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Rapport de recherche

A STUDY TO IDENTIFY THE MANPOWER REQUIREMENTS FOR THE EFFECTIVE UTILIZATION OF AN INTERACTIVE GRAPHICS DESIGN DRAFTING AND MANUFACTURING SYSTEM

by

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EXECUTIVE SUMMARY

Industry Trade and Commerce contracted the Canadian Institute of Metalworking to survey those Canadian companies presently using Computer Aided Design technology and provide, from the results, a document that can be used as a benchmark for Canadian industrial interactive graphics systems installations. The study centered on the manpower requirements to successfully implement, manage, program and operate an interactive graphics installation.

The study surveyed 53 companies located in Canada (85%) and the United States (15%) that are currently using interactive graphics equipment. With the implementation of CAD over the past few years, some companies have been exceedingly productive, while others have experienced disastrous results.

Properly utilized, the CAD system should be as persuasive in design or drafting as the business computer has been in accounting. To ensure this level of competence, many factors must be considered with regard to the organization and integration of the system into the work site, and these parameters must be reviewed and adjusted continually during the first years of operation to establish the most effective use of the system.

Prior to purchase, the potential user should investigate several systems to assure himself that what he buys will be adequate for his needs. There are many good CAD systems on the market, and once a system appropriate for the site's needs has been chosen and installed in the office, it must be integrated into the existing workflow and produce the work volume needed to meet its financial goals. The productivity of a CAD system is directly linked to the ability of the system to address the user's problem, and the ability of the operator to address the system. Assuming that the decision on which system to buy was a good one, the problem then lies with the staff to be able to address the system with their understanding of the company's problem.

Most industries feel that an operator who understands his particular job, i.e. architecture, manufacturing etc., is more useful than a person with high technical mastery of the system. If an operator does not know his job, the system is not going to help him. While most people agree that the development of human resources to direct and augment the influx of this new technology is a necessity, a knowledge of the subject of application should be the primary consideration. Once a department has amassed the people necessary to complete the given tasks, they can then be trained to use the system to their advantage.

With proper preparation and education, CAD staff will accept the CAD system as a useful tool rather than as a threat to their jobs, and will learn to use it for their own career development as well as for the economic benefit for which it was purchased.

After the systems were installed, those companies who had taken advantage of either vendor or public training prior to the installation, found that they had much higher productivity gains than those who hadn't.

To determine the amount and type of training required, it is necessary to identify the amount of time needed to learn to use a CAD system. In this area, the amount of time needed to approach the summit of one's capabilities depends once again upon the application.

In mapping or electrical applications, where simple graphic data entry is required, a high school graduate with typing or keypunching experience should be proficient within two weeks. For the more difficult design tasks, it can take anywhere from twelve months to thirty-six months for CAD/CAM operators. The time needed to reach peak efficiency is dependent upon the amount of software knowledge necessary to perform the essential operations and the amount of knowledge that the operator has concerning his own area of application.

With regard to training of new staff, most companies feel that on-the-job training programs and CAD/CAM courses at the college and university level are the best way to increase skilled labour in industry. Industry is not in need of "computer" personnel for the implementation of CAD technology, but could make use of personnel trained in their particular area of application, but with a familiarity to computer aided design or drafting technology.

Once the system has been installed, and the operators have received initial training, it is highly recommended that upgrading courses be taken regularly. These courses or upgrading sessions will provide an in-house technical base for the expansion and full utilization of system capabilities.

Due to the wide variety of CAD users, both vendor and public training is aimed at a universal understanding of system capabilities, and cannot address the user's application in any detailed manner. After the successful implementation of a system, the existing staff develop short cuts and routines that are unique to their type of application. Training by existing in-house staff is thus more useful in that it allows the trainee the benefit of instructors who have experience both on the system and with the problems that he or she will be required to address, instead of the necessarily generalized instruction offered by the vendor.

Documentation is an essential ingredient in maintaining a smooth running CAD installation, especially where shift work is involved. As all members of staff are not generally as concerned with system procedures as with the execution of their particular task, precious time can be wasted as a result of "obvious" changes in system procedures. Computer people are noted for their general lack of communication skills.

Within one year of the computer's installation, more than half of the companies surveyed had less than 75% of their original staff, and 31% had less than 25% of the staff that they had employed when the system was introduced. This indicates that a large percentage of users have had to hire a substantial amount of new staff to operate and maintain their CAD facility.

Most companies found that their staff left due to higher salary offers from other companies or installations. Because the drafting design and manufacturing staff are still expected to make the same aesthetic judgements in addition to being able to utilize the computer and being aware of updates and software releases, most operators feel that they should receive some remuneration for their extra effort. "Keenness" is one of the most important factors in a speedy start-off time, and monetary gain is certainly an added stimulous.

It may be true that anyone can be taught to use a computer aided design system and be productive, but levels of productivity are important. For 25% more pay, a person can be three times as valuable to the company as another person. This observation relates to a fairly sophisticated application, where the user required a good overall understanding of his subject area and application.

Once the system is in good running order, it is to the company's advantage to keep trained staff, as new employees will take considerable time to assimilate company procedures.

Whether the person to take over is a new employee or an old employee taking on new responsibilities, off-hours retraining must be sold to the participant who often has family ties and responsibilities that influence his decision to engage in after work classes. In the present economic climate, many employees are willing to undergo retraining at any time to keep their positions, but a good working relationship between the college and industry will make the most of available equipment and manpower.

As the job descriptions of each operator will be greatly altered, many problems concerning job scope and jurisdiction may arise, and management should be ready to assist personnel in defining their parameters.

In general, most of the people who transfer to CAD systems find the work interesting and envigorating. With the introduction of CAD technology into the educational institutes and the promotion of CAD capabilities through conferences and seminars, Canadians should be able to expand their knowledge of this new technology and become more competitive on the world market.

INTRODUCTION

Although Canada has always been considered a land of natural resources there is no doubt that our survival on the global market will be related to our use of technology more than any other factor. The rapidly emerging use of computer aided design and computer aided manufacturing has provided substantial productivity gains for many manufacturing companies since the middle 70's and should play an important role in increasing canadian productivity during the next decade.

According to the U.S. National Science Foundation Centre for Productivity "CAD/CAM has more potential to radically increase productivity than any development since electricity". In the mapping environment, computer aided mapping has transformed the nature of planning, design and maintenance of both public and private records, allowing an extension of the traditional mapping and geocartographic functions to include extensive detailing not possible by manual methods in addition to expanding the use of mapping and planning in general. The evolution of electronic technology has advanced concurrently with the evolution of CAD technology, each process being interdependent upon the other's advancements. In engineering, CAD provides an effective means to harness computer power to design, manufacturing, documentation and quality control tasks in a multiplicity of applications. In short, Computer Aided Design and Drafting equipment is greatly accelerating production in a wide variety of applications, and becoming an integral part of the Canadian working environment.

Computer Aided Design can be defined as the ability of a designer to use a computer to create geometric elements that can be assembled to form a design or model of any three dimensional object.

The geometric model may be created interactively through continued dialog between the designer the computer system or through batch or time sharing methods generally utilized by larger computers.

