pinch Plotters
This is a mix of the previous two plotters. The paper is driven backwards and forwards by the pinch rollers and the pen is moved over the paper by the carriage unit. Mainly used for drawings up to a maximum of A3 paper size.

Electrostatic plotters
This type have a large number of fixed writing heads under which special paper or acetate film passes. If a mark is to be made the appropriate writing head places a charge on the paper or film which attracts toner to make the actual marks. Multi-coloured drawings are produced by passing the paper or film through toner baths of appropriate colours.

This type of plotter produces a drawing using the same principle as the Raster display. Drawing Data is sent to the plotter line by line, starting at the top left hand corner of the drawing and moving across and down to the bottom right hand corner. These plotters can be up to two metres in width and are ideal for very large drawings.

What output device?
Prior to deciding on which type of printer to use in a CAD system it is worthwhile considering the following requirements:-

- Quality of Printed Output
- Size of Paper
- Type of Paper
- Accuracy of Printed Image
- Speed of Printing
- Cost
Buffers

Speed of data transfer from the computer to a printer or plotter is extremely fast compared with the speed at which the printer and plotter can react and produce the hard copy. It is for this reason that all printers and plotters are fitted with a buffer. This acts as a temporary Storage Area. It can vary in size such as 2 KBytes to 2 MBytes. The larger the buffer the sooner the computer is released to perform other tasks.

2.17.3 Storage Devices

The Computer

There are basically three types of computer:-

- Mainframe
- Mini
- Micro

The micro computer is usually a standalone system and there are various types of processors used. These are:-

- 8080 XT type
- 8086 AT type
- 386 type

While all the above are suitable for single item draughting only the last is suitable for modelling or work connected to Industrial Design/Product Design.

Computer Operation/Principles

Basically the modern computer should be viewed as a simple calculating machine, controlled by a memory unit storing a sequence of instructions which it obeys. The stored instructions are called the program, and are held electronically within the computer's memory. The larger the memory, the more instructions can be held, which implies that the machine can be used to undertake larger sequences of computation. So it can be seen that a computer system consists of two basic elements: the hardware is the electronic machinery that undertakes the calculation and manipulation of numbers, whilst the software is the sequence of instructions driving the machine and no matter what hardware
you buy, without the software the machine is unable to operate.

A computer operates by using sequences of electrical pulses of equal duration and during one unit interval of time a pulse is either detected or not. So the code assigned to an item is a sequence of pulses...1 or nonpulses...0. For example the letter A is 11100001. Electronically the signal would look like a wave form.

Each pulse position is called a ‘BIT’ (BINARY DIGIT).

The relationship between code combinations and bits is very simple and is represented by the following formula

\[2^{\text{BITS}} = \text{Code combinations.}\]

This means that if 2 is multiplied by itself Bits number of times, the answer produces the code combinations. So to encode the 26 letters of the alphabet, one requires at least 5 bits, providing thirty-two different code patterns, but a computer must also be able to handle numbers, which implies the need for an extra ten patterns 0 to 9. Therefore six bits would be required giving 64 codes, which is more than adequate. The spare patterns are in fact used for other symbols such as : * ú $ % etc.

This cluster of bits is called a byte, giving 256 code combinations. (This figure also relates to how many colours are encoded, in graphic systems because bytes are also used to encode colour information hence the option in some packages of 256 colours.) The fundamental structure of the computer code is the byte, which can encode all the possible symbols (upper case and lower case). The most popular coding system employed within the computing industry is ASCII: the American Standard Code for Information Interchange.

Modern computer memories are fabricated upon Silicon chips which are capable of storing tens of thousands of bytes of data. Apart from storing numbers and text, the memory must be capable of holding the instructions which ultimately drive the machine. To encode these instructions and their references to the computer’s memory, more bits are necessary. So by joining four bytes together and getting 32 bits you enhance the speed of operation. This cluster of bits is called a word and holds one machine instruction. So on a 32 bit computer each instruction requires 4 bytes to hold it whilst on a 16 bit machine requires 2 bytes. The 32 bit machine will operate faster.

Memory size is always specified in terms of its byte capacity, a special notation has evolved due to the sizes concerned. The notation involves the letters ‘K’ and ‘M’
1 KByte implies 1024 bytes
1 MBytes represents 1048576 bytes or \((1024 \times 1024)\)

The reason for this stems from the way in which memories are fabricated, which is in the form of a matrix of electrical elements, notice that \(32 \times 32 = 1024\).

Digital computers use the binary number system so data is stored in the form of binary digits (bits). To ease processing, data is handled in strings of bits or words e.g. one word may be 8, 16 or 32 bits and in a larger computer 64 bits. Depending on how the data is handled, this in turn relates to the size of the main memory of the computer through direct addressing.

Formula for the memory capacity is \(MC = 2^N\)

where \(MC\) = Memory Capacity
and \(N\) is the number of bits/word.

The main memory size is important as at any given time it must contain the instructions in the program being executed however programs are paged in and out of memory from the disk as needed. This in turn creates a need to know how fast those instructions can be accessed. Speed naturally relates to cost and is based on advances in semiconductor technology, as such bipolar is faster than MOS which is faster than core in semiconductor technology. A solution to running large amounts of instructions in a computer with a small main memory is to write the program in many small modules in a technique called overlaying. Thus each module can be called into main memory from an auxiliary memory and written over previously called up modules. There is another technique that accomplishes the same thing automatically which is called virtual memory. This works by continually swapping information between main and auxiliary memories which makes a small computer appear to have a much larger main memory. The most common swapping technique is called paging. This implies the processing capability of the computer will determine the productivity of the work station.

The computer and other necessary parts are all mounted on a single board called a Motherboard. The motherboard has several expansion slots to which expansion cards are fitted. Thus connecting them to the system, for example, serial cards and disk controllers.

The motherboard will contain the following:-

- CPU
• RAM
• Math Coprocessor
• ROM
• Input/Output Ports
• Expansion Slots

• CPU: Basically the brain of the computer. It decodes the program and performs the instructions within the program.
• RAM: Used to store programs and data, 640K - 16 MBytes
• ROM: Factory set data can only be read from the chip. It is used to hold the Basic Input/Output Instructions (BIOS).
• Maths Coprocessor: This has to be fitted for CAD operations to help with the calculations by speeding up the whole process.
• Parallel Port: Used to send data to external devices such as printers.
• Serial Port: Used to send (Output) and require input data from external devices for example a plotter.
• Keyboard Connection: Self Explanatory
• Monitor Connection: Monitor graphics card uses one of the expansion slots or is part of the Motherboard.
• Expansion Slots: Set of expansion slots that allow add-on boards to be fitted such as Memory Expansion Boards.
• The motherboard however does contain other essential components necessary to run the computer but they need no further explanation for the purposes of CAD awareness.

Processor Types

CPU Types:

• 8086 Processor - 4.7 MHz to 8 MHz - 8 bit processor - PC or XT IBM type computer or compatible
• 80286 Processor - 8 MHz to 20 MHz - 16 bit processor - At IBM type computer or compatible
• 80386 Processor - 16 MHz to 32 MHz - 32 bit processor - IBM PS80 or 386 type computer or compatible
• 80386SX Central Processor Unit: All the benefits of the 32 bit 80386 processor but at a much lower cost. Suitable for CAD
• 80486 CPU: Latest replacement for the 80386. The clock speed is 25-33 MHz plus very high
processing power making very suitable for CAD especially 3D work.

**Hard Disk**

The hard disk can store between 20 & 320 Mb of data. It holds the CAD programs and all the drawing data.

Mass Storage device - main parts are the Head motor, heads, disks, disk motor, motor controls interface to computer.

Data is sent from the computer to be stored (write) on the hard disk or is sent (read) from the hard disk to computer. Read data is read off the hard disk and write data is sent to the hard disk.

**Terminals**

This is an input/output device and it provides a link between the user and the central computer. There are two types of terminal in common use:-

- Dumb Terminal.
- Intelligent Terminal.

**Dumb Terminals**

These are not computers. It can only input or output data to the central computer. Any processing of data is performed in the central computer. The continuous transmission of data which causes delays makes the dumb terminal unsuitable for CAD use.

**Intelligent Terminals**

These have their own local processor which can carry out a number of tasks independently of the central computer.

The main CAD programs would be loaded in the central computer with certain functions such as the screen handling functions for example Zoom, Pan being passed to the terminals processor. Local processing is performed at the terminal. When CAD commands such as SAVE or LOAD are called, the terminals communicates with the central computer and the processing is performed by the central computer.

Terminals are connected to the central computer by one of the two methods:-
Direct Connection (Hard Wiring)

This method is only useful over short distances. The terminal and Central computer are directly connected to one another using cables and suitable interfaces. A further limitation of this method of connection is that each terminal requires a separate cable linking it to the central computer.

Modem Connection

This stands for MOdulator DEModulator. It is an input device. Digital serial data from the terminal/computer pass through the Modem, becoming Analogue data to the distant terminal/computer then back to digital data.

Data Storage Devices

A project carried out on a CAD system will consist of more than one drawing and although the data is produced in the computer's memory RAM it is necessary to have some method of storing this data in such a manner that it is kept safely and is also easily accessible if required at a later date.

Floppy Disks

Two types

- 5.25" Capacity 360 KBytes or 1.2 MBytes
- 3.5" Capacity 720 KBytes to 1.4 MBytes

These are mainly used to store drawing files as a back up to the work stored on hard disk. Files stored on a hard disk can be transferred or copied to a floppy as a back up in case of mains failure or fire.

The read/write heads of the disk drive move across the disk to store the contents of a file on the disk (write) or to extract the contents of a file (read) when requested by either the program or the user via the computer.

Hard Disks

They have a capacity from 10 Mbytes to 120 Mbytes. The magnetic disk is contained in a sealed unit.
but the read/write heads move in the same manner as in a floppy disk drive. It is essential for CAD work due to the size and complexity of the programs.

**Tape Storage**

Two types:-
- Streamer Tape
- Tape Cartridge

Both of these types of storage device store data sequentially and are therefore ideal for the mass storage of data. The streamer tape is generally used to store the contents of a hard disk at the end of a working session. The cartridge can be used as a working store but suffers from very slow access times compared to a disk.

**Network**

A network is a communication system connecting a number of computers via which data may be shared. There are many types of network in use but they all have the following characteristics.

- A large number of computers can share a single peripheral printer thereby reducing hardware costs.
- Computers may work independently of each other or share data via the network.
- The network must have a controller which connects the computers and peripherals together. The controller may also contain common software for use in the network.
- There is no limit other than cost to the size and complexity of a network.

**1.3.1 Process of Justification**

Review of how all the steps in the earlier stages interacts/could interact with each other. For example comparisons between:

- Needs against Capabilities
- Financial Status against Costs

There are two basic ingredients to the justification process - Money and the type of Work and the two
types of justification processes are therefore the Financial and Technical Justifications. The company has to have sufficient financial resources to cover the costs of a CAD system which meets its requirements. It also must have the type of workload that would benefit from the transfer from manual methods to computer methods.

1.3.1.1 Costs

The important point to remember is that when you invest in a CAD system, getting it right first time is imperative. The cost of failure is high. Investing in a CAD system is a serious and costly decision which can bring enormous benefits if company management make the effort to examine the whole business and consider the potential strategic impact of CAD.

There are different types of cost involved in the purchase of a CAD system and they have their own aspects associated to them. The different types of cost are:-

- Justification
- System Purchase
  Justification of costs for:
  - Starting up
  - Continuation
  - Maintenance
- Service Contracts
- Training
- Office Adjustment
- Maintenance - what is required
  - Continuation/maintenance -
    - Service contracts
    - Parts breakdown
    - Levels of maintenance -
      - In house repairs
      - Skilled

In the planning stages for CAD the issue of cost is a very important factor. It is often the main deciding criteria for either the continuance with the purchase of the system or the level and type of the system finally purchased. The type of cost first encountered when purchasing a system is connected with the justification of the system. This is an area where potentially, mistakes can be
made, especially if using traditional costing procedures.

Any cost justification exercise needs to start from a clear definition of what it is that we are trying to do; that is, the establishment of a set of objectives against which the project can be measured.

A Design Consultancy has to be a viable business concern just like any business today, and it, more than ever, is about continuously improving the "competitive edge".

Cost Justification is essentially about comparison but it is becoming increasingly obvious that present day Costing and Accounting Systems do not always provide useful benchmarks against which to measure the potential of new ideas. Current systems often base all costs on Direct Labour hours, regardless of the fact that these have shrunk to only 10% - 20% of total costs by the application of JIT and other techniques. The division or allocation of large overhead costs to these small amounts leads to difficulties. It is also not entirely satisfactory to use Machine Hour rates. This is a situation not so applicable to a small Design Consultancy where there are not so many indirect labour costs and all labour is more closely connected to related working costs. It is not the case, therefore, that justification can be based around comparison with staffing costs. However there are some considerations on staffing that do have to be considered and so once having defined work flows within the company these considerations are:-

- How many staff will use the system?
- How will you select them?
- Are they interested in CAD?
- Do they have the appropriate skills?
- If not, how will these skills be developed?

The single most important factor in successful personnel selection for a CAD system is enthusiasm for its implementation.

1.3.2 Financial Justification

Financial appraisal is, of course only one of the tools used in the justification of investment. It is the most difficult to use but often the first to be applied. It is important that the accountancy and financial sectors of a company are both fully aware and fully committed early on, as questions of justification may need considerable effort. It is also important to agree early on upon the financial appraisal methodology, the contents of any financial model, and the basis of all the forecasts used in the
process. The financial appraisal is basically the prediction of the financial results which will be produced by a project over a period of its own lifetime, the comparison of these results with general go/no go criteria target guidelines, and finally the integration of these predicted results within the wider framework of company forward planning to assess the effect on the Profit and Loss Account and Balance Sheet, which is where the translation of one accounting conversion to another becomes difficult. So what is basically meant by Financial Appraisal or Financial Justification is that it is a simple calculation of savings against costs carried out to justify the purchase of an item to produce a pay-back period.

Financial appraisal should be considered as being a three stage process.

1. Construct a set of predicted financial results for a new project on a standalone basis.
2. Comparison of the results of stage one with those factors representing existing arrangement.
3. On successful results of the previous two steps, the integration of such predictions into the more comprehensive accounts maintained by the company particularly into the forward financial projections which should be prepared as part of the full effect of the project, on the “bottom-line” can be assessed.

The appraisal needs to be made in a form which takes account of all revenue and cost generation activities - whether these be direct costs, indirect costs, or any other form of cost term which is being used by the company. This facilitates later integration into the predictions of Profit and Loss Accounts and Balance Sheets.

The object of financial appraisal is financial justification and justification aims at overcoming doubts and disbeliefs. It also covers "lack of conviction" rather than an outright rejection of proposals.

Project Time Scale is an important element in Financial Appraisal. Investment in a CAD system can be over a period of time and the factors involved need to be carefully considered. The economic life-expectancy of a new piece of equipment may differ from its effective technical life expectancy. By technical life expectancy I mean by its technical obsolescence. This is a factor which is changing drastically in the rapidly moving world of CAD. To assess this, companies use typical criteria such as setting targets for Simple Pay Back, or for Return on Investment, Internal Rates of Return and Net Present Values. This requires the use of analysis techniques.
The most common method is Simple Pay Back - that is the time taken for savings to recover the investment. It is the most simple to understand and to calculate. The drawback here is that no account is taken of the time value of money or the actual technical or economic life of the system.

Another form of simple analysis used is to assess the Return on the Funds Invested (ROFI) which is calculated in a similar way to Pay Back although it is expressed in the opposite way. The time value of money and the life of a project can be taken into account by using discounting methods. Both Internal Rates of Return (IRR) and Net Present Value (NPV) techniques have their advantages and disadvantages. They are reportedly becoming more commonly used and are relatively easy to perform on small computers using the widening range of analysis software currently available. The problem with this is that it is unlikely that Design Consultancies would have this kind of support readily at hand. The first two methods of analysis are therefore the most suitable to be carried out by a Design Consultancy.

To carry out the evaluation of the quantifiable elements in a Financial Appraisal you first need to start by establishing a "Bench Mark" or "Reference" against which to measure the predicted results (savings) of the project. This is taken to be the "Status Quo" situation but to incorporate the time element, the "Status Quo" situation needs to be projected forward. This is difficult as no company can stand absolutely stationary and isolated from the outside world e.g. labour rates change, material costs change and the market changes. The "Status Quo" case for a Design Consultancy would be the case of doing nothing and carrying on as before. However, the cost of doing nothing is not as easy to establish e.g. how do you predict what not having the system will cost in terms of work contracts?

1.3.2.1 Aspects connected with Costing CAD equipment

In the justification stages for CAD the issue of cost is a very important factor. It is often the main deciding criteria for either the continuance with the purchase of the system or the level and the type of system finally purchased.

Competition with other companies is likely to be intense and rival companies will no doubt be equipping themselves with the latest technology as well. Marketing issues are likely to be more intense also. The alternative aspect to be considered is what happens if the company does not get the work increase as predicted? This has to be considered for the obvious reason of getting a complete overall picture for the appraisal.
Non-CAD companies often state that their working area is not suitable for CAD as they are in an area of one-off designs. This shows the ignorance about the potentials of CAD. It should be shown that even one-off designs have geometry or contain standard parts that CAD can handle more quickly and that some parts of a design can be used at a later date - all of which leads to better performance times than manual work.

When evaluating systems it should be remembered that the CAD system is not only as a solution for replacing the drafting board but it has a potential impact throughout the engineering, manufacturing process and modify how that process is organised to maximise the returns on the investment. This type of analysis should consider whether the system be used with dedicated operators or as a shared resource among a number of part-time users. What is the impact where manufacturing is involved in the design process during the concept stage, rather than once the drawings have been completed? What information can be passed to materials planning and finance systems during the design process so that cost optimisation can be considered?

Ultimately, the real value of the system is not the hardware nor software, but rather the value of the design and documentation databases and 'experience' stored within.

The system must be treated as a profit centre for which the only goal is to make money as fast as possible. If you measure volume you get output. If you measure efficiency you get activity, if you measure throughput you get profit: lower inventory, faster response, better quality, leading to higher profits - rather than outmoded concepts such as utilisation, labour efficiency, cost per part.

Accounting in modern manufacturing is currently in a state of transition, accompanied by some uncertainty. Ideas such as JIT have won almost unquestioned support, but the accounting systems to complement them are lagging behind. It is possible, however, to see common threads running through the new ideas. These include the trend towards overall performance measured rather than departmental costing, the use of several different accounting yardsticks rather than one, and the need to involve production staff in accounting processes.

The accounting methods discussed here show that the costing of CAD equipment is still in its infancy and it is understandable that companies are not using a truly practicable method for the cost justification for the purchase of CAD systems. It also suggests why, potentially, other feasibility studies carried out by companies have not been continued into system purchase and explain why some companies consider CAD too expensive for their company.
The justification has to be well balanced and any areas of objection should have responses clearly explaining how these can be overcome. It helps identify the cost areas and prevents the mistake of only acquiring the prices for the software and basic hardware then later finding out about the extras such as Computer Installation, training, computer consumables, colour graphics cards, maths co-processor, mouse or graphics tablet, output devices, maintenance contracts, software updates.

1.3.2.2 **Hidden Costs**

These are illustrated by examples such as Software, training, commissioning, maintenance.

These are principally caused by grossly underestimating the fundamental nature of the changes which are required. These span all facets of the organisation but especially attitudes, functional roles, resources and time.

One hidden cost is the cost of an incorrect decision caused by factors such as skimping on expenditure or incorrectly identifying the real needs of the company.

Unsuccessful CAD installations are often due to the wrong system being chosen and good benchmarking can avoid this.

Identification of your cost areas, prevents falling into the trap of asking only for the cost of CAD software and computer, only to find a complete installation demands more: colour graphics, maths coprocessor, mouse/graphics tablet, a plotter/printer, training, (post and pre purchase) maintenance agreement(s). Cost allocations might be withdrawn if hidden extras comes to light.

Cultural dislocation can cause productivity and losses can persist until fully operational.

1.3.2.3 **The Attitude**

The use of a CAD system requires/can require a different attitude to working methods. So the need for propaganda, training and personal development is paramount. These organisational changes and development of new attitudes are likely to be very expensive and most effectively achieved when driven from the top, down. A champion is required with the commitment and authority to drive development along. Without that champion it is likely that costs will be incurred in all manner of ways especially by delays in making decisions. When treading new ground many decisions, by their nature, are difficult and not clear cut. The champion creates essential momentum for change and
must be, in essence, an executive at the highest level in the organisation. To avoid delays and their inherent costs, the need for change must be understood by everyone. Pledges to carry out tasks must be made and kept.

1.3.2.4 Functional Barriers

Quality is not the preserve of any one working function. It has to be translated into specifications and standards to which everyone must pay heed to ensure their conformance is secure. Proper consideration of the term “design for manufacture” offers major economies.

I feel that with the growth and expansion of CAD, the company which does not follow the CAD route will soon stand alone amongst its competitors with CAD and, is likely to suffer accordingly. Keeping new designs within the envelope of the new processes is also vital but occasionally ignored. The whole ethos of separate design and production engineering functions should be forgotten and new concepts created.

1.3.2.5 Time and Resources

Hidden costs are bound to be incurred if appropriate efforts are not put into any development. It has been found that if the firm is successful in changing attitudes and generating enthusiasm for change, special attention should be paid to the assignment of time and resources as people take too much on and expertise only comes with user experience of the system.

1.3.2.6 Cost Prediction

When predicting cost benefits it is prudent not to predict grossly inflated cost savings and to use realistic assumptions and payback periods when carrying out a financial appraisal. There are difficulties when carrying out this work. The real problem is that it is notoriously difficult to get real information on the savings that can be achieved.

As explained earlier, payback to CAD expenditure in terms of staff reductions is not a good policy for either staff motivation reasons or what is now being recognised as suitable cost financial practices. A more palatable way would be to argue in terms of ways to maintain staff levels or prevention of further growth. This could be argued in terms of savings against the costs of company growth such as increased staff salary bills, greater space costs, more equipment and material costs.
Companies should use current work to derive a working budget and determine an approximate investment for software, including specialised application modules and libraries. Companies should do the same for hardware, including peripherals such as a plotter. This would be achieved by adding 10 to 30 per cent to cover training and start-up consultancy, also another 10 - 30 per cent for furniture and facilities.

Lower cost systems may require a higher percentage of extras. This is the total investment required. While it may seem that some of the nonsystem costs are high, remember the first six months are the most critical. Skimping at the outset in training and support will cost much more later and delay the effective return on investment. At the end of the justification process the company will be able to decide if it should proceed with the purchase or discontinue with it.

1.3.2.7 Quantifying the costs

The next stage is the quantification of Direct Costs and Savings. The direct costs of a CAD system are fairly straightforward to establish and assess. The direct savings from the CAD system are harder to establish and are partly dependent upon the individual company's particular situation. Pitfalls can arise on the cost side of the calculations such as estimates of the investment required - how many times does the initial cost estimate advanced by a supplier bear little relation to the final quotation?

1.3.2.8 How can these be quantified?

Some benefits are more easily quantifiable than others, the following are some of the more easily assessed benefits:

Increased Productivity - Work involving projects that require a great deal of repetitive work; modification or updating are real beneficiaries.

Shorter lead-times - CAD speeds up and concatenates the design-to-manufacture cycle, getting better products out to market faster, giving companies a competitive edge. Take the opportunity to open up new markets and produce more diversified and targeted products.

Improved Accuracy - Clarity and precision provided by CAD has all sorts of positive benefits. Eliminates ambiguity and gives designers confidence that their concepts will not be compromised. Better communications between engineers, designers, management,
Better quality designs - 

CAD allows designer time to try out "what if" solutions. Analysis, simulations and evaluation programs mean that 'no-hopers' are caught on the screen rather than later. Reduces the need for many prototypes to be made.

More accurate cost control - 

Easier to work out exactly how much a product will cost to make. Reducing stock and work in progress. Hard copy drawings take up a great deal of physical space - storing this information in a computer database makes it more accessible and more likely to be consulted and liberate valuable office space.

More and better information - 

Availability of DTP and related presentation technologies can be used to provide more and better information easing communication making it easier to sell their ideas.

The next stage is the quantification of Indirect Costs and Savings. These are often not so easy to quantify. Indirect personnel savings start with items like reductions in indirect personnel e.g. less intermediate supervision. It is also necessary to include the potential cost savings from other personnel reductions such as fewer inspectors and quality control checks.

One aspect of appraisal is the consideration of the unquantifiables. The analysis, quantification and summarisation of the above direct and indirect savings may or may not justify the investment when all costs, direct and indirect, are included. Therefore the next stage is trying to find "other" savings and this involves estimating figures for the items termed as "unquantifiables". The type of "unquantifiable" benefits that can occur are:

**Flexibility -** The ability to respond more rapidly to changes in products, enquiries and to be able to offer shorter lead-times.

**Improved Image -** The ability to react faster to clients' requests will encourage them to return with future work and possibly even to give favourable advertising to other potential clients.

**Improved Management Control -** Information can be more easily checked and copies of work/alterations can be conducted more easily.

One approach to deal with the benefit of improved flexibility is to demonstrate the effect on costs by comparison to previous work and relating to where it would have been advantageous.
The benefits gained from CAD lead to higher quality and service level, improved flexibility and ultimately higher productivity. Justification is made more difficult by the intangible nature of many of the benefits which are harder to assess and by their nature are intangible. Such as:-

Competition with other companies is likely to be intense and rival companies will no doubt be equipping themselves with the latest technology as well. Marketing issues are likely to be more intense also.

An alternative aspect to be considered is what happens if the company does not get the work increase as predicted? This has to be considered for the obvious reason of getting a complete overall picture for the appraisal.

How much is the ability to carry out changes worth? Cost justification is essentially about comparison.

There is an understandable preoccupation with the purchase cost of the hardware and software without considering the full cost in use over a typical five-year write-off period. The tendency is for smaller partnerships, unused to making large capital investments, to limit their choice to low-cost solutions which may not give them all the facilities they need, or take the drastic step of floating their companies on the stock market to raise enough cash to implement mainstream CAD throughout the office.

1.3.2.9 Developing Financial Justifications

Justification is not a matter of assessing savings in £ per task but is a far broader subject. Much of the benefit of CAD comes when data can be recalled and rapidly modified, or when data can be shared and accessed by staff other than those who created the data. Successful CAD demands confidence in the ultimate benefits of designing, documenting and manufacturing products within a system, not with a pencil and paper. There are many tasks which in themselves receive little benefit such as one-off drawings but there may be substantial downstream benefits in completely different departments. So it is important that department heads will have to adopt an unselfish attitude towards putting in effort for which they receive little in return and the question is who funds their staff to do this philanthropic work?

The basic rules are:-

- Do not rely on conventional cost-justification techniques.
• Traditional Return Of Investment does not work either.
• CAD is not another drawing board or photocopier.

If the company has decided on a global buy-in then it must have the approval and the support of the entire senior management very early in the justification. This may require a lot of persuasion to do this so it is important to look at the gains:-

1. Respond more quickly to market needs and reduce the time to get them to market,
2. Increase design, drafting and manufacturing productivity,
3. Improve quality and reduce scrap,
4. Provide benefits to other departments.

Take a 'top-down' attitude to benefit analysis. It is important to develop your own list of desired benefits and give them priorities and target dates for achieving them so you should consider what it is worth to the company:-

• There are still signs that companies perceive that possession can still be of value and there is still genuine competitive advantage in the mere fact of having CAD. Companies see that having CAD is technologically progressive promising a total quality view. So promoted this way, it can give a competitive edge over CAD-aware firms.
• Release new products 12 months earlier?
• Reduce your work-in-progress by £X
• To give every prospect the most outstanding proposal they are likely to receive from any competitor?
• What sort of reduction in scrap or rework can be achieved?
• The numbers used in your assessment can be seen to be numbers out of thin air but it depends on your depth of analysis of the company potentially, they could be very accurate.

1.3.2.10 Two-level support needed for the financial justification

Department Heads

Worry about manpower costs to use CAD.
Concerned over impact on committed task completion dates.
Directors

They should each visualise the opportunities for their own functions, whether Finance, Production, Design, Technical Publications.

Justification can be reduced down to the investment to match the anticipated benefits. That takes:

- An awareness and understanding of the technology at all levels.
- Reasonable (achievable) expectations in the short term.
- Confidence in the ability of existing staff to grasp and apply those CAD tools effectively.
- Confidence that the tools themselves will do the job.

So, does investing in CAD still make sense? Before proceeding any further, senior management must reaffirm their commitment to invest in this technology. There is nothing more frustrating for all involved than to go through a full evaluation process and then to find that management were never really committed to the investment in the first place.

Your basic investment should cover three basic areas: hardware, software and training. Having completely assessed why you actually need CAD, the justification will lead to a cost figure which will include all these basic requirements, plus any continuing development and consumables.

To help establish this it is useful to develop a portfolio of design, drafting and manufacturing work being carried out currently then define what the company wants to be doing over the next 2 or 3 years. This establishes the needs and helps to establish the budget.

1.3.3 Problems with the financial Justification

The type of cost first encountered when purchasing a system is connected with the justification of the system. This is an area where, potentially, mistakes can be made, especially if using traditional costing procedures. The benefits of desktop design have been well documented, but quantifying them so that they will convince a bank manager, a boss or accountant is another matter. The greatest failing of system suppliers and those budgeting for CAD systems is to concentrate on a once-and-for-all purchase of hardware and software. Experience has shown that computer hardware becomes obsolete quickly, and better software solutions appear all the time, so that a continuing investment must be maintained with provision for improvement and replacement. One way of doing this would be to develop a pattern of growth, with a minimum of two workstations to allow training to
proceed alongside productive work. System costs over five years account for less than 20 per cent of the total running costs, and they are falling. Running costs include training (a frequent reason for not achieving a planned improvement in productivity is failure to spend enough money or spare enough staff the time for adequate training), maintenance contracts, insurance, consumables, provision of backup facilities, software updates and hardware expansion. And a low-cost solution could work out to be a bad buy in the long term because of the correspondingly lower levels of support available, the lack of networking and database management and the memory/speed limitations. When a low-cost solution has been opted for this lack of foresight will mean that a first system will either gather dust in the corner evermore or, more likely, be expanded enormously soon after purchase of the pilot system. The world is full of frustrated users awaiting delivery of the next few workstations. Even now there are few companies that can specify the bottom-line quantifiable benefits of a CAD system. The failure of traditional accounting systems to throw any real light on the value of new technology is also mirrored in cost accounting systems.

Top management's in Britain and the US still believe that the only proper justification for investment is the ability to demonstrate financial 'payback' in terms of measurable cost savings over a short period or by means of discounted cash flow calculations. This was the reason that suppliers attempted to sell their equipment on the grounds that it would save their customers substantial costs in terms of the draughtsman's labour.

The organisational implications of Information Technology, the quality of working life and expectations of staff are often skated over.

1.3.3.1 When CAD is seen as a means of reducing drawing office labour.

Traditionally in the case of CAD, the difficulty of justifying investment in CAD has led the people responsible for the justification process to use very high estimates of productivity improvement, with ratios of three to one being commonly quoted. This implies that once CAD is fully implemented, two thirds of the existing staff would no longer be required. Some companies have used even higher ratios, such as four to one, implying even greater labour reductions.

This sort of justification has needlessly to say, reduced the chances of an enthusiastic and effective implementation of CAD, and when, as inevitably happens, the labour savings are not achieved, management is tempted to blame an uncooperative workforce rather than accept that the original estimates were unrealistic. Although there will be some tasks which provide high productivity improvements, this will be offset by the fact that draughtsmen may only spend about a third of their
time at the drawing board. In fact there was no evidence to suggest that CAD has resulted in redundancies. In fact, the claims of improved productivity are highly subjective and of doubtful validity with virtually no factual evidence to scientifically quantify the effect. Interestingly in Design companies those who were working with CAD have intended to maintain their staffing levels and increase work load rather than reduce staff. However, it could be argued that their justification was still based on a reduced work staff as they would have required more staff if using manual methods. In some cases the price of the CAD equipment purchased was based on the cost of hiring new staff for expected workloads.

For example, suppose a CAD system is being appraised which will save five jobs in the drawing office, speed up lead times and increase flexibility and quality. Most companies would quantify the savings in jobs making no attempt to quantify the intangibles. In consequence, when the system is introduced, the CAD operators are unhappy because jobs are being lost and the unquantifiable benefits go unmeasured. Moreover, because drawing often accounts for a low percentage of a product cost, the investment cannot be proved worthwhile in the first place. One of the features of CAD or MRP is that the benefits can take two or three years to appear. When they do appear, they will probably occur somewhere else in the organisation.

In the case of a consultancy, the advantages talked about could manifest themselves further down the line, for example in the clients production cycle. The consultancy might not be able to identify whether these advantages had occurred unless they had some analysed feedback from their clients. Indirectly, it could mean that they gain further business from the client in the future but this would be an intangible factor. One company I visited stated that on the introduction of a computer system that offered combined CAD with CAM facilities, they found that design costs had actually increased. This factor under older accounting systems would suggest that the Design Department was actually being inefficient in its working. However, the savings appeared in the Manufacturing Departments and the Quality Control Departments. The Design Manager had to press the Heads of these Departments to analyse why they had found improvements. It was only then that they established it was due to the improved performance of the Design Department attributable to the use of the new CAD system. The company concluded that they would have to adjust their accounting methods for departmental budgets.