Once the model has been created it can be filed or stored for later recall and subsequently utilized to create two dimensional pictures where alpha-numeric data can be added. These pictures can then be used to create two dimensional layouts such as maps or drawings depicting the typical electrical, structural, mechanical assembly used by industry. The design concept, finished model, NC tool paths, dimension and hard copy drawing information can all be stored in a common data base that can be accessible to all disciplines within a company.

A BRIEF HISTORY OF CAD

Just over a decade ago, CAD/CAM was the exclusive province of the aerospace and automative industries. CAD/CAM installations were considered a major investment in even the largest firms, the installations themselves costing in the millions of dollars. The introduction of microprocessors has revolutionized the industry by making available reasonably priced computers with increased computational abilities. J. Michael McLean in his publication The Impact of the Microelectronics Industry on the Structure of the Canadian Economy summarizes the situation by saying: "Electronic circuits have advanced from vacuum tubes and discrete semi-conductors into increasingly complex integrated circuits. Today micro-processors condense tens of thousands of transistors into a few square millimeters. Such devices are 1,000 times less expensive than their predecessors of thirty years ago, and require 50,000 times less power and 300,000 times less space despite improved speed and reliability." (1)* Microprocessors are the heart of a CAD system, and the evaluation of computer aided design has been equally rapid.

During the mid 50's, CRT's were being used in the display of military command and control problems but such displays were passive in nature. By the late 50's, the SC 4020 developed by Stromberg Carlson was capable of processing computer data from tape and producing a graphic image on a special CRT, on sensitized paper or on film, but this was still a passive process,

During the 60's, Norm Taylor of Itek, Thurber Moffet of Convair, Donn Parker, and Ed Fitzgerald worked together to develop the CDC Digigraphics system which was a preliminary

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(1)* J. Michael McLean, The Impact .... Canadian Economy, Institute for Research on Public Policy, March 1979, pg lx drafting system with limited capabilities. Concurrent with the Itek/CDC activity were other significant activities at IBM, GM, MIT, Lockheed and McDonnell Douglas. GM's "DAC-1" system was presented in 1964, and *"Sketchpad" by MIT was presented by Ivan Sutherland in 1963. "Sketchpad" was the first presentation of interactive graphics to the general public, indicating Sutherland as a major figure in starting practical interactive graphics on its way.

Lockheed Georgia's Research Laboratory started a Man Computer Grahics team in 1964, and the first short university course was available in Detroit concerning "The Applications of Computer to Automated Design" during the same year. Major figures in the development area during the 60's are Steven A Coons, for his Surface Patch Technique, Bob Mann for his work on Project MAC Machine Aided Cognition, and Jim Kennedy for his CDC 3300 system software.

McDonnell's CADD and Lockheed's CADAM were both initiated in the mid 60's. In late 1965, IBM, Lockheed, McDonnell, North American Rockwell, TRW and Rolls Royce formed a classified project called DEMAND. The objectives of this 4 year project were to set forth graphics requirements in an IBM environment.

Enthusiasm and understanding of computer graphics was beginning to swell in the late 60's, and computer vendors such as Calma, Applicon and Computervision had started working on "turnkey" or packaged hardware/ software systems.

By 1970, Computer Interactive Graphics were available to the larger companies, and conferences, seminars and books were disseminating CAD information throughout the states and Canada; Volumes such as David Prince's <u>Interactive Graphics</u>

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* Sketch pad, a Man Machine Graphical Communication System, Ivan Sutherland, MIT, Thesis MD.

for Computer Aided Design, 1971, Newman and Sproull's Principles of Interactive Computer Graphics 1973, Chasen and Dow's Guide for the Evaluation and Implementation of CAD/CAM Systems, 1975, and S.H. Chasen's Geometric Principles and Procedures for Computer Graphic Applications, 1978, did much to inform the public on the mushrooming CAD environment.

The first Siggraph meeting took place in 1974. Siggraph is the Special Interest Group for Graphics under the ACM, Association for Computing Machinery. This first conference drew 325 attendees. The Siggraph conference of 1982 drew close to 6,000.

By 1976, rastor graphics technology began to emerge, including colour, high density drawings and selective erase at very low costs. This aspect, coupled with the improved microcomputers made high quality graphics available at a reasonable price.* (3)

Many independent CAD promoters were presenting interactive graphics seminars throughout the U.S., introducing industry to the benefits of this new technology. Carl Machover, Jim George, Steve Levine, Barry Pollack, Joel Orr and Ken Anderson are just a few of the people who were working on the acquisition and dissemination of CAD information.

IGES standards were initiated in September 1979, allowing an interface between two or more systems, and promoting a more integrated use of CAD in industry; and the NCGA, a more CAD/CAM oriented organization, was formed in the same year.

During the late 70's, Computer Graphics software had begun to trickle into the market place from several companies, Pat Hanratti's AD 2000 and CDC's CD 2000 are perhaps the most remarkable. Other software systems are giving special attention to 3D colour, hidden line removal, solid modeling, texture and more.

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*(3) A full account of the history of CAD is available by S.H. Chasen, Historical Highlights of Interactive Graphics, Aug. 1981.

Computer Interactive Graphics by 1983 has become accessible to a wide variety of users for several reasons.

1. The cost is no longer prohibitive for medium and large companies
2. Systems are increasingly "user-friendly" and can be used as a tool by people with little computer background
3. The applications are widening daily to engulf areas of applications not previously explored through graphics.

With the superior knowledge of our retrospective vision, we can judge the impact of electricity on industry during the first half of this century. The implementation of computers during the second half will be no less universal nor monumental.

What Comprises a CAD System

A typical CAD system is comprised of a central processing unit with processes information to be dispersed to the various peripherals; a mass memory for storage of system software, proprietory programs and drawings; hard copy units such as an electrostatic printer/plotter, electromechanical plotter, or computer output microfilm; a back-up storage unit, usually a Mag tape drive to store and archive files; and design terminals.

In addition to the basic hardware, a CAD system can be hooked up to a high speed paper tape reader, a high speed paper tape punch unit, typing console for hardcopy printouts or NC tape machines for direct transfer of information

The design terminals are interfaced to the main computer and interact directly. In general, the terminal consists of a display monitor which displays the created image; an alphanumeric CRT (Cathode Ray Tube) which displays the entered commands, the results of calculations, system messages and prompts; an electronic drawing board or digitizer and an entry keyboard. Using these devices, the operator enters points to create lines, arcs, text, dimensions or other necessary information.*

Prior to purchase, the potential customer should investigate several systems to assure himself that what he buys will be adequate for his needs. Once a system is installed, it must be used as a part of the normal function of the office; an extra tool . To be successful it must be integrated into the existing work flow, and produce the work volume needed to meet its financial goals. The work flow should be defined from the top designers or engineers on down to the data entry personnel, to ensure maximum utilization of time and power.

Properly utilized, the CAD system should be as pervasive in design or drafting as the business computer has been in accounting. To ensure this level of competence, many factors must be considered with regard to the organization and integration of the system into the work site, and these parameters must be reviewed and adjusted continually during the first years of operation to establish the most effective use of the system overall.

Thankfully, the human factor is still a large consideration in the productive use of a CAD system. With proper preparation and education, CAD staff will accept the CAD system as a useful tool rather than as a threat to themselves, and will learn to use it for their own career development as well as for the economic benefit for which it was purchased.

The knowledge of Computer Aided Design in the manufacturing world is mushrooming. The applications are as diverse as the system configurations, and it is the responsibility of

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* Information on CAD terminals can be found in

1. Carl Machover and Robert E. Blauth, The CAD/CAM Handbook, Computervision Corporation. Bedford, Mass. 1980.
2. James D. Foley, Andries Van Dam, Fundamentals of Interactive Computer Graphics. Addison-Wesley Publishing Company, Inc. Philippines, 1982.

Canadian industry, Canadian people and the Canadian Government to prepare for these changes, and implement them as quickly and efficiently as possible.

OBJECTIVES

In the economic environment of the 80's, there is no question that Canadian prosperity is going to depend on high technology. In industry the emerging use of Computer Aided Design should provide a major vehicle for increasing Canadian productivity during the next decade. To provide the most efficient use of this new technology, it is necessary to identify and eliminate any major constraints which would impair a speedy integration of CAD into Canadian industry. One major constraint is available - skilled manpower.

In response to this constraint, the Technical Innovation Studies Program of Industry, Trade and Commerce (ITC) has sponsored this study to determine:

1. What is the role of the CAD operator in the initial stages of a system's use, and as an aid in its continuing effectiveness.
2. What the manpower requirements are for a company to successfully implement, manage, program and operate an interactive graphics system.
3. What type of training would be most useful to industry for speedy and productive integration of CAD personnel.
4. What types of courses should Canadian universities and colleges be implementing to aid Canadian Industry in the Computer Graphics area. Training and experience will be discussed in relation to both the operator's development and his use in the organization as a unit.

Because CAD technology is making such a significant impact on Canadian companies, many government programs are aimed at accelerating the use of CAD in industry to boost the overall economy. This report will indicate industry preferences in government sponsorship, and areas of strength and weakness in the existing programs.

HOW DID CIM ADDRESS THE OBJECTIVES

To address these objectives, CIM prepared a questionnaire concerning the acquisition, operation and management of CAD systems. This questionnaire was forwarded to 86 Canadian companies and 10 specially selected American companies who have been using CAD for a period of one year or more, and resulted in 55 completed questionnaires.

Interviews were carried out with firms in British Columbia, Alberta, Ontario, Quebec, California, Michigan and Massachusetts. 96% of the responses are from companies who are using systems that have been purchased in a ready to use state, commonly known as turnkey systems. Most turnkey systems are modular, both in hardware and software programs. The user can select the hardware configuration, particular computational processing and graphic output capabilities that best serve his needs. The systems represented in this report are in order of user's responding: Intergraph, Calma, Computer Vision, Autotrol, Unigraphics, Omnitech, Applicon, Gerber and Megatek. The other systems were assembled according to user specifications. Two responding companies were using more than one system.

The report was augmented by visits to vendors, telephone conversations with new users, and CIM's experience with CAD over the past two years.

As a result of this effort, the following report represents the response from the questionnaire concerning system acquisition, operation and management.

The rationale for the report can be justified by stating that, with the implementation of CAD over the past 7 years, some companies have been exceedingly productive, while others have experienced disastrous results, occasionally preceding the termination of the company. Those companies who are anticipating the use of CAD or have just begun using this technology can greatly benefit by examining the attitudes and experiences of present users.

THE SURVEY QUESTIONNAIRE

The survey questionnaire was divided into three parts. The first part identified the types of industries using CAD, a brief look at their rates of productivity acquisition procedures and success with the system. Secondly, management was asked to identify key staff members and give information concerning their experience, education, and training. Finally, the questionnaire asked CAD personnel to assess the available training, identify areas where training could be improved, and point out major constraints to the increased utilization of CAD in the Canadian industrial spheres.

Application Areas for Computer Aided Design

Computer Interactive Graphics are being employed in a multiplicity of applications. To understand the manpower requirements for a CAD installation it is necessary to examine the purpose of the CAD system within its respective environments.

Often one system is used for a variety of purposes within the company itself. The report will deal with the manpower requirements, expectations of personnel, training requirements and course criteria concerning the following disciplines.

Manufacturing including mechanical design
Electrical Application: ICs, PCs.
Mapping and Cartography
Engineering; Structural Civil, Design

Computer Aided Design is a boon to each of these industries, and although the applications are diverse, the system is being utilized in somewhat the same way for each application.

Professor David C. Gossard of the Massachusetts Institute of Technology explains this way:

> *The key element to remember is information. The conversion of raw materials into finished goods requires the generation, refinement and transfer of an enormous amount of information. Historically, information has been generated by rubbing graphite on paper, refined by applying rubber to that graphite paper, and ultimately transferred by mail pouch. Information is an essentially weightless commodity capable of moving at the speed of light. Micro-electronic circuit technology has now given us expensive little engines with fantastic information-handling capabilities. To the extent that we can integrate this capability into the production process, we can produce a higher quality product in a shorter time with more flexibility to respond to market changes.

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*David C. Gessard, A CAD/CAM Story, the CAD/CAM Handbook, Computer Vision Corp. Bedford, Massachusetts, 1980.

Manufacturing Including Mechanical Design

At the terminal or design console, the designer uses an electronic tablet and a function keyboard to select and invoke geometric construction processes embodied in the system software. These construction processes permit the definition of three-dimensional geometry. Through a series of commands, the designer enters a mathematical description of a part that, once generated and stored in the system memory, is never lost or recreated. The time required to initially input three-dimensioned geometry is not significantly less than the time required by conventional methods, but subsequent revisions of that geometry can be performed many times faster than by manual methods.

Once a preliminary design has been created, both geometric and nongeometric information is stored in the database. At this point, the engineering personnel perform various types of analyses to guarantee the design's viability. The 3D design can serve as the base for finite element analysis, stress analysis, or heat transfer, and the original geometry can be easily modified for recommended changes.

The process planning group then makes decisions as to what manufacturing processes are required; machining, sheet metal forming, casting,injection, molding and any other machining processes. The CAD system can automatically generate a process plan to identify the processes required, the order in which they are to be performed, tooling requirements and the like.

The computer is then used to graphically simulate the metal removal process on a CRT. Checking of NC programming is aided by animation of the tool path on the graphic display. This enables the part programmer to easily visualize tool motion. A newly programmed NC Tape can be viewed on the display screen to detect potential errors before they reach the shop floor. All the information related to that tool path is stored with the model on the common data base, and can be reaccessed when necessary.

The skills of the designers and NC programmers are augmented by the interactive graphics unit. Their created geometry can be accessed later to be used on subsequent parts. Having a common data base allows the rapid generation of information to all levels of production, and the ability to modify the part at any stage, making sure that all relevant information is updated. In addition to improved productivity, the user may derive intangible benefits not easily linked with dollar values, such as improved drawing quality, and the ability to verify any information at any time.

Electrical Applications

In today's electronics industry, interactive computer aided design systems are fast becoming an economic necessity. Electronics is an intensely competitive field where the manufacturer who gets his product to the market first, generally captures the larger market share.

The need for lightweight, complex and densely packed electronic equipment for the aerospace industry created a widespread trend toward the use of intricate and multilayered printed circuit boards (PCBs). The necessary accuracy and high resolution, .001" or better, presented the designer with an ever more monumental task. The introduction of CAD has greatly decreased design and production problems.

Similarly, CAD has been a major factor in reducing the cost of integrated circuits. Once the domain of the military and avionics applications, ICs are now an integral part of practically every modern electrical device from clock radios and wristwatches to sophisticated computer complexes.