Problems with financing CAD projects can be compounded by the 'hidden' costs - software, training, commissioning, maintenance. Until operators are fully conversant with the system, this affects true efficiency being realised and causes productivity losses which can persist for a year or more. The benefits of a system are clear; higher quality and service level, improved flexibility and, ultimately,
higher productivity. Not all these gains fit neatly into the cost categories of materials labour or energy - thus making the problem of justification much more difficult by the intangible nature of many of the benefits. Where a project does not meet the required justification criteria, the 'gap' in money terms between viability and nonviability be tabulated and 'traded-off' against the intangible benefits for example if an extra £10,000 would make the project viable, are the benefits of increased flexibility worth this amount over the life of the project?

The effective introduction of CAD can guarantee competitive survival, but for many design firms perceived costs, difficulties, and threats to 'creativity' prevent it.

CAD, when effectively introduced, can guarantee competitive survival but many design firms still see the negative issues which prevent its introduction such as perceived costs, difficulties and threats to creativity and for a company champion to be appointed to help prevent the costs of indecision. Enthusiasm is not enough and a step-by-step guide is necessary to explain, in practical business terms, what is necessary. By promoting the possession of CAD as a technologically progressive stance offering a total quality view it can give some competitive edge over non-CAD users. Business could then possibly be gleaned from other companies using CAD.

Incorrect procedures for CAD selection causes unrealistic expectations and needs. This can result in the incorrect choice of a CAD system which can give rise to the legends of CAD horror stories. This is where mistakes often occur. Solutions to this type of error are proper training and good benchmarking. It should always be pointed out that Computer Aided Design is what it is all about and that it encompasses all the other aspects of design work and not just draughting. The computer system could be used for other tasks - DTP, databases, spreadsheets or analysing.

When deriving the estimates for the justification process it should be stressed that it is important that realistic figures be used so that you can make realistic assumptions and expectations of payback. The danger is by predicting huge cost savings there will be establishing the grounds for those opposed to the system to say that the system has failed. Another form of justification that should be avoided is it should not be made by using a reduction in personnel as this causes decrease in motivation and increases resistance to change.
1.3.4 Technical Justification

1.3.4.1 Developing the Technical Justification

Apart from financial justification there is also technical justification; a subject that should be run concurrently. This is because it is necessary to consider the circumstances of the system either not working or not working as well as expected as they are part of the financial appraisal. So to make the financial appraisal effective, it is important that the criteria on which the Yes/No decisions are to be made are quite clear. The technical justification needs to address the question “What if it doesn’t work as well as predicted?”.

So once the company has defined the environment of benefits, work flows and staffing the system will be operating, it is useful also to consider the particular functional capabilities needed to achieve those benefits. The following checklist is worthwhile considering:

- Drafting 2D & 3D;
- Modelling - wireframe, surfaces and solids;
- Structural Analysis;
- Product Visualisation;
- Availability and flexibility of standardised parts and assembly libraries;
- Drawing Management and retrieval;
- Ability to interface with other in-house software as well as exchanging information to customer/supplier systems;
- Specialised applications software systems;
- Ability to tailor your system, its commands and their database to meet changing requirements.

CAD linework is often stated as a cold format and that it does not have the aesthetic appeal which a good manual drawing has. Imaginative use of the line thickness parameters and plotter settings can go a long way to remedy this and, once a drawing has been plotted, it can act as a base for human touching up if that is what is required. CAD users would also point out that if a manual drawing has had more than one draughtsperson working on it then it is always possible to see the joins no matter how good the designers are. A CAD drawing would not.
1.3.5 What else needs to be considered?

Choosing a supplier can depend on the industry experience they are able to provide, the quality and level of support and the hardware they offer. Apart from the actual system then it is good to consider who will be the system seller. Consider carefully both larger and smaller vendors. Large vendors may have a breadth of capability and services; smaller vendors may offer more tailored niche solutions.

Recommended methods for doing this are:

1. Ask each vendor to provide budgetary quotes to include necessary hardware, software (including applications), training and implementation consultancy for years one, two and three. Training should be complete for two people per VDU, plus one or two persons to act as system managers.

2. Plan for training additional staff due to turnover, new projects and applications.

3. Test vendors with benchmark samples of real work. Get them to explain how they use any special techniques such as macros or applications.

4. Judgements that the company has to make about the vendor:
   - Do you think the vendor has the ability to meet your requirements?
   - Check with customers of vendor.
   - Is 'hot-line' support available?
   - How reliable is the vendor in terms of his commitments?
   - What is the quality of system and training documentation?
   - What is the procedure for hardware maintenance?
   - Who is responsible?
   - If dealing with multiple vendors, who is responsible for overall problem resolution if the problem is clearly attributable to hardware or software?

A positive customer base is one of the best signs of a good vendor and system. Invariably the final decision will be a compromise based on many factors: system functionality's, vendor capability and cost are the three major factors. In today's difficult economy, cost may seem most important. In general, it is not. Placing yourself with a good dealer will help you to avoid the larger problems; however, there will be some aspects involved in the introduction and set-up of your CAD system which your dealer may not be able to help you with.
A CAD system will be with the company for a number of years and potentially have a profound impact. Its main worth will not be the immediate cost of the hardware and software, but rather the 'intelligence' and information contained within its databases. These accrue and increase in value over time.

When choosing a CAD system, selecting the correct vendor can be as important as selecting the correct software. A supportive vendor will continually show the customer how to receive the maximum benefit from his investment over time.

1.3.6 Should we be bothered by what other people have got and why?

When the company is in the process of selecting a CAD system it is very useful to be aware of what is currently being used by the companies rivals and clients. The work involved in doing this should take place during the evaluation stage of the selection process.

1.3.7 Preparation on how to evaluate the system once purchased

1.3.7.1 Is the purchase a success?

Few companies ever carry out a post-installation audit to see if the projected savings matched the actual ones. In any case, no-one who values their job wants to have to admit that an installation they recommended is a financial failure, so the original report is usually conveniently forgotten and, usually, the investment itself is given no more thought. One part that unites the two justification processes is the establishment of the success of the system. So, while conducting the justification processes, companies should define how the success of CAD investment will be measured and draw up a time-frame for achieving this success. It would depend on what results any one company is looking for and when they need them by. The company will have to determine the timing, cost and complexity of the system and its implementation. They must calculate the expected financial benefits of a CAD installation and how quickly these are attainable. This will be achieved by concentrating on the value of the benefits the company originally specified as being important to the organisation but they should remember to allow for a learning period. However, when evaluating the system it should be realised that some of the major benefits of a CAD/CAM system are not easily quantifiable. How do you determine the value of catching an error during the first week of a design programme rather than two months into it; or the value of being able to pass design data directly to suppliers rather than just send them drawings, for example?
2.1 Aspects of Management in the Selection Stage

Timing of the study.

Problems of balancing the complexity of the task and the rapid change of the market place can arise here by not keeping the System Specification to a reasonable size.

Anticipating realistic performance figures.

The error of these early assumptions led to the apparent failure of these systems when an evaluation stage was carried out to assess the system.

Senior managers should be involved in the initial stages of implementing a CAD project when the reasons for adopting CAD and its potential impact on the business are being determined. Whereas in practice, senior managers have their greatest involvement later in the project when money is being spent, and that unfortunately is the stage that has least influence on the CAD system implementation.

The changing aspects of computerisation brought about the development of its own practices and implementation methods and tend to reflect the manner in which the new technology operates.

CAD systems should mirror the changing needs of the business at the rate the company changes.

Short development cycles and small, flexible teams are the answer.

Large projects best split into manageable modules.

Only some tasks, such as using parametrics to produce general arrangement drawings, give substantial gains but there are many others where the gains are only marginal.

The method of working is not the only aspect that requires rethinking. The justification of new equipment also means the need to re-evaluate the costing procedures of the accountants.

If draughtspeople only spend a third of their time working on a drawing board then even if CAD could eliminate this time completely the productivity gain would still only be 1.5:1.

It is an error to rely principally on Drawing Office savings to justify CAD. This is because when the company is in the situation where it will soon have to replace the CAD system, probably with a more sophisticated and expensive system, the failure of their first system to make any significant labour savings means that the drawing office managers would have no credibility if they tried to justify replacement with claims of further DO savings.

The assessment of the other areas in which CAD helps is one way that new costing principles can be
devised.

CAD is able to produce benefits for a company outside the Drawing Office, the problem is in identifying them in a financial justification is only part of the problem. Managers also have to be able to select a specification that allows them to achieve these possible advantages.

It has been known for a long time that CAD has other more realistic benefits but they are often considered as intangibles and therefore regarded as unquantifiable.

All intangible benefits that can be identified can be redefined into quantifiable terms and included in a financial evaluation.

One way that these intangibles can be appraised is :-

When the sales of the company increase and that it is due to using CAD then that increase can be evaluated against the costs of the design department.

The problems of using outdated methods are illustrated by the following:-

Part of the problem faced by managers when trying to make a case for buying a new CAD system is that companies still use ‘Pay-back’ to justify capital projects. The apparent advantages offered by the old methods have their obvious points. However, these advantages are illusory and have no true value when used in conjunction with computer technology. The problem is that CAD is really a long term investment where the time taken to achieve the full level of savings may be longer than the required pay-back period.

An alternative method which overcomes the problems associated with pay-back is Discounted Cash Flow, DCF. DCF has two techniques which can be applied and these are:-

1. Internal Rate of Return IRR
2. Net Present Value NPV

IRR is the easiest for non-accountants to use, principles being the same as a Building Society mortgage. However, the main difficulty with using DCF was the discounting process but this has now been overcome with the development of computer programs such as IVAN. Now the main problem is identifying potential benefits in financial terms so that they can be included in an evaluation and related to the cost of the technology required to provide the benefits.

Apart from the incorrect costing aspects, companies tend to use the old textbook responses which they have read about. So, when they come to invest in CAD, they select a particular system on the basis of DO criteria, before trying to justify it financially. For example, they think of potential benefits in general terms such as 'better quality drawings', 'improved documentation' or 'keeping up with the
competition. So if the 'new' claimed benefits are to be included in the evaluation stage, then really the starting point for selecting a CAD system must be to identify the potential returns whose benefits may initially be defined in general terms, but they can be redefined into financial terms and estimates made of their magnitude. For example:-

CAD can be used to produce faster, more accurate and better presented quotations. The Marketing Department may agree that this could increase the percentage of enquiries turned into orders and estimate the potential increase in sales volume. This implies that the estimated figures can be converted into financial terms e.g. contribution to overhead recovery. The indicators for progression onto the next stage are seen to be the completion of the last.

Only once the potential benefits are identified should work progress to start defining the required technical specification. By identifying the most important advantages, the programme for implementation should be based on trying to maximise profitability by obtaining these advantages as soon as possible. Investment appraisal should not be treated as a final pass/fail hurdle but as an integral part of selection.

2.1.2 CAD systems in small businesses

CAD systems have many potential beneficial uses in small businesses offering advantages such as improved information, better planning and control, the possibility of business expansion without the need to employ extra staff and improved client service.

However, the selection process is important no matter the size of the company and it should comprise:-

- A set of defined objectives for the system
- A set of defined objectives for the company

2.1.3 Participation

This approach is different from one where a consultant, or any other individual, chooses a computer for a client. Actual numbers participating will vary according to the size of the organisation and scale of the project.
Principally it will be those who have first hand knowledge of the requirements and who will need to make the eventual choice work and should be the main participants in the work. So before any work can start it is necessary to create a team unit to carry out this stage. The successful implementation of a CAD system requires the support from someone in the company supporting its case. This all depends on the structure and size of the company as to that person's current title i.e. board member or senior partner. Whoever it is, that person becomes the CAD champion. In most company structures the champion would have an uphill struggle to convince others of the merits of CAD. The progress made will be due most probably in spite of them, rather than because of them.

The act of selecting whether or not to use computer aided methods in the design process is still a viable alternative at least in the consultancy role. So there is still the choice. Product Design is not an island of activity and is influenced by the other working activities it interacts with. The trend in these other areas of influence have been towards the adoption of computer aided methods.

The selection stage is where companies ask themselves questions to determine what they want to achieve with this technology. It is also when they start to determine what they can afford by asking such questions such as:-

- What do we really need to get just now?
- What can we leave till later and how can we plan for this now?
- Why is it necessary to upgrade/modernise?

The selection phase determines the limitations financial, physical and practical by examining the problem areas, the advantages and disadvantages of working in CAD, and specifically in the packages that are of interest to the company.

The work also has to cover the following areas:

- Issues of training
- Issues of staff movement
- Issues of high costs
- Issues of control
- Issues of interest
- Issues of introduction of new ways
- Issues of the need to change - whether or not these exist
2.2 Selecting the CAD system

The structure of the selection process consists of a number of distinct phases.

### 2.2.1 Stage One

This stage really only involves the clear statement of the results of the justification stage.

The identification of preliminary issues requiring resolution. For example:

- Areas of activity needing clarification
- Data such as volumes and projected growth needing collection.
- Review the company objectives by standing back and deciding where the company is going. A company strategic plan may already be in place. However, it should cover at least the following issues:
  1. Target markets for the company both traditional and new ones.
  2. How would you ideally like to operate with clients?
  3. What are the goals for product margins and volume?

You should be able to determine the preliminary issues based upon:

- Sound knowledge of how the company operates currently. This will form the foundation for building the new system.
- Current working procedures need to be analysed thoroughly as this will determine the requirements of all management and staff who will use the CAD system both directly and indirectly.
- Careful consideration is needed of all the essential facilities necessary to solve existing problems of the business and meet anticipated future requirements.
- This analysis facilitates you to specify what the system must logically do and what information must still be collected.

Questions that you should be able to answer about your organisation

- How stable is the demand for the company's services?
- How busy are the staff in the company?
- Do any of the staff have any previous CAD experience?
- Are the present procedures in the company formalised or are they very flexible?

The following answers to the above questions which would be very helpful are:-

- Company has a relative stable demand for its services.
- Staffing levels are relatively high for the work load.
- Staff have some previous experience.

However, if the answers are not helpful then you could:-

- Increase the staff time available.
- Try to time the project to coincide with the slack period of the year.
- Sort out your manual procedures prior to attempting to computerise them.
- Develop the skills and knowledge of your staff by some form of training.
- Try to delegate the responsibilities of the selection team on a long term basis to free their time for the system development project.

This stage gives you the knowledge of the company's requirements to identify potential solutions for a new system - computer based or not. You will be in a position to state if, and where, a computer can assist and also how far to take computerisation at present by being able to draw up a detailed requirements specification based on an agreed budget requirements specification. It should be drawn up in such a way that best describes, in detail, the facilities of the proposed system and the acceptance criteria.

2.3.1 Stage two

Review the present situation by evaluating what must change in the way you work today in order to satisfy those identified company objectives. It is also useful to establish where the opportunities are which you know you have missed today because of the way things currently are. The identification of these areas helps enormously towards specifying what you need in a CAD system.

Another helpful method of identifying needs is the use of what can best be described as a company information map.

All activities in all departments need to be analysed to determine the following:-
• What information is created there and why?
• What information flows in and out of that function and why?
• What are the existing systems and what need is there for information compatibility between them?
• Are there other companies whose systems you will need to communicate with?
• If yours was a ‘green field’ site, how would you ideally set it up?

These questions help set up the information map and it would help play an important part in the planning for, introduction and growth of the CAD system within the company. The map should be shown to all relevant groups within the company so they can agree to the accuracy of the contents. By looking at this map it might prompt changes which will benefit the company even without buying the CAD system.

This is essentially a feasibility study about the company’s viability of installing a CAD system. It is facilitated by determining the cost effectiveness in terms of end user requirements by considering the advantages gained:- increased productivity of skilled staff, reduced product development times and a more viable product.

The problems that can occur at the feasibility study stage are:

• End users do not know what they want because they do not know what is available.
• Whether to start with a budget in mind or to carry out a feasibility study to determine the cost and then ask management to fund it.

2.4.1 Stage Three

This stage evaluates the feasibility of the proposition to implement the system at the present time. It will be possible to say whether the benefits from the new system sufficiently outweigh the cost of developing and running it. This is achieved by considering the following:

• Technical Feasibility.
• Operational Feasibility.

The above is covered by the preparation of a statement of requirements covering technical, commercial and contractual aspects. It is important to consider both the short term requirements
and the long term requirements.

2.4.1.1 The Preparation of a Statement of Requirement (SOR)

The actual exercise of carrying out this process will highlight any substantial internal gaps of knowledge such as:

- Current Activities
- Highlight areas of uncertainty
- Indecision about the future.

Basically, it consists of the relevant parts of the feasibility study but developed with further information added to form the exact specification of the systems requirements. It will contain a list in order of priority such as essential, highly desirable, desirable and 'would-be-nice' facilities. In practice it is best expressed totally in terms of your facilities and software requirements with no hardware configurations specified except in the broadest terms; e.g. 2 A2 plotters required or colour screen necessary. The biggest problem is to specify a system that cannot be met within the budget. You might decide to adopt a corporate policy of buying particular companies which will form a restriction to any of your requirements.

The following illustrates what work from the justification stage needs to be formalised in this stage:-

1. A summary of your business activities and operations to be computerised.
2. The background to your decision to seek a CAD system.
3. A list of all the inputs and information required to be output from the system and frequency of output from the system.
4. A list of any computer hardware already used, indicating if any interfacing is required.
5. An indication of the amount of historical company information which is to be stored.
6. A list of any acceptance requirements which have been established.
7. Do you have to change to the computer at all and what is the case for the change.
8. If you already have a CAD system then another acquisition will have policies such as whether it is to replace/extend the current system or a new installation.

All these can be translated into technical requirements for capacity to expand and enhance hardware and software in fairly specific ways. The assurance of ongoing compatible supplies and support in these areas is also relevant.
The most successful method is the 'top down' approach to prepare the short term plan and it should cover:-

- Identification of those short term objectives you have set yourself into their order of priority.
- Decide which tasks could most significantly affect your ability to meet those short term goals. These are the prime targets for CAD during the first two years.

It is important that the CAD solutions you implement in the short term do not compromise the long term needs. For example, in the short term, it might be better to purchase a more powerful, expensive, computer than at first thought necessary since this will allow future development than a cheaper and less adaptable machine. It is important to remember that the asset that is most precious is the information created on the system rather than the hardware used to create it.

The long term plan of action should cover:-

- Strategic actions necessary to achieve your agreed long term objectives.
- A definition of the 'ideal' method of operation.

The plan should not be constrained by the limits of current technologies or financial restrictions. It is like a design brainstorming session which means this is really an 'ideal' outlook of the way the company would like to work and what work it would like to present to its clients.

One major part of the early planning is the need to build CAD awareness. You need to know what is feasible, available and affordable. To do this you must therefore determine :-

- What is currently possible with the available technologies ?
- What does each level of capability approximately cost ?
- What will be the short term benefits ?
- What will be the long term benefits ?

What are the ways of building awareness ?

- Courses on CAD.
- Seminars and conferences.
• Publications.
• Exhibitions - this is best for window shopping.
• Visits to existing users - this source is best for the truth about benefits and work selection.

The increased awareness will help you determine your important needs:

• Layout the tasks to be carried out both short and long term.
• Attitudes to contractual terms and conditions require definitions of users’ needs to be clearly set out.
• Acceptable terms and conditions are achieved by you knowing what you want, what is feasible and have an appreciation of the laws of contract as applied to a transaction of this nature, or access to informed guidance in this area.

Specific tasks that have to be performed

• What is the structure of the information?
• Volumes of data handled?
• What are the inputs and outputs? (for example, drawings, part’s lists).
• What requirement for data exchange with other systems?

2.4.2 Software Specification

Generally software off-the-shelf is not aimed to satisfy the requirements of end-users in particular application areas. When selecting the software, the first thing is to match the requirement with any viable concerns on the market by journals, contacting software houses, computer vendors. The company has to establish whether or not it will satisfy the specification at a reasonable cost. If it does then the solution is to buy it. Only as a last resort should a new program be written.

Often software houses offer a demonstration pack of their packages capabilities which allows companies to use it for evaluation purposes. They are usually reduced versions of the full commercial package. It should be remembered by users that a licence is usually required for each machine that the package will be used on and unauthorised copying is a breach of copyright - so if a few stations are to use software it might be worth considering a site licence.

The increased awareness will let you define your software requirements as you will be able to carry
out the setting and weighting of criteria for assessment with pre-set gradings.

- Identify the essential software facilities.
- Decide on methods of working e.g. 2D or 3D surface or solid models?
- What application-specific software is needed?
- Define how data will be created and managed in the system.

The last aspect is very important and is often neglected by first time buyers. The questions to ask for this would be:

1. What will you want to do with the information created?
2. Will you ever wish to locate a drawing on the basis of a certain part number having been used in it?
3. If this is the case then it needs to be defined in the selection phase.

2.4.3 Other relevant parts of the software specification

2.4.3.1 Interfaces with external programs

- Are there facilities for extracting data from the database, for example into a computer file with a specified format, so that the data is readily available for use by an external application program such as graphic material for a finite element analysis program?
- Are there facilities for the reverse process?
- Is there a need for an interface with a specific applications software?

Open ended systems may not seem important initially, but this aspect is likely to increase in importance as computer applications become more co-ordinated and integrated.

2.4.3.2 Is it necessary to have interaction with other systems?

Communication is an important factor that should be carefully considered when evaluating the system as this has implications for the future growth and development of the proposed system.
2.4.3.3 Communication with other CAD systems

Other organisations with whom there is some association may be operating another CAD system.

Define the data exchange needs with other systems.

- Alpha-numeric exchanges are easy whereas graphical exchanges in 2D or 3D are more problematic. CAD data exchange can be performed either with a dedicated direct conversion program written specifically for the programs involved or by converting data into a neutral intermediate format such as DXF or IGES.

This requires the following questions:-

- Is there any requirement to pass drawings in digital form?
  If yes :-
  1. Are there special interface programs available so that data can be passed from one system to the other and vice versa.
  2. It may be that only the elementary items such as lines, arcs and characters are transferred with no higher structure. Then it is difficult to interactively modify the received drawing.
  3. Do both systems conform to the IGES or DXF standard?

Specify the operating system on the basis of:-

- Portability expectations across different hardware.
- Number of concurrent tasks/users.
- Data management facilities required.
- Networking facilities required.

The operating system will usually be determined by the CAD software chosen.

2.4.4 What other software factors are there?

Associated nongraphic data

- Is it possible to input and store nongraphic data?
If yes:-
• How easy is it to handle the input and to manipulate text and numbers?
• How easy is it to change the information already held?
• How easy is it to change the form of the associated data for different types of components?
• Can the system automatically keep a record of the number of instances in which a component is repeated?
• How flexible and easy to use are the sorting and report producing facilities?

The last feature is vital if the system is to be used to create schedules and part lists. Useful features are the ability to:-

• control the order,
• spacing,
• arithmetic manipulation and summations of columns, input of headings and control pagination useful.

2.4.4.1 Programming

• Are there any facilities for the user to program macros?
  If yes:-
  1  What features are there in the programming language, for example for jumps and loops in the coding?
  2  How easy would it be to use?
  3  How efficient would it be in operation?

2.4.4.2 Multi-user Working and Security

Consideration of the volume of drawing work to be undertaken makes it possible to answer the following question:-

• How many 'systems' are required?

The answer will help to compare it to tenders from suppliers when they give their proposal of number of systems. Money might override this decision making area.
• Can the software support multi-user working simultaneously?  
  (even if only one workstation seems necessary, there may well be a need for it in the future)
• Does it allow more than one person to work on the same project simultaneously?
• If 'yes', then how does it work in practice?
• Is there a security arrangement, perhaps controlled by the system manager, to prevent improper changes by unqualified people.

2.4.4.3 Specialist Applications Software

The first CAD package obtained may well be a good general purpose draughting or modelling system but needs are likely to develop for specialist application programs. However, you should ask the following questions:-

• What other applications software is currently available from the supplier?
• What is currently being developed?
• If relevant to the customers needs, at what stage is the development work?

2.4.4.4 Software Support - Maintenance and Software enhancements

Documentation

The quality of system documentation is often a guide to the quality of the system itself. The term documentation is covered by the following categories:-

• Marketing brochure
• Training manuals
• Reference manuals.

What is the quality and sufficiency of the last two categories?
System documentation is often bulky, its organisation, layout and indexing need to be assessed.

Training

The supplier will usually include a specified number of his staff's man days for training and instruction of a reasonable number of the customer's personnel.

• How many days?
It is advantageous to check on who would actually undertake the training and whether they could adequately relate to the customer's staff and their requirements.

**User Support**
Customer support is an extension of the initial training, it covers:

- Getting the user out of difficulties of his own making.
- Overcoming system failure due to program bugs.

A system which other users have found to be reliable, reasonably easy to use and robust is of considerable advantage. Periodic updates, are one means by which a supplier can eliminate minor bugs and also to make improvements to the efficiency and capabilities of his system. The supplier will usually supply these as he will have no wish to maintain difficult software versions at different sites. So it is important to review the supplier.

- What is the supplier's capability to undertake this work?
- How many staff does he have engaged in this role and how does this relate to the number of systems installed?
- Where are the support staff located in relation to the customer's offices?

**Major Upgrades**
Upgrades in software capabilities are structured as optional modules to provide, for example, 3D viewing or colour facilities. Alternatively they may be compatible applications packages, usually these are not included in the normal maintenance. The user may find that they are both highly desirable and highly expensive. What constitutes a minor upgrade included in the normal maintenance contract and what becomes a separately priced module, may be far from clear, attitudes of different suppliers can vary. Perhaps the only guide to the future is to examine the supplier's past record in this respect.
2.4.5 Define growth requirements

All the following points need to be covered in the specification:

2.4.5.1 Physical expansion

- Adding more CAD seats and what will be needed.
- Greater storage capacity.
- More powerful processors to cope with growing workload.
- Enhanced hard copy devices bigger/faster/better.

2.4.5.2 Expanded opportunities also mean growth of a different kind

- Different tasks using same software.
- Application in other departments/areas using the same software.
- New software to tackle new applications.

2.4.5.3 Data exchange in the future.

- Networked systems within the company.
- Linked systems outside the company via telephone.
- Communication via media e.g. optical disk.
- All exchanges will need careful planning and most will need conversion or formatting software.

2.4.5.4 Support requirements

The supplier will need to offer a package of support services covering:

- Installation planning advice.
- Training of system manager and users.
- Maintenance of hardware and software.
- Guidance on system use.
- Guidance on data structure, capture and build-up.
- System planning and on-going development.
Support is important to smaller companies and large customers alike. When choosing a company for its support you should try to choose a company that looks as if it will be around in the future. A factor that is not too easy to establish in this financial climate. The people that are not offering good after sales are currently the people who are suffering even though their system prices are the lowest. Some resellers choose to boost their margins, by adding value to the machines, in the form of services which they can charge for. These services range from machine installation and networking to training. These services are usually an extra charge but they are often worth it, especially for smaller companies which may not have the in-house expertise to do the job on their own.

2.4.5.5 Hardware specification

Governing Factors

Cost

Software-driven demands
- The choice of operating system
- The CAD software itself and the minimum hardware needed for satisfactory performance
- Network requirements

Capacity demands
- On-line disk storage.
- Archiving and back-up storage devices.
- Processor speed to match the tasks given to the system.
- Memory size (RAM) to match tasks and also to support the specific Operating System and CAD software.

Other Hardware factors

Quality/user acceptance
- graphics screen size/resolution/colours.
- speed of redraw/zoom/pan.

Hard copy output devices
- plotter choice - pen or electrostatic
- single or continuous sheet.
- Plot size/precision/speed of plotting.
- How will you produce colour hard copy from screens?
  1. ink jet
  2. electrostatic
  3. camera
When evaluating hardware costs the following aspects are useful to remember:-

Cheap 'clones' can be good value for people who know what they are doing but not for beginners. Beginners are advised to pay the extra to buy from a local dealer who should demonstrate the machine thoroughly and provide support once it has been bought. This is because many clones are not really built to last and can give problems after a year or two. While others are designed using cheap components that spoil performance, such as slow hard disks or poor monitors. Some are fine until the owner tries to upgrade them, when a puny power supply, oddball case design, unusual disk controller or other surprise can prevent the machine from being updated. A rare few quite simply do not work properly.

2.4.6 The Specification

The system specification should be:-

- Concise and task oriented.
- Written by users for users.
- Top priority is Software functionality.
- Lowest is actual speed/brand of hardware selected.
- Make clear distinction between the 'essential' software facilities and the 'nice to have if you've got it' type.

2.4.6.1 Specification structure

Introduction
Should set out basics of invitation to tender.

Systems and Volumes
The work load to be processed should be clearly laid out.

Programming and Software
This should contain the questions and criteria relating to application software, operating system.
In any software package the following features should be examined:-
• Drawing construction method
• Types of drawing construction aids
• Editing methods and their ease of use
• General ease of use of the entire package
• Performance and accuracy
• Interfacing with other required packages
• Documentation

Communications
State whether or not you will need networking in the system.

Technical Specification
• Engineering details of hardware should be laid out.
• Security.
• Systems Validation.
• Transition and Set-up.
• Finance.

It is easy to give primary importance to cost and it does need consideration but in perspective with:-

• Weighed up against tangible costs of hardware and software.
  consideration of the tangible such as:-
  • Cost of disruption to the company from selecting a weak system.
  • Cost of training staff to operate a complex CAD system.
  • Benefits can be intangible too - e.g. improved customer relations.
    It is important to remember the minimum requirements as well.

• Software
  • This will be determined by your requirements.
  • Negotiating with suppliers.
  • Evaluating possible solutions and negotiating with suppliers is a time consuming activity.

• Suitability
  A supplier cannot be deemed responsible unless that purpose is clearly and adequately defined. This definition must be a part of SOR and should declare itself so to be.
Mandatory and Desirable Features

This list gives you the criteria for comparing CAD systems.

Cost
- One-off cost - purchase price of the hardware.
- Ongoing costs - e.g. software, maintenance contract.

Performance
- Single or multi-user operation, speed of response to enquiries, time for particular operations to be undertaken

Functions
- Scope of the system, application areas, data contained in individual records.

Support
- Provision of training, documentation, manuals telephone hot-line support, updates of programs.

Capacity
- Long term storage of information, growth possibilities.

Reliability
- Average rate of faults, methods of recovery of data and programs.

It is important however to be prepared to modify the specification. Should this be necessary it can be achieved in the following areas:

- Limit the difference between what the business currently does with the data and what the new system is planned to do, to make the target more achievable.
- Limit the functional complexity of the new system requirements to make it easier for staff to understand, test and implement.
- Limit the technological complexity of the computer selected for implementation to ensure that the hardware does not let you down.
- Long term support for the system available from the supplier and other sources to meet the needs of the inexperienced but busy small business.
- Try to ensure the system resembles as far as possible your preferred way of working.
- It is not always wise to purchase the very latest as you are then acting as a guinea pig since support expertise is always developed later than the new technology released.
- Is there any long term support available for the system?
- Check your supplier out and ensure he has detailed knowledge of your company requirements and that he will be willing to support you indefinitely and not just while it is being installed. Check this out by asking lots of questions which test the knowledge of your prospective supplier and be sure to ask other businesses which have used the system for some time. (See following section.)
2.4.7 The Supplier

The other aspect of choosing the software is choosing who will be the supplier of this software. The services offered by this person might also be a critical deciding factor on the final package chosen.

2.4.7.1 Datum Point concept.

This concept is used to avoid any unacceptable practices by suppliers. This recognises the fact the work actually implemented will differ to some degree from work specified. So the Datum Point acts as a reference point from which both the actual work load and the performance of the equipment is measured. A reasonable interpretation needs to be adopted e.g. to recognise inescapable step functions in the growth of equipment capacity. 30% increase in cost is not justified in an 8% increase in workload.

2.4.7.2 Formal Status of Documents

There are two key documents and they are:-

1. The customers statement of requirements.
2. The suppliers proposal.

These form the basis of the contract eventually entered into between parties. Both parties must be clear as to the contractual significance of both statement of requirements and proposals.

2.4.7.3 Computer Contracts

Study the small print as suppliers want to enter into contractual agreement on their own terms. The contracts usually include clauses covering the following areas:-

- The parties involved - specify who is the purchaser and who will have the rights to use the system.
- The subject matter of the contract refers to both the hardware and the software. It may also refer to vendor's literature and the onus is on the purchaser to be aware of what is being proposed by the vendor.
- Location of the computer installation - normally specify the exact addresses of where the system may be operated. Extension to these rights, as in the case of
change of address or involvement of subsidiary offices, will require further agreement and possibly extra cost.

- Delivery and Installation - dates for delivery of various items of hardware and software - if these are not all required in the first instance - will be specified. Vendors often have the tendency to promise dates for supplies which cannot always be kept.

- Price - amount due, terms of payment and itemised cost breakdown should be stated in addition - any ancillary charges to be incurred in the case of support and technical advice.

- Copyright details where the software has been commissioned by the purchaser.

- Use standards of performance and conditions under which the system should operated will be specified by the vendor. Any restrictions on the use will be stated. You should consider carefully if any of the restrictions placed will affect any business developments planned or possible.

- Maintenance of the hardware is normally subcontracted to a third party after the warranty has expired and the name and conditions will be specified. All serial numbers and descriptions of hardware items will be included.

- Software licences and maintenance of the software will be stated. Period of the agreement, terms of termination of the agreement, use of the software and updating arrangements. You are normally only buying the right to use the software. You do not own it and, therefore, cannot sell it to anyone else if you subsequently find you do not need it.

### 2.4.7.4 Negotiating Posture

The time to conduct negotiations is before a choice is made for the following reasons:-

- Once a choice is made a customer's negotiating power virtually vanishes.