In both I.C. and P.C. design, CAD has removed a lot of the noncreative, repetitive tasks, and has allowed the designer to explore design alternatives without the delay and cost of actually fabricating experimental parts. Many other electrical applications, such as wiring diagrams and layouts, derive the same advantages.

With the use of CAD, drafting tasks such as hand-drawn lines, repetitive layout work, editing, checking and updating have become much less tedious and consequently, less error-prone. By manual methods, even minor modifications require considerable checking and clerical work, whereas with CAD, all changes will be automatically updated in every area that will be affected by this change.

System commands permit the display, editing, retrieval and storage of data that partly automate and totally streamline the design process. The ability of the system to manipulate the entered data in a very short time allows a designer much flexibility in optomizing the placement of all necessary components. When each new item is added to the overall layout, the designer can be certain that it is perfect in every detail, plus making sure that the desired elements don't violate any design rules or process imposed constraints.

When CAD tools are used, many errors impossible to detect with the human eye, can be corrected well before the design is committed to fabrication, thus minimizing the cost to rectify that error.

The complexity of wiring diagrams, I.C. and P.C. layouts have evolved at an almost exponential rate. We have long since past the state where the designs for such layouts are feasible using manual methods. CAD is an essential ingredient in keeping a company competitive in the fastmoving electronics market, where leadtime is a crucial factor.

Mapping and Cartography

Large scale mapping is a vital function for the effective operation of all municipal corporations. Accurate and up-to-date records for fire and police protection, planning, transportation, utility services and taxation are needed on a daily basis.

Energy related industries, forestry, oceanography, mining, and many other companies are also in need of efficient mapping facilities to be productive. The types of information needed for each industry ranges from genetic, ecological and physiognomic to geomorphological, cultural-historical, legal and municipal, but the requirements for an extensive library of overlaying information, and the rapid production of high quality maps is fairly universal.

The major advantage of computer based mapping is the ability to manipulate and organize a wide variety of information, then isolate desired information when required. Once the surveying and data entry operations are complete, the computer mapping installation should:

a) provide database management facilities to store and retrieve a large number of "elements" of different graphic types, each having an unlimited number of variable length attributes.
b) offer data collection, input, and verification facilities for the elements.
c) generate reports and maps of any desired area of high cartographic quality at any suitable scale, according to user's specifications.
d) incorporate selection, classification, modelling, and management facilities.

The layering and calculation abilities of comptuer aided design systems allow the merging of multiple thematic surveys along a common geographic area for ease in handling and comparing of information. This information can often be entered by a high-school graduate with a good mind for details. Once the data is entered along certain parameters, that information can be produced on paper or film according to the user's requirements.

When updating of information is required, the system will assure that, once the revised information is included, it will appear revised on any subsequent readouts until a further revision is made.

For many applications, the integration of computer equipment into the facility has so greatly expanded the use and management of information, that no comparison can be made with previous methods.

ENGINEERING: STRUCTURAL, CIVIL, ARCHITECTURAL

For Civil, Structural and Architectural purposes, the CAD system offers freedom from the tedious, time-consuming chores that have little to do with technical ingenuity. CAD allows routine engineering tasks to be performed quickly and accurately, and by storing the information in computer memory rather than on papers dispersed throughout the office or area, the transfer of data from one source to another is quicker, more reliable, and less redundant. Once the information has been entered, the computer can perform functions which include finite element or structural analysis and structural database management. Linear static and dynamic analysis are generally included.

In addition to being able to correct and verify information at any time, the system typically provides values for shears and moments, and specialized programs for solving general structural problems involving beam spans, space frames, plane trusses, section properties, steel beams, steel columns, reinforced concrete and flat slabs.

Frequency-analysis programs, dynamic load analysis programs and plane-truss analysis programs can all be entered to calculate joint displacements, stresses, reactions, modal shape values, general forcing functions, natural frequences and most other necessary data.

Beam section programs are also available to calculate moments of inertia, centroid locations, areas or lengths, radii of gyration and related data.

Many revolutionary designs can be entered and calculated, allowing the designer to view the structure as it will appear in addition to testing and modifying of the necessary data. Extra calculational abilities and viewing capabilities augment the designer or engineers skills, and allow the examination of many more design concepts than were feasible by manual methods.*

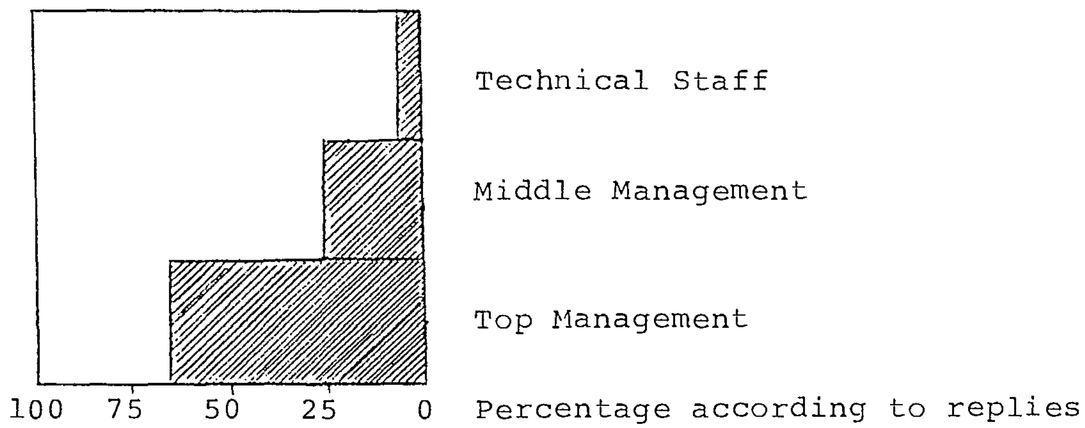
The computer has been such an integral part of the development of engineering technology, that most users in this field view CAD as a natural if not predictable extension of existing engineering practices. The applications, however, are so diversified that the use of CAD technology in particular is not as universally accepted as in the mapping or electrical fields.

Who Makes the Decision on which Systems to Buy?

In order to understand the role of the CAD system within the office, it is necessary to examine how it got there.

Due to the high cost of CAD systems, an extensive justification is required. The final decision on which system will address the user's problem most accurately is not an easy one to make.

Who Makes the Decision to Buy

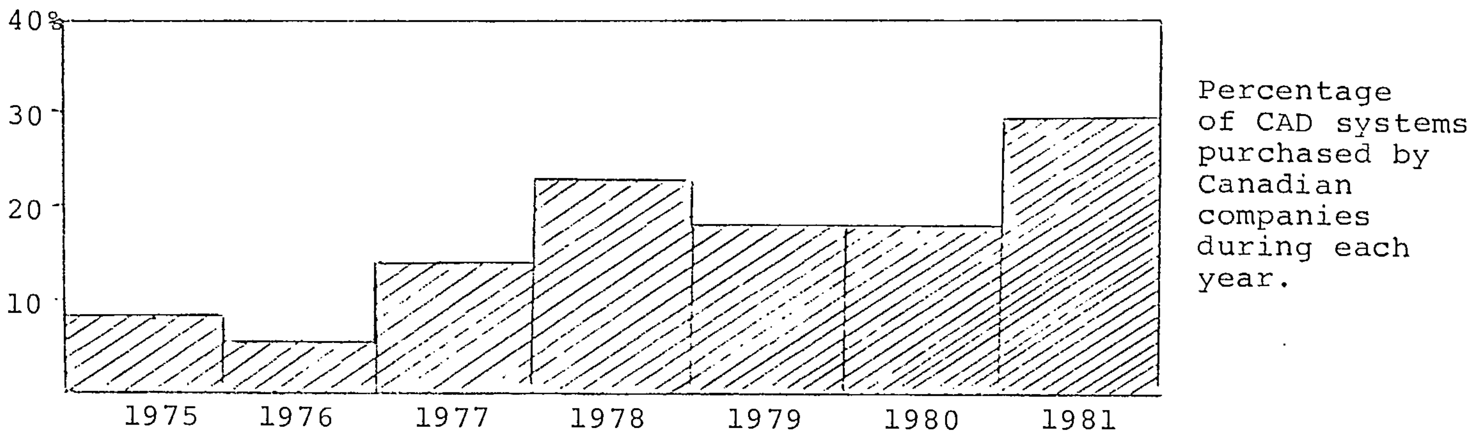


* Computer Aided Engineering, 1982 Systems and Software Annual, Robert Z. Chew, Penton IPC Inc. Pg 119.

Of the turnkey systems, 77% of the companies bought display terminals to link with their system after they had been using it for 6 months or more. 58% supplemented their systems with additional alphanumeric screens.

Interactive graphics were not available in any form before 1970. Most of the systems were bought between 1977 and 1981. The following graph illustrates the growing involvement with CAD over the past 8 years.

Growth of CAD on Replies



Who Makes the Decision on which System to Buy*

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Due to the high cost of CAD systems, an extensive justification is required. The final decision on which system will address the user's problem most accurately is not an easy one to make.

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* Good Guides to a Pragmatic choice of systems are:

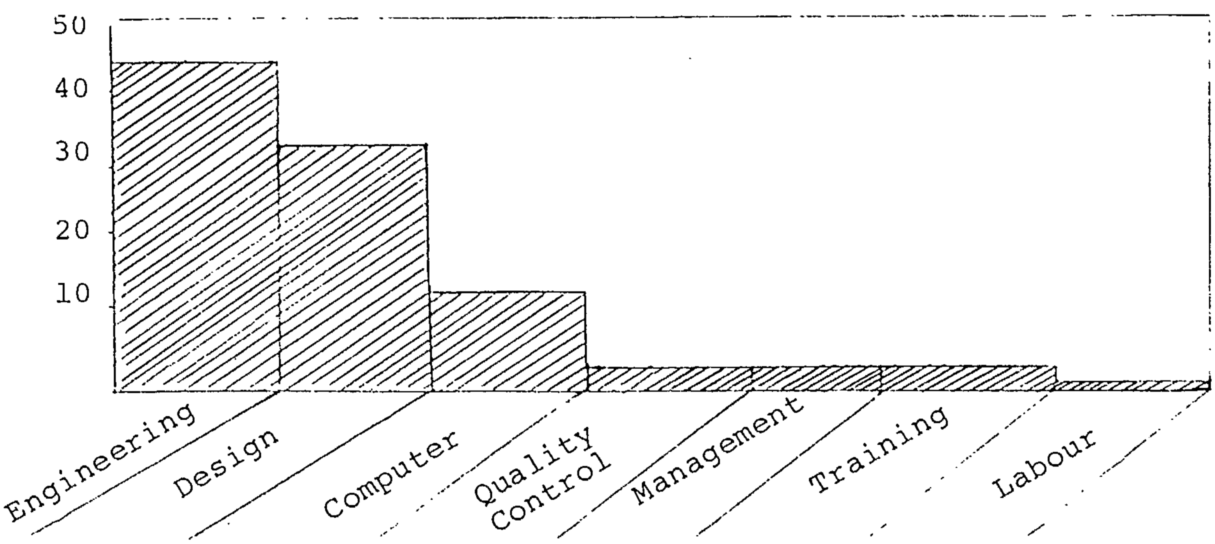
1. Chia P. Day, Ranjit K. Roy, Michael J. Yoshuus, Computer Aided Systems The Road to Selection, The first annual conference on Computer Graphics, in CAD/CAM systems, MIT, Cambridge, 1979.
2. Sylvan Chasen, CAD/CAM Fundamentals - Practical CAD Considerations, Lockheed - Georgia Company.

When deciding on a particular system, top management usually makes the final decision to buy or not to buy. The majority of companies, 39 out of 53, formed committees within the company to consider the acquisition of a system. The committees were comprised of various areas of the company.

The following graph illustrates several very important points. The most important point is that the design and engineering staff were the major influence (78%) in the decision on which system to buy. As several million man hours are required to create the software for a CAD system, it is not surprising that CAD vendors all have areas or applications where the software is more advanced. Most companies feel that the design and engineering staff are the most qualified to judge these capabilities in conjunction with their own applications.

It is interesting to note, however, that computer personnel made up only 12 percent of the acquisition committees. This would suggest that most companies considered the computer to be merely a tool which could be programmed or manipulated to their specifications, once the correct system was purchased.

Quality Control, Management and Training personnel each represented a small portion of the acquisition committees, having little influence on the final decision. Surprisingly, Labour represented only one percent of the acquisition committee, suggesting that Labour only gets involved once the system is installed.



Representatives of the Acquisitions Committee.

3 companies were unsure of the conditions of acquisition because there is no one presently employed who was employed at the time of purchase. Of the remaining 13 companies, 9 hired consultants and 4 had a CAD/CAM representative who decided on the system.

How do CAD Users View their Competition?

In 1983, there are several companies already in existence that would not be so without interactive graphics. Service bureaus such as Gridline Graphics in Ottawa and TCD Graphics in Toronto are quintessentially CAD outlets, providing drawings and layouts for local companies. The production of P.C. Boards is inextricably linked with interactive graphics equipment. Companies producing IC's and PC's are all making use of computer graphics. CAE Electronics in Montreal is one of 5 companies in the world producing Airplane simulators, also an impossible task without the use of interactive graphics.

Most of the larger companies such as General Electric, Monenco, Gulf Oil, etc. are part of large multinational companies whose major competitors are making extensive use of Computer graphics in many facilities. The medium and smaller sized companies are also finding that their major competitors are using computer interactive graphics in some part of their production.

How Users View the Competition

In Canada today, there are over 31,000 manufacturing establishments, employing over 1,700,000 persons *(1). These industries include all types of manufacturing from metalworking and energy to leather goods and food products. At this point, it is impossible to estimate how many of these companies could make productive use of CAD technologies. A recent survey by the Canadian Manufacturers Association *(2) states that 14% of Canadian companies are currently using CAD techniques for engineering design or drafting.