- Any worthwhile comparative evaluation will take into account the total offer, including any points concerning which negotiations are necessary. A feature which has not yet been formally committed in negotiation cannot be assessed.

- Type of topics needing to be negotiated, although they could vary, typically are:-
  - Terms and conditions, standby arrangements, preliminary testing facilities, software developments and any features which purport to be specially adapted to the customers particular needs. Furthermore, if a choice is made but no agreement executed whilst negotiations are
concluded, then it is legal and legitimate for disappointed suppliers to endeavour to have the decision changed.

2.4.7.5 Comprehensiveness of Proposals

Proposals should be required to quantify all the "services" (support, training, machine time, manuals) which are included in the quoted price and to quote prices for the others. There should be no hidden extras.

2.4.7.6 Creating a purchasing specification

A small team should be appointed to lead the company through the period of purchase. This team should be the people who have carried out the ground work for the selection phases of the project as long as there is a financial expert within the team. If not, then one should now join the group. It is not necessary for the team to leave their primary roles within the company as the duration of this work would require effectively only 25% of their working week. Once this has been completed the company will be able to order the system of their choice.

2.4.7.8 Total Cost Comparison

When costs of proposals are to be compared it is essential that like is compared with like. It requires the full costs of putting each proposal into effect to be carefully calculated and not merely the sums actually payable to the supplier or other third parties.

2.4.7.9 Cost of Evaluation

The amount of effort absorbed should amount to less than 2% of the systems costs. It would consist of staff costs and overheads which means the actual marginal cost is therefore much less.

2.4.8 When buying a system

Points to watch out for:

- Give it a lot of thought before you buy a computer from the High Street. If you do, you must make sure you will be helped to get the system running and that if any problems occur, someone will sort them out for you.
Should avoid buying one that is currently considered obsolete, obsolescent or unnecessarily flashy. Avoid buying one that cannot handle the type of work you want to put on it.

Try to avoid paying out too much money before the installation is up and running.

It is important to consider the future, as well as the present, as this gives an indication about the choices you have made about your system. Small CAD systems reach the limit of their capabilities quicker than imagined and this is a factor when planning for the future.

It should be remembered that it is inevitable that there will be a necessity for system upgrades and enhancement in the computer's lifetime. It will happen in both software and hardware. The changes could include adding extra memory, disks, workstations or new software. So when purchasing a new system the eventuality of possible upgrade requirements should be kept in mind and included in the requirements specification.

It is important that you find a reputable dealer who will sell the company both hardware and software and give advice on what to buy and help to install it. There is a wide range of dealers depends partly on the IT market you choose. DOS-based resellers range from the simple to the in-depth. The lowest level of the reseller market are the commodity dealers or the boxshifters whose only aim is to sell as much equipment as possible.

Great care should be taken as to the vendor, should they go to the wall because then that cheap computer looses its support. More significant to actual hardware maintenance is software support and training. It is important that the company establishes that the vendor can offer support at the end of a telephone line, when you want it. If the dealer cannot supply this service then the company has to find agencies that can. When considering the purchase it is important to decide how many of the staff require training they should be aware that the training cost will be a significant component of the PC investment, usually costing more than software itself. It is possible that small companies will be able to find a local dealer more suitable as they are likely to be able to offer the right level of service required for starting out. However for IBM and Compaq PCs it is recommended that an authorised dealer be used who can be recommended by the manufacturers themselves. When deriving a costing appraisal for a system then it should be stressed that it is not always the cheapest system that is the best buy for absolute beginners in CAD.
The following questions should be asked when considering the supplier:-

- How long has the supplier that you intend buying the system from been in business?
- Who do they deal for?
- Are they designated dealers and what grade?
- Who are their major customers?
- Can you talk with them to establish the type of service they are getting?
- How many support/engineering/sales staff do they employ?
- Are they main agents or distributors for any of the products you are interested in?
- Do they have to pass your queries onto a third party?

The following questions should be asked when considering the sales staff

- Do they appear to be knowledgeable?
- Is there an ordered structure of backup contacts familiar with your account when the salesman is not there?
- How is the salesperson paid?
  Sales staff with a very small salary and a large commission need to sell in order to make a living so they have a vested interest for themselves and not your company.
- Does he schedule regular meetings with you to monitor your progress, or does he only want a quick sale with a speedy departure?

The following could be considered a guideline for the purchase of hardware and the software from a vendor:

2.4.8.1 Hardware

- What repair policy is on offer?
- How long does it take and at what cost?
- Can you purchase diagnostic programs and spare parts at reasonable prices?
- Will your vendor loan you a machine while yours is repaired?
- This brings up the issue of companies following a backing up regime. To utilise the service from the vendor the company has to have a full set of back up data and programs to transfer onto the loaned machine.
2.4.8.2 The Software

- Let your needs guide you so that you are not persuaded into buying a super program which means reorganising your business to fit it.
- What is the policy on fixing bugs within the system?
- What is the policy of installing any new upgrades to the program?
- Will you automatically be advised when new versions or fixes are available?
- To overcome the possible eventuality of loss of security and support by your vendor becoming bankrupt, it is advisable to get a system that is fairly standard.
- A program which is not quite the 'ideal program' from a major and reputable supplier could be better in the long term than an individually tailored version from a small company, especially for small companies.

2.4.9 Other aspects of the requirements process

2.4.9.1 Human Issues

Systems understood by your staff are more likely to encourage a 'local expert' to emerge from the company's staff who can answer many of the queries which arise.

During the process of company assessment and selection it is vital that attention to the human issues of the working environment of the proposed new system are considered by the following methods:-

- Use of outside advice and assistance to help the business in determining requirements, selecting a system and implementing it with the organisation.
- Gradual process to convert to the new system to enable training to be effective and the business to respond. Clear business objectives set for the computer system to meet to ensure that the system is functional and effective.
- Involvement of staff throughout the phases of selection and implementation to reduce fears and promote support and understanding.

The last factor overcomes any resentment that might otherwise be incurred as it will:-

- Establish support for the change. Consultation rather than confrontation to ensure staff accept new process.
- Establish support inside your business. Get backing from those directly involved
by getting their ideas on the matter.

There are also two levels of staff awareness:

- Staff experienced in purchasing a CAD system are already aware of potential configurations, software facilities and extremes of costs.

The other level is when the staff have no experience it is necessary to ask:

- Is the system cost worth the additional cost of getting expert outside guidance to get it right?

One method of answering this question is to derive an outline list of requirements which specifies those facilities considered to be essential in the proposed system. For example:

A small design office may require the following facilities within the proposed system:

- Two and three dimensional drafting system software for small engineering components.
- Three workstations with maximum graphics facility of resolution and colours required.
- Facility to access centralised component databases.
- Large, high quality digitising tablet for input of drawings.
- A0 plotter for output of hard copy.
- High quality printer for printing components lists.

Discussions with end-users can help in detailing the requirements of the drafting package. A priority list of extra facilities could be useful. These would not be stated as essential requirements of the system and can be gleaned from journals and demonstrations or exhibitions. It is useful to consult the end-user and get their opinion of the proposed system. The danger is in selecting a system without proper consultation with end-users and choosing a system based on a slick demonstration. It should be remembered that in demonstrations, the content is carefully chosen to give a smooth, high quality presentation, showing the system's good points and avoiding non-existent facilities or weaknesses within the demonstration system. It is the purchaser who must determine, by asking the pertinent questions, or by experimentation, if the system will satisfy the requirements.
2.4.10 Aspects of Management at this Stage

2.4.10.1 Potential CAD roles within a company

While CAD is considered to be a loss of skills in some areas there is a developed need for new roles within the company. It really depends on the size of the company and the workload that is created in these new posts but they could be either new full-time jobs or they might be new working activities written into current working job descriptions. They need not be full-time activities and they could be spread amongst the workforce as it stands. The listed new activities descriptions would answer the following question:-

- What roles are necessary to establish in the system so it runs efficiently?

2.4.10.2 So what does the new working role require from the workforce in terms of skills and knowledge?

Review of CAD related aspects

New problem solving skills are needed by designers such as:-

- Pattern Recognition
- Knowledge of design rules and relationships
- Complex decision making
- The ability to process large amounts of information quickly.

Moreover, the work pace of a job increases with CAD as decision making is now paced by the computer and not the person. This suggests that CAD is likely to lead to information overload. It will change traditionally self-paced jobs into jobs paced by the computer. While such changes to the job as information overload and reduced control over work pacing are likely to lead to increased stress, studies supporting this claim have not, as yet, been carried out.

2.4.10.3 Computerisation of the Working Procedures

One of the biggest changes for office workers would be the introduction of shift work and all that is entailed in the disrupted personal and social life and unsocial working hours. In management terms, this is a matter of calculating financial returns on capital equipment. Large CAD systems are very
expensive and rapidly become obsolete. Therefore, it is necessary to achieve high financial returns in a short time, and this can mean running the machinery 24 hours per day. A situation which has already happened in some design offices. The Technology is usually mainframe based and a strong personnel argument for implementing competent microbased technology which allows companies the freedom of not having to implement shift work.

When deciding about the purchase of a CAD system it is useful to get people to break down their time into work activities to establish the length of time spent on the drawing board and the time spent away. This would help establish working ratios of staff per computer seat and to establish if it is necessary to have one machine per member of staff.

2.4.10.4 Deskilling

There is work being carried out in Artificial Intelligence sectors which is trying to break down design skills into small unskilled sub-tasks. This kind of research would seem to lend itself to attempts to transform design activities into a highly controlled and tightly timed sequence of discreet, unskilled tasks. It is also an argument being made by some people about current CAD applications. While it may be true for Artificial Intelligence programs, currently it is an incorrect statement about CAD packages.

The reverse argument is also frequently given i.e. CAD frees the designer from low level menial and repetitive tasks and allows the designer's skill to be developed and applied at higher levels. In fact, what often seems to happen in practice is that CAD systems are applied in ways which force further differentiation of skill levels amongst different grades of design staff. Information from various sources have indicated that it has been found that skill requirements of some jobs were increased, with senior designers making almost exclusively "high level" decisions such as conceptualising and problem definition. By contrast, junior designers who typically made "low level" decisions such as detailing had those decisions taken over by CAD, reducing skill requirements even further.

It is not disputed that the introduction of CAD will mean changes - some detrimental - but some to the advantage of the designer. So the new skills that are seen to be necessary now are:-

- Fluent use of symbols.
- Ability to work by using information in different dimensions and planes.
- Increased abstraction to manipulate programs and numbers rather than designs.
- Ability to develop personal strategies for problem solving rather than using existing
proposals and the ability to change from directly creating alternatives to selecting the best variant of solutions provided.

What can be concluded from this, is that CAD inevitably entails some new skills. At higher levels of the office hierarchy these probably create new opportunities as well as imposing new demands. At the lower levels they tend to de-skill or to replace altogether the jobs of junior staff.

2.4.10.5 Job Satisfaction

This could fall depending on how the equipment is implemented. The fall would be due to the adoption of one or more of the following:-

- Shift working.
- Formalization.
- Routinization of activities.

One of the potential effects of CAD is that it can open new career opportunities. This has been found to happen as a result of general office automation with new career paths being opened up. Design engineers and drafters working with CAD have taken on such new jobs as Internal CAD consultant, CAD training co-ordinator, systems specialist, marketing of CAD services to other departments in the organisation. There is the possibility that some organisations might not take this opportunity which could mean CAD operators getting more dead-end careers than before which would breed discontent.

Increased job satisfaction can be achieved not by CAD but by increased productivity, creativity, quality of work varied tasks, and responsibility over work that resulted when some organisations implemented CAD.

Job satisfaction in a CAD working environment seems to depend more on job design and office management factors than on the technological change to CAD.

2.4.10.6 Design Quality

It has been suggested, for example, that CAD systems impose limitations on what kinds of objects can be designed. This has been apparent especially in terms of the limited shapes or range of components that a CAD system can handle. Conversely it has to be recognised that some objects e.g. a microprocessor could not be designed without computer aids.
The introduction of new technology is bound to have some effect in the working environment so those going to be affected should be involved in the redesign of their jobs. There are different ways of looking at the introduction of change but there is one type that is not a good example:

People are inherently resistant to change and need to be pressed to adapt rather than encouraged by active involvement in the process. The prospect of change being imposed like this could cause the workforce to react negatively. It could lead to apathy, low commitment and in consequence a high incidence of errors. There may even be active attempts to block and undermine the new system. So although there may be gains in the short term from overriding resistance, in the longer term these human issues will be detrimental and so, therefore, they cannot be swept under the carpet.

The aspects of change bring their own difficulties and therefore require their own solutions. The introduction of computers does bring about the necessity to evaluate the working practices of the company. This happens as managers are coerced into confronting new problems.

When a company is carrying out its build-up to CAD, the important point to remember is what the thought of its introduction can mean to its work force. This is one of the important aspects in the successful introduction of any new working practices, especially the introduction of computers to the working environment. This is because the introduction of computers is understood to mean more efficiency and that machines can do the work of more than one person and so, therefore, a computer means less staff. This is a throw-back to the way financial justification was carried out by companies for computers with outdated methods. However it has been reported that in some offices the introduction has meant an increase in workload and in staff. In general, areas of working the introduction of IT has typically resulted in a flatter organisational structure. That is fewer levels of management are required due to factors such as less necessary supervision. This produces fewer promotion channels and results in a spread of experience for managers in the same post rather than moving to other posts. Managers planning the introduction of new office technology need to take this consequence fully into account by involving supervisors in the planning process and helping them towards evolving a role of support and leadership rather than in control. This is a step towards developing a team structure and increased technical leadership.

So the introduction needs to address the peoples' fears:

- Of redundancy.
• **Dangers to health.**

It is necessary to be aware of where potential dangers to VDU operators can arise. To avoid them it should give strict adherence to the ergonomic factors such as lighting, humidity, glare, noise, heating. There is little known about the long term effects of using the new technology. However, many of the problems associated with VDU operation stem directly from task-inherent demands such as repetitive elements, variability in system response times and feelings by operators of excessive control of their work performance by the machine itself.

Attention to the design of jobs is needed from the outset to avoid this kind of repetitious and over-controlled work. Jobs should include tasks which are not screen based otherwise the need for regular rest periods should be strictly observed.

• **Fear of the unknown.**

• **Fear of skill loss.**

Such as draughting skills such as layout of drawing work.

• **Acquisition of skill gain.**

The immediate fear is keyboard skills with longer-term fears of better knowledge of engineering design and production techniques.

It should be remembered that it is the people not the technology who should be the determinants of the way in which the work is organised.

• **Fear of being unable to adapt, too old or not clever enough.**

This is where good awareness training helps to overcome these fears.

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### 2.5 Stage Four

This stage is the preparation stage for the system's installation. In practice, the organisational problems of installing a new computer system can be greater than the simple technical one of finding a system to do the job. This is because staff attitudes to changing work practices can cause major headaches. Involvement of end-user staff alleviates these problems.

#### 2.5.1 Size your storage needs

Once the requirements have been established they can be used to compare the software available at the time. There is a multitude of software packages at first glance of the market and trade shows but the criteria laid down by the company can help reduce this to a manageable number. It is useful to bring this down to the ten best packages. This means the packages can be evaluated further to
match company requirements. The mistake is to talk to only one or two sales staff and then purchase a system which is not really compatible with company needs. The medium to large companies tend to go for systems that are more powerful than needed and the small companies tend to opt for systems that prove to be under powered for requirements. This is only a tendency and there are always exceptions to the rule. So a company should consider the following points:-

- How many people will be using the system?
- For example, a small team that will use the system all the time and therefore be very familiar with it or a large group of people but who are infrequent users of the system which means the system needs to be easier to use.
- How large are the design tasks?
- Is the system to be used only for specific tasks such as draughting?
- Is the design work based on a team effort which will require a network arrangement?
- Will a standalone arrangement be more suitable?
- What size of paper drawings are needed as this will determine the plotter requirements?
- What is the typical output of drawings that the company has and the expected output of drawings?
- Is colour necessary to the work being carried out on screen?
- Does the output need to be coloured?
- Does the company require any special tasks of the system?
- What is the planned growth of the company?
  a) short term
  b) long term
- What other areas could the system/information be used for?

When the basic requirements of the CAD system are determined the next task is to obtain information on the chosen range of packages. Information of this type can be found frequently in magazines which carry out many surveys on this matter which should be a good starting point. The software program is much more important than the hardware so it is important to deal with CAD companies that offer good backup support.
2.5.2 Locating a suitable system

Once all the requirements are determined and the needs of the company established, the next stage is to evaluate the software on the market. So quite clearly the market has to be assessed. This can be carried out by:-

- Consultation with like companies.
- Consultation with educational establishments.
- Local computer suppliers - classified directories, local contacts.
- Small business centres and microcomputer system centres.
- Computing press, industry and trade literature, consumer literature.
- Software system directories which are provided by many of the main computer hardware suppliers.
- Seminars and Exhibitions.

The work allows the company to draw up an invitation to tender based on the requirements specification. The information extracted from this will specify the system facilities which are to be met by the vendors. The invitation should be sent out to a range of suitable system vendors. A shortlist of systems can be drawn up from the tender documents based on the system facilities, delivery times, maintenance offered, price.

The market will have been established and packages identified making it now necessary to choose some software for further evaluation. The problem at this stage is that it is possible to have a requirements specification which cannot be satisfied by a system within budget. This will result in no tenders being submitted or worse the system bought does not work. It is also possible to buy a system that is too powerful with the potential problem being that it may be very complex and difficult to use and it may also be unable to pay for itself in your financial environment.

2.5.3 The calculation of full costs of acquisition and realisation for each proposal.

When requesting a demonstration it is a good idea to supply the company with a sample drawing as many companies can only give a demonstration on a pre-set component. This approach will help in deriving a short list of software packages. The following aspects of the software should be checked:-

- Cost of the software updates
- Frequency of the software updates

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• Does the software conform to the required drawing standards?
• The amount of training required and its cost. Remember a single day is pointless.
• Can the software be tailored to individual needs?

2.5.4 The negotiation of contractual terms and conditions for each offer

Once the list of packages is reduced to something like four, then costs can be compared.

The input of basic evaluation results together with management overviews of identified issues to formulate a recommendation.

2.6 Stage 5

This stage is when you put your requirements and specifications into practice. This is the purchasing section. However before actually going through with the purchase it is worthwhile to consider the options available.

2.6.1 Alternative methods of system acquisition

There are now other alternative methods to purchase a system:

The options are simply to purchase or lease. However, both these options have alternatives themselves.

When purchasing they are:

• To buy the system brand new.
• To buy the system second hand.

When leasing whether to go for:

• A short term which can be understood to be a form of renting.
• A long term lease.
• What type of lease.

The first point to establish is what the difference is between purchasing and leasing. The following quote clearly defines the distinction:
Essentially it is a matter of ownership.

- Buy a computer with cash, credit card or overdraft, it is yours.
- Hire purchase agreements also eventually give you title to the equipment.

In either type of lease ('lease rental' or 'finance lease') agreement the equipment belongs to the finance company (the lessor), and at the end of the agreement the equipment is still theirs.

When it comes to Tax, the difference is important.

Bought equipment, whether outright or on an HP agreement, you can claim the standard capital allowance deductions - 25 per cent of the value in the first year, and 25 per cent of the residual value in successive years.

Leased equipment you can only claim tax relief on the interest paid and not on the capital. Also you cannot claim capital allowances although all payments are tax deductible as a business expense.

Leasing companies stress the difference between short term rentals and long term leasing as it sounds good but it is not as advantageous as it first appears.

- Leasing is not financially advantageous when you are registered for VAT because you can not claim it back which means it is almost cheaper to pay bank interest rates on a loan to purchase the same system.
- Renting a system can be considered one way for a small company to evaluate whether the equipment will do what they want before committing themselves to purchase which in the long term would be cheaper than buying an incorrect system. This would be particularly useful for small companies with little computer experience and knowledge to assess a high end computer system, they could establish the benefits and compare it with their requirements. If this was to be recommended to a company then it would have to be pointed out that the company should check that the company renting out the computer is careful about reinitialising its equipment between customers as this is a potential source of virus infection.

When the system is bought the cost of the original equipment is just the start of the expenditure. Other expenditure comes from:-

1. Maintenance, support, upgrading and the 'enhancement of system'
2 Delays in repairs can throw production schedules to the wall.

The criteria in a selection process can favour leasing capital equipment, and the nature of the equipment itself, which requires frequent skilled maintenance, will also make leasing attractive. The point to remember is that PC's have a long life, are usually very reliable and typically require little maintenance.

When purchasing a system one disadvantage is with the rapidly changing technology which can leave a company with a soon-to-be obsolete system. However, with their reliability, the older PCs can be put to other tasks such as, word processing. So, unlike many items of capital equipment, the computer can be doing useful work for long after you have realised the capital cost. Another way of continuing the usefulness of the system is the system's ability to be upgraded.

2.6.2 The advantages of leasing

It helps the leasee company to control their cash flow because instead of the necessity of finding a large lump sum to purchase a system the company can spread fixed payments over several years and budget accordingly. Financing for leasing specific equipment is often easier than arranging a bank loan or an increase to an overdraft.

Leasing is one way of protecting your equipment from obsolescence. It allows the leasee company potentially greater flexibility over the rapidly changing technology. The disadvantage is that when the equipment is returned, the leasee will have no tangible assets to show for the cost. It is also very important that the company reads all agreements very carefully. This would help avoiding any long term agreements that would lose the advantage of keeping up with technological change and economically would have been cheaper to purchase. The term of payment should match the useful life of the equipment to the leasee company.

At least when the company is involved in the purchasing of a system then it has tangible assets to show at the end of the year to add to the anticipated increase in productivity that a system would afford. It has the drawback that there is the chance of selecting the wrong choice of system.

2.6.3 Purchasing Options

Purchase the system secondhand. A viable option for companies new to computers or who are smaller businesses with only a modest capital. This option should be approached with caution as the
secondhand market is not as developed as other markets. The purchase should be made from a reputable computer dealer providing a sound maintenance contract and other user support facilities regardless of the machine's age.

Purchase of a brand new machine. This gives a better deal as they are usually sold as a package encompassing start-up software and first stage support.

Purchase by mail order. This option is now becoming established with several reliable manufacturers, such as Dell or Compuadd. However, mail-order firms are really just dealers; there are the good and the bad.

There have been many reports that have used technical specifications to justify one piece of hardware over another but none have been able to openly say how to handle like with like. There is no real way other than common sense but while it is difficult to separate the good from the bad, it is not impossible. You have to ask questions but beware answers which are hazy or confusing. If the dealer can not or will not explain, trust your intelligence and interpret it as his failing, not yours.

2.6.4 Leasing

2.6.4.1 Leasing Options

There are essentially two types of lease and they are Finance Leases and Operating Leases.

2.6.4.2 Finance Lease

Under a finance lease, the risks and rewards of ownership but not the actual legal title are substantially transferred to the lessee. The company taking out a finance lease effectively 'owns' the leased equipment in all but name. Basically, a finance lease is divided into two periods; primary and secondary.

Primary Period
In the primary period, the lessee will pay the rental consisting of the capital element plus the interest. The capital element to be paid must amount to 90% or more of the fair value of the asset. A general rule applied here is that the capital, plus the residual value of the leased asset, must equal its initial value. The residual value is what the asset is worth at the end of the primary period. So the lessee will end up repaying the whole value of the equipment to the lessor, plus the margin which gives the
leessor, plus the margin which gives the lessor their profit. Therefore it can be seen that the bulk of the rental payments are made in the primary period. This is usually 3 to 5 years for computer equipment.

**Secondary Period**
This is from the end of the primary period to the point where the lessee scrap the equipment. The rentals will essentially be nominal, reflecting the small residual value of the asset. So it can be seen that should a company want to keep the system for the whole of its useful life that a finance lease can be very cost effective.

Effectively the assets concerned are the lessee’s in all but title. They thereby accept all the practical burdens of ownership including the need to maintain and ensure the equipment although the finance for this may be lumped in with the lease. Some leases may even permit the sale of the equipment to a third party at the end of the primary period. The bulk of the proceeds, possibly 90%, being returned by the lessee. A finance lease with a purchase option is illegal.

2.6.4.3 **Operating Lease**

An operating lease is a rental agreement over a specified term whereby ownership and included risks and rewards stay clearly and firmly with the lessor. Other services such as maintenance may or may not be included.

An operating lease is shorter in term than a finance lease and it is never more than the effective life of the asset. The rental payments tend to fall short of the fair value of the asset. So the lessor depends on the residual value of the equipment and will need to lease it again or to sell it in order to make any profit.

2.6.5 **Accounting Treatment**

Concerning accounting and taxation purposes the distinction is important.

2.6.5.1 **Finance Lease**

The financial assets are treated in the balance sheet as if they have been purchased outright. The corresponding liability is the obligation to the finance company. The depreciation is charged to the profit and loss account over the primary period of the lease as is the interest element of the leasing
2.6.5.2 Operating Lease

The rental payments charged to the profit and loss account and when they are incurred. Nothing is recorded in the balance sheet and the assets are clearly not the lessee's to depreciate.

These differences can be profound for some businesses. The lease appears in the company's balance sheet where the details must be given in the annual statement. A fact which highlights that with a finance lease it increases a company's overall indebtedness which possibly could prove embarrassing or inconvenient. Rental payments under an operating lease can be hidden away in some obscure heading in the profit and loss account. Conversely, if the company's revenue budget is heavily committed, a finance lease may be preferable.

2.6.5.3 Tax

Both types can offer Corporation tax advantages. Where assets are acquired under a lease, the leasing company who is the true owner claims the capital allowances and can pass these on to the lessee in the form of lower lease payments.

The 1984 Finance Act reduced the tax advantage of leasing by changing the system of capital allowances, and lessors have now the need to sell their services more on the basis of cashflow and debt structuring benefits which can still involve the timing of tax liabilities.

2.6.5.4 Costs

Long-term rental charges are low compared with the costs of short-term hire. For example you could pay only twice as much to rent for a month as you would for a week, and you could expect a contract extending over a number of years to bear charges at a rate less than half that of the standard monthly rate.

The comparison of the relative costs between finance leases and operating leases in detail is considered to be inaccurate. In theory, finance leases would appear to be cheaper than operating leases over the same period of time. However, the extra benefits offered with an operating lease such as flexibility, security and support, have to have a value especially in the constantly changing world of computer equipment.
Should the company be taking out a lease the following checklist needs to be considered:

- How much has the company to pay?
- Are the payments fixed or variable with interest rates?
- Who is responsible for maintenance, insurance, installation and transport both at the start of the lease and the end?
- Does the manufacturer's guarantee remain valid?
- Can you upgrade some or all of the equipment?
- Can you add components such as maths co-processor, bigger screens, more memory?
- If you can do any of the last two questions will it cost extra?
- Who in your organisation is responsible for arranging and authorising leases?

2.6.6  Comparison of the merits of leasing and purchasing options

2.6.6.1  Tax advantages

Leasing offers possible tax advantages particularly for tax loss companies. However, the advantages are limited by the rules relating to finance leases on how to treat the asset in accounts.

2.6.6.2  Cash Flow

The monthly payments required by rentals are less demanding on financial resources than an outright lump sum.

2.6.6.3  Ease of administration

The overall financial position of a company is not as important to leasing companies as it would be for other types of lenders.

For administrative purposes the simplest situation is an outright purchase of a system.

For a finance lease it is complicated to administer and account for as there is a complex algorithm for calculating the monthly interest amounts. An operating lease is basically simpler but will cost more.
2.6.4 Costs

An outright purchase for cash is the cheapest option but the advantages for spreading the commitment over a period of years should be considered.

There are very few other costs under an operating lease as maintenance and other potential expenses are included in the rental payments and rapid repair or replacement of faulty equipment should minimise system down-time costs. These type of costs are all extra when the system is purchased.

2.6.5 Interest costs

No leasing finance such as bank loans may attract a variable rate of interest. Leasing payments are fixed in advance covering the duration of the lease. The possible disadvantage of this would be a fall in rates. The balancing factor to this however is that the lessee company have a known price which they can plan and budget for.

2.6.6 Flexibility

An operating lease provides extras such as maintenance, support, speedy delivery, regular system upgrades and the ability to terminate the contract at the lessee's convenience. To ensure this advantage is achieved and protected it is important to read the small print of the contract. Flexibility is important in the rapidly moving world of computers when software upgrades require ever increasingly more powerful computers.

2.6.7 Peace of Mind

An operating lease can be so structured that responsibility for keeping the equipment is the lessor's and not the lessee's. This ensures the computer system will be operational most of the time. In contrast to this is when the computer system is purchased the company have to bear all the headaches and pay extra for a maintenance contract.

2.6.8 Evaluation

A short term rental allows the company to sample the latest equipment on the market before committing themselves to an actual purchase.
Regardless of the method of finance whether you buy or lease you still need to bargain intelligently for the total package on offer. A major factor discouraging purchase is the fear, that the technology will be out of date before the system has settled down to performing useful work. Computers over five years old are still capable of performing useful work.

You should consider the following when deciding to buy or lease:

- What roles or functions carried out by staff within your company can be satisfied by the older slower machines.
- Let the appearance of genuinely useful and necessary software be the trigger point for acquisition of new equipment and not a paranoia of being out of date.
- Are there any strong financial reasons for the company opting for some form of lease or rental? If so, then this is the way for the company to follow.

2.6.7 Purchase Decisions

This stage requires the drawing up of a purchase requirements check list so that an evaluation of various sources can be carried out and final comparisons drawn just prior to purchasing a system. It is the time when you have to come to terms with a real system from the so far ideal system drawn up in the earlier evaluation stage. The compromise stage. The following are typical questions that a company considering the purchase of the system need to ask themselves.

- Why do we want a CAD system?
- What do we really need to get just now?
- What are we looking from a particular system?
- What can we leave till later and how can we plan for this now?
- How do we propose going about the task of determining the requirements for a CAD system?
- What are the essential elements of a feasibility study?
- Should we be bothered by what other people have got and why?
- How would you arrive at a vendor shortlist?
- What points need to be addressed in a technical evaluation?
- Our manual methods are quite successful so why should we spend thousands on a system nobody knows how to operate.
- While I can appreciate the advantages that CAD offers to the work that I do, I do not have the capital to invest in a system.
• I have neither the money nor the work type that warrants the investment.

2.6.8 Investment

By choosing a system that is well supported and hardware that can be readily upgraded it can be considered that the outright purchase of a system is actually an investment. Along with this is the fact it is the information produced by the system rather than the system that is the valuable commodity.

If an outright purchase is difficult, or not feasible at the time the company actually requires a system, then it is possible that the company can still purchase the system and spread some of the cost over a period of time by using a bank loan. In this case, you need to match the life of the loan to the estimated business working life of the asset. However, either way, in the long run buying outright at the beginning can work out to be the cheapest option.

2.6.9 Trends

Upgrade existing systems rather than buy new ones.
To buy the software and the hardware together.
It is possible with the range of software on the market now to buy the hardware first.
The suggestion being that software and hardware should not be considered as individual entities.

2.6.10 Assess the opposition

2.6.10.1 What software and hardware is being used elsewhere?

When a company is in the process of selecting its equipment it is essential that it does not wholly perceive itself to be an isolated area of activity. It has to be aware of what its customers do and what computer equipment they might use. Communication of ideas is a vital aspect of design and communication of information is a vital aspect of the efficiency of Information Technology. So when the selection process is being carried out in the evaluation stage it is important to be aware of the software and hardware being used where, if for no other reason than for the consideration of communication of ideas.
2.6.11 Invitation to tender

This is derived from the requirements specification. It contains sufficient information to enable system vendors of both hardware and software to appreciate the system requirements such as a priority list to determine if a system configuration can be proposed. Contractual information included in this would be:

- Maintenance required
- Maximum delivery dates
- Details of acceptance
- Date by which tender submission should be by
- Details of penalty clauses should be given for example failure to meet delivery dates or pass acceptance tests.

2.6.11.1 Advantages and Disadvantages of including the system budget

- If the requirements specification is vague then vendor may be unable to determine the system required i.e. whether a low end micro or a high end mini.
- An included budget can cause vendor to use it as a target even if cheaper alternatives are available.
- Generally an order of magnitude costs can avoid stating a specific sum and what should be inclusive of this sum.

2.6.11.2 Tender Documents

This is the return from vendors to the company's invitation to tender. The suppliers state how they propose to satisfy the company's requirements specification. They will vary in size but should specify proposed system in detail.

1 List of hardware with capital or lease costs.
2 List of software included in hardware costs.
3 List of software not included in hardware costs such as third party software with capital or lease costs.
4 Maintenance costs for hardware and software per year.
5 Environment requirements e.g. power supplies and air conditioning.
6 Delivery dates.
Comments on the above points:-

- Points 1-3 enable company to determine if system will meet demand.
- Point 5 Environmental requirements examined carefully to see if a special power supply or air conditioning is required.
- Point 6 With the proposed delivery dates it is possible to see if the system’s introduction will fit in with the work schedule of project deadlines.
- Point 7 This will agree or not with acceptance tests and specify how the system is to be paid for. For example, if acceptance tests are to be run then the vendor may require 25% paid on delivery and remainder when tests are complete. It is not wise to pay for the system entirely on delivery, or after, until the acceptance tests are complete.

| 2.7 | Stage 6 |

This stage is the evaluation of the submitted/chosen CAD systems.