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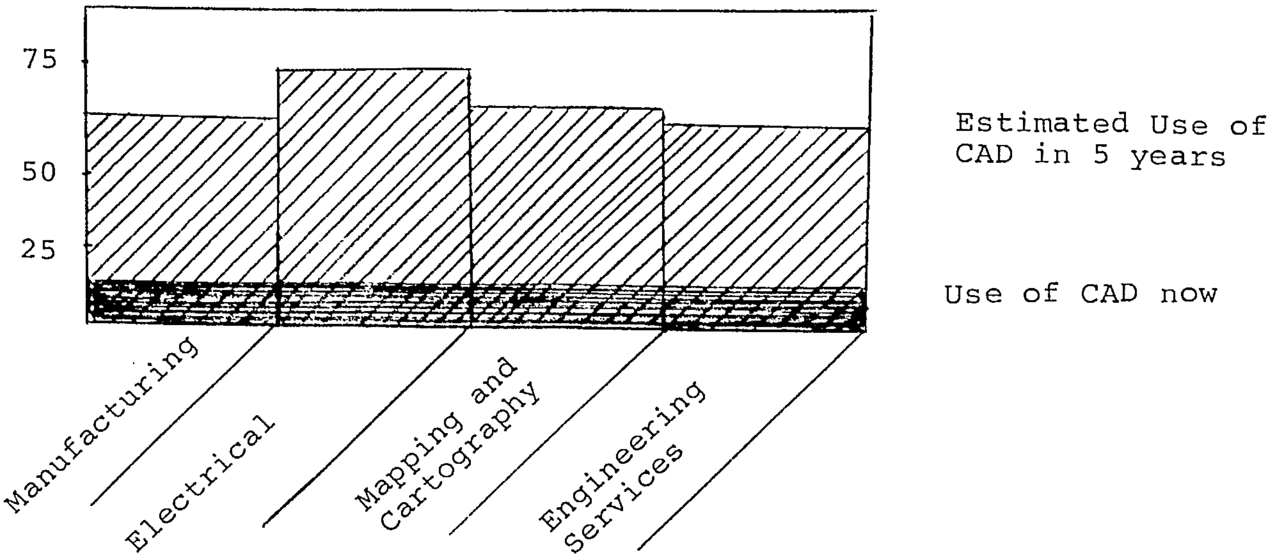
*(1) The latest figures are from the Canadian Year Book, 1980-81. Statistics Canada, K1A 0T6, pg. 664.

*(2) Information needs of Canadian Companies on Computer Aided Design and Computer Aided Manufacturing, CAD/CAM, based on 450 responses.



In order to determine the overall view of users towards CAD, we asked each user to comment on the technology level of their competitors in 5 years. Again each application has a different expectation for their competitors and many of these applications have many additional considerations.

In manufacturing, it is generally agreed that the larger companies are the first to investigate CAD. 84% of the manufacturing companies that responded to the questionnaire have over 1,000 employees. Due to the rapidly deflating computer and calculation costs * small and medium sized companies will soon be using CAD technologies as well, thus users have stated that 70% of their competitors will be using CAD within five years.

In the electronics industries, many companies stated that 100% of their competitors are using CAD now, as I.Cs and P.Cs are virtually impossible to produce manually. The projected figures for electrical applications across the board is 83% using CAD by 1987.

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* <u>An Overview of CAD/CAM in Canada Today,</u> Jack Scrimgeour, I.T.C. Has further information concerning CAD and computer costs.

Similarly, most of the oil and energy related companies are using CAD now, while most municipal mapping agents are not. The projected five year figures is 72% of mapping related organizations will be using CAD in five years.

Engineering services are difficult to define and cover a far broader scope than the above applications. Their projected five year figure is 67%.

For those companies competing with other nations, the competition is much more stiff, largely due to nearsighted government policies. In Japan, as an example industry pays only 7 percent for capital as opposed to 18% or more in North America. Hundreds of millions of dollars have been allocated to developing companies over the past ten years.* Both the Japanese and the Germans have placed an intense interest on manufacturing, productivity and quality in the last 20 years while North Americans have been "asleep at the wheel".

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* Silicon Valley, National Geographic, October 1982.

PRODUCTIVITY OF A CAD INSTALLATION

Different Productivity for Different Applications

In order to identify the manpower requirements of a CAD installation, it is necessary to determine the role of the CAD unit within the office, and its impact on the general productivity of the company.

Because of the nature of their respective businesses, each application for the system produces different productivity rates and a wide difference in time span for the systems to become productive. The survey results have been divided into four separate classifications:

1. Manufacturing including mechanical design
2. Electrical applications, I.Cs and P.Cs
3. Mapping and Cartography
4. Engineering Services

for a more accurate account of productivity in each area.

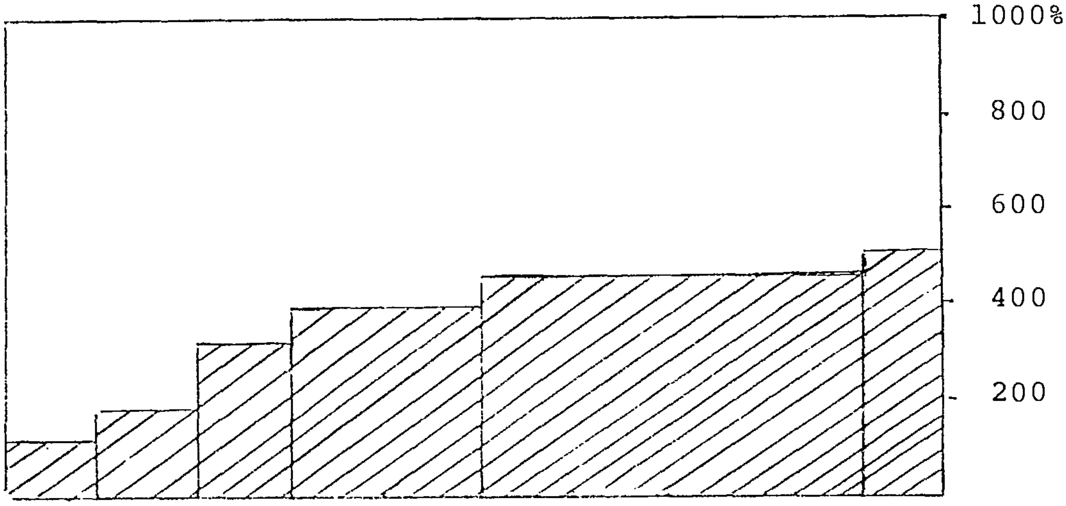
Manufacturing

With regard to manufacturing, the advantages of an interactive graphics system are manifold. In the design stages, multiple parts can be designed within a limited time span, or left to be calculated and constructed overnight. Through the use of automated design techniques, multicavitied and undulated surfaces can be constructed in a fraction of the time necessary to produce the same part through manual or computer assisted methods. Heat transfer finite element analysis, aerodynamic qualifications and similar engineering data can also be calculated with considerable time saving.