2.7.1 Shortlisting of Vendors

This is one of the difficult stages of the procurement process. Potentially the company will be faced with 20-30 tenders with each of a size of 40 pages or more describing the proposed configuration of hardware and software. It is not simply a case of accepting the cheapest quotation. It is important to establish that the company can provide the hardware and software needed during the systems lifespan. This means a requirement for a set of selection criteria covering technical evaluation, cost comparisons and contractual issues. During this stage some bench mark tests may have to be carried out on similar configurations to the proposed systems to determine accurate measures of the selection criteria and ensuring the systems approach the requirements.

2.7.2 System Evaluation

The requirements specification lists priorities of facilities. These can be used as initial evaluation criteria to determine how the tenders satisfy the requirements.

One method would be to form a table of requirements and for each tender to tick off those
requirements which are met. Those not meeting the essential ones can be quickly dismissed. The more complex system would require a weighted scoring system to be used. The information from benchmark tests is obviously very critical.

After the technical evaluation has been carried out then it is possible to assess the usability of the system, a very important issue. This is because large gains may be made in productivity, product development times and product quality. The assessment for this quality is serious. It is not a case of taking some time to play with it but requires careful thought to build it into the benchmark tests.

2.7.3 Computational Power of the system

- The software and hardware must be capable of executing the end-user configuration.
- The software has to give satisfactory results in terms of response time, presentation results and file storage.

Some fundamental requirements are:-

- Sufficient processor power to run the end-user applications giving satisfactory response times to work being carried out.
- Sufficient primary memory (RAM) to run the operating system services and end user packages.
- Sufficient secondary memory (Disk) to hold the operating system, utilities, end-user packages, data files and databases.
- Facilities for system support - disk backup.

The feasibility study should have yielded the order of magnitude of figures for the size of data sets used. Thus giving an initial impression of the primary memory required for working data and secondary memory for file and database storage. The operating system and/or program code storage would be extra to this.

The only real test of a configuration is to run it under tasks that are exactly the same to the end-users' requirements. This is not usually possible but in practice it is possible to:-

- Extrapolate from benchmark tests run on similar configurations during the feasibility study.
- Extrapolation from previous experience with similar technology.
• Ask users with similar configurations and applications for their comments.
• Software houses can advise on practical configurations and often specify needs of particular programs in terms of processor power, primary memory and secondary memory.

2.7.4 Measures of Performance

MIPS - Millions of Instructions Per Second.
Mflops - Millions of Floating point instructions Per Second.
Kips - Thousands of Logical Inferences Per Second.
Whetstones - Arithmetic Performance.
Dhrystones - non arithmetic performance.
I/O bandwidth - The rate at which information can be transferred between processor or memory and input/output devices and interrupt handling capability.

2.7.5 After Sales Support

Tendors will describe the hardware and software maintenance available and any training provided.
Vendor Company Viability - to ensure after sales support, evaluation of company's track record in terms of sales, profits, location and number of maintenance and support staff. Many vendors will supply a list of customers which can be appraised for running benchmark tests or comments about support.

2.7.6 Cost Comparisons

Once the technical requirements satisfied then cost can be evaluated.

Relevant Factors
• One-off capital costs of hardware and software.
• Recurrent costs of hardware and software.
• Installation costs e.g. power supplies and air conditioning.
• Costs of training system support and end-user staff.
• Recurrent costs of hardware and software maintenance.
• Staff support costs e.g. computer specialists.
• Costs of possible upgrade paths.
2.7.7 Contractual Arrangements

Simply the larger the system the more complex the contractual details.

The basics to consider are:-

- Delivery Dates.
- Acceptance Tests.
- Payment Dates/Schedule.
- Maintenance Contracts - what is covered and for how long.
- System Upgrades - Options.
- Consequential Loss.
- Exclusion Clauses.
- Order, installation and acceptance tests.
- Training
- Maintenance - costs typically 7-12% of hardware capital costs

2.7.7.1 Benchmarking

Purpose is to test the shortlist of systems to gain an impression of the configurations which will come near to matching the requirements. The tests should cover the following aspects:-

- Small number of tests representative of the work load to be carried out on the proposed system.
- Tests should cover:-
  - The essential
  - Highly desirable
  - ‘Would-be-nice’ requirements
  - How easy the system is to use.
- A scoring system determined to aid the evaluation of tenders.
- Tests must be on a similar system configurations to those systems the company is interested in.
- Talk to people operating a similar configuration already.
- Once the system is installed you should carry out acceptance tests ensuring the requirements specification is met. These are usually a more thorough version of the bench mark tests.
2.7.8 Problems with this stage

Benchmarking fails to show how well the system works in the hands of an inexperienced user. This can happen when a drawing is sent to the supplier prior to demonstration which gives them a chance to customize the system by adding special commands to solve the test cases faster than apparent at the time of demonstration. When work is sent to the supplier first then exactly what has been carried out to customize the system should be explained, time taken. When it is not made apparent then the results do not reflect the basic power of the system but its adaptability and skill and diligence of the demonstrator. Many demonstrations are just a guided tour of facilities. The other problem with demonstrations is that demonstrations of software are generally on empty systems with very little data stored another factor which gives a false impression of response times. Other users of package with time to develop maximum workload would give more accurate result. Try to get the demonstration using an in-house drawing.

When carrying out the evaluation it should be remembered that the most heavily advertised popular systems may not be the best for your requirements.

2.7.8.1 Who makes the Decision?

Producing a specification of requirements, identifying the systems which meet those requirements and deciding on which supplier to buy from is a business activity common to any investment in capital. The consequences of this particular decision are likely to have a long-lasting effect on your business. The choice should be made on the basis of the best supported system to meet the essential requirements. Planning for the new system conversion and use is essential. The real impact comes when the new system is to be implemented within the small business environment. The conversion needs to be well planned and gradual wherever possible.

It is likely that in small organisations the evaluation material would be seen by the decision maker but not so in large organisations. Therefore the actual function of the evaluation process needs to be very clear. It is best regarded as a means of filtering out the unfit and of presenting to senior management a comprehensive basis for making an informal choice.

The "mechanical" processes of basic evaluation should not be regarded as imposing a decision. One side effect of this approach is the need to give the final decision makers an appreciation of the processes applied. This both helps them to judge the quality and character of the data eventually presented to them and discourages any reception of direct approaches to them by suppliers
representatives.

2.7.8.2 Decision for CAD

When you make the decision to purchase a CAD system the golden rule is:-

- Make your decision after careful deliberation on all aspects involved with CAD in the cold light of day.

In the decision making part of the process the company has to finalise the contract to purchase the system.

2.7.8.3 Common Criteria for Decision

It is not enough to state requirements and invite responses. It is vital to determine basis on which responses will be judged. Defining criteria for assessment is also essential to adopt a means of allocation to the correct relative importance of these criteria and to prepare this material as independently as possible of any likely offering from suppliers. It must be ready before any proposals are received. The criteria as requirements must be oriented towards user satisfaction - largely drawn from Statement of Requirements.

The question of the 'success' of a computer system is a relative judgement made in many different ways by those involved. What is successful to one person may be a failure to another. It will depend on your expectations or your experiences with other systems.

However it should be agreed on :-

- Why is the new system needed?
- What is hoped to be achieved by the new system?
- How are you going to recognise whether the new system has met the agreed needs?
2.8 Stage Seven

This is the stage it is installed. It will be necessary to carry out the acceptance tests.

2.8.1 Training

As decided in the requirements criteria it will be either in-house or from vendor or an outside third party.

2.8.1.1 Computer Appreciation Skills

- Prevent/Overcome Fears
  - Possible loss of jobs.
  - Total change in what is expected in the office.
  - Health risks involved.

- Skills
  - Show what it can and cannot do.
  - Outline of company policy and strategy towards the use of computers.
  - Summary of the types of application which the company is intending to place on the computer in the first instance.

- Computer Operations Skills
  The operators and system manager also need some basic training on how to operate the hardware being used. Try to ensure that more than one member of staff knows how to do this.
  For example - paper jams, switch on/off all kinds of machinery, check various devices are operating correctly, perform some routine maintenance work such as replacing ribbons, paper. Experimenting with printer operations, trouble shooting of the technical nature can save many a call-out on maintenance contract and downtime of system. This will highlight the need for a systems maintenance routine to be established. A daily/weekly one will be performed by in-house staff. This will cover activities such as disk backup, hardware and software maintenance performed by the system vendor or a specialist maintenance organisation.
2.8.1.2 Lessons to be learnt

- A smoky atmosphere is known to be detrimental to the condition of magnetic disks, so it is wise to implement a "No Smoking" zone around the equipment.
- No drinking or eating in the vicinity of the machine, even if the rest of the office does not operate in this way.
- Care in the handling and storage of the floppy disks.
- Floppy Disks need respect and care and so it is wise to train staff to look after the equipment. It is really such a fragile media to invest in with regard to the drawing information, so respect and care of all floppy disks are the wisest philosophies to be trained in.

2.8.1.3 System Knowledge

The more technically minded or computer curious members of staff will be interested in the operating system and the language of the computer and they are likely to become the company's in-house experts.

System Utilities are the programs which come with the computer rather than the application package.

Examples of the types of information which the operator or person acting as system manager needs to know are:-

- How to find out what is stored on a disk by looking at the relevant directory on that disk.
- How to find out how full the disk is by looking at the status of the disk.
- How to prepare a new disk and ensuring there is a system track recorded with utilities on it.
- How to make security copies of a disk or a single file by using the copy command.
- How to print out a directory of the disk contents for checking.

2.8.1.4 Software Package Operation

The supplier should provide some training in basic operation but this may not be sufficient to acquire an adequate level of skill. The free training included in the overall price of an application package is often little more than a demonstration by a salesman and rarely enables the purchasing company's
staff to learn how to operate all the system for themselves. They will have to perform all the functions
themselves, in a slow and methodical way before experience is retained. The experience should
preferably be 'hands-on' training while being helped by the trainer.

It is a worthwhile business investment to arrange some extra training for both routine and non-routine
procedures.

2.8.1.5 Selecting Staff to be trained

It should not just be junior staff. Senior staff need to establish the philosophy of self-reliance from the
outset. While junior employees may be the quickest to learn, it leaves the business wide open to
disruption should staff leave unexpectedly.

When selecting the staff to be trained it should be remembered that it can take 4 - 6 months for
people to become efficient and to work faster than they could on paper.

2.8.1.6 Staffing Roles

In smaller concerns the system maintenance tasks can be shared out relieving the necessity of
specialised staff. Mini-computers and distributed workstations on a network will require more
specialised staff for tasks such as:-

- Maintaining and installing a complex operating system environment.
- Centralised disks on file servers to be backed up.
- User codes allocated.
- Software reports verified and reported.
- Hardware faults verified and reported.

2.8.2 System Implementation Staffing Matters

One aspect of a successful implementation is the staff involved with the system and the necessary
skills required.

In large companies there are three types of support staff who each provide different services:

- Facility engineers - oversee the day to day running and maintenance of a system
- Application engineers - help end users make the most of a system through
tailoring applications by the use of 'macros' and determining the best practice.

- System engineers - assess the changing needs of the business and bring the CAD system in line with these changes.

The benefits of a support team are clear: apart from more effective use of a system the 'meddle factor' is eliminated. With a badly supported system an estimated 15 per cent of a designer's time is spent either working around system shortfalls or improving the system. This leads to non-standard working practices, non-standard designs and non-standard workstation configurations.

The strategies of the implementation process must be carefully considered so that the proposed system is used to its fullest potential and at its most cost effective. Two possible options to maximise use would be either shift work or split working days. There are a few problems with shift work:-

- Design is an area that traditionally does not follow this pattern of working.
- The cost of paying staff to work out-with normal hours might be prohibitive.
- Staff may not wish to work shifts.

The alternative is split working days, where the designers have periods of the day allocated to working on the computer. This option might be seen as being too formalised or restrictive so another variation to this option would be to create teams of designers allocated to one machine. The team would be responsible for their own time allocation and would work as a team, deciding who is to use the system, when and according to the demands of each job.

2.8.3 A summary of the Implementation stage would be:-

- Consult widely with employees at the earliest possible stage.
- Make a clear statement of objectives and benefits.
- Allow for changes in supervisory roles.
- Allow for changes in job design.
- Create awareness of the new technology.
- Users and specialists should work together.
- Ensure the key people really understand the system.
- Give users early 'hands-on' play experience.
- Allow for lengthy time scale for the introduction and training before full efficiency can be expected.
- Fill new jobs created by CAD to be filled internally wherever practical.
• What roles are essential and what are not?
• Are they full time occupations?
• What will this mean in terms of money?

2.8.4  What are the roles created when a CAD system is introduced to a company?

2.8.4.1  Senior management Role

This is distinct and separate from the other roles and has to be carried out by someone at director or partner level. The level at which policy is made and budgets controlled. This means that no one else can perform the duties of this role. However, despite this, there is work which can be delegated from this role but this should not be done either out of necessity or lack of knowledge.

Important that senior management are capable of performing all tasks in the CAD office. Opportunities arising from a CAD strategy will not be grasped if the strategy has not been written at the highest level but who also has relevant experience of the design department. So because of this it would be helpful if this person was a designer with project management and recent CAD experience. However, in most companies with little IT experience, this will be a rarity.

2.8.4.2  Computer Expert’s role

This potentially could be a completely independent role created by the introduction of a CAD system to a company performed by a member of the company’s computer staff, should the company have such a department. If this is not the case, then other options would be:-

• Identify a computer buff amongst the staff.
• Use the expert user provided that person has sufficient skills and time to carry out this role.

An expensive last resort would be to employ a consultant on a task-by-task basis. In the case of small companies, these tasks will have to be performed by the enthusiastic user relying heavily on his dealer for help.
2.8.4.3 CAD clerk's Role

In data management there is always need for clerical support. Tasks would be stock control, ordering publications and general clerical duties. The person would need to be trained to be able to obtain data, so key-board skills would be helpful. CAD duties are unlikely to take up more than 10 per cent of their time - depending on the size of the installation so this role could become part of some ones overall working role within the company.

2.8.4.4 Systems Manager's Role

Should the installation be of medium to large size, then it might be useful to split the bulk of the work between this role and the CAD Manager's. The CAD Manager being responsible for management issues and the Systems Manager responsible for the technical issues and the day-to-day running of the system. The Systems Manager has a technically-oriented role and responsible for the smooth running of all the CAD systems in the design office. In this role, he would report to the CAD Manager who is responsible for the policy making.

2.8.4.5 Establishing Master Files.

This is one aspect that is not considered by companies when they are planning the implementation of the system and it is one that could have dire consequences should something 'go wrong' with the hardware or even with the office. The concept of backing up your system should be expressed quite vehemently to companies.

2.8.4.6 Tuning

Enhancement of the facilities such as recovery procedures, data security and integrity, system faults, environment. These are aspects of implementation when the company is more familiar with the system.

2.8.5 Evaluation of the system.

Determination of the success of the implementation of the system is necessary to establish the efficiency of the strategies applied - hence the working efficiency of the system. So it is beneficial to evaluate the system and critically examine its role within the company.
The following are example questions that should be asked as part of this evaluation:-

- Does the system still fully meet your objectives for the provision of information?
- Is the computer system running smoothly?
- Do bottlenecks ever occur, such as drawing, printing or plotting?
- Are all the facilities of software actually being used?
- If no, can your business make use now of other reported information or facilities?
- Can the system be extended to meet any other management information?
- Can the data belonging to one system be manipulated by other company software tools?
- Is business routine established and running smoothly?
- Is there any need for further training to maximise the use of the system?

It may be decided to keep the old system operational in case of any unanticipated problems. Checking results of the new system may lead to modifications in the way software installed or in the business procedures supporting it. Most CAD systems have many ways of operating it.

2.8.5.1 What are the chances of success?

Computerisation will have been a successful venture if you are able to use the information from the computer system to improve your business in some way. Successful systems also prompt other staff to use the information in ways they had not previously anticipated and eventually the system is extended.

2.8.5.2 Terms of Investment

- It is the people who operate the system rather than the hardware that is the real investment of the company.
- When CAD hits mainstream design then there will be widespread changes in the design profession.
- Fewer people able to carry out more work thus it allows higher salaries to be paid.
- The full effect will not be realised for about another 3 to 5 years.

Whatever the system finally chosen, there will be a time that it will become obsolete. Hardware tends to have a useful working lifespan of 3 to 4 years. Maintenance costs start to rise once the machine is over 3 years old. This increase can eventually lead to replacement rather than repair. The
implication with this life span is with auditors who are used to capital items having a lifetime of seven to ten years.

In terms of software this has an even shorter life span. Regularly software houses release new versions of their packages which repair known faults and offering enhanced features. The problems that can happen here are:-

- Software houses tend to aim their products at the latest systems. This forces users who need to use the latest versions of software to scrap computer systems which appear to be quite viable at an earlier time than first thought necessary. Another factor with software houses constantly updating is that over a very short period of time, the size of a software package can double or treble, making it impossible to run on older equipment.

The other aspect of rapid advances in hardware technology is hardware vendors can be left with last year's equipment so they offer particular configurations for sale at special or discount prices. These offers should be viewed with care because of the following:-

- The latest versions of software may not run on the old systems.
- System components and boards may no longer be in production making system upgrade expensive or even impossible.
- Maintenance of older equipment can be very expensive.

2.8.5.3 Existing system Enhancement

Staff will have experience of using the older system so training in only necessary on the new aspects. Care should be taken if this strategy is taken to avoid the trap of being stuck with obsolete technology. So a review should be carried out every few years to consider total system replacement. If new software is proposed to be used on the system it is important to ensure that vendors are aware of the exact configuration of the system - processor, memory, disk, numbers of users. This will aid vendors to determine if their package is available for that configuration and if so whether there are sufficient system resources to support it.
2.8.6 The most likely pitfalls in the selection stage

2.8.6.1 Potential mistakes by a first-time buyer

To assume that buying a computer system is all about numbers and specifications.
It has been found there are many subjective reasons that should not be ignored such as:
The attributes of one system might appeal over another. Attributes such as its design, feel of its keyboard or helpfulness of the selling agent.

To be mean with the money
The general principle is that first-time buyers should avoid bargain basement prices. This is because exceptional prices could mean poor quality construction, out-of-date model, design failings that do not show up until upgrading is necessary.

Incorrectly identify their drawing requirements

Other areas are where ignorance fails to recognise needs can be seen in the following quotations.
The first group concerns drawing management.

Users often encounter problems with managing the drawing and other document information on their system. This occurs because few systems come supplied with any significant means to control the creation and destination of the valuable data files that represent the drawings.

People new to CAD have little understanding of the need to manage drawing data. They often only learn when they find their system discs are full and no one can recognise many of the drawings or whether they can be deleted or archived. The parallel situation in a conventional office is where document registers, files and circulation lists are used, and approval mechanisms are enforced to ensure that no uncertified document falls into the wrong hands.

Minimum requirements in any drawing management system are:

- Controlled allocation of drawing numbers
- Method of identifying:
  - unapproved drawings
  - drawings ready for approval
  - drawings rejected from the approval mechanism
  - approved drawings.
The means of identifying drawings status should be the means of controlling access to the data, the distribution of the drawings and the archive mechanism.

Proper identification of needs is useful for determining factors other than the software package to use. By having identified your requirements by sampling your work currently in the drawing office to see factors such as:-

- Time taken to do the drawing.
- Parts listing.
- Numbers of drawings produced and sorted by:-
  - Size.
  - Type.
  - Complexity.
  - Amount of repetition.

The size analysis will help to determine plotter characteristics, as will the throughput.

Where some possible benefits can be realised by a design practice.

- The data held in the computer from which the drawing is created can be analysed by other programs, provided the system has a drawing database interface language available.
- Use of programs such as parts listers.
- Analysis of graphical data to provide information such as areas, volumes, weights, positions, forces.
- Greater benefits can usually be achieved when there is additional data in the drawing database.
- Sometimes it is more effective to hold information about drawings in a drawing register. This has the attribute that it classifies a part according to its shape, function, material and manufacture which could be useful in tracking down 'similar-to' components. When this attribute conforms to one of the well-known coding systems it could be put into the drawing data after the component has been approved.
Hardware problems
Computers are not the infallible systems that some people still think them to be. CAD systems have faults that are solely their own and could be considered as "points against CAD". They also show how the planning of drawing work is necessarily different to manual methods.

- The machine most needed will develop faults at the most inconvenient times.
- Plotting is a bottleneck area. It is a time-consuming task usually carried out once the whole job is ready for plotting. A factor that highlights the problems of the bottleneck as all the drawings need to be plotted for a deadline.

Working Practices Problems
There has been and still is a reticence about the adoption of the necessary working requirements to efficiently use CAD systems.

- When designers do not adapt their way of working to compensate for the weaknesses of CAD packages.
- They consider that if CAD is a tool to help why does it take so long to use it productively?
The implementation stage is really the final stage of the selection process. It is the proof that all the earlier work was correct. This stage is protracted over a time span of approximately one year.

3.1.1 Preparing an Implementation Plan

First stage uses the information from the Selection stage to identify what requires changing and planning to implement the system. Thought must be given to the physical installation of the system. Aspects such as:-

- Power Supplies e.g. filters or separate power supply.
- Lighting/screen position e.g. to avoid glare and hence eyestrain.
- Comfortable seats, adjustable tables, reference tables.
- Networking cable (if needed) important to avoid hostile areas - the use of optical fibre being recommended for really hostile environments.
- Location of plotters and printers, ideally they should be separate in another room or area to subdue the associated noise with these devices.

The person responsible for the position of this system is the System Manager. He should be organised as he will have to:-

- Establish Procedures.
- Agree and set standards e.g. dimensions, text/line styles.
- Controls data creation and storage.
- Select work.
- Vendor contact for all support requirements.
- Identify and implement macros, part libraries, interfaces with other systems, new application software.

This person should be second to the CAD champion. As the Systems Manager will be the 'one at the sharp-end'. It is important to establish the terms and conditions of acceptance. The important aspects to remember are:-

- What the warranty cover exactly includes and for how long.
• Whether training is an extra or not and how much, if it is an extra?
• Who is responsible for the cabling of the stations and the testing of them?

The time when the system is officially 'accepted' is important as the company will be liable for payment on acceptance. For example:-

• Is acceptance when the system has passed all relevant diagnostic tests or when the company is satisfied that the facilities are all present and operating?
• How the software is supported?

Whether or not any non-standard software is involved such as a special routine which has been created for the company. The question to ask is:-

• Is the routine guaranteed to be compatible for ever with the main system or what happens when it is not?

If it is not a formal vendor product:-

• What guarantees do you really have?
• Who is responsible for any mixed-component systems. If this is established early on, it clarifies the situation and allows peace of mind.

Once the system is chosen, the matter of training should be planned for and how it is to be carried out. The following is one recommended way:-

• Choose enthusiasts first.
• Plan to finish basic training at the moment the system arrives.
• Delay training on advanced facilities such as 3D modelling until basic facilities are well understood.

Beware any negative attitudes as this may destroy confidence amongst those who have yet to be trained on the system. Should the person with the negative response be higher in the company than the Systems Manager, then some more subtle ways might be employed such as:-

• Getting the people trained on the system to carry on working manually thus slowing their learning curve and reducing the impact the system has on the
company in the early days.

- Insisting that certain work be carried out manually which again reduces output of the system.

The system set-up should be planned so:-

- Standards and defaults to ensure consistency of work.
- Data structure based on research that studied the needs of all affected departments.
- Back-up and recovery procedures i.e. fireproof safe for copies, back-up routines established, possibly daily back-up.
- Plotting procedures for mundane tasks such as to who cleans out the pens or cuts off the plots.
- Establish access controls/passwords/users directories.
- Monitor a system usage and performance.
- Produce a company system handbook which contains all the standards and procedures for all to refer to.

A work plan should be organised to facilitate the implementation. The following is one method after initial training has been carried out for example:-

- Select modest work first.
- Set achievable and measurable goals for first 6 months.
- Identify symbols/parts for capture.

It is also helpful to create a standard demonstration for visitors to minimise the impact on production and present the best image whenever required. It is essential to prove the short term success of the investment to the senior management e.g. the Board of Directors and any other affected departments.

The introduction of the system will have an effect on current work and this should be allowed for, such as:-

- Current projects being handled manually.
- Throughput to/from other departments.
- Acceptance of new style output by other departments such as plots or prints.
• Time scale for CAD based work
  • - allow for learning curve of new users.
  • - casual users produce casual results.
  • - no database in the early days which is the equivalent of the worst case situation in a job.
  • - there will be the inevitable snags.

So the advice is to be cautious with the implementation plan and do not over-commit CAD results. The detailed implementation of the system is dependant upon the planned expectations of the system of each individual company. No one situation being similar however, there are some areas of commonality, these being:

• What to do if it does not work?
• What to do if it does not come up to expectations?
• How to manage the system?
• How to use the information the system can give?

To properly carry out the implementation plan it is necessary to discuss the above topics in detail.

3.1.2 Implementing your New System

Irrespective of the actual choice of the CAD system i.e. the software package, the brand name of the CPU and screen, the actual implementation of the system has to be carried out so that the proposed and desired benefits are realised. In each individual case, no matter how fastidious the previous stages have been, it has all been essentially theoretical. It is only when everything has been fitted, switched on and is working that flaws will be recognized. This is particularly so when dealing in areas where people are inexperienced or have acted through misguidance which has resulted in incorrect assumptions and wrong decisions can well mean the success or failure of a system. However, even if no errors have occurred, through experience in working in a situation it is always possible to identify areas that could be improved, bettered and in need of some form of change. The real value of the CAD system will be the information produced. The realisation of the value will come from the use of the information produced.

The selection is only the first step along a difficult path for your business. The smooth implementation of the chosen system into your business needs some careful thought and planning if you are not to be disappointed in the end. The implementation can be divided into two sub categories...
which are:

- Technical
- Human

3.1.2.1 Technical

This part is the product of the planning stage and this section covers:

- Getting the system to work the way required by the company
- Using the data produced to its fullest extent

The Technical Appraisal (Evaluation) of the system methods are:

- Tests
- Worker to machine ratios
- Qualifying Expectations

Consideration to any necessary physical changes in the work place such as -

- Power Supplies
- Lighting/Screen positions to reduce glare
- Comfortable seats, adjustable tables, reference tables
- Networking (if applicable)
- Location of equipment such as computers, plotters and printers
- The company should realise whether or not it is affected by what other people have got. It should also have decided whether or not they need to be aware of their rivals' equipment.
- The company will know what roles are necessary to be established for the system to run smoothly/efficiently by evaluating what roles are essential and what are not. The company will also be aware on whether or not they are able to cater for these activities with current staff or whether it will need staff purely to work on these occupations.
- Any advantageous changes to the current working methods will be understood and the company will be able to utilise them to their fullest.
Consideration to any changes necessary in the working roles such as -

- Outline of essential roles necessary for system efficiency.
- Can the roles envisioned be catered for with the existing staff?
- Do more staff need to be employed, if so do they need to be specialists?

Developing an awareness of what other companies have by way of systems.

- The financial aspects involved in the technical side would cover the following:
  - What equipment is necessary for it to be operational?
  - What equipment can be purchased at a later date?
  - What are the costs of the materials, ancillary equipment?
  - What equipment is necessary immediately to be operational?
  - What equipment can be left until the company can justify purchase?
  - How the company can allow for this type of development?
  - The plan will allow for all the costs to be identified such as equipment, wages and materials?

More importantly, the timing of the upheaval which will result from the new system is a delicate matter. The advantage of external factors e.g. temporary slumps in business activity should be recognised and taken advantage of in the implementation and scheduling of key aspects such as training.

So the plan to time the introduction of the system is:-

- Try to coincide with a period of low business activity.
- Conversion period - training - when to carry this out.
- Resources - Manpower needing to be trained immediately, eventually, and when can this come about.

3.1.2.2 Human

The training issues involved:

- Who to train?
- What to train to who in the relevant areas of the company?
• Establish if there are any learning problems and be able to control them.
• Whether the training has been successful.

What are the opinions of the workforce to the system?

• What fears they have on the health hazard?
• What changes there are to the working roles?
• What working conditions are governed by the ergonomic criteria?

Staffing matters such as:

• The financial aspects involved in the human section covers the costs of salaries for CAD personnel.
• How to avoid making someone indispensable.
• How to choose who to train and for what role.
• What makes a good operator.
• What policy to follow if is necessary to dismiss a CAD operator.
• How to protect the system from 1) Viruses.
   2) Malicious vandalism.
• What stance to take on security in relation to computers.

3.1.3 The need for planning

If the CAD system is not suited to its intended users, there will be problems in its implementation and usage. Should problems arise at this stage then this points to the difficulties of comprehension that can exist between different groups of professionals involved in a company structure. This is not new, but in the current commercial environment where the success or failure of a technical product now depends on user acceptance this difficulty is becoming of profound importance. The successful implementation of any system will be dependant on the complexity and detail of the planning carried out. The implementation of the system is the operational use of the computer and the realisation of the performance requirements laid down by the company's purchase team. Through inexperience and/or misguidance, this is when it is found whether or not the system is all that was promised or even expected.

Probably the reason why your company is introducing CAD is to increase its productivity, what is not properly appreciated is that for the initial months productivity will actually decrease. This will reflect on
the CAD system and those not familiar with CAD will assume it is because the CAD system is inferior. By proper planning you can prepare people for this drop so that they actually expect it and when scheduling work they can take this into account. The work flow will need to slow down for a while until every user becomes fully familiar with the system. While this familiarisation period is underway it does not prevent real work from being carried out. So work can carry on through the training period but it will need time for the learning curve to increase. Humans need to learn, practise and assimilate the information. Anyone learning CAD will need fixed periods away from the system: five to ten minutes every 60 or 90 minutes is fine, but it is essential to allow ideas and concepts to take root.

Smaller businesses can be more at risk than large. They are less likely to have in-house expertise in either health and safety or computers, and often have fewer resources for updating equipment or furniture. Too often they rely on suppliers for advice on selecting, installing and maintaining their computer systems, and few dealers seem able or willing to advise on health and safety. User-centred design and Human/Computer Interaction (HCI) is increasingly being recognised as a way of providing competitive edge, as well as making life easier for the users of advanced technology systems. The main obstacle, though, has been UK companies' reluctance to acknowledge what has been clear in Australia, the US and some of Europe for years - people get hurt and productivity plummets if computers and their environments are not geared up for human needs.

3.1.3.1 Changing Software Performance

The rate of change in the software is one that can easily be underestimated by companies. The working life span of the software is not always realised and budgeted for. The change is often a factor of the software houses rather than the need of the respective industries. The companies seem to believe that to keep up with the competition they have got to be able to announce a revision every year - even when they have not got anything worthwhile to add. This implies that the new features that are added each year tend to be a mixture of good and bad: some are worth having, while others are likely to be used very rarely, or else they are so time consuming that they slow the system down and defeat the object of the package.

The result of all this activity from the software houses is that with nearly every new revision, more memory is required. This gradually uses up all the free memory that the company requires for the storage of data and operating packages; this is another area where the expectation of a company is let down as less memory is left for operations and the computer takes longer to carry out the tasks asked of it thus resulting in an earlier upgrade or new purchase of a more capable machine.
The other point about this is every area has its own idea of what is relevant to a package and what is not. What is sometimes forgotten by people is that the package they have chosen is to be used by more than one type of design discipline which might use a slightly different set of requirements. This is one drawback about the purchase of "off-the-shelf" software since the software houses are trying to satisfy a wide market with the one package. So the package will have redundant commands for some areas of work.

However, one problem which is universal is the lack of commonality to be found between packages from different companies. The command names change from package to package as does the terminology. The packages use terms very different to the terms and phrases used by manual draughters. This suggests that the terminology used by the software houses is at fault and the difference is more due to one company wanting its package to be seen to be different from another company's package. Alternatively, it is due to the fact that it is written by a programmer who has no drawing experience. Those packages that are supposedly written in conjunction with a field expert e.g. an architect still appear to suffer from this terminology problem. It could be said that sometimes you are left wondering exactly to what extent the expert had in any input to the work.

It would be advantageous if more design professions took a more active role in software development. The current problem about this difference in command terms is the computer manuals. The majority of computer manuals that are provided with systems are incredibly poor. They appear to be written as a last minute decision and almost with distaste that someone should need to use them. The layout of them is more suited to a systems engineer than someone about to use the package to draw something. The package tutorials are another weak feature of current packages.

The other argument about using a manual is "why should we?". They are not enjoyable reading. The current trend by the software houses to skirt round this problem is to supply on screen help. This is really still not an ideal solution as I am back to the question of "why should we?". The ideal would be that the human-computer interface should require no help as it should be so naturally friendly. Now is the time for designers to help software developers "humanise" the software or to help to rationalise the command structure terms.

Whatever the cause, the complaints about package terminology might eventually disappear like all terms which are changed and modified to suit the demands of the present. This is just like language which develops and eventually envelopes words and phrases so that it eventually evolves into a new language. For example the English which is spoken today is nothing like the English of the past.
Middle English which was once spoken in Britain was more akin to modern German than modern English. Computer jargon is a perfect example of how language changes. Visit a computer exhibition and you hear people talking in MIPS and FLOPS and they know what is meant but like most computer jargon it is a shorthand version or abbreviation for a chain of words which has gradually become these weird and wonderful words of computer jargon. No doubt this terminology will become a part of the English language.

The implementation brings questions such as "Have we chosen correctly?". There is always a better machine being built or better software being written. The performance of micros has changed and the market has broadened over the past few years and micros are being incorporated into larger systems. The resulting point is that the software companies are unsure of which operating system they should support. For example MS-DOS, OS/2, Macintosh, Unix or all of them.

The nature of CAD is that by carrying out more concept work on the computer there is a greater increase in concept ideas through an evolutionary development type. This greater generation of easily altered ideas helps the interaction/communication between designer and client. This method of working would be best employed in 3D work. The use of CAD has the opportunity to work from concept through to prototype to finished product. This could be further developed with the suitable software and, in turn, this can be further developed into the production of manuals and marketing/advertising brochures. Thus maintaining utilising drawings into post manufacturing use.

The issue of using the software leads on to the aspects of information storage and protection. The company should be advised to implement some form of back-up procedures - for example, individual work could be backed up to floppy monthly and weekly back-ups for team projects. This should be carried out onto two sets of floppies, one set acting as a master set that is never actually used for drawing work but only for the storage of data and the copying of data to other disks for eventual work. This is certainly the case for those working in the construction industry, although other areas should be aware of the fact that there is the growing need for CAD. Users need to protect themselves concerning copyright ownership in project contracts. Hardware and software warranties expressly exclude liability for losses resulting from their use even if the CAD system is at fault. Quality management is increasingly important because of compliance with BS5750, the standard for quality assurance systems.

BS1192 Part 5 might appear in construction contracts as it establishes guidelines for construction CAD drawings such as Layering conventions. It also sets out general principles for CAD terminology and management. It is also expected that users will need to preserve their data in some form for
more than 15 years to ensure they can defend themselves against actions under the Latent Damage Act 1986.

One need for planning is to identify any potential bottlenecks so that the system can keep running at its most efficient. One such problem area is the pen plotter, the production drawing of finished designs. However, what the specifier tends to overlook is how check plots would fit into the congested plot priority queue so that design details could be resolved in the meantime, without causing jeopardy. This failure could be to the detriment of target productivity of issuing finished drawings.

The CAD system is typically specified in terms of overall productivity and quality benefit. For some, achieving improved quality through using CAD in the normal design cycle, can be the sole productivity justification for CAD. However, whichever productivity benefit wanted, be it straight productivity, productivity with improved quality, or quality alone, this inevitably means the formation of a significant bottleneck arising not only at the plotter, but additionally at the design managers 'in' tray. This is simply because there will be an increase of plots being submitted for checking.

So, regardless of whether you are aiming to improve the quality of design, or you simply want to produce more designs, the process is typically reactionary and therefore follows an evolutionary path of continual amendment. In summary, whatever the productivity challenge you have set for the design office, it inevitably means that you, the design manager, will have to make a greater number of decisions more frequently.

For example, you require your CAD team to be three times more productive than the traditional design office designer/draughtsmen team. This means, to achieve that aim, your own productivity must also increase accordingly, by making three times as many design management decisions.

At the end of the day, a design manager can do very little about reducing the number of decisions he has to make on a daily basis. If the manager is ahead of a schedule based on the design cycle of the traditional drawing board, this does not necessarily mean he can spend more time on quality. The manager has to achieve good quality, but he does not need reminding that his boss wants increased productivity in terms of meeting those production deadlines. After all, time costs money.

The development of drawing office management systems is seen to alleviate the problem whereby it allows the manager to check drawings in an electronic format and reduces the need for paper check prints. The drawing office management systems are not CAD systems themselves and they equip
the manager with all the tools which that role requires to effectively manage the design team without the manager having to learn all about the CAD system. This combined with electronic mail systems allows the manager to communicate with the design team directly with each individual member. The job accounting programs can be a measure of the cost of the job and the efficiency of each individual designer/draughtsman.

You cannot expect a CAD 'super user', blessed with design acumen, also to be a good man manager while doubling up as a systems administrator. He may have some of these qualities, but will be unlikely to have all of them.

This problem is therefore remedied by the drawing office management system. The adoption of a modern design office management system means the CAD manager has also be a man manager. If your organisation is big enough, you should have at least one individual charged with systems administration, leaving the CAD manager to get on with being a CAD 'super user'. This gives the CAD manager the ability to keep the information database up to date.

The last obvious benefit provided by a drawing office management systems is the management of drawings, revisions, issues, and 'as-built' drawings by letting the system help you in keeping database records up to date. Without such a system, keeping track of drawings even in small office is no easy task. In a large office it can be a nightmare. By creating the title block for each drawing, managing revisions and requesting plots through the drawing database management system, the problem is solved.

Proper drawing management means another aspect of quality creeps into the scenario of good office management. For example, when a client telephones and asks to see drawing 2050/d/21E, you should be able to put your hands on it in an instant, thus providing quality customer service. To provide a quality service, you must have procedures that are quality assured. Today, new customers like to feel confident that you have implemented quality assurance procedures. They are doing this by asking you to show your BS5750 accreditation. This is something you cannot get accreditation without implementing a good, modern, drawing office management system operating over a network.

The CAD system is usually perceived as comprising the hardware to perform the task and the software to give the commands and it is often thought that the acquisition of the CAD system is the final hurdle and once purchased the problems are over. The research has shown that this low awareness of the issues concerned is the cause of some of the problems encountered by companies involved in the questionnaires. Some have moved on from these mistakes to develop a system that
is both efficient and problem free. This is the level that companies just starting in CAD activities want to reach as soon as possible so that they are viable, competitive companies in a market that has become even more competitive due to the recession. To achieve this they have to be more aware of the aspects of CAD and the methodologies that need to be applied for efficient implementation of the system.

There is little or no regard given to the third part of the CAD system - the human factor. The problems that occur here can be simply overcome by an increase in the awareness to human/computer matters. This increased awareness is closely involved throughout the process of CAD system acquisition to implementation.

3.1.3.2 Management

My understanding of management is the process of the administration of an activity and that really in CAD matters, management is essentially no different from any other management activity. The difference is that it operates at different levels of involvement and method. So, when relating this to CAD awareness, it should, therefore, be understood that the level of CAD awareness required within a company will be different and it will reflect the management structure within the company.

CAD management issues cover a wide range of aspects and issues; some of them are products of the current technological level of operation. These are prone to the rapid changes that occur in this technological working environment and the pace of change seems to be increasing exponentially. This change is a result of either new technical advances or new ways of utilising current technical knowledge and this is equally applicable to the software. In fact the software is the more volatile of the two technological components of any CAD system. Programs can potentially change many times in a year - updates and new versions. New software with new innovations are constantly being released. The very fact that the change is so rapid is an issue that has to be managed when working in CAD activities.

The essential fact is that CAD only brings a radical change in working methods but not to the essence of what design is about. So the basic issue is really about managing the change in working methods that CAD brings. This is a concern that is affecting all areas which are introducing computer technology. This is very much a fact of what is currently threatening the design professions which are still essentially new to the use of computers and the revolutions they cause in the working environment. While traditional rules of work practice allow for a clear delineation of business tasks and processes at every level, the deployment of IT increasingly blurs these boundaries. Information
Technology continues creating new information links at a very fast rate, which gives managers a continuous flow of new possibilities. This is probably true for companies which currently run a highly structured management system. However, smaller design consultancies tend to operate on a less formal management level.

It is perhaps the realisation to what computerisation now means to working methods that designers are reluctant to introduce it. Most people tend to shy clear of change as it is usually inconvenient and can sometimes herald an altered state from bad to worse. By avoiding change it negates having to learn how to manage that change with its inherent problems. It has been argued that the proper management of one change is a preliminary state of another change.

Design management has to realise that the use of CAD is not just a case of introducing new machines to the company but that these 'new wonder' devices bring their own crop of problems which require solving. They also bring their own required changes for the design manager.

These changes for the design manager mean that there are new qualities being asked for, which raises the question what are they? Development work in this area suggests that the new manager has to play more of a hybrid role. The role means they have to be an individual who can combine both design managerial skills and computer skills and is equally at home in both areas. They will also have to restructure all working practices.

The fact that the introduction of CAD to a company will affect more than just the immediate operators is not very well appreciated by many novice companies. So the administration of change is the first problem which companies have to realise and plan for. There are no real answers to this problem and the right answer for any given company will be dependant on the company. All that can be advised is that the company rethinks its internal structure and be ready to adapt it if, and when, it becomes necessary.

3.1.4 Administration

CAD Management is a complex activity which is made up of various subsections which can now be discussed further. This essentially can be described as the organization involved in running the system which can be broken down into two sections which are:

- System Organisation
- Company Organisation
3.1.4.1 System Organisation

One aspect of the system that needs to be very well considered is the manner in which the created work is stored. The more work that a company carries out, the more it creates drawing files which accumulate on the hard disk. This means that drawing files for standard components and symbols for current jobs have to be resident on the hard disk as well. This is primarily so they can be accessed daily. The result is that there will not be sufficient memory for the storage of all past work which, therefore, means that these old files will have to be archived onto floppy disks, magnetic tape or optical disks. While not seen as a productive activity it is very worthwhile as each drawing, whether archived or resident on the CAD system, represents a considerable investment in time and resources. For that fact alone it is essential to organise and manage this investment. This holds true for any CAD installation, small or large. The way to control this material is through the use of a drawing management system which will make handling of this data more efficient and eventually increase drawing productivity.

Every company will have its own individual conventions for drawing numbers and for classifying projects, procedures for drawing revisions, checking, approval and for monitoring project costs. They might even change from project to project, as companies are continually developing ways to improve their working practices. A CAD drawing management system must therefore be flexible, so that it can meet individual company needs and adapt to changes in drawing office practices. It must be capable of storing fields of information about each drawing, such as: project, drawing number, DOS directory, drawing title, engineering discipline, draughtsman, revision level, approval status, date created, date last edited, time spent working on the drawing.

The information content requirement will vary from company to company so the required number of fields will also change. The content of the fields will vary. Some will be numeric, some alpha numeric and some just text. The information has to be kept consistent between the drawing's title block and the database of the drawing management system. However, some of this information need only be recorded in the database of the drawing management system and will be deliberately excluded from the drawing itself. For example, the time spent working on a drawing. This information is needed by the drawing office for the invoicing of the job but the company would not want to tell the client this sort of information. However, there will be quite a lot of duplication of information as well. The information will be held within the drawing itself, either in its title block or elsewhere on the computer such as the DOS directory structure. A flexible system will also be configurable so information can be automatically copied into, or from, the database. The drawing management system should also be
capable of powerful search and report facilities which would help the CAD manager to find the required information to satisfy any queries in a variety of situations ranging from the simple to the complex.

The most common and simplest mistake is the creation of ad hoc files. Inevitably it will become impossible to identify the contents of these files' contents. This is when, with hindsight, it is appreciated that it would have been better to have been more organised from the beginning. Not only in the creation of files but in the use of a proper layering convention. One way to prevent this is the stricter use of any relevant conventions which would then ensure that the files generated from the work are much more useful and data is properly structured allowing for easier manipulation.

Conventions are essential not only for managing a company's own data but also for exchanging data with others. Interior designers would find reference to BS 1192 Part 5 useful as it is the guide for the structuring of Computer Graphic Information in the Construction Drawing. There is not the same specific type of standard for industrial Design drawings.

The aim of BS 1192 is to give assist on the production of graphical information needed to provide communication with accuracy, clarity, economy and consistency of presentation, between all concerned with the construction industry. The standard gives some indication of the important future standard for data exchange. This is called STEP, the Standard for Exchange of Product Data. This is currently met by such standards for interim use as IGES, although DXF is the recognised industry standard. Layering currently has no standard nomenclature although a defacto standard has been set up for the construction industry.

Information Protection

It is mistakenly understood that computers are the expensive aspect of a CAD system where really it is the information stored within the system that is the really valuable commodity. This is especially true in these days of manufacturers lowering the prices of hardware. When planning a system it is, therefore, an important consideration of any facilities that can be acquired which can aid the protection of information. An aspect that should be made clear to companies ignorant of computer requirements. The simplest form of protection is the simple matter of backing up the information stored on hard disk. Back-ups help overcome other disk problems such as faulty disks. There are programs that are available which can recover data from a damaged disk, or data that has been 'deleted' from a disk. Prevention is better than the cure. The cost of backing up will be a function of the cost of the backup software, the cost of the back-up media, and the frequency of the back up process. The cost of not backing up can be measured by the cost and the time involved of recreating
Data Management

One important aspect of CAD management is Data Management. This generally includes activities such as file naming, layering structures, backing up and any other form of activity that is related to the manipulation of the information stored on the computer.

This aspect of IT systems is the control of the information produced and the fact that this involves a new working activity effectively which is secondary to the actual design role which is often neglected. However, it is one of the activities which actually helps to organise the working environment. They greatly enhance the speed and quality of working with CAD. One cardinal rule should be that individuals are responsible for their own data and should not rely on others to back it up for them. Files should be regularly saved, either manually or using an automatic routine, such as half-hourly intervals and certainly if the machine is left unattended. This way is the easiest method to organise and is just a matter of getting people used to carrying this procedure out as a matter of habit and preferably as an automatic gesture. The CAD manager would do a weekly back-up, using a tape streamer onto alternating tapes, so that there is always a week old and fortnight old store of the files. Daily back-ups are unlikely to be feasible, taking into account the wasted man hours and the extra cost of tapes, unless, of course, there is a central file server.

The problem of this spread of responsibility is keeping track of the work by the drawing office manager. This is a difficult area to police, hence the devolution of responsibility. Keeping a record of this devolved organisation structure is a potential problem area and is one that requires an organised approach if it is to be efficient. The details of all archived projects should be recorded in a database for future reference. Also, a disaster recovery plan has to be devised. This is not just about insurance or a plan of what to do if one of the workstations goes down. The plan must consider where the money should come from.

Product libraries will almost certainly become more essential in the future. Manufacturers are increasingly putting their product details onto CAD and particularly AutoCAD. That is one way that CAD will make drawing work quicker than current manual ways. Another of the ways that CAD work is more efficient and quicker is in the area of alteration and the use of 'standard parts'. Their strength is exactly the opposite of the weakness of manual methods. Manually-produced libraries of standard details have invariably failed, chiefly because no two details are exactly the same and a redraw is usually preferred to make fiddly amendments. In some respects, CAD changes all that, as one of its strengths is the ability to easily change drawings.
Many of the libraries of standard symbols, as covered by BS 1192 Part 3, are available on CAD and are yet another management burden. There are a number of other conventions which can be adopted in the office. For example, text fonts for final detail work.

Standardisation of industry drawings for CAD could be one way that future developments can help the transfer of information. Screen colours are useful for denoting line thicknesses on plots. The CAD layering working party of the construction industry special interest group section of the AutoCAD User Group have proposed that the third field in the layer name could be a number indicating the line colour which in turn would plot to a specific pen thickness, where colour is set by layer and not entity. With good management, a system should also relieve everybody from the burden of managing and securing their own data and programs - a task that, in practice, many standalone users perilously neglect to perform.

A network is one way which can help make a system economical provided of course there are a sufficient number of users because expensive peripherals can be shared and with site licences for networked applications software and PCs on a network, need not be as powerful and as expensive as standalone machines.

3.1.4.2 Company Organization

The introduction of a CAD system requires that the company structure is in need of change, an elementary part of this structure is in the office layout. The layout involves some rethinking of the office in relation to equipment. This is also referred to under the staff heading describing new roles or activities but there are some relevant aspects of accommodation planning under the administration heading as well.

Enforcement of the 90/270/EEC act will be by HSE Inspectorate in factories, schools and colleges, but by Local Authorities in offices and shops.

This is the first legislation from the ineffectual Data Protection Act, to cover human factor aspects of displays. It seeks to strike a balance between guidelines for good practice and mandatory requirements. The obligations are on the employer for the welfare of the employees who use displays. In some sectors where display usage is intensive as in the news publishing sector, unions like the NUJ have been aware of the issues for some time and have negotiated stringent agreements with employers. Professional engineers and designers, however, are spending an increasing amount
of time working with CAD systems, combined with the use of PCs or other computers for word processing, financial and project management tasks. Yet these professions rarely belong to unions or concern themselves with their working environment because of the engrossing nature of the work. The predominant effect will probably be felt in the white-collar industries. Unions will use the regulations as leverage to negotiate improved working practices with employers, who will in turn stipulate their requirements in long term contracts for workstation furniture. Equipment installed before the end of December 1992 will not have to comply with the directive until the end of 1996. It is more likely that computer displays will be replaced during that period rather than being upgraded. The EC Directive for visual displays is 90/270 and for work places it is 89/654. The most relevant standard is an emerging one ISO9241 which is entitled:

- Ergonomic Requirements for Office Work with VDTs.

It is planned to have 19 parts, four of which have been published to date.

3.1.5 Accommodation Planning

In the 'rush' towards the purchase of the system, this area of operation can be easily forgotten as, apart from a change in working methods, the actual working environment changes as well. This part involves the consideration of the users of the system as well as just the office space.

The following considerations should be made when planning for the system:

- CAD equipment is heavy and bulky when taking into consideration all the peripheral devices.
- Furniture needs to be strong to take the weight.
- Tables are better than desks as this allows for more room for legs underneath and allows for more flexibility in altering working positions.
- The furniture should be chosen such that it does not have corner legs which would impede corner working which is recognised to be the most popular ergonomic arrangement.
- The furniture should be arranged in a semicircle around the operator in a U or L shape.
- Each workstation needs to be provided with sufficient double-switched socket outlets for the computer, command screen (if it does not feed off the computer), high resolution monitor.
• Shared input devices would be a digitising tablet and possibly even a scanner.
• Each workstation cluster will probably share output devices - at least one plotter and probably a printer as well. These will probably be co-located and require electrical sockets.
• The need for a possible plotter buffer should not be forgotten.
• If relocatable uplighters are opted for, then power will be required for these as well. Some equipment power cables should be on a dedicated circuit and the hardware unit should have a warning attached to it, detailing who should be notified if an electrician needs to switch off the power.
• Each workstation will need a shelf or drawer for instruction manuals. Plan chests will also be needed for drawings.
• The main storage required will be to serve the output devices which can include plotting paper, printer paper, pens, floppy's and magnetic tape.
• Plotters can take up to five different types of paper and several A sizes including A0.
• Space should also be allowed for rolls of paper where roll feed to the plotter is preferred.
• In conditions of very poor environmental conditions in the office then it might be necessary to store the plotter paper in the same room as the plotter itself to allow it to stabilise.

The long-term aim must be to give immediate access to a CAD workstation to all who need it. However, in the short term, it is more sensible to allow the expansion of the equipment to be demand driven as the initial installation proves itself. On the other hand, it should be remembered that there is a minimum level of equipment needed to achieve significant advantages, especially in a multi-disciplinary office.

When considering the working environment for the system it is necessary to remember the output devices and what effects they have in terms of function, cost and environmental effects. When siting the workstations, if there is no immediate enclosure for the pen plotter, one may have to be constructed at cost. This cost should be considered with the other associated plotter costs to determine the choice of plotter.

Pen plotters are the weak link in the CAD set-up and many believe that their days are numbered. Their advantages are that they are cheap and, when the pens are working well, they provide a high quality plot which can be in colour. On the other hand, they are slow, noisy and unreliable. The pens
need careful management and tend to dry up or change in tone halfway through a 45-minute plot. If it is possible to identify universal problem areas in a CAD system then the aspect of plotting is definitely one area. This is a bottleneck to all areas that use CAD. It is one of the decision criteria when selecting a system. Plotting times are well over half an hour for a typical A1 drawing, so a set of working drawings can take several days to plot and may well absorb someone's attention for most of this time. This is a very real cost and the delay may be unacceptable.

3.1.6 CAD User Ergonomics

The health risks associated with using computers can be grouped into four main problem areas: back pain, RSI, eyesight problems, and radiation. Only the effects of radiation are not commonly agreed as a computer-related hazard.

Back pain - caused by poor posture, inappropriate equipment and long hours hunched in front of a screen.

RSI - is really a mix of various complaints and has been known before, in forms like housemaid’s knee. Historically, RSI was confined to manual occupations, but the rise in office working, the keyboard and a broader professional class has seen numbers continuing to rise. The experts do not yet agree about the common cause for keyboard RSI. All RSI complaints affect soft tissue, such as muscle and tendons, although neck and shoulder injuries can also occur. Two favoured theories for the cause of RSI include strain through repeated actions and overuse, leading to retarded tissue recovery (much like the strains and rips of sports injuries). Individual RSI complaints include numbness in the hands and arms, sharp pains, tingling, and loss of motor skills. They have different labels depending on their location. Bad posture and poorly designed working environments are major RSI triggers, along with stress and heavy workloads.

Eyesight problems - come from screen flicker, reflection or glare, among other causes. Symptoms include tiredness, dry eyes, dizziness and difficulty in focusing.

Radiation is one area that has not been conclusively proven either way.

3.1.6.1 The Work Environment

It is important that the layout of the office is carefully considered so that the ergonomic requirements are met. This could require completely rethinking the present layout no matter the inconvenience that it might temporarily cause. There is a growing awareness in official channels of the need for setting out minimum standards covering workers in VDU activities. This awareness has arisen to counter the cavalier attitude that is regretfully the predominant one. In my opinion it is more symptomatic of the
smaller companies but it is not exclusive to them. It could be argued that for every company that takes the matter seriously there will be another that does not. At best, companies probably only pay lip service to tackling the problem. However, with the new directive it will have to change, eventually. Employers will then be legally responsible for actively evaluating the risks faced by staff and taking appropriate action. The UK was the only member state which did not support the resolution, and the Health and Safety Executive (HSE), the official Government body, is reluctant to admit that such specific laws are effective.

This growing awareness can be seen in the European Communities Council Directive of the 29th May 1990 90/270/EEC. This states:

"the minimum safety and health requirements for work with display screen equipment (fifth individual Directive within the meaning of Article 16 (1) of Directive 87/391/EEC)".

The directive uses the following definitions:

"Display screen equipment: an alphanumeric or graphic display screen, regardless of the display process employed.

Workstation: an assembly comprising display screen equipment, which may be provided with a keyboard or input device and/or software determining the operator/machine interface, optional accessories, peripherals including the diskette drive, telephone, modem, printer, document holder, workchair and work desk surface, and immediate work environment."

The directive preamble obliges employers to keep themselves informed of scientific findings concerning workstation design and stresses that the ergonomic aspects are of particular importance for a workstation with display screen equipment.

3.1.6.2 Employers' Obligations

- Employers will have to perform an analysis of workstations to evaluate the safety and health conditions which their workers find themselves in the course of their work for the employer, particularly as regards possible risks to eyesight, physical problems, and problems of mental stress.
- This means the employer is expected, on analysis of the situation, to take appropriate measures to correct any risks found with regard to eyesight, physical problems and mental stress. The initiative is firmly with the employer and ignorance is no excuse. At first sight it looks as if the employer is being asked to take on quite a lot, however, the employer will enjoy a work force that
is healthy and comfortable, and hopefully more productive. It may be stating the obvious, but happy employees really do work better. And if computer problems are recognized as early as possible, sufferers are saved unnecessary harm, and possibly permanent damage.

- Without prejudice to article 10 of Directive 89/391/EEC, workers will have to be given information on all aspects of safety and health relating to their workstation, particularly information on measures applicable to workstations that are mentioned under Articles 3, 7, and 9.
- Under every circumstance the company has to keep the workers or their representatives informed of any health and safety measure taken in compliance with this Directive. Essentially, it will not be good enough for the employer only to assess the risk but it will require the staff to become involved in this section. The employer will be expected to inform staff of any risks involved. This is in line with the United Kingdom's Health and Safety at Work Act which makes everyone responsible. However, the European act reinforces the manager's role in anticipating risks and dealing with them appropriately in co-operation with the staff.
- Without prejudice to Article 12 of Directive 89/391/EEC, every worker shall also receive training in use of the workstation before commencing this type of work and whenever the organization of the workstation is substantially modified.
- Employers must endeavour to ensure that workstations that were put into service after 31 December 1992 meet the minimum requirements laid down in the Directive's Annex.
- Employers must endeavour to ensure that workstations already put into service on or before 31 December 1992 are adapted to comply with the minimum requirements laid down in the Directive's Annex not later than four years after that date.

3.1.6.3 Ergonomics of the workplace

To maximize operator performance, the ergonomics of the workstation needs to be carefully considered. There are 2 levels:

1. Ability to communicate with the terminal
2. Operator's comfort level

Item 1 is more a factor of the workstation and is considered later.

Item 2 can be further split into two main categories:

- Environment around the workstation
- Workstation itself. This is discussed in the Hardware section.
However, considering the first subsection this section deals with the conditions which externally affect the efficiency of the system and the operators involved.

3.1.6.4 Space Requirements

The workstation has to be designed so as to provide sufficient space for the user to change position and vary movements by adhering to the recommended dimensions. An important point that needs careful thought is the space that the system and operators are going to be working in. There should be enough space for the workers to find a comfortable position. This space should provide sufficient space for user to change position and vary movements. A factor of the space around the workstation is the climate which is a factor of the following constituent parts:

- Temperature.
- Humidity.
- Air movement.
- Radiation Hazards.

Temperature

The directive discusses it under the title of Heat.

Heat

The equipment should not produce excessive heat which can cause discomfort to the workers. Where the equipment does generate heat, there should be sufficient ventilation to keep the temperature of the room at an ambient level. There are two aspects of the thermal environment to be considered. VDUs may be sensitive to extremes of heat and cold and although these should not be found in any office there are many working environments in which such extremes do occur. VDUs also generate heat and although it may be at the height of summer that such a quantity of heat would be objectionable it is worth ensuring that vents or grills for cooling air will not create draughts or hot air blasts for other staff.

Thermal Conditions

The introduction of electronic equipment into an office is likely to alter the thermal environment. For example, the equipment can generate heat and create air movement.

- Ambient room temperature is 19 degrees - 23 degrees for jobs involving extensive periods of seated work the difference between the temperature at floor level and
at head level should not exceed 5 degrees Centigrade.

- Heat build up in areas around equipment should not exceed 3 degrees above ambient level.
- External surfaces which can be touched should have a surface temperature no higher than 50 degrees Centigrade.
- Rate of air movement less than 0.25m/s.
- It is recommended that air is changed at a rate of 1.3L/s/m².
- Where any components of equipment use a cooling fan, the air expelled by the fan should not cause discomfort to the equipment operator or to nearby operators.

The relative humidity should be between 40% and 60%. Advice on control of undesirable static electricity can be obtained in BS5958.

- Ventilation should be sufficient to prevent overheating. It should also prevent the air drying out, which aggravates problems of static and dust.
- Laser printers need good ventilation - at least half the air changed every hour. It is dangerous to site them in inhabited rooms smaller than 25 cubic metres, and they should not be sited in clusters. People should not sit next to the air vent, and ozone filters should be changed at the recommended intervals.
- Dot matrix printers are noisy. It reduces the distraction if they are sited away from users, or under soundproof hoods.

Chemical Hazards
However useful in the upper atmosphere, ozone, which is a compound of oxygen, is a poison here on earth. It is emitted by badly serviced laser printers and photocopiers. Effects include irritation of the throat, lungs, nose and eyes, headaches and dermatitis. Toner for laser printers can contain carcinogens and should be handled with care, wearing protective gloves.

Radiation
The directive recommends that all radiation, with the exception of the visible part of the electromagnetic spectrum, should be reduced to negligible levels to the point that does not hazard the of worker's safety and health. There have been stories of new machinery causing health hazards since the typewriter has been linked with a health hazard. One medical journal even mentions a 'paper clip pulp infection', invented by a man who wanted offices to install his 'safe' paper clip dispenser. There are two sides to this and to the layman there seems no clear cut answer. Statements that all operators are being exposed to emissions of electromagnetic radiation are true. However, the radiation the VDU beams at us straight into our eyes is a form of radiation called light. However, other evidence continues to draw different conclusions. In 1989 a report by the US
Congress Office of Technology stated that there has been an increasing evidence to demonstrate that, under specific circumstances, even weak low-frequency electromagnetic fields can produce substantial changes at the cellular level and, in a few experimental settings, effects have been demonstrated at the level of the whole test animal.

VDUs do give off radiation, the most obvious one being the visible light, but there are other radiation emissions which are only detected by sensitive instruments. Most of the emitted radiation is very much less than radiation occurring in the natural environment from sources such as the sun. All the emissions from the VDU are well below the levels considered to be harmful by expert responsible bodies such as the National Radiological Protection Board in the UK.

There are essentially two types of radiation:

- High frequency radiation, which comes out of the screen much like a television, isn't a problem because most of it is absorbed by phosphorous in the display.
- Low frequency electromagnetic radiation (EMR) which builds up in fields around electrical currents is the type where the main question mark hangs over.

All electrical equipment gives out some form of EMR, but usually in a field so weak or distant from people that its effect is negligible. But people have to work much closer to VDUs than they would normally sit to watch TV. This potentially puts the operator bang in the middle of the invisible EMR field around the terminal. Most modern screens emit far less radiation than those of the early 1980s, and manufacturers such as Taxan and Hitachi make low radiation monitors. Disturbing research from the US and elsewhere associates a range of medical conditions with the proximity of dense EMR, typically surrounding large electrical equipment and power lines, or building up locally around PCs. Most computer manufacturers have quietly responded to the concern over EMR by casing the inside of machines with metal to absorb it. Some are even treating screens in a similar way. The claimed effects of EMR over-exposure are fatigue, persistent ailments, and other chronic conditions. However there is still no overwhelming conclusive evidence. The Health and Safety Executive has conducted a four-year study into the subject, but its conclusions are not available yet. Sweden, a leading light in computer health and safety, has set strict guidelines for limits to EMR fields and also electrostatic discharge. These are adhered to as de facto standards. If you are worried that any of the above syndromes apply to you, seek medical advice. Trade unions, ergonomists, and independent associations can also provide guidance.

One of the fears that has arisen is whether these emissions are harmful to pregnant women. The National Radiological Protection Board do not consider that these emissions from a VDU will put
either the woman or the unborn child at risk. This is true even if the woman works full time at a VDU during the pregnancy. The radiation will be no higher than that encountered from the natural background levels. This means it does not add significantly to the natural background level. By way of an illustration the ionising radiation is much less than the natural background and it is lower than that which one person receives from standing close to another person. The human body is slightly radioactive. Where it has been noted that miscarriages have a higher level of occurrence than the average figure investigations show that they are not peculiar to VDU work and are to be expected on the basis of statistical chance rather than a result of VDU work. The very latest research studies have not been able to show a link between miscarriage or birth defect and VDUs. However, a problem can occur when a woman who has already had difficult pregnancies in the past and has anxieties about radiation emissions, it is the fears that can cause problems rather than the actual emissions.

The older the VDU the more likely it is to develop faults, for example, drift and jitter of the images on the screen. The brilliance control may need to be increased but this does not mean an increase in any non-visible radiations. The only requirement is that older units will need servicing to reduce any deterioration in visual quality but not for radiation checks. VDUs are different to televisions as while they share the same technology the VDU is manufactured to a higher standard. However, people look much more closely into a VDU than they would at a television and the images tend to be smaller and made up of words instead of pictures. This point means it is much more important to get the environment right and ensure the VDU is adjusted properly.

However, the controversy surrounding computer monitors has been further increased by recent suggestions that weak electromagnetic fields are capable of interacting with biological systems. It is known that ionising radiation can change the structure of cells, producing conditions such as cancer, cataracts, miscarriages, and deformities. It remains unclear exactly what level of ionising radiation is harmful to man. The standards for exposure set in most western countries are based on the most common form of CRT technology, the television set. But most people do not sit 18 inches away from their TV set for eight hours at a time. Since there is no known safe level of exposure to ionising radiation, the argument of pressure groups such as Trade Unions, is the lower the level the better.

To the question of "Do VDUs cause any other health hazards?" the answer is simply, no. Where it has been reported that operators have complained of itching skin or redness of the face and/or neck it has been found that it has been coincidental and nothing to do with the VDU. Where there is a problem it seems to have been caused by the combined effects of a dry atmosphere at the workplace and static electricity near the VDU. This is why it is important to monitor the offices humidity.
However, very few operators experience these skin complaints which suggests that it is confined to only people with particularly sensitive to such conditions.

The Health and Safety Executive states that VDUs cannot cause epilepsy but some people already suffering from photo-sensitive epilepsy, which it considers to be an unusual form of the condition, may be susceptible to flickering lights and striped patterns, both of which can occasionally be seen on VDUs. The Health and Safety Executive goes on to state that some sufferers have worked with VDUs without causing an attack.

Humidity
An adequate level of humidity should be established and maintained. This would alleviate some of the conditions described in the last section namely; itching skin or redness of the face and/or neck.

3.1.6.5 Lighting

Incorrect or poor lighting is usually demonstrated in the most common way by sore or tired eyes, headaches, temporary impairment of vision. The most common causes are poor lighting, poor screens, poorly designed software, and poor quality paper input documents. Computers are not known to cause any permanent damage to the eyes, but the symptoms, including headaches which can last into the evening or the weekend, can seriously impair the user's quality of life, and the quality of their work. The matters concerning the screens will be dealt with later on, so for now let us discuss the lighting conditions.

Room lighting and/or spot lighting (work lamps) should be used to ensure satisfactory lighting conditions and an appropriate contrast between the screen and the background environment, taking into account the type of work and the user's vision requirements.

Provide adequate contrast between screen and background. Possible disturbing glare and reflections on the screen or other equipment shall be prevented by co-ordinating workplace and work station layout with the positioning and technical characteristics of the artificial light sources to minimise glare and reflections from screen. When positioning equipment it should be remembered that lighting should be taken into account. The lighting includes room lighting and any spot lighting. The employer should ensure that there is satisfactory lighting conditions and appropriate contrast between the screen and background environment. This requires considering the type of work being carried out and the user's vision requirements. The point is to prevent any possible disturbing glare and reflections on screen or other equipment by co-ordinating workplace and station layout with the
positioning and technical characteristics of the artificial sources. The position of the workstation should consider all sources of light such as windows or other openings, transparent or translucent walls, brightly coloured fixtures or walls which can cause glare. The position therefore should have no direct glare as far as possible and have no reflections on the screen. Windows should be fitted with a suitable means of adjusting the covering to attenuate the daylight that falls on the workstation.

3.1.6.6 Lighting and Workstations

Screens themselves have improved in design and CAD monitors are reaching very high scan rates, reducing flicker to a minimum. However, even the best screen can be made unsatisfactory by poor ambient lighting. Excessive ambient lighting reduces the visibility of the VDU and can affect the health and productivity of the user. The two problems of lighting are glare and reflection.

Glare is the sensation produced by luminances within the visual field which are sufficiently greater than the luminance to which the eyes are adapted, causing annoyance, discomfort or reduction in visual performance. A relatively low level of light makes reading a VDU easier as opposed to a high light level for a paper document. The ambient lighting level in an office accustomed to paper will be too high for the VDU, resulting in a loss of contrast and wash-out of the image.

Reflections, often called specular, are the result of focused light which conveys a particular image to the user. The user can see his or her face, windows or lights in the background or other reflection in the VDU. The unwanted information is ignored by the operator, but the unconscious effort in doing so is considerable and may cause stress.

Workstations should be designed so that sources of light, windows and other openings, transparent or translucent walls, and brightly coloured fixtures or walls cause no direct glare and, as far as possible, no reflections on the screen. Windows should be fitted with a suitable system of adjustable covering to attenuate the daylight that falls on the workstation.

Proper lighting is essential so that both VDU screen and hard copy can be read without undue visual discomfort or fatigue. A wide variety of recommendations exist for lighting levels in VDU operations. The American National Standards Institute (ANSI, 1973) recommends minimum illumination levels of between 750lux and 1600lux for a general office environment, depending on the quality of the hard copy used and the type of tasks performed. For VDU workplaces it is recommended that illumination levels between 300-500lux are used. Although there are some recommendations as low as 200lux with supplementary task illumination.
Glare as a factor in VDU operations can be classified with respect to the effect of glare (i.e. disability glare versus discomfort glare) or the source of glare (i.e. direct glare versus reflected glare). Discomfort glare is likely to produce a subjective feeling of discomfort in individuals without a significant short-range decrease in performance, whereas disability glare interferes with the ability to distinguish visual objects within the field of view and, hence, causes significant decreases in performance. Reflected glare (sometimes called veiling reflections) is characterised by VDU screen regions with high background luminance levels caused by the reflection of light from other sources. Reflected glare from sources such as overhead lights can also have serious impact upon display legibility. Reflected glare may be either specular or diffuse. The reflections may be perceived by the operator as image(s) (e.g. light fixtures, walls) or as bright spot(s) on the screen. Because of the curvature of the screen, reflections from high luminance surfaces in much of the work area behind the operator may be visible on the screen. Such reflected glare decreases the effective image/background contrast in portions of the screen. In extreme cases, such glare may "wash out" the image entirely. High levels of reflected glare can approximate the luminance of characters on a display at the low end of the acceptable character luminance range (45-160 cd/m²). Excessive reflected glare can increase visual fatigue and can contribute to poor operator posture as operators change position in an attempt to read characters obscured by glare.

Another factor related to visual discomfort and fatigue is the contrast between materials being read for example on the VDU screen and other background sources of high luminance in the work environment. Excessive contrasts within the operator's field of vision can lead to difficulty in reading the display and to visual fatigue due to the repeated need for light/dark adaptation. Maximum luminance ratios within the operator's field of vision of between 1:3 and 1:10 have been recommended.

Glare can be minimized, if not completely avoided by using the following techniques.

- Light fittings should be shielded so that the source of light is not visible from working positions. Use of shades or shields around the fittings and indirect lighting such as uplighters should be explored.
- The amount and direction of day time light through windows should be controlled. Internal blinds and curtains, external shades and reduced transmission glass are all techniques which can be applied.
- The room should be arranged bearing in mind the effects of natural and artificial lighting on the equipment to be used and the tasks to be carried out. For example, CRT displays used in bright
conditions will have reduced contrast between displayed image and its background whereas liquid crystal displays need a light source because they operate by reflecting light.

- Equipment should be arranged on the workstation to make the best use of local light conditions and to avoid any potential problems. Display screen should ideally be placed at right angles to windows and between (and parallel to) rows of luminaries. Source documents should be placed in well lit areas of the workstation.

- The tilt and swivel adjustments on the display (or workstation) and other equipment e.g. copy holders should be used to get optimum working conditions.

- Anti-glare ‘treatments’ of the display surfaces is now common and may prevent any adverse effects of working with displays in offices with inappropriate lighting. E.g. such treatments are louvres, meshes, polarisers, hoods, sprays and filters. These reduce luminance but improve contrast - the drawback is that resolution may be poorer. If these are used it important that the display complies with part 3 of BS7179. The effectiveness of anti-glare treatment may vary with different lighting conditions.

- Among commonly recommended measures are repainting offices with dark, neutral colours or grey tones, lowering of light levels and blinds on windows.

Surface Reflectance

All surfaces in the field of view should be carefully considered. A general rule for surface reflectance is that it should decrease from ceiling usually 75% to floor 20% - 40%. Computer screens should be positioned to minimise reflections and glare.

Even though potential radiation hazards are not proven, it makes sense not to point the back of a cathode ray tube screen which produces the most radiation at the person sitting opposite. Screens can be turned off when not in use. Lighting should be adequate for reading paper documents but not so bright as to obscure text on the screen. Different people have different requirements so this should be taken into account. Ideally light should shine at the ceiling, not from it. Where used, strip lights should be fitted with diffusing shades, and flickering elements should be replaced promptly.

Office Decor

Avoid having sources which will cause images of high luminance such as light fittings and windows reflected in the display by positioning the screen where possible between, rather than under, a row of lighting so that the line of sight is parallel to the light fittings and any windows. To avoid direct or reflected glare, the most suitable form of artificial lighting is a totally illuminated ceiling alternatively, direct lighting by low luminance light fittings or indirect lighting could be used. In these cases the ceilings, walls and floor should have at least a medium reflectance to avoid gloom. Glare from
windows should be eliminated by the use of light absorbing film, curtains or blinds.

Office decor poses problems of contrast and reflectance. A high contrast environment can engender glare and may disturb visual processes. High-reflectance wall, ceiling or floor surfaces may also lead to glare as a result of overall light levels. Conversely, low-reflectance surfaces may create gloom. Restful, glare-free offices will usually feature medium reflectance and low contrast.

Windows, paintings and foliage may be useful as visual relief centres during prolonged CAD work. This is because during extended periods of writing or reading, the body performs unconscious involuntary relief for the eyes by simply looking away from the task at distant objects.

### 3.1.7 The Workstation

In terms of workstation design, a number of factors can influence worker comfort and health. These are keyboard height, viewing distance, viewing angle, and chair features, lighting (luminance, contrast, colour and glare from the screen, general lighting in room). There is evidence that computer use is behind a wide variety of eye and muscular problems, often due to inadequate office planning.

One of the most difficult compromises which must be made is to provide sufficient lighting adequately to illuminate source documents or other printed or written materials, without lighting up the VDU screen and reducing its contrast. Indeed it is not even entirely satisfactory to provide individual directional lighting (like that of the angle-poise type) for the reading of documents and have a more diffuse, lower level of illumination for viewing the screen and other activities. The human eye then continually has to adjust from light to dark when moving from screen to paper and the greater the difference, the greater the amount of adjustment.

The VDU screen therefore should not be completely black or completely shaded since this increases the difference between screen and source papers or documents. By the use of baffles and diffusers fitted to overhead lighting and by appropriate positioning of the lighting a satisfactory compromise can usually be achieved. It is usually possible to tilt the screen a few degrees away from the vertical to provide a suitable viewing angle and degree of illumination while also preventing unnecessary reflections from distracting the user. Reflections and glare in a VDU are possible from a variety of sources ranging from the screen and stainless steel trim to dished key-tops and light-coloured keyboard surrounds. If the trim round the terminal is unsatisfactory in this respect the manufacturer should be approached and asked to change it or at least treat it with a non-reflective coating or paint.
The work desk or work surface should be sufficiently large with low reflectance surfacing to allow a flexible arrangement of screen, keyboard, documents and related equipment. Where a document holder is fitted it should be stable and adjustable. It should be positioned to minimise the need for uncomfortable eye movements.

There are other aspects of the work surface that need to prevent other problems such as RSI.

3.1.8 Muscular/Skeletal (RSI)

RSI can debilitate the sufferer for months or years, and in some cases can permanently cripple. Symptoms include:

- Pains in the hands, wrists, arms, neck and shoulders.
- Swellings.
- Numbness in the hands and arms.
- Muscular spasms.

3.1.8.1 Workdesk or work surface

The desk-surface requirements for input of information should be adequate for the largest drawing used. Adjustable viewing angle may be required or a wall provided for hanging large drawings. Shelving under the desk for book-storage or drawers may also be necessary to raise and lower desk height. Adequate leg room mandatory. Essentially the work desk should allow the worker to have enough space to find a comfortable working position.

Work surfaces or desk space may be needed to lay out, to read and to write on documents and printouts. The work surfaces should be appropriate for such needs both in terms of size and in position and accessibility. A document holder between a detachable keyboard and the VDU screen can be useful for supporting source documents at an appropriate reading distance. It should be stable and adjustable and positioned so that it minimizes any uncomfortable movements. While working at the VDU, the user may wish to store computer printouts, other work material or even personal belongings, such as a handbag. Another storage need which is often neglected is for a short-term 'buffer area' where incoming or outgoing documents or work can be 'batched' or sorted. Items such as calculators, pencils, also need to be stored.
3.1.8.2 Size of work surface

- To accommodate a display, the keyboard and documents/document holder, the minimum length provided should be 1200mm and minimum width of the surface should be 600mm. (Although a length of 1600mm and width of 800mm is preferred.)
- The finish should be matt to minimise reflections from overhead or task lighting.
- The surface and supporting framework should be free from sharp corners or edges. The avoidance of unintentional movements of equipment such as keyboards or telephones also needs to be taken into account.
- A display should be supported such that information displayed on any part of it can be seen without undue raising or lowering of the eyes or head. Displays lower than seated eye height and within 60 degrees of horizontal line are acceptable.
- Work surface height - where it supports both the keyboard and the display as above.
- Where the work surface is adjustable it should adjust from 660 - 770 mm.
- If the work surface is not adjustable it should measure 660 - 730 mm (machine operators desks - general purpose desks respectively). CAD has the need for the tables to be adjustable.

3.1.8.3 Palm Rests

Located in front of the keyboard they can offer support for user’s hand and forearms. The usefulness of this device is dependant on the tasks.

3.1.8.4 Storage facilities

Basically should match the demands of the tasks being carried out.

It should enable the following:-

- Personal effects.
- Disks.
- Blank paper, forms and ribbons for printers.
- Documentation which advises users on the use of the equipment.
- VDU screen cleaning materials.
3.1.9 Arrangement of equipment

The location of the equipment on the work surface should be such that most frequently used items are in prominent positions. If component includes manual controls then they should be within easy arm's reach. If component displays information - should be placed so that displays can be easily read.

Work surface must be sufficiently large and of low reflectance. An adjustable document holder must be provided.

3.1.9.1 Sitting room

- From the front edge there should be a minimum of 450 mm unobstructed leg room and 600 mm foot room. The foot space at floor level - at least 150 mm high.
- The clearance across the knee hole underneath the work surface at least 580mm, although 610mm is preferred.
- At the front edge of the work surface, distance from the floor to the underside of the work surface shall be not less than 620mm.
- Where using or working from paper documents, a document holder is often useful. It should be adjustable both in height and angle. It should be of a size which comfortably accommodates the size of the documents being used. The surface of the holder should be non-reflective.

3.1.9.2 Work Chair

The chair should be stable, allow any operator easy freedom of movement and adopt a comfortable position and to enable the user to type with elbows at about 90 degrees. It should have adjustable backrests to give maximum support to the lower back. This is particularly important for part-time or shift workers who share a desk. Shorter people may need a footrest to enable them to sit at the correct height. To be able to comply with that specification, the seat needs to be:-

- Adjustable in height.
- Seat back should be adjustable in both height and tilt.
- A footrest should be made available to anyone who wishes for one.

Swivel chairs however can cause pain as they never allow the operator's back to fully rest and cause
stress because of the constant shifting motion that goes with sitting in a non stationary chair. Comfortable seats should also be provided and they should also be adjustable. No matter how well designed the chair and table is, sitting in the same position for long periods of time can cause problems and are therefore undesirable. The operator should therefore be encouraged to alter their position as frequently as possible. The type of seating required depends on the length of time the user is likely to spend at the VDU and how frequently he or she will need to move away from it during interaction. A swivel chair (with a stable base but without arms) can be used to provide mobility if a fixed chair is not appropriate.

Some tasks, such as referring to indexes or telephoning, require frequent movements away from the terminal, and a 'sit-stand' arrangement may be preferable; that is, the work station is placed at a height suitable for standing operation but for seated operation a high chair or stool (with a stable base) is provided.

- Chair - comply with BS5940 Part 1 1980
- Footrest - comply with clause 9 of BS5940 Part 1 1980
- Necessary in cases where chair height is set in position which does not allow the VDU user's feet to rest flat on the floor. Should not move unintentionally while in use. The surface should be nonslip and of sufficient size to allow some freedom of movement approximately 450mm long and 350mm wide.

3.1.9.3 Office Planning

Thought should be given to the source of the power supplies because great care should be taken to avoid cables from crossing or in any way being near to where people move about the office.

One aspect of positioning the equipment is its location of equipment. Hardware such as plotters and printers should be ideally be separate in another room or area to subdue the associated noise with these devices.

3.1.9.4 Man-machine factors

There are a number of dimensions or clearances which may need to be adjusted in a given work station to suit the size and shapes of the potential users. There are three main areas in which to check the fit between the user and the VDU workstation.
Can the user reach and operate the controls?

The different controls which a user may need to operate at various points in an interaction should all be easily accessible. The major controls which may need to be operated are keyboard, special functions key, power or other VDU controls (e.g. brightness), modems. There are also likely to be a number of controls on other office equipment which the user may have to operate in conjunction with computer equipment, e.g. lighting, telephones, calculators, photocopiers, heating.

Can the user see and read the displays?

The different displays which the user may need to read or use during the interaction should be at a suitable distance and not, for example, concealed by other objects if the user sits down.

Can the user work in a comfortable position and get in and out easily?

There are a number of basic clearances which are necessary to prevent the user having to adopt an uncomfortable or damaging posture either when using the workstation or when getting in or out. Thus, for example, short operators may need a footrest, but adequate knee clearance is required between table or desk and seat top. The screen should be at a comfortable viewing distance.

Suitably sized equipment and seating is necessary not just for comfort, essential though this is for efficient work, it is also a matter of health and safety. Back problems account for a substantial proportion of industrial ill health, and bad work station design is a major contribution to poor posture and backstrain.

3.1.9.5 Workspace factors

If more than one user, or group of users, is to share the VDU then there may be difficulties in locating the terminal in a mutually convenient place. If it is located in one user's office, there may be interference to the normal work of the office caused by other users either interacting with the system or queuing up for their turn. To overcome these difficulties it may be appropriate to place the VDU in a separate room altogether. If this room is open to a wide range of people then various security devices may be necessary to prevent unauthorised use or to limit access to specific facilities. Such devices may include badge readers, passwords or a locking power supply; they can all be effective in limiting or preventing unauthorised access but are inconvenient to authorised users.
Terminal work stations require a considerable quantity of equipment and materials to be accessible to the user and unless adequate provision is made for rubbish, such as scrap printouts from Teletypes or associated printers, wires from VDUs, modems, telephone, the result is clutter, which is not only aesthetically unpleasant but can also present a real hazard.

Access will be required to even the best equipment (or perhaps especially the best equipment) for routine servicing and maintenance. It is worthwhile also considering when designing the work station what access might be needed for non-routine repairs and servicing. Maintenance access should not be regarded as the main consideration as it should be only infrequent or at least less frequent than normal usage.

3.1.9.6 Environmental Factors

There are a number of different physical environments to consider, in each of which the VDU can create a problem or be threatened. Its location should take account of these and should result in a suitable environment being created.

There are a number of features of VDUs which lead to potential safety problems for users. In addition to the electrical hazards common to other office equipment, VDUs have high voltages at various places within them and although these should be well protected under normal circumstances, it is important that all metallic objects should not be able to fall into sensitive areas through grilles or slots.

The VDU itself is vulnerable to a number of hazards ranging from vibrations or knocks to fluctuations in the power supply which can cause screens to clear and data to be corrupted. Even if these effects are temporary they can be extremely disruptive to users. Hot coffee split down the back of a VDU can be considered a chemical hazard, but more typical chemical hazards are that the plastic components may be attacked by cleaning solvents and inflammable liquids may be ignited by sparking contacts.

3.2.1 Solutions to work place

3.2.1.1 Office Design

• Apart from moving, there is not much that can be done about the basic fabric of a building. However, decoration and layout have significant ergonomic influence.
• Cabling should not trail across the floor, or round people's feet. Should be securely fastened so that they do not represent a hazard. Should follow the guidance given in BS6390.
• It makes a huge difference to workers psychological well-being if people have control over lighting, heating, ventilation.

3.2.1.2 Position of workstations within a room.

• Access - People using the workstation need to be able to gain access to them and the width of access-ways and the space behind chairs should not restrict this.
• Maintenance - The design of the workstation and its position within a room should not hamper service engineers access to all parts of the equipment.
• Work flow - objective is to provide a work environment which will facilitate the efficient operation of the VDU and provide the user with comfortable working conditions. In particular, the combined effects of light, noise and heat are Important in determining the work environment.

3.3.1 The CAD Hardware in the Workstation

This is essentially where man/machine interact. With regard to the machine it is where hardware and software combine to allow the man (user) to perform and interact i.e. create graphics information, graphics input, display and graphics processing.

Regardless of the scale, the graphics workstation will always include the following four elements:

1. Graphics Display
2. One (or more) interaction devices
3. Workstation processor (or at least a controller)
4. Interface link to the host system or other stations

The capabilities of these items will vary greatly from one system to the next e.g. in the size, resolution and speed of the graphics display but their organisation within the workstation will not.

3.3.1.1 Display Screen

• The characters on the screen should be well-defined and clearly formed, of adequate size with adequate spacing between the characters and lines.
• The image on the screen should be stable, with no flickering or other forms of instability.
• The brightness and/or the contrast between the characters and the background should be easily
  adjusted by the operator, and also be easily adjustable to ambient conditions.
• The screen must swivel and tilt easily and freely to suit the needs of the operator. It should also
  be possible to use a separate base for the screen on an adjustable table.
• It should be possible to use a separate base for the screen or an adjustable table.
• The screen should be free of reflective glare and reflections liable to cause discomfort to the user.
• The brightness levels of the screen should have ample range of adjustment for each intensity
  setting. To facilitate this adjustment, the screen should be easily seen while carrying out the
  adjustment.
• Glare from the screen surface is reduced by having only natural lighting in the display area. The
  problem with this is that it potentially has a great range of intensity. It can vary from less than
  ambient to well over 100,000 lux.
• The screens should be orientated so that they are at right angles to windows thus preventing
  natural light from shining directly onto the screen's surface or be in the operator's field of view
  when working at the display. It is also helpful if the top of the screen is tilted forward slightly so
  that any light is reflected downwards away from the operator's eyes. This is preferably carried out
  in manufacture. If this is not effective in overcoming any glare then it is necessary to consider the
  use of a non-glare screen. This detracts from external sources but also, unfortunately, from the
  display. If the task requires frequent looking back and forth from the display to a source
  document it is helpful if document and display are equally well lit and both were a similar distance
  from the human eye. Finally, the operator should make sure that there are no layers of dirt or
  grime, or even finger-marks on the screen.
• The CRT-Screen should be adjustable for correct viewing angle, colour, intensity.

3.3.1.2 Display Screen Equipment

The minimum technical requirements for displays are set out in the 90/270 EC Directives Annex with
the proviso that they can be revised to take account of technological progress. This applies to
workstations, provided that the inherent characteristics of the workers tasks do not preclude them.

To better understand the ergonomics of the CRT, it is helpful to study the brain. First of all, the brain
can only perceive up to certain limitations; designing over these limitations is wasteful. Designing
under these limitations will cause eye strain or create less productive workers. For example, the rate
at which the scanning is repeated is known as the refresh rate of the monitor. If the rate is too slow,
the eye can possibly detect flicker. In television, the refresh rate is 30 Hertz. This is fine for many
images, but it is not suitable when constantly displaying alphanumeric text.

Other factors:
- Human perception of colours.

In most cases the number of colours perceived is 75 "Yellows" and with 256 "Reds".

3.3.1.3 Graphics Display

The terminal can be a raster scan which is similar to a TV set. Direct view storage tube which is similar to an oscilloscope, or Random-scan vector display. Screens can be monochromatic (black and white) or colour. As more and more work can be performed on the terminal through simulation, the computer and graphics workstation are the key hardware elements of the CAD concept. High resolution is needed by the complexity of the demands of computer graphics and is met by a starting value from 1024 by 1024 to more than 4096 by 4096 pixels. (A pixel is the minimum picture display element represented as a point with a specified colour or intensity element.)

As a guide the system must be able to:

1. Manipulate symbols and shapes on screen/real time
2. Other demands may include presenting images in a 3D format.

These demands require a sophisticated front end minicomputer or large mainframe computer. These two requirements can be used to trace the history of graphics development i.e. CRT displays and host processors (computers). There are 3 types of workstation hardware including stroke, storage tube and colour raster CRT's.

IBM was the major proponent of stroke technology until the introduction of its 5080 colour raster product in 1983. Stroke systems offer significant speed of response, which advantages for fast picture update and well matched to the high speed I/O channel and CPU performance of IBM and Univac mainframes. Stroke systems offer limited colour capability and have a tendency to flicker as picture content becomes complex.

Raster scan resolves the fast update problem and the potential flicker problem. The picture can be refreshed at constant rates exceeding normal (current) television quality. It also offers the benefit of full colour capability. First introduced into CAD in 1980, it fast became the standard which most
turnkey vendors offer.

Due to the advantages and disadvantages of CRT types, certain modes of operation were adopted by various vendors to match workstation performance. Stroke systems take advantage of fast update and utilize a screen menu for selection of Interactive function. To circumvent slow erase and update for storage tubes, a tablet menu with a large set of function alternatives was employed. Raster workstations offer flexibility for either screen or tablet update. Secondly, complex images in full colour can be presented without flicker. This allowed expansion in the 3D solids modelling, Robotic kinematics, workcell simulation and 3D piping areas.

3.3.1.4 CRT technology

Raster-Digital information defining the state of each pixel is stored in RAM in display controller. Thus a 1000 line display resolution with 8 colours would require 3 million bits of RAM (1024*1024*3).

Interlacing
If lights are turned on or off fast enough, the eye perceives the light to be on. The on/off rate at which flicker is noticeable can vary from 20 Hz to nearly 100 Hz depending on the light source. So with interlacing, we skip every other line and then pick up the "skipped" lines during the next scan.

Resolution
It is the number of addressable, controllable display, or picture elements, or number of co-ordinate locations on the display screen. Low resolution screens i.e. the televisions start in the 320 by 240 range, medium resolution 640 by 480 and high resolution 1024 by 1024 or more.

It is also affected by distance between user and screen. Thus a TV screen is not disturbing to a viewer due to the viewer's distance to the screen, while a medium resolution screen terminal is disturbing to a CAD operator due to the closeness to the monitor.

In raster graphics, straight lines or edges drawn at angles close to the vertical or horizontal axes tend to stairstep. This is because the pixels are not continuous but when resolution is high, stairstepping tends to diminish. Another method is a technique called anti-aliasing. The small jumps are toned down by gradually increasing/decreasing the intensities of the pixels adjacent to the true line so they blend into both the background and the line. A substantial number of calculations are needed for each pixel and calculations can severely degrade the system speed if it is performed in the software. Electronic CAD work is not as seriously affected by this problem of resolution as compared to
mechanical engineers, as electrical engineers tend to deal in abstractions, whereas mechanical engineers, and others in similar work, require the highest resolution for solids modelling and image analysis.

**Bandwidth** - this indicates the speed at which the monitor can accept data from the computer measured in megahertz (MHz or millions of cycles per second). As the resolution increases, the amount for retrieval of information on CRT increases, requiring more time for retrieval and display. For example filling a 640 x 480 screen with 8 bits for colour control by using a 9600 baud serial line would take 5 minutes. There are 2 methods to increase data transfer rate:-

- use parallel ports, this gives video memory direct access to host computer memory, host would control the rate of exchange
- direct memory access (DMA).

Screen size is measured diagonally. So the amount of information on the screen is function of raster image which is independent of screen size. Screen size affects power requirements and fragility of the shadow masks. Other displays are flat panel displays, Plasma display panel (PDP), Electroluminescent (EL), Liquid crystal displays (LCD) and Electrophoretic (EPD).

Colour can enhance communication for the following reasons:-

- Calling attention to specific data or facts e.g. charts or graphs.
- Information more comprehensive and appealing especially when portraying process or natural objects.
- Can identify or label and reduce errors by separating important information from secondary information.

3.3.2 Keyboard

The keyboard has to have the following characteristics:-

- Tiltable
- Separate from the screen so as to allow the workers to find a comfortable working position avoiding fatigue in arms or hands.
- The space in front of the keyboard shall be sufficient to provide support for the hands and arms of the operator. The operator should not rest their wrists on the edge of the keyboard or desk or bend their hands up at the wrist.
- The keyboard shall have a matt surface to avoid reflective glare.
• The arrangement of the keyboard and the characteristics of the keys shall be such as to facilitate the use of the keyboard. It is advised to keep a soft touch on the keys and not to overstretch the fingers. Good keyboard technique is important in prolonged operation.
• The symbols on the keys shall be adequately contrasted and legible from the design working position.

In poorly designed workstations people who have spent long periods at the keyboard find they get pains and discomfort in the arms, shoulders and neck. They are caused when the workstation force the operator to adopt a fixed position for long periods or make awkward or rapid repetitive movements of the head, body or arms. On the whole the symptoms will quickly disappear when they stop work, only in some cases will it be serious. This is why it is important that both job and workstation be designed to minimise such occurrences.

• It is desirable that any and all adjustable features of the system are used to meet the operators own needs but it should be remembered that some movement is advisable but repeated stretching movements are not.
• There should be enough space for any required documents.
• Eye level relative to screen, source document, Input peripherals (keyboard, function boxes.)
• Hand and arm movement relative to Input peripherals.
• Input peripherals-keyboard should be moveable in all three planes. Light pens require a counterweight.
• Output peripherals - may be a shared device.

Excessive keyboard height can lead to musculoskeletal fatigue due to the static loading imposed on the operator by the need to keep hands in an elevated position. The recommendation for the height of the home row keys in a fixed height work station is 720 to 750 mm. The US Military Standard 1472B(USDOD, 1974) specifies a working surface height of 740 to 790 mm, which approximates the customary keyboard height range for typing in most offices in the United States.

It is recommended that the angle between the upper and lower arms be between 80 degrees and 120 degrees and that the angle of the wrist be no greater than +/- 10 deg. This would require that the keyboard be approximately at, or below elbow height, which varies from 605 mm for 5th percentile females to 820 mm for 95th percentile males. On the other hand, sufficient clearance must be allowed for the operator's legs (645 mm for 95th percentile males). Thus, either a fairly wide range of
adjustability or some compromises between leg clearance and keyboard height are necessary. Some authors recommend fairly high working surfaces (keyboards) used in conjunction with footrests.

Proper viewing distance is important in minimizing visual fatigue, and incorrect viewing distance or angle can lead to awkward operator postures. Viewing distance should not be so great that the characters subtend less than the minimum arc required for reading. A viewing distance of 450 to 500 mm, with a maximum of 700 mm, has been recommended regarding screen viewing angles. Generally these recommendations place the centre of the VDU screen at a position between 10 deg and 20 deg below the horizontal plane at the operator's eye height. Some authorities make the additional recommendation that the top of the screen be below eye height, while others recommend that the top line of the display be 10 to 15 degrees below the horizontal, with no portion of the screen at a angle of greater than 40 degrees below the horizontal.

3.3.2.1 Summary of Dimensions and requirements to aid proper posture

When the operator is sitting at the terminal.

- Face to screen distance of 350 -600mm (700 max).
- Eyes cast down at screen at an angle of 15 - 20 degrees approximately.
- Adjustable backrest. Height and Tilt.
- Adjustable height of seat pan ideally 340 - 520 mm. It should be possible to adjust position while seated.
- Seat has a stable base.
- Support in front of keyboard to support forearms if needed.
- Angle between upper and lower arm should be 90 degrees.
- Clearance between table and operators thighs.
- Keyboard height (distance from home row of keyboard to floor): 28-29 inches (0.71-0.74 metre) for sustained professional keying. 28 to 32 inches (0.71-0.81 metre) for other e.g. casual keying.
- Operator spacing (centre-to-centre distances between work stations): 28 inches (0.71 metre) minimum. 48 to 60 inches (1.2-1.5 metre) preferred.
- Leg room, width: 18 inches (0.46 metre) minimum at knee height. 24 inches (0.61 metre) minimum at foot level.
- Leg room depth: 12 inches (0.3 metre) minimum at knee height. 18 inches (0.46 metre) or more preferred at knee height. 18 inches (0.46 metre) minimum at foot level. 24 inches (0.61 metre) or more preferred at foot level.
• See-over height (if operators are required to look over workstations)
  Seated work stations:
  42 inches (1.1 metre) or less for women.
  54 inches (1.4 metre) or less for men.
  Standing work station:
  54 inches (1.4 metre) or less for women.
  58 inches (1.5 metre) or less for men.
• Writing Shelf:
  12 inches (0.3 metre) minimum depth
  Minimum width dependent upon number of documents.
  Allow 1 inch (250 mm) spacing between documents.
• Source Document position:
  To left of keyboard for data entry tasks
  To right of keyboard for tasks that require notations or written entries on the
  source document.
• Telephone equipment position
  Usually left of keyboard.

It may even possibly need completely enclosed room-lets for each CAD user, climate controlled with
everything possible to make operators productive.

3.3.3 Noise

It is important to take into account the noise emitted by equipment belonging to workstation(s) when a
workstation is being equipped, the aim should be such that it is positioned that it does not distract the
attention or disturb speech.

One of the main advantages of VDUs compared with their Teletype forerunners is the greatly reduced
noise level while operating. They are seldom completely silent, however, since many have cooling
fans or transformers which can whir, roar or hum. The level of these noises may be low but their
frequency or other characteristics can make them distracting in an office environment. The likelihood
of the VDU forming a focus for other activities should also be considered when its location is being
selected. The user at the VDU may be involved in activities which demand considerable attention and
concentration and so it is also important that its location should reflect this need and avoid sources of
excessive noise.

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According to BS7179 the Noise Level in the workplace should not exceed 55dB(A) for tasks requiring a high degree of concentration and 60dB(A) for other VDU tasks.

3.3.3.1 Methods for minimizing effects of noise

Noisy items of equipment, such as printers, should stand on a surface which absorbs the sound. If the noise generated is still high, then an acoustic cover or screen should be fitted. Noisy equipment should be located away from people whose concentration might be disturbed. However, location has still be convenient for those who need access to the equipment.

3.3.4 Other Influences:-

Working hours.
Activities during working day.
Disturbances caused by co-workers that can also affect productivity.

3.3.4.1 The Work Content

Computerisation often leaves people staring into a computer screen seven or more hours a day, which is no good for their health. Ergonomists recommend that no one should spend more than half their working day using a computer; otherwise they could be at risk from a host of physical and psychological problems. The ideal solution is to redesign the job so computer and non-computer work is shared.

Stress

Poor working conditions can be very stressful especially when the human factor is not considered and the job is determined by the system, not the human requirements and since the fact that computers allow us to work faster this also puts people under pressure. Inevitably, many people are going to have to work with bad equipment. However, by adjusting certain elements and learning about good posture, many problems can be dealt with in the short-term without spending lots of money.

Worker consultation and participation

It would be useful if consultation and participation of workers and/or their representatives takes place in accordance with Article 11 of Directive 89/391/EEC on the matters covered by this Directive, including its Annex. This section is in line with the Social Charter and in conflict with the current UK
Government's approach to industrial relations.

3.3.4.2 Working Role Tasking

What changes there are to the working role?

Employers will be obligated to analyse the work activity; to break it down, to evaluate the safety and health conditions, to prevent workers suffering from problems with eyesight, physical problems and problems of mental stress. Then to remedy risks found by taking appropriate measures.

3.3.4.3 Daily Work Routine

- Employer must plan workers activities such that daily work on a display screen is periodically interrupted by breaks or changes of activity with the deliberate intention of reducing workload at the display screen.
- Consultation and Participation of workers is a desired activity.
- Protection of workers eyes and eyesight.
  - Workers entitled to eye and eyesight tests before commencing work
  - On regular intervals thereafter.
  - If they experience visual difficulties which may be due to display screen work.

Workers will be entitled to an ophthalmological examination if the results of the test referred to above show that this is necessary. The employer will be expected to pay if the results of the test referred to above or of the examination referred to above show that it is necessary and if normal corrective appliances cannot be used, workers must be provided with special corrective appliances appropriate for the work concerned. At no times will any measures taken pursuant to this Article involve workers in additional financial cost under any circumstances. Protection of workers' eyes and eyesight may be provided as part of a national health system.

There is a section which allows the Annex to be updated in conjunction with developments in technology, developments in international regulations and specifications. British Standards are due to release BS 7179 which is based on the international standard ISO 9241. This is based on work being carried out by The CEN Ergonomics Committee TC122, through Working Group 5. It has, to date, released the first three parts of the international standard.
3.3.4.4 Operator/Computer Interface

Designing selecting commissioning and modifying software designing tasks (on-screen) the employer should consider the following:-

1. Software suitable for task
2. Software easy to use, where appropriate adaptable to operator's level of knowledge or experience, no quantitative or qualitative checking facility may be used without knowledge of workers.
3. Systems must provide feed-back to workers on their performance.
4. Systems must display information in format and at a pace which are adaptable to operators.
5. Principle of software ergonomics must be applied in particular to human data processing.

The introduction of a CAD system for some would mean only minor changes of their job structure and content. However, for others it could be more radical. Existing job tasks might be modified or made redundant forcing new methods of working to be adopted. New work tasks would also be created. The advent of the new technology should be seen as a way to review current working methods and consider alternative ways of organising the job content. Ideally the content would include a mix of visual and mental tasks, requiring VDU based work and non-VDU based work. This would achieve a variation which can be used to break up work and allow the operator to work efficiently on the screen but achieve recommended rest periods. The implication of job design for existing tasks and related tasks should be considered as early as possible in both the planning and systems acquisition process. In most CAD tasks, natural breaks occur in the progress of the work and indirectly help the performance of the CAD operator by preventing the onset of fatigue. However, in situations where the work is continuous or of lengthy duration then the operator should introduce rest pauses which ultimately will help maintain their attention and concentration.

Some operators find that very long response times, those which are variable or those where the operator is uncertain of the delay to expect may lead to frustration and fatigue and impaired productivity. Technical disturbances, equipment failures and system breakdowns have similar effects and therefore should be minimised as far as possible. Operators should be made aware of the procedures to follow when such problems occur thereby ensuring work continuity and this can be brought to their attention during training.
Regarding training there are some considerations worth establishing which would allow the operator to achieve a measure of comfort and satisfaction. Everybody's skills are individual and capabilities and attitudes differ widely so training should take this into account by matching training to the requirements of the individual. The training needs can be broken down into two categories which are basic introductory needs and skills acquisition combined with the relevant knowledge to perform a set job within a defined system.

**Introductory Needs**

Can cover the following:-

- Basic facts about the purpose of the system,
- Explanation of the major functions of the new system,
  - How each part works,
  - How each part interacts.
- Depending upon existing skills and experience the detailed training would cover some or all of the following:-
  - How to use the system within current working methods at its most efficient.
  - How to interact effectively with hardware.
  - How to use the adjustable features of the furniture.
  - What to do in an event of a system failure.
  - How to exit the system when it does not perform as expected.

When the work task is continuous or sustained then it may lead to problems with fatigue. There have been studies which report difficulties in eye focusing among workers who have spent more than six hours a day at VDUs for over four years. Many tasks involve natural breaks when the person moves about to carry out other aspects of the work. However, jobs should be designed to ensure that there are frequent breaks which will help to reduce any build up in fatigue. It is always better to choose the break rather than a fixed rest break.

When working with a VDU it is important that the operator changes his position often as in any worktask where the person stays in the same position and concentrates for a long period of time then it commonly causes headaches and eyestrain. The VDU is not the sole cause of these ailments. Where the VDU is badly positioned then problems may arise or if the workplace is poorly lit or noisy. Screens that have drifting, flickering or are jittery are very tiring and should be immediately corrected.

The Health and Safety Executive does not consider it necessary for eyes to be tested before
commencing work with a VDU although the EC directive coming into being favours testing. The Health and Safety Executive says that there is no medical evidence that using a VDU has any long term effects on either eyes or eyesight. It does not consider any VDU tasks to be more difficult, visually than other office work. Although it has found that some people find that reading from a VDU screen is tiring even when all other precautions have been taken. The Health and Safety Executive then recommends that the person should have their eyes tested.

**User/Computer Interface**

In designing, selecting, commissioning and modifying software, and in designing tasks using screen equipment, the employer should take into account the following principles:

- Software must be suitable for task and easy to use.
- Software must be adaptable to user's level of knowledge or experience.
- No checking facility may be used without knowledge of user.
- The principle of software ergonomics must be applied.

There may be other problems when the work to be done involves both paper reading and VDU work and the overall drab effect in the office may be undesirable. One solution to these problems, which also can reduce the radiation mentioned above, can be a shield between the VDU and the user. If earthed, the shield can stop the static field and, if correctly designed, can eliminate glare and reflection. The most effective products tend to be those with very fine meshes, coated with a black, light-absorbing coating.

**Workstation checklist**

The first step in the process is to identify the range of likely users and establish both the range and the limits of such characteristics as age, body size and experience, in addition to examining the various tasks they will perform in using the computer and in other associated parts of their jobs.

1. Overcrowded desks cause frustration and inefficiency.
2. Eyestrain causes temporary absences and the company may end up paying opticians' bills.
3. Headaches can lead to poor productivity and high rates of absenteeism.
4. Unsuitable furniture can cause repetition strain injuries. These can cost up to £50,000 in damages.
5. Accidents can injure staff and damage equipment.
6. Stress causes poor productivity, high rates of absenteeism and increased staff turnover.
7. Fear of radiation risks causes poor productivity and high staff turnover.
Ozone poisoning from printers and photocopiers can keep people off work for days, sometimes weeks.

Excessive heat causes poor productivity.

Environmental health officers have powers to enforce health and safety legislation. This can prove to be expensive.

Individual tolerance to the health hazards caused by computers varies enormously. However, for all but a few people, computers are safe if properly used.

User and task factors would involve the following:

- Who will use the work station and what tasks will they perform?
- Range and limits of users' characteristics?
  for example
  - Age.
  - Sex.
  - Body size.
  - Experience.
  - Training.
- Tasks to be performed?
  - Activities.
  - Functions.

3.3.4.5 Man-machine factors

Will the work station suit the size, shape and other characteristics of the actual or potential users?
Can the users reach and operate the controls?

such as:

- Alphanumeric keyboard.
- Special function keys.
- Power and other VDU controls.
- Other computer equipment.
- Other office equipment.

Can the user see and read the displays?

such as
- VDU screen.
- VDU control and indicator lights.
- Other equipment displays.
- Source or other necessary documents.
- Look-up lists, operating details.
- Other office lists or directories.

Can the user work in a comfortable position and get in and out easily?

such as:-

- Posture.
- Leg and knee room.
- Table and desk height.
- Seat height.
- Stretching or bending.

Workspace factors: will the workstation suit the tasks the user needs to perform and the job aids required?

work surfaces such as:-

- Size.
- Number.
- Accessibility.

Storage?

such as:-

- For printout and manuals.
- Other work documents.
- Job aids (such as calculators, pencils).
- Personal belongings.
- 'Buffer' for batching.
Seating?
Such as:-

- Adjustable.
- Swivel or fixed.
- Arms.
- Stable.

Interaction with other equipment
such as:-

- Telephone.
- Calculator.
- Printer.
- Plotter.

Sharing the VDU?
such as:-

- Queues.
- Access.
- Privacy.
- Security.
- Audience effects.

Clutter?
such as:-

- Bins for rubbish.
- Trailing wires.

Maintenance access?
such as:-

- Regular.
- Non-routine.
Environmental factors: is the physical environment conducive to effective use of the VDU and will the VDU create an environmental problem for users or others?

Acoustic environment?
such as:-

- Noise caused by VDU.
- Noise caused by ancillary equipment.
- Noisy environment for users.

Thermal environment?
such as:-

- VDU sensitive to heat
- VDU generating heat

Visual environment?
such as:

- Adequate light for source documents.
- Adequate ambient illumination.
- Reflections from screen or other surfaces.
- Glare from screen or other surfaces.

Safety environment?
such as:-

- Chemical hazards.
- Electrical hazards.
- Vibrations/knocks.
3.3.5 Solutions

3.3.5.1 Job Design

- The biggest threat to people's well being is often what could be described as 'poorly fitting jobs'. It is common for the introduction of computers to downgrade a formerly skilled clerical job to the level of a production line function whose only skill is the ability to touch type. Variety is much more important than specific cut offs like the length of time staff can work without a break.

- In job design the best way to find out what is best is to consult the staff. If possible set up a user group to provide a forum for suggestions and the airing of grievances. Paying extra money should not be seen as a substitute for good job design or an increase in working hours. Introduce the maximum variety into individual jobs including the trivia such as using the telephone, photocopying. Using a computer should be only part of the job. Do not eliminate human contact.

3.3.5.2 Working Practices

Having designed workers' jobs for maximum flexibility, it is essential that day to day working practices support the aims of that design.

It is very useful to have a health and safety policy, and to circulate it to all computer users and managers. People ideally should not spend any more than half their working day, or about four hours, in front of a computer screen. It is in everyone's interests for people to take frequent rest breaks, as a matter of routine and not just when they get tired eyes or aching muscles. Advice on the frequency and duration of these varies, from 30 seconds every five minutes to 15 minutes every hour or two. During the break people can do some non-computer work, exercise stiff muscles and look down the corridor or out a window to reduce eyestrain. Ideally the breaks should be taken away from the computer. In a well designed job the breaks should occur naturally, especially as enforced rest breaks at inconvenient times can do more harm than good. The important thing is to create a culture in which all staff realise the importance of rest breaks and do not feel guilty about their own or jealous of other people's or think people are being lazy.

Try to ensure an even workload. Stress and muscular/skeletal problems are often caused by sudden bursts of over work. The 'big brother' style monitoring of people's work can be very stressful; the EC directives will make this illegal without worker's knowledge. Paying piece rates, or giving bonuses for
high productivity, sounds attractive, but it greatly increases stress and can significantly increase the risk of staff developing problems like RSI. Some experts recommend a maximum of 10,000 keystrokes per hour but individual tolerances vary so much that even this figure will be too high for some.

3.3.5.3 Training

Training should not cover just how the system works, but also ergonomic factors such as: correct posture, any keyboard shortcuts available; how to adjust furniture; screen brightness and contrast; when to take rest breaks and how to use them; what the early symptoms of computer related diseases are and the importance of seeking medical advice early.

An important feature of each part is the inclusion of procedures for user performance testing. So rather than specifying an element of legibility, such as character height, the standard defines a user performance measure for legibility in terms of speed and accuracy and avoidance of discomfort.

This development of standard are relevant to the real problems experienced by users, tolerant of developments in technology and flexible enough to cope with the interaction between factors. Danger of the standard concentrating on the physical aspects of hardware, which are easiest to specify and measure and overlooking soft cognitive issues.

3.3.6 Problems with the directive

- The vague definition of terms leaves wide scope for interpretation. It is not obvious e.g. whether the definition of workstation includes factory and industrial displays. A worker is defined as one who 'habitually' uses the display screen equipment as a significant part of his normal work. What do these terms mean? It has all the makings of a banquet for the legal profession.

- Different EC countries will implement the directive differently according to local politics and different standards bodies such as BSI, DIN, CEN. Disputes from one country to another will lead to uncertainty for both suppliers and purchasers of display equipment. The onus for VDT compliance will almost certainly be transferred from employers to manufacturers through contractual obligations. Although the spirit of the directive is to protect users and let them participate its effect may well be to force great expense onto manufacturers through the need to assemble a formidable array off test equipment and expertise. For example, Part 3 of the
emerging standard ISO9241 deals with visual display requirements, calls for both complex measurement procedures of screen characteristics and controlled user experiments to assess subjective aspects such as legibility and discomfort. Manufacturers will have to set up their own human factors teams and usability test facilities or else call in consultants to do the work for them. The added expense will inevitably be reflected in the increase price of display equipment. The companies that will feel the expense most acutely will probably be the small to medium enterprises, despite a clause in the Directive to the contrary. The cost of compliance is potentially huge, even for simple items e.g. if every chair used for operating a display must have an adjustable seat and back rest then vast numbers of chairs will need to be replaced throughout Europe. Similarly if all users of displays are entitled to eye test regularly or on demand then this may be seen by opticians as a veritable licence to print money. In purely practical terms there are not enough skilled ergonomists in the world to test and measure all the VDTs in the offices throughout Britain let alone Europe. Enforcement of the new regulations arising will be left to the appropriate Inspectors, but will they be adequately trained? How will Environmental Health Officers, already squeezed of resources by the Government, rate the priority of a low contrast office display screen relative to, say an unhygienic hospital kitchen or an infestation of rats.

There are two aspects that cause stress and these are RSI and screen flicker.

Although more research is needed for both syndromes to determine their true causes, widespread fears about their effects are setting the pace for development of equipment and codes of work practice. RSI, or its more popular term of Upper Limb Disorder, affects the hands, arms and shoulders. In severe cases, sufferers can virtually lose the use of their limbs. RSI seems to be due to poor positioning of keyboards coupled with excessive use under stressful conditions. Prevention depends not only on better designed keyboards but also on improved working patterns, training, furniture and office equipment.

The perception of flicker in fluorescent lighting and computer displays can cause headaches, attacks of agoraphobia, eyestrain and other visual problems. The problem is that flicker on displays cannot be measured easily, because it depends upon the screen brightness and contrast, ambient lighting and the type of information displayed. Also the rate above which flicker is not perceived varies for different people. Draft Standard ISO9241-3 recommends, flicker free for 90% of the population which implies a refresh rate of about 84Hz for non-interlaced raster displays with normal short persistence phosphors. The latest generation of graphic cards for PCs refresh the display at rates of about 70 to 75 frames per second. The Video Electronics Standards Association (VESA) are working on an 84Hz
standard. It is expected that a 100Hz one will be achieved by the end of the decade.

3.3.7 **System Evaluation**

The methods of evaluation of a system will be different as each company will have its own criteria based upon its reasons for selecting the CAD system initially. However, there will be a central basis of topics. Performance indicators for CAD systems will be different for each application, but will fall into one of four categories:

- Time.
- Quality.
- Product performance.
- Cost.

Assessment areas include design and development lead times and overall part count.

Some companies fail to qualify the benefits gained and/or the efficiency of their systems because many managers believed that because their systems were performing well there was no need to measure the benefits.

3.3.7.1 **Reviews of their system with the intention of upgrading/modernising**

Problems with companies failing to evaluate their systems properly can cause problems for them when it comes to forming the justification case for the next system. The establishment of a proper evaluation system makes it easier to appraise the current system and deciding if it is necessary for the company to upgrade the system, purchase a new one or leave it until a later date. The evaluation would be able to give better parameters for deciding when this later date will occur.

3.3.7.2 **Review of competition and trends in the market**

The review of what is happening outwith the company is a vital and necessary part of the evaluation study of the current system and thereby determining the current effectiveness of it. Part of this review allows the company to:-

- Be aware of what everybody else is using.
- Keep abreast of developments.
This knowledge maintains their appreciation and understanding of the changes and advances in the CAD sector.

3.3.7.3 Staff

What makes a good operator and is it different from a good designer?

This suggests that CAD is another working task, such as secretarial, which it is not. The first important criteria is that the person is qualified with the necessary design skills that the work is in. Some Architectural practices have employed people with CAD skills who have no construction design experience. They are using these operators as a go-between for computer and themselves. This leads to duplication of some work that is unnecessary to do had the person been properly skilled. This is a short sighted expedient to a shortage in skilled labour in this area of design. This is their way of saving on the training costs currently incurred by the move into CAD. A situation that is likely to occur in companies purchasing a system for the first time.

The potential problem which can occur is that the Design Manager is not conversant with the aspects of CAD and, more specifically, with the software. For example:-

Example Background
The company has decided to operate a CAD system and rather than train their current staff they have opted to employ an outsider.

The Problem
The Design Manager has no computer experience and, therefore, no way to determine the selection requirements or even the validity and skill level of the candidates.

The Solution
There is no real foolproof test to determine a candidate's worth that can be applied universally to all companies. Each company has to develop its own test to meet the specific requirements of the company. However, there are some useful qualities to look for:-

- Must have relevant experience in the field of design being carried out. (This is paramount over any computing skills which the candidate has.) Obviously this is verifiable and can be checked with past employers.
- The candidate should have some relevant experience and a good attitude to learning.
- A basic understanding of the operating system being used such that they can copy, read, edit and delete files safely and generally be able to move about the directories smoothly.
• In situations where the system is already installed in the company then some drawing tests can be carried out. Nothing complex - just something that has the basic 'ingredients' of the work that would eventually be carried out such as geometry of the design, text, dimensions. The drawings produced need to be accurate, well planned and well organised. By that, I mean they should use a layering convention and suitable line and colour codes. The drawing should be produced in a reasonable amount of time. They should be able to find any requested drawing and be in control of the system. In new systems, these can be drawings that come with the software to demonstrate its potential. The candidate should show that they know how to back-up and maintain the system to avoid any possible loss of information.

• The candidate should show they are willing to learn and accept criticism well. They should be prepared to experiment yet know when to get assistance from initially the manual and then, if necessary, from someone else. Attitude is not an easy thing to test for but some feedback from past employers and the candidates own CV can give indications. A candidate with a poor attitude is likely to expect more money after training and would be prepared to move elsewhere once trained. This would be detrimental to the company giving the initial training.

3.3.7.4 How can you avoid making someone Indispensable?

This is a flaw of small companies where manpower is a premium and people tend to specialise in their own particular niches. It is always a good idea to try to double up working skills to overcome problems such as illness or holidays. This helps prevent downtime of company output. The change to computers only acts as a further catalyst to this polarisation and company dependence on key personnel highlights even further the need to prevent employee skill specialisation. This could be overcome by a proper implementation plan where workers share CAD seats and they alternate working on them. The working ratio of one worker per CAD seat would only be an important factor if there was only one person carrying out the design work for the company. In this case it would be an issue even if they were using only manual methods.

3.3.7.5 Staff selection - what is required to start up in CAD/to become operational?

This gives rise to discussion of the following points:-

Required Skills

• Picking designers by their creative abilities to render and make models to work on CAD?
• Changing aspects of skills and the inability to see that there is a change of skills.
Pay Considerations

- Why should this company pay for training just so staff can go off and get a better paid job elsewhere?
- We do not pay them extra to use pens so why should they get more for using computers?
- Do computers really mean an increase in skill level that warrants better wages?

Some people see that by using CAD systems designers will be faced with a loss of skills and that they will be no more than skilled clerical staff.

In fact this is not really so applicable to CAD skills although it could be argued that there will be a decrease in the designers ability to manually ‘draw’ engineering drawings. The skills do change but new ones are needed and some are developed. This is regardless of the ‘wonder software’ being used. The advantages of what the CAD system can offer here is surely recompense for any loss of draughting skills. Basically, the designer still needs to be able to think.

Managing the system

- Never be satisfied. All change may be disagreeable, but proactive change is generally less so than the other sort, since at least we feel somehow in control of it. So experts recommend you perform regular audits on IT systems to see how they could be improved, especially if they are not performing as well as expected.
- Managing change is all about being honest, with yourself and others. Developing IT systems is not easy. They seldom arrive on time or to budget, and they usually involve someone working at the weekend and having sleepless nights. So there is really no excuse for pretending that this time it will be different.

3.3.8 Security

3.3.8.1 What stance can we take on security?

The CAD Manager is responsible for deeds - and misdeeds - on the system and any illicit copying by your staff might impinge on you.

The Federation Against Software Theft recently secured the first jail sentence in the UK for a software pirate. He was copying well known, expensive software and selling it - a criminal act. You may be thinking ‘nothing to do with me’ - but are you sure?
FAST believes that illegal copying within a company causes at least as big a loss to the software industry as copying for sale. It may not be criminal, it may be done with the excellent intention of saving money, but it is still against the law of copyright. It is up to management to be aware of their legal position and the activities of their staff.

3.3.8.2 What constitutes computer security?

When you 'buy' a software program, whether it is a database, spreadsheet, a business or specialised program, you or your company pay for the right to use it (which involves an act of copying), and sometimes the right to make a back-up copy. The back-up copy is for security and is not intended to be run at the same time as the supplied software.

Consider that someone in your company is copying illegally. They are putting your company at risk of being sued by the owner of copyright in the program.

Security is therefore about preventing the company being taken to court for pirating and it is about the company protecting it's own 'created data'.

3.3.8.3 What policy do we follow if we sack a CAD operator?

This is more of a problem with the easily destroyed information in computer systems than in the design work of the past. However, the policy that companies operated in the past when they sacked someone should probably be more carefully carried out now. They would be advised to keep a close watch on the person and his work to see that no harm is being carried out. It would be advised not to let the person near a CAD terminal within the company once informed of the sacking. Rather than work their notice it would be easier to let them go immediately on paid notice rather than the necessary scrutiny that would have to be carried out otherwise. The reason for the sacking is immaterial. The individual might feel aggrieved and to try to carry out some form of revenge.

3.3.8.4 Do we have to look out for sabotage?

It is a different set of circumstances if the operator is leaving under other circumstances such as moving to another job or even redundancy. Although the latter might require careful thought for each individual, there is no obvious answer and is really up to each company to adopt their own strategies. All that can be carried out by an outside party is to make companies aware of the possible situations so they can plan ahead for eventuality.
Another form of damage depends on the working practices of each company which makes them more or less susceptible to this form of harm. Does the company accept any disks from outside the company at any time? If it does, then they might contain viruses. Prevention is better than any other method. However, if it is a functional necessity then there is software that can be used to detect such viruses - at least the well known ones. A strategy for prevention would be laid out in a training package and would answer the following questions:

How can we protect our system from 1 Viruses?  
2 Malicious vandalism?

An increased awareness of computer aspects at an early stage would help lessen the possibility and reduce the need of such possibilities. The company would be better able to plan and handle any such situation. That is the only real answer to the problem.

3.3.9 Aspects of Training

• Who to train?
• What to train?
• How to choose who to train and for what role?
• Establish if there are any learning problems and being able to control them - helps decide if training has been successful.
• Opinions of the workforce to the system.
• Health Hazard fears

The computer is designed by engineers for engineers and as such it fits the engineering regime. It is a highly disciplined regime, working with mathematical accuracy in a way that engineers can appreciate. Designers do not operate in this way, the whole process of thought and transmission of ideas relies on a much more flexible expression. The designer needs the freedom to express form and shape - he needs to draw and visualise.

3.3.9.1 Attitudes on Training

• Buying hardware and software is no guarantee that they will be used efficiently.
• Training is now on the increase again, having been cut back at the start of the recession. However, while training in computer-aided design can be very effective in increasing user skills, and hence productivity, how often is that investment planned?
The progress of packages means there is an even bigger need for training to operate them efficiently. AutoCAD is a fine example. AutoCAD was the most commonly used package by companies participating in my surveys. It also appeared to be the one that companies were eventually going to use. While the trend in the computer industry is for Graphical User Interfaces which make operating computers more readily understood, CAD packages that are tending to be used by Product Designers are becoming more sophisticated and complex. Certainly more problems arise in 3D CAD systems than in 2D CAD systems. Since 3D is the medium that Product Designers work in, and need to work in, it is the growing ability of microbased technology in handling 3D programs with increasing quality of visual representation that is making CAD more popular with Product Designers and, therefore, training should be carefully considered.

The early releases were very easy to use, and could be put through their paces quite well by someone whose training could, at best, be described as rudimentary. Today, AutoCAD is an immensely capable and powerful product, although the trade-off is always against simplicity. The more it can do, the more you have to know to use it to its limit.

Training needs to be quantified and evaluated but companies and organisations using computers often fail to plan properly. Although spending sizeable sums of money, they are not justifying their expenditure on computer training.

It is hard for companies to justify expenditure on training. Companies do not appear to justify their need for training and spending authority is given without any formal definition of why and what training is needed and how it contributes to the overall objectives of the business. Among those companies which were able to measure, the training benefits were seen as:

- Improved Productivity
- Improved Quality of Work
- Retention of key staff with the improvement of their skills

Of all the many available options, it is impossible to pick one approach that is better than all the others. Some training companies and consultancies offer schemes to assess the training needs of an organisation, but remember that they do have a certain vested interest in the subject. The most important thing, apart from realising the need for training in the first place, is to assess your needs realistically and then proceed with care to make sure you get the best value.
The preferred method of training appears to be 'in-house training' provided either internally or by external specialists. This was reported as being preferable to public training. Considering the ad-hoc nature of these arrangements it is important that the supplier is both responsive and flexible. The problem with in-house training is that it may comprise of anything from written timetabled courses to reading from the manual.

Training is a necessary form of preparation for the successful adoption of any new activity. This is just as true for using a pencil as it is for using a CAD system. They are skills which require a learning process as opposed to talents which cannot be taught. However, while learning new skills, it is possible to discover talents within a person. There are two levels of learning that can be associated with a CAD system. The first level being the educational aspects of learning about generalities of CAD usage and capabilities. This is closer to the awareness training that is necessary for companies to fully realise what they can do with the new system. The second level is the training to use specific packages and the necessary skills in utilising them to perform the required functions in the creation of a design.

Problems which companies encountered with their training methods were:-

**Length of time before becoming productive.**
Learning CAD is not a one-off process, but a continual exploration of new techniques and fine-tuning of existing knowledge. Productivity is the ultimate aim of CAD and new methods of increasing it are always arising. Operators need to grow and become proficient, by careful application of stimulus.

**The time for getting experience between courses was too long.**
Several months' practice with AutoCAD is vital between courses.

No responsible training centre will allow users to attend a five-day, basic-to-advanced training course - it is seen as pointless as nothing would be achieved after the second day as the trainees would be hopelessly overloaded.

**Cost of courses was too high.**

**The content of the courses was too much for the short time allowed for them.**
The courses have a maximum of three trainees who bring in their own projects and work through problems under close supervision. This is a more efficient arrangement for those organisations who are working to deadlines and who know what they want. At a slower pace, evening courses, for example at a local college, can be spread over several months.

Companies experienced difficulties in organising staff to get time away from their main working tasks within the company.

**Organising time to practice with the system.**
Hands-on experience, for all beginners, is vital for a good understanding.

Companies found that they had to change their working methods to comply with the chosen software.

Difficulty in understanding the manual.

Training given was not effective on user techniques.

Finding a high-quality trainer with a good knowledge of both AutoCAD and your industry is vital with the intermediate and advanced courses. However, someone with good training skills and a sensitive approach is more important at beginners' level.

In connection with the above, training sessions should be:-

- Relatively brief.
- Interspersed with periods of practice to consolidate skills.

The time and duration of the training should be carefully considered to avoid any loss from the usual gains from training. For example:-

- Little benefit will be derived from intensive one-and-a-half or two-day training courses such as typically offered by suppliers.
- New skills may rapidly decay if there is no opportunity to use them. This should be remembered if a delay occurs between training and installation.

Short training times made familiarisation with the various commands difficult.

Some who were self taught doubted if they were working and using the system efficiently.

You may recognise the scenario: you have just bought new equipment with a clear purpose, but it gets passed on to users who never realise its full potential. Once users find a method that works for them, they stick with it, even if it's not the best - or correct - way. Telling them to read the manual may help. But most manuals are pretty dull, and many are positively intimidating; few users read as far as the appendices. And while helplines are useful, constantly calling them up is not a long-term solution.

The training did not take account of the range of CAD experience of the trainees.

- When selecting courses and CAD training colleges, the emphasis should be on getting the course which is right for you. The greatest waste in training is when someone is sent on a course which is above their abilities.
- Inevitably, users will overestimate their skills when reporting what they can do.
- The reality is that training is essential at all levels: a must for managers as well
as operators. To obtain the maximum benefit from investment, training should be a continuing mandate in any company.

There are two basic questions which have to be asked in relation to training when preparing to use a CAD system.

1. Is there a need for training?
2. Who needs to know what within the company?

Question one asks if the company already has personnel who are familiar with CAD systems and in particular with the one being chosen. The second question follows on since it asks just what do people need to know in order to carry out their new roles.

In answering the second question you have to consider the following aspects:

- How to choose who to train for what role and why?
- Selection of personnel for training.
- Decisions necessary to start up in CAD: make operational
- Level of training necessary for staff.

3.3.9.2 What are the training levels?

Training levels:

- Awareness training - for the whole company
- Package User Training - operators
- Systems User Training - operators & CAD manager
- Management training - Managers of company

Package training levels

Basic package training for new starters.

This is seen as 3-5 days intensive training concentrating on package drawing and editing commands, blocks, relevant DOS commands giving an elementary knowledge of file management.

An improver's course

This is based on the operators achieving efficiency. The course covers symbol libraries, attribute extraction, menu customising, scripts and use of AutoLISP routines.
It is seen as being a two day course after the operator has had three to six months working with AutoCAD.

Using Add-ons
This course offers productivity improvements in the relevant sphere of work. Most add-ons have a tutorial booklet in some form. However, some instruction from an experienced user is very effective.

This type of training overcomes situations as when staff are under pressure to produce drawings, there is seldom time allocated to staff for development purposes. Frequently, enthusiasts will spend a vast amount of their own time developing an efficient, customised system.

Specialised training
Such as 3D surface modelling and AutoLISP programming and instruction. It would be extremely useful to have an in-house expert who can do this sort of work. This is because it can save countless hours by automating all those tedious procedures.

New release update training
This includes new releases of the basic package. AutoCAD has a policy to release a new version of its basic package every eighteen months. Therefore, it is effective to have existing users receive up-to-date instruction on new releases away from the everyday pressures of the job.

Management appreciation courses
What has not happened is any realisation on the part of management that these 'new' ways of doing things could contribute more towards their profit.

To overcome common complaints from operators such as lack of management understanding, inappropriate purchasing of hardware and peripherals and no comprehension of the total capabilities of the software. Awareness training for managers would help reduce and even eliminate these complaints.

Companies whose executives can be persuaded to attend an appreciation-type course will profit enormously. Management needs to be made aware that CAD is more than just a drafting tool - so show them the hidden power of CAD to exploit the drawing database and the productivity attainable from a customised application. The training should recognise the fact that people learn at different rates. This will help overcome the fear of being left after a short, and probably only half digested, training period with a manual, an unfamiliar terminal and a pile of work to be achieved under
pressure, from impatient superiors who anticipate immediate gains in productivity from the introduction of new equipment.

Every company has its own individual philosophy but those which wisely use any slack time as an opportunity to house the skills of their users will have the edge on their competitors. It is certainly a false economy to skimp on training.

3.3.9.3 Training Strategy

The discussion on training so far suggests there is a lack of consideration to the actual needs of the companies real training requirements. The only solution to this is the adoption of a training strategy not just when planning to buy a CAD system but as an ongoing requirement.

It is important to establish:-

- Who needs to be trained.
- What they have to be able to do.
- When they have to be able to do it.

Sources of Training

The obvious first step in developing a strategy is to consider what the possible options are to the training.

- Inefficient use of computer-trained designers' time teaching others and one or more workstations would be tied up in the process.
- Designers with considerable computer experience might not yet have the sufficient mastery of the system necessary to teach its operation to others without difficulties.
- Mastery of the intricacies of a system does not necessarily mean having the necessary skills to pass on this knowledge to others.
- More convenient to pay for training when necessary and know that it was being taken care of by somebody else.

Generally the type of training most vendors carry out is no more than an introduction to the commands and they are not prepared, or capable, to organise comprehensive courses to suit any one particular company; hence you may need to consider other sources of training such as consultants, educational establishments and computer manufacturers. This is where the purchase of
one of the leading packages is an advantage as you may be able to get first-class training at a local college by professional educators, or at a bureau.

Specialised specific training is becoming more popular with the increase in CAD sophistication. However, it depends very much on the qualities, knowledge and abilities of the trainer and people with such experience are thin on the ground and much in demand. Another option is computer-based training, something likely to become more popular as the use of multimedia technology increases. A third method is that of a hybrid approach which includes custom-written documentation and/or computer-based training is another way to cut the actual cost per student per day. This would also provide a constant source of reference material. Finally, video-based courses are already appearing in various areas, providing a useful and cost-effective way of training that can also be returned to and re-used many times.

What are the issues necessary in a training programme?

Training staff for the operation and use of a new computer system involves providing them with the required knowledge, competence and confidence at many levels. It varies according to what part each individual has to play in ensuring a smooth operation of the system within the business.

Awareness training conducted before the system is installed ensures that all managers will recognise the strategic importance of CADCAM and its implications and uses throughout the company, not just within the design and production departments. Managers will then acquire a deeper appreciation of the technology together with the commitment and confidence needed to plan the future. Management training enables design and production managers to control the CAD resources effectively. To appreciate the strengths and limitations of the system, these managers need hands-on training without the detail required for operators.

With the system installed, the rest of the company can get awareness training via seminars and demonstrations stressing reasons for installing CADCAM and its relevance to the company.

So for a company that is about to introduce a CAD system, the following should be included in the content of an awareness training course:-

1. What is CAD?
2. What are its advantages?
3. Who in the company has any knowledge of CAD?
4. Do they know enough to purchase a system?
5 How do the other members of the company feel about CAD?
6 What are the costs?
   - Training needs to be justified, qualified, evaluated and its value
calculated.
7 Can the company afford it?
8 How long will it take to introduce it and become productive?

3.3.9.4 The preparation of the Training Schedule

The evaluation phase will have established the extent to which training is necessary but will include
the following aspects:-
Staff need to be trained in what the system is meant to achieve:-
   - How it operates
   - How to collect data for the system.
   - Where the information is best used.
   - Changes in procedures are inevitable and staff need to be both aware of and
     competent with the new procedures.

By deciding:-
   - What skills are required.
   - Who is to be trained.
   - When is this training to be scheduled to be most effective.

The danger of an inadequately thought out training strategy is where aspects such as quality of
training have not been considered is the supplier might not be a suitable source of training. The
training is liable to be incomprehensive and patchy. Proper training involves a wide range of
computing knowledge depending on the level of participation which the working role has to interact
with the system. It need not be too formal, or expensive, to ensure that your staff are familiar with
the company. However, there is a wide variety of new skills and knowledge relating to the computer,
the software, that requires to be learnt.

Who to train first?
Problems can occur when companies undertake the selection process on their own without the wealth
of experience available that experts in this field have accumulated. When the company has not used
computers before, the mistake is to allow the strategy development and system selection to be undertaken by a keen designer or designers. It is unlikely that this person or persons will have sufficient knowledge of CAD systems except for reading the odd journal article and looking at all the tempting advertisements. These are the personnel who are often tasked with moving the company technologically into the next decade. The dilemma faced by companies is how to get relevant experience. Designers fresh out of college will probably have used computers but this does not make them experts. Research has shown that companies tend only to involve upper management late on in the decision making process. It is therefore important to stress that CAD training should start as early as possible - even before any decisions are made other than that CAD is now desirable to have.

Regarding training, therefore, they are the first people that need to carry out some awareness training. Sources of awareness training are:

1. Journals and magazines
2. Exhibitions
3. Conferences and seminars
4. CAD vendors
5. Courses
6. Consultants
7. Awareness programs of seminars, literature and videos sponsored by Industry associations, government departments, and educational institutions.

Once the selection team are conversant with CAD, the next group of personnel to be trained to the same level are the managers and key users who will be directly involved with selection process. These are the people who will have to agree on the benefits and justification and who will assist in defining user requirements and who are responsible for making the system a success. Once the requirements are defined and the evaluation of the most suitable systems is complete, the next step is to gain approval for capital expenditure. Failure to proceed can occur here when those people who have to act on the proposal do not appreciate the impact it can, or should, have on the organization in terms of a new way of doing business and new ways of working. Therefore, this is the next category of people who require training. This level require awareness training on the potentials of CAD. One more critical factor in the success of a CAD installation is the support of senior management, because success is not instantaneous, the benefits may not be seen for some time. Awareness training to this level would help them to understand the complexities and to help them keep faith with the directives of the implementation scheme.
To summarise, therefore, the first people to train are those who require the training most urgently and those who, as a result of the training, will be able to show successful results quickly. Visible success is the best inducement for further progress. This suggests that the best person to train is the person who will be responsible for running the system and developing the company CAD strategy. If this is more than one person, then it should be those people who are to develop the CAD strategy and selecting the CAD solution before any real investment starts. Potential users of the system should start training before the system is installed so that when the system arrives it can be used immediately for some project work. This would give positive psychological results to all members in the company. By the time the training course is completed, the person responsible for the system should have follow-up actions and procedures should be in place to ensure trained personnel are able to consolidate their new skills. This avoids the chance that after training, people will become frustrated and demotivated which can happen when people, having been trained, cannot utilise their training.

### How many users to train?

As I have said above, those who will make serious use of the system. It should be remembered that it is difficult for more than three people to use one screen effectively on a single shift basis. So this can give a rough guide for estimation to match company personnel with equipment bought.

Training is a continuous process i.e. new staff or those not previously affected by the system will require basic training as circumstances alter. Those previously trained will need to learn more to further improve the effectiveness of their use of CAD. This will be induced at least by the introduction of upgrades in the software or even occasionally by the hardware. The operators will find that in application, training is a continuous process of improvement and learning from experience and this is where user groups can play a vital role. This works best when the most effective methods for operations are found, they can then be documented for the benefit of all in the user group.

### How many staff require training?

This will be a function of the number of staff within the company who have a design role and the policy established by the company when it was planning the system. Based on the research todate and the new EC directive on working conditions, a rough rule of thumb guide to the problem of how many would be that companies will eventually need two to three trained operators per workstation plus the essential system supervisors.

Computers tend to demand new work activities such as maintenance of the hardware and managing the system. Companies will either have to employ new staff or adapt current working roles within the
company. Smaller companies such as Design consultancies will find that once they have purchased the system they are more susceptible to outside influences because of their inability to justify the full time employment of such experts.

If the tasks are not too demanding of time then smaller companies can increase their independence by training people and allowing them some time in the working day to carry these tasks out. To avoid dependence on one person it would be ideal to have 2 to 3 people for such training.

**What level of staff to train**

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<tr>
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<th>Computer Appreciation Skills</th>
<th>Computer Operation Skills</th>
<th>System Knowledge</th>
<th>Software Package Operation</th>
<th>Use of Computer Information</th>
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<td>Management</td>
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Once the system has been selected and plans for installation are under way the operators should now receive training in how to operate the software.

**Package User Training - Basic**

Basic training for the operator is based around hands-on-training on the relevant system. The duration of which will vary with the complexity or inadequacy of the software. It should be remembered that no one leaves such a course an expert in using the system. It generally gives no more than a grounding in the system use. This would be enhanced by further training at a later stage, once the operator has had some time to become familiar with the lessons given. The next level of training would then build on this experience and give the operator more instruction and in this way, his ability to use the system would be improved.

The basic operator training could come from any one the following: the system vendor, educational institution licensed by the vendor or by the company's internal training team. This level of training does not teach the individual how best to use the system in a particular company environment and after such a course many users will still not be particularly efficient when using the system.

**Typical course content would be:**
Overview of system.
Details on the operating system.
Introduction to basic commands and functions.
Some information on designing in two and three dimensions, dimensioning a part drawing, generation of a few plots and details of data.
Drawing management procedures.
Introduction to macro and menu development.

This type of training will be very practical but much of the potential benefit will be lost if it is not possible to have maximum hands-on access. Complete novices would gain by having an acclimatization class to computers.

Just as it is important to have hands-on experience in the training it is also important that the students are able to put their newly gained knowledge into practice as soon as possible after the end of the course so that they can cement the groundwork. There have been instances when companies have considered that employees on completion of a training course, would be fully conversant in the CAD package. A close analogy would be someone who has just passed their driving test: Officially able to drive a car by themselves but whose skills have still to be developed. This aspect of consolidating newly acquired skills can be easily forgotten especially when companies are extremely busy and/or the trainee is an important part of the company's design team.

**Package User Training - Advanced**

This would be given as a series of courses matching the steadily progressing ability of the user. This should be given a few months after basic operator training. It is expected that by then staff have acquired sufficient competence with the system. In any system it can be found that there are many more ways available of carrying out a task than shown in the initial training. This level of training therefore shows that the operators discover the possibilities and it teaches them the most effective way to apply the functions to particular applications.

The training would be based around hands-on training in the same fashion as the basic training. Course length would vary with each system.

**Management Training**

This could be in the form of reading matter for out-of-hours learning and a series of two to three hourly sessions, possibly carried out in the evenings.
The core knowledge for the managers would be:

1. Inform managers of the overall objectives and capabilities of CAD.
2. Discuss management issues in the mixed manual/CAD environment.
3. Provide some practical experience.

The training at this stage addresses the managing of a CAD environment. It involves understanding issues such as controlling a mixed CAD/manual environment. How to decide what work should be done using CAD and what is to be done manually. It means ensuring that work is organized and carried out according to procedures. The training would also include hands-on training so that managers can operate the system to the extent where they can examine drawings, models and interrogate the database. This training achieves the same level of control that the managers had when it was all a manual procedure.

This level of training is rarely appreciated when the system is implemented and almost never budgeted for in the CAD proposal. However, it is this level of person who is responsible for ensuring that the perceived benefits are realized.

3.3.9.5 CAD Systems Management User training

Whoever is responsible for organising back-ups, managing passwords, starting and stopping the system and ensuring that maintenance is carried out regularly must have the appropriate training. Training for this level of awareness is usually given by the system vendors and is usually included in the purchase price. Training should take place at the time of system installation. The CAD manager and support team should have detailed knowledge of the system and know how to operate it and how to carry out application tasks with it. Most of the knowledge will not come from the course but from experience.

3.3.9.6 Cost of Training

- Quality training is not cheap. Frequently, its intangible nature is not appreciated by those who control the purse strings.
- A reasonable figure would be 10 per cent of the capital value of a company's systems on an annual basis.

1. One point worth considering is what is the cost of not carrying out the training.
2. Awareness training may cost very little except for the price of some journals, videos and seminar
fees. The cost of time lost by not giving training may be considerable.

3 Training costs contain a component directly related to the cost of training and a component due to the loss of production during training time.

4 Costs of training may appear high but they should be compared to the cost of investment of the system purchased.

5 Costs of trainers can be very high and variable. The amount of training relates to the complexity of the system, the cost of the trainer will depend on the contents of the course. It is not possible to give an average value for the cost of training for the above factors. The CAD manager requires to identify and quantify the training required in the particular company. There is always the temptation to reduce the cost of training by cutting the training budget. This is counter productive as only well trained people will be able to deliver the promised increases in productivity.

6 Ways of keeping costs down would be to use cheaper lower grade machines for training purposes whenever possible.

7 The cost of training over several years will exceed the cost of the CAD system.

There are some things you can do to reduce your training overheads. The first is to ensure that managers and supervisors are very highly trained, since they will then be able to support the ongoing training of their staff. By seeing training as a continuous process you can avoid having to spend phenomenal amounts achieving total training at the outset. Using senior staff to do your training is not cost-effective at all - but they should be seen as a support resource, additional to outside suppliers. Training is a bigger investment than buying equipment.

The need for formal and structured training is greater now than before. It is impossible to justify investment in AutoCAD if, by skimping on training, you are restricting its use to levels attainable with Autosketch. Extreme? Real examples of this exist.

3.3.9.7 Quality of Training

The obvious problem is how to identify a good training company. These can be listed as follows:-

- Ask colleagues for recommendations.
- Contact the software manufacturers asking them for an approved establishment.
- Look for small classes and modern dedicated equipment.
- Then make a shortlist of suitable companies.
- Prior to deciding on the particular company especially when you are considering carrying out a lot of training is to invite the companies in and ask them to carry out...
a presentation. Then it should be possible to develop a relationship with the training supplier that allows two-way communication about the trainee company's staff and the training company's courses.

By and large it is better to use someone specialising in one or two subjects; you will gain from their detailed understanding of the subject. If a training company offers a whole range of diverse courses, you may find it offers no particular specialisation in anything. However, this does not automatically mean you should opt for a small company: if they offer ridiculously cheap courses, it is right for you to be suspicious of them. They are probably unable to afford experienced staff.

Ask the training company if it will put together a training plan. They should at least be prepared to come in and talk to the people concerned, evaluate their strengths and weaknesses and tailor their courses appropriately. There will be a fee for this type of consultation, but it will be nominal if it means that you will eventually build a training relationship with that company that guarantees them work over a long period. Finally, be prepared to get the training company to report back on the progress of your students: the good companies will recognise that a short course can only be one part of the learning process for most students and should be willing to let you know how to further develop the people being trained. The relationship with your training suppliers is critical to the success of using an outside company, and that relationship has to be reciprocal to monitor the effectiveness of the training supplied.

It is extremely difficult to evaluate a course even when a company's staff are on the course. It regards that the primary interest of the training company is that the trainees perceive they are getting value for money. The training company therefore does not monitor effectiveness which is not necessarily the same thing. The company receiving the training is primarily interested in whether the training is making their staff more productive and better able to handle the package. Good training should encourage the trainees to experiment and therefore learn more on their own.

There can be no substitute for practical experience. Send someone on a course to see how they fare and do some evaluation afterwards - not straight away when they are still flushed with enthusiasms - but two weeks later. Ask the participant for their view of the course, not just its mechanics.

One problem that can be encountered is that there is still a tendency for training organisations to say yes to everything, and worry about the consequences once they have your commitment.

Poor training is regularly cited as the most common cause of system under-achievement, yet
companies are still prepared to spend a lot on the technology of CADCAM but very little on vital training and support. Companies are occasionally reluctant to give their staff any intensive training as they suspect that the staff, once trained, will move to a new job with another company. It would appear they would rather have an inefficient workforce which stays than an efficient one which may not move. Improvements to working conditions and improved salaries might be more of an incentive to retain staff. This would consolidate the investment in training.

3.3.9.8 Determining when to implement training

Training is both an investment and an overhead to the normal operations of a business. The company will still require to be profitable whilst staff are being prepared for the implementation of the new system. Slack within a business should be seen as a very valuable asset that can be used for training purposes and time to acquire any necessary skills.

Effective training is not taken in a long, intensive session away from the company. People learn more thoroughly if the training sessions are short and interspersed with the chance to try things out themselves. Of course the real learning will take place when a person has the actual need for skills, which usually coincides with the system being implemented and operated.

3.3.9.9 Putting Training Into Practice

It is particularly difficult when the overall level of the system knowledge is low, to apply the new skills to everyday work. So unless suitable work is available, the trainees will rapidly forget what they have learnt. Even if suitable work is available, they will quickly find themselves unable to solve relatively simple problems that are outside the scope of the training source. This suggests that there is a need for a transition phase between training and unsupported everyday use of the system. This is backed by my own experience of training degree students in Napier University who, after going through an intensive block training period under close supervision, tend to require support when going solo the first time. This is often because there is a time period between training and carrying out their first unassisted drawing caused by commitments to other aspects of their course.

Progression starts with a theoretical introduction to system use, followed by hands-on training. Then the user must be able to practice with examples that are drawn from typical use but are not part of the current workload. Ideally during this period support should be available on call. The next phase starting to work on "real" tasks, support needs to be at hand. If a problem arises, the users need to be able to find assistance rapidly. Otherwise, time will be lost, mistakes made and despondency will
set in. So the role of the CAD manager here is to see that at the end of the training period, there are sufficient resources and suitable work available for the trainees. There is no point in training large numbers of users if there are not enough facilities for them to put their training into practice.

**Company Independence**
Experience is gained through working with the system and company experts arise out of the staff but it is worthwhile remembering that the hardware and software manufacturers are dealing with problems which gives them a wealth of experience which any individual design company cannot surpass. So while it is important to encourage individuals within the company to develop their computer skills, it is important that it can get assistance from experts outwith the company as well. It is an aspect which could be included in the purchase agreement or it could be an extra policy taken out at the time of the purchase. It would pay for itself in reducing downtime of the computer and it does not involve tying up any staff in trying to sort out the problem when they could be more profitably be getting on with their primary task within the company.

### 3.3.9.9 Identification of Training Needs

1. Before looking at any form of training, make sure you have a firm idea of future strategies as well as present use of software and applications. It is pointless initiating training if the hardware or software it covers is to be changed in the near future, so plan ahead.

2. If you are looking to get more value from current hardware and software, make an honest evaluation of the current level of knowledge among users (and system administrators, where appropriate). Assign someone to that task or set a simple test for a sample group. If you are considering training while planning investment in new systems, check that your existing ones do not offer the functions you need: you could find all you need to spend is the cost of training.

3. Assess who really needs training. Could a few trained personnel carry it out internally, and if they did, how would the costs of allocating them to a training role compare with investing in outside training for everyone?

4. Ask about training options from your direct supplier, preferably when you buy in the first place, but be aware that the situation may change at any time. Although many are identifying training as an extra source of revenue, they are first and foremost, suppliers of hardware or software. If the supplier is not the original manufacturer, particularly in the case of networks and applications, try to get advice from the original manufacturer too, as they may run an authorisation scheme covering training.

5. Find out more about the company offering the training: what qualifications do the trainers have, how big is the company, and how long has it been going? Try to obtain some references.
6 Look carefully at the proposed costs: once you have paid for accommodation and travel, does it really save money to send staff away to a training centre, or is it be cheaper to keep it on-site? Be particularly careful to establish all the costs, particularly for bespoke courses where there are no listed prices, checking that they include possible travel, equipment transportation and accommodation charges.

7 Find out about cancellation charges and be realistic about their implications.

8 If it is a course being run just for your organisation, are there limits on numbers? What happens if the number of attendees drops below your stated estimate, or you wish to increase the number?

9 What happens if the company offering the training cancels? Get a written guarantee of the minimum notice it will give if this happens.

10 Be prepared to shop around. With the increased interest in training from all sides, the market could become very competitive very soon.

3.10 What to do if it does not work?

The first and most immediate checks are for the obvious errors.

- Check you have followed the manufacturer's instructions for unpacking the hardware if you are installing the system yourself.
- Check the obvious first:- power switches, cables correctly fitted.
- The operating system is now usually installed so this allows you to check the central processing unit.
- Check you have followed the correct procedure for installing the software you have chosen.
- Essentially you must establish that the system is operational and there are no functional faults.

If it is not an obvious easily remedied fault then you have to rely on the manner in which you purchased the system.

The method of payment that gives the purchaser the most control is one where only a small deposit is paid to the supplier on signing the order and then to have contracted with a finance company to pay the balance of the purchase price on a deferred basis.

An ordered computer system is not just a set of boxes and floppy disks, so if the supplier fails to deliver all or part of what is ordered, he is liable for what is actually ordered and therefore liable for what is termed 'a total failure of consideration'. This is a most serious breach of contract.
It is best to follow the procedure as laid out below:-

- Write to the finance company explaining the situation and notification of stopping the payment.
- Stop the payment and claim money back from the financial company.
- Write to the supplier demanding the return of the deposit.
- If the supplier cannot pay - hold on to the computer system until you get your money back.

3.3.11 What to do if the training is not as expected?

If a company does not receive any training or if the training is performed by people who say they have never seen the system before then, this is a breach of warranty.

The action to follow then is:-

- Write to the supplier telling them that there will be no more payments and ask for proposals to remedy the situation.
- Notify the finance company informing them that your payments to them are stopping.
- The purpose of this exercise, assuming that you wish to continue with the system, is a reduction in the purchase price of the system. Please note, you want a refund in cash, not a free terminal or any other kind of appeaser.
- The action to take if there is no instruction manuals with the system is :-
- Write to the finance company and computer supplier stating that you cannot use the system and, therefore, this is a breach of conditions of the agreement.
- Stop paying everybody, tell them why.
- Then give the supplier a choice to take away the system and give you your money back with interest.

3.3.12 Poor Sales Support

The action to take if you do not receive proper sales support is:-

The first proviso is that the vendor is a 'box-shifter' as if this is the case then a company cannot expect any post-sales support. The same is true with a high street store. However, if the organisation is substantial, then the procedure would be:-

- Stop paying your suppliers,
- Notify them in writing why and demand the necessary support to be given within a very short space of time.
- Poor support means the company is left to its own capabilities so it must be prepared to work hard on learning about the computer system and installing it by itself into the business.

If supplier's staff make repeated attempts at installing the software or hardware and fail then the action is:
- Notify suppliers
- Stop paying them
- Give a choice to install the system within one week or you will throw the system out and demand your money plus interest. If vendor does agree to install your system, the purchasing company must be prepared to follow the vending company's every move. When dealing with defective hardware and software it is important that no time is lost in getting it to work. Notify your suppliers in writing and use the one weapon left to you - do not pay them any more money.

If a problem should be encountered when installing the computer system then the summary of your actions is:
- Do not pay.
- Throw the computer system out or, if you choose to continue, demand money and performance.
- Only believe actual results. The world is full of good intentions.
- Ride your supplier hard until you get what you have paid for.
- Understand that your suppliers' problems are their own.
- Do not compromise.
- Do what you say you will do. Demand the same from your supplier.
- The company should rely on its own business judgement. It is probably supported in law.

3.3.13 Software Issues

Buying in software for use by the business may seem straightforward but problems can arise if matters over the possible intellectual property are forgotten. It does not matter whether purchased package is bought outright, semi-customised or bespoke software, in virtually all cases the manufacturers will impose restrictions on the use of their product, which will usually be controlled under a licence agreement. So while firms may think that they are buying goods outright, they will in fact only be taking a licence to use the software. Under the law of copyright it is the author or software developer who owns the copyright. If the purchasing company want to own the copyright in the completed product then they must ensure that it is legally assigned to them under the contract. Licences may often contain restrictive conditions such as use on one computer only, or at a particular site, or for a specified purpose. Rights to copy the software are usually restricted to the making of
one backup copy for emergency use. Companies should realise that severe penalties exist for infringers of copyright. The owner can get an injunction to prevent the user from continuing to use the software, demand its return and obtain damages. The terms of the licence must be carefully read to see what you can and cannot do with the software. The extent of the protective measures will vary depending on the cost of the software, the nature of the agreement and, of course, the credit worthiness of the supplier.

For the purchaser of simple proprietary of standard software the exposure to risk is generally minimal. Once the purchase price has been paid, the licence to use the software will normally be perpetual although problems could arise if the supplier ceases to exist and further copies are unobtainable. The way to maximise your investment would be to take the maximum number of back up copies permitted. The selection procedure for the system should check the vendor's ability to survive.

- Check the credit status of your proposal licensor.
- Establish if it is possible to 'own' the software under the contract.
- Ensure access to the source code.
- Make sure payments to your licensor are not fixed, but relate to what has actually been achieved so far in your development project.
- Make payments at the end of projects when you are happy with the software.
- Move quickly if the licensor looks likely to become insolvent.

3.3.14 What to do if it does not come up to expectations?

The most obvious reason for this is due to poor communication with the vendor. The company's requirements were not put down in clear print about what it was looking for. This reflects the selection process. Another possible option to this is poor communication within the company. Assuming it is the design office staff who stated this, then at some stage of the system purchase, the parameters had to be changed to suit the price and this change was not notified to all concerned.

Some of the ways that were stated in the questionnaire were:

- The system was too slow under full working load.
- Slow CPU requiring an upgrade sooner than company had expected.

It again comes back to improper selection procedures and incorrect specifications or incorrect reappraisal of requirements to comply with financial limitations.
3.3.15 How to manage the system?

The workforce requires education and training to match the ever-changing working methods in technologies that is inherent with CAD technology and its use. The introduction of computer technology to the working environment requires a change in management techniques.

There are two alternatives:

1. A more open levelling management. This is a more human method.
2. More stepped hierarchical. This is more liable to breed discontent.

The American National Research Council sponsored 2 surveys in the areas of CAM, CAD, CIM. The conclusions were the same. They can be expressed thus:

"These new technologies require organisational changes, attitudinal and cultural shifts, creative initiatives from managers, co-operation, integration, involvement, less hierarchical organisational structure and higher levels of skill in the operating workforce".

My own personal experience suggests that Type 1 management is more readily found in the smaller companies and everyone works more as a team with less definition in the organisational structure. Type 2 tends to occur in companies when they become larger and a structure is seen to be necessary to organise the company. Just where this shift occurs depends on the individuals concerned in any given company. I do not personally consider that this change to a Type 2 management system is necessary.

3.3.16 How to use the information the system can give?

The majority of CAD systems sit quietly in the drawing/design office, being used for the same activities by the same people day after day. This is a serious waste of valuable stored information as well as wasted opportunities for many other activities in the company.
3.3.15.1 Win Internal Support

- Demonstrate the potential of the system to all departments.
- Publish a regular progress report such as a newsletter which all departments receive. The intention being to spark interest in the use of the information generated.
- Offer to automate specific tasks for other departments to demonstrate, by example. However, this will need extra finance.
- Hold Internal seminars to show off what you have achieved as well as to explain what could be achieved across the company.
- Encourage drawing exchange with CAD systems in other companies as it is a great learning opportunity and will facilitate possible future exchanges.

3.3.16.2 Advertise the systems capabilities

- Prepare a set of stunning, though relevant, demonstrations for your prospects.
- Dedicate a station for Sales and Marketing purposes?
  - Sited in a smart office?
  - Sited in the reception lobby?
- Get good coverage in the Annual Report and any other company literature.
- Do not forget to show the system to existing customers, suppliers, and subcontractors, to update their perceived image of you.

Although your primary task as a design department is getting drawings out the door to contractors, the factory floor or clients, there is no reason why you should not use your new-found skills and abilities to great effect throughout the company or organisation. Many companies view the CAD department as a profit centre, working under fixed charges and rates. You may consider that a wider role is possible within these constraints. You know that the CAD system can easily produce a high-quality graphics output, so if you need some drawings of your products for marketing purposes, make sure you can both meet that requirement and that it is internally accounted for in some way.

Facilities management is another service to be offered. Producing mapping and location plans, organisational charts, will all help to keep the CAD department in touch with the rest of the organisation. So, when the next budget review comes around, you should be able to justify expenditure on more equipment, such as a faster plotter, for instance - if you have got your costing right.
3.3.16.3  Exploit the database

The data in your CAD system is the most valuable asset, not the hardware or software. Constantly seek additional uses for the system and that data.

Such as:-

- Drawings to DTP systems for manuals, parts catalogues
- Drawings/models to DTP for sales proposals.
- Design analysis using CAD part geometry.
- N.C. toolpaths using CAD part geometry.
- Material take-off directly from CAD drawing.
- Use CAD system for office/production/warehouse layout.

Capture data already held elsewhere.

such as:-

- Site survey data.
- Standard building components and fittings.
- Architect's plans.
- Mechanical assemblies e.g. motors and pumps.

3.3.15.4  Drawing Exchange

Plan carefully with help from the suppliers

Two methods:-

- Direct conversion e.g. Octal Inc. converters.
- Neutral format such as IGES or DXF.

DXF is the more robust, simple format for CAD exchanges in 2D.

IGES is much more elaborate but workable with care and can handle 2D drawings and 3D models, plus all sorts of embedded information.

All drawing exchanges require both parties to identify by discussion and testing the 'lowest common set' of graphical entities supported by both systems. For example, system x can hold information of 255 levels and system y is limited to 63, then any data on levels 64+ in system x will not arrive. Alternatively system x may be able to define a fillet surface between two intersecting warped surfaces whereas system y has no fillet surface entity. It would be better to avoid trying to send such data.
3.3.16.5 Listen to the operators

- Encourage better practice input from them.
- Let the users define the improvements they feel worthwhile.
- Let them carry them out too!

Examples:-
  - Novel productivity tricks to get the job done faster.
  - Special macros to automate frequent procedures.
  - Opportunities for new software.
- Build CAD supplier relationships.
- Trust is crucial for long term success.
- There will be problems, whatever you do

for example:-
  - Software will sometimes disappoint you either because of missing or inadequate facilities.
  - You are bound to make poor selections of work for the system and then regret it.
  - User skills may decay if their use becomes casual.
  - The system manager may leave - a very good reason to have everything well documented.
  - Regular reviews with supplier of progress and performance.

Provided the attitude to future requirements is to take the form of keeping as many options open as possible, a definition on those features which are concerned with potential and undefined requirements can be made. In fact, the requirements in this section tend to resolve themselves around the prospect of explaining capacity to deal with needs such as :

1. A larger volume of the work already specified.
2. New transactions or record types within the same framework.
3. Completely new systems.
4. The addition of interfaces to other systems larger or smaller.

These needs can be translated into technical requirements for capacity to expand and enhance hardware and software in fairly specific ways. The assurance of ongoing compatible supplies and support in these areas is also relevant.
Terms and Jargon Used
CAD equipment is appearing in a wide range of places and affecting the working environment. For example they occur in Television Design Departments and studios have wall to wall racks of digital equipment, Architects, Industrial Designers, Typographers, Audio-visual Artists, Animators, Interior Designers, Weavers and Fine Artists are beginning to employ computers. The common denominator for all these walks of life is that they are finding that computers have their own technical jargon and even with the explosive growth of micro-computers has created a world in itself. It has its jargon of bits, bytes and ASCII code, plus new concepts of machine operation and speeds that baffle the lay mind. The best way to understanding any new subject is to master the jargon, this Is essential as new works and phrases are necessary for labelling new concepts and processes.

The section is divided into the following two categories:-

- Hardware terms
- Software terms

### Hardware

#### Hard Disk
Mass storage device, capable of storing from 10 to 300 Megabytes of data. CAD applications require a 40 80Mb hard disk unit with fast access times.

#### CPU
Accepts instructions from the computer program and carries out a sequence of logical operations.

#### RAM
Standard RAM is 640 Kilobytes but for CAD applications a RAM size of 4 to 8 Mb would allow more of the CAD program to be stored in it, resulting in faster access times. RAM is volatile, it loses all stored data when power is switched off.

#### ROM
The BIOS chip is a ROM chip, it contains essential programs, required by the computer.

#### RS232
Interface which has an agreed standard pin connection.

#### BAUD Rate
Data is sent from the computer at a rate of between 110 and 9600 bits per second. The Baud Rate of all equipment must be set to the same value such as the computer and the plotter.

#### Buffer
All computers work in set cycle periods, controlled by an electronic clock. The speed of the computer is determined by the clock speed. The speed of the clock is measured in MegaHertz (MHz). For CAD applications a clock speed of 16MHz(2D) to 30MHz(3D) is required.

#### Dongle
This is the trade name for a security device that is used to prevent unauthorised use of the software. The device is fitted to either the serial or parallel port. It is an electronically coded device and the software continually checks for its presence during the housekeeping routines.

#### Screen Resolution
The screen resolution is calculated by the number of screen pixels times the number of scan lines. The greater the number of pixels and scan lines the higher the screen resolution.

#### Tape Streamer
A tape streamer is a large type of cassette unit that operates at high speed. It holds large amounts of data. 40 to 120 Mb units are normally used for CAD applications. Main use is to back up the contents of a hard disk.

### Software terms

#### Magnetic Tape
Storage medium that can hold very large amounts of data. It is a sequential access system. The tape must be wound on to reach the next data location.
Screen dump
This is the term used to describe the operation of printing the keyboard print screen contents. Pressing the keyboard print screen key or using a program command will cause the contents of the screen to be dumped to the printer.

Soft Reset
This is the term used to describe the operation of resetting the computer without switching the power off. It is reset by pressing the controls - CTRL key, ALT key and the DEL key simultaneously.

Hard Reset
This is the operation of resetting the computer by switching off the power then back on again. This method should only be used if a soft Reset is unsuccessful. The computer should be left off for a few seconds before switching the power back on again.

HPGL
Hewlett Packard Graphics Language. This contains a set of instructions for plotting and printing drawings. Many manufacturers make their machines Hewlett Packard compatible.

Digitiser
Flat table like device on which a drawing can be placed. A puck is used to enter X and Y positions from the drawing. The table is an electronic device containing a grid of fine crosswires. The signal from the puck or pen allows accurate X and Y co-ordinates to be obtained.

Scanner
An Input device that allows an image/text or graphics on paper to be copied into the computer's memory and displayed on the screen. The scanned image may then be edited as normal.

Window selection
One method used to select part of a screen image or drawing for further work. The user selects two points for example top left and bottom right to define the window.

Group
A CAD command that allows a number of single lines that make up a drawing to be treated as one object. The group can be manipulated, moved copied etc.

Primitives
In the case of 3D modelling, they are the basic shapes used to construct the model for example rods, cones and spheres.

DXF
Drawing Exchange format. An agreed format used for interchanging drawings between CAD systems. Allows a drawing drawn on one type of CAD system to be saved as a DXF file and then loaded and used on a different system.

Palette
A boxed area on the screen containing a range of colours or icons that may be selected with the cursor.

Backup
This is the operation of making a second copy of a drawing file or program, in case of damage to the first copy. The users work should be backed-up at least once an hour. The hard disk contents may be backed-up to disks or tape streamers.

K or Kb
This means Kilo i.e. 1000. Kb stands for Kilobyte. In computer terms 1Kb is 1024 Bytes

M or Mb
This means Mega i.e. 1000000. Mb stands for Megabyte. In computer terms 1Mb is 1048576 Bytes.

IGES
Initial Graphics Exchange System. International Standard for the format of 2D and 3D drawing/design and CADCAM programs. The format can handle data from solid models and transfer the data to other CADCAM systems.

Write Protect
Method used to prevent data being accidentally erased from a disk. In the case of 5.25" disks a sticky label is placed over the disk open notch to convert it from a read/write disk to a read only disk. The 3.5 have a small 'switch' which does the same task as the sticky label.
Software
Expert Systems
They have been defined as intelligent computer programs which use symbolic inference procedures to deal with problems that are difficult enough to require significant human expertise for their solution. Human experts can be compared with conventional computer programs.

Human skills arise from the possession of expert ability and knowledge in a specific subject area. These skills grow as more and more experience is gained. Human experts can explain and, if necessary, defend the advice they give and are aware of its wider implications. Human experts determine which knowledge is applicable rather than proceeding algorithmically, step by step. Human experts can and frequently have to, act with partial information. In order to supplement this, they ask only sufficient and pertinent questions to allow them to arrive at a conclusion.

Conventional computers differ markedly from programs which act as experts, specifically:
- They are usually complex and difficult for anyone other than their designers to understand.
- They embody their knowledge of the subject area in terms designed for computational efficiency such that this knowledge is intertwined with the control parts of the program. Thus the knowledge is implicit in the program in such a way which makes it difficult to alter or change.
- They cannot suggest to their users why they need a particular fact nor justify their results.

Thus, expert systems aim to capture the ability of human experts to ask pertinent questions, to explain why they are asking them, and to defend their conclusions. These aspects are unrelated to a specific domain of knowledge and apply to all experts. Expert systems are computer programs which attempt to behave in a manner similar to rational human experts. They all share a common fundamental architecture even if the knowledge encoding mechanisms differ. An expert system will have the following components:

An Inference engine
This carries out the reasoning tasks and makes the system act like an expert.

A knowledge base
This contains the expert's domain specific knowledge and is quite separate from the inference engine.

An Explanation Facility
This interacts with both the knowledge base and the inference engine to explain why an answer is needed at a particular point or how a question can be answered; further it is used to explain how a conclusion was reached or to explain why a specific conclusion could not be reached.

A State Description
This contains the facts which have been inferred to be true and those which have been found to be false during a particular session.

A Natural Language Interface
Few expert systems have this yet.