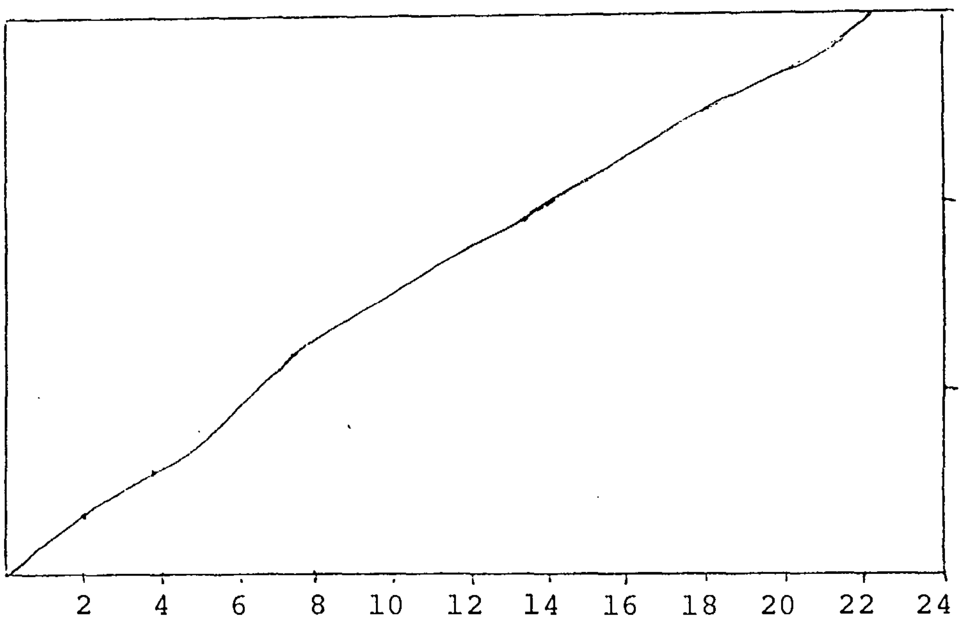
Once the part to be produced is designed and analysed, the interactive graphics system will produce N.C. tapes for manufacturing. For small jobs, the system takes as long as APT programming would take, but for large and complex applications, the ratio is anywhere from 2 - 1 to 10 - 1. Again the productivity rates are difficult to calculate because many of the applications are simply not possible using conventional methods. The companies who responded to this questionnaire have found increases as follows:

The following graphs will illustrate

1. The maximum rate of productivity of the CAD system within the companies who responded to the questionnaire according to the specific application.
2. The length of time in months needed to reach a productivity rate of 300%.

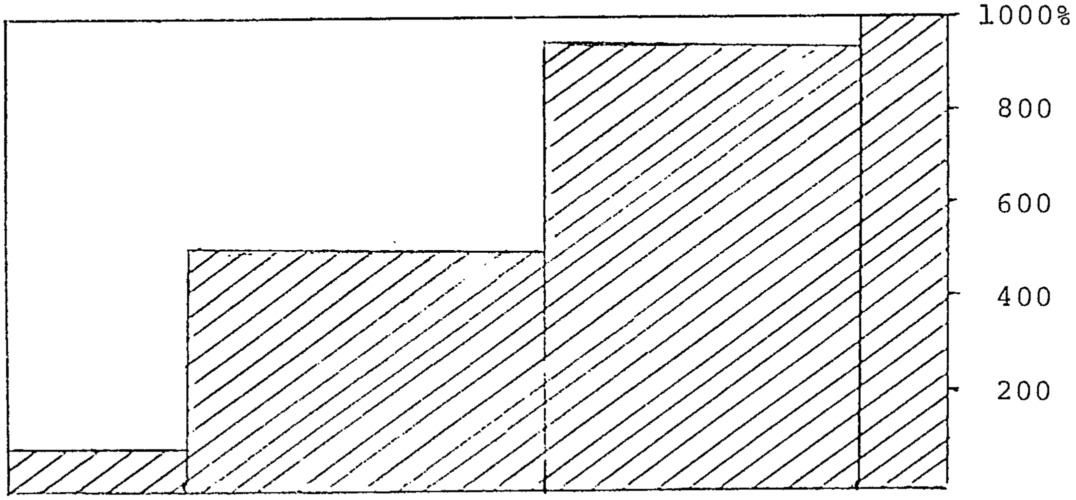


Distribution of Companies

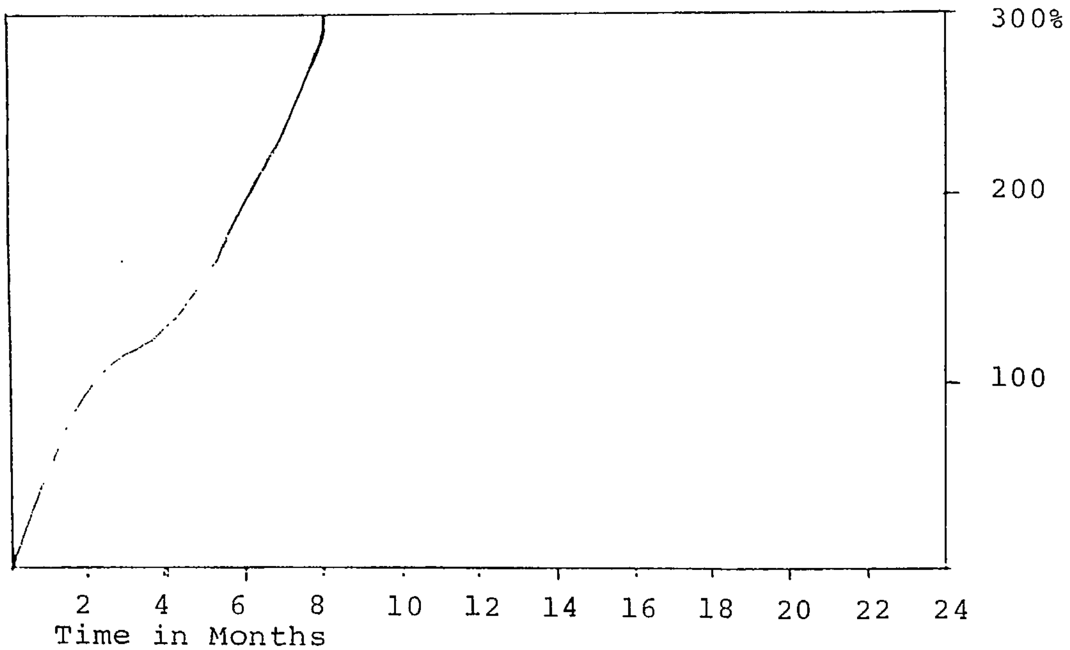


Electrical Applications

The evolution and production of Printed Circuits and Integrated Circuits are intrinsically linked with the development of interactive graphics equipment. Up to 70 percent of the production of P.Cs is simply not feasible by manual methods. The accuracy and detail of many electrical applications is also an important factor. Of those who could viably measure their productivity the results are as follows:

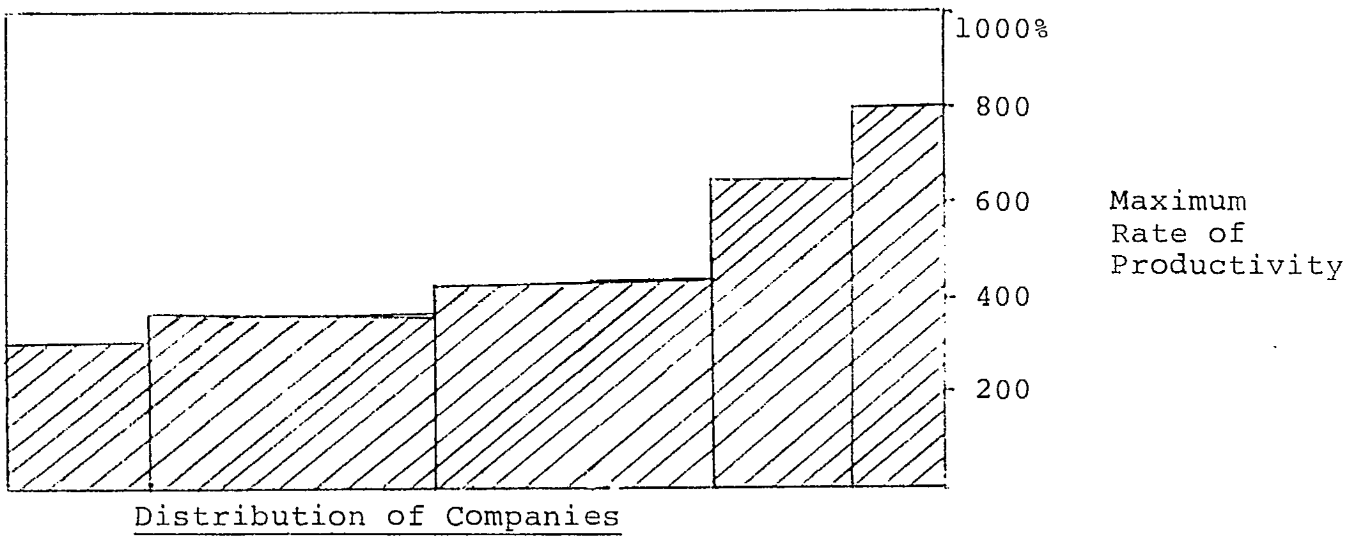


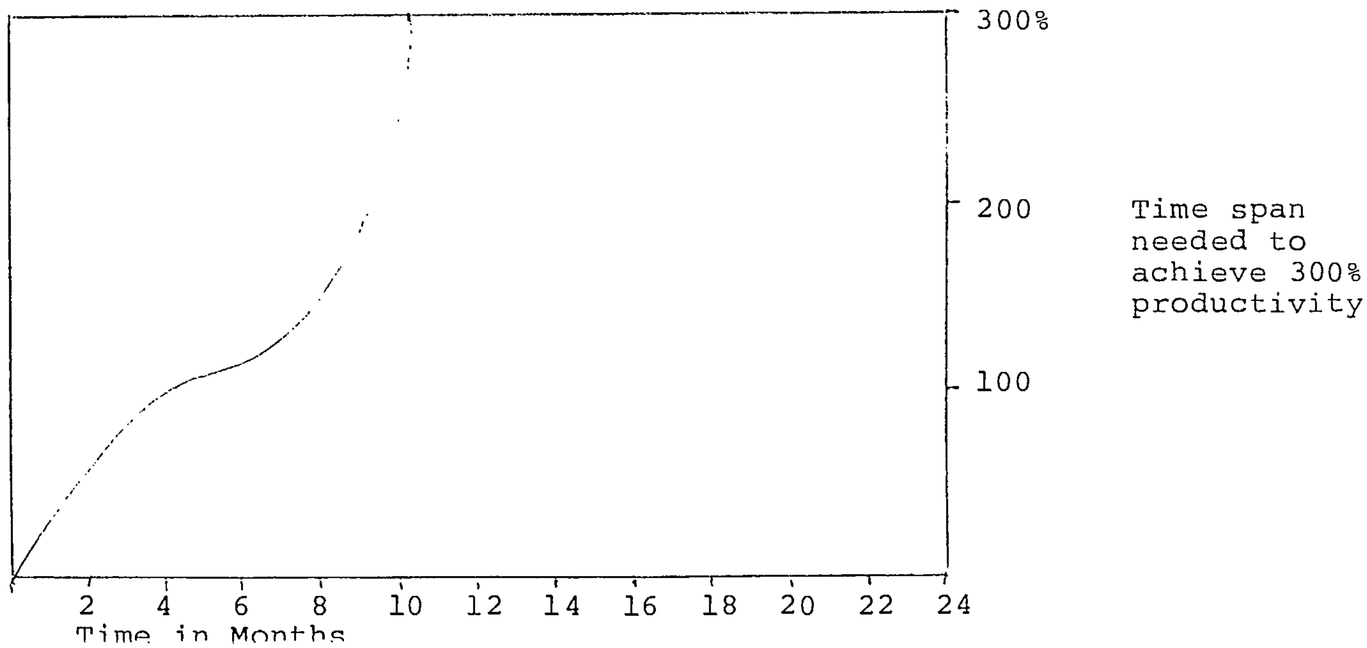
Distribution of Companies



Mapping and Cartography

Similar to the electrical applications, the introduction of Computer Graphics to Mapping and Geocartographic related industries has expanded their use of cartography to such a degree that "productivity is not really an issue". In both the electrical and the mapping operations, many, if not most, of the non-graphic information would be impossible to coordinate manually.





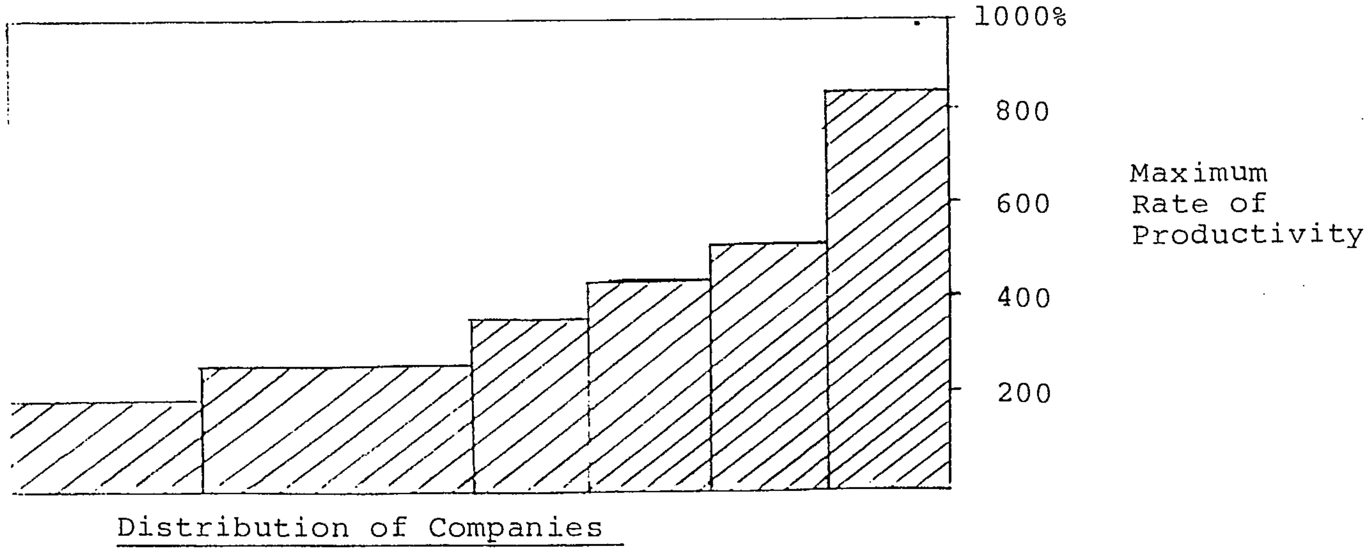
Where the production of maps for utilities, construction or related verification purposes is required, the availability of immediate up-to-date information is essential. In the public utilities sector, a data base that is accessible for hydro, water mains, roads, sidewalks, electricity, postal information and taxation purposes will be of great use.

Engineering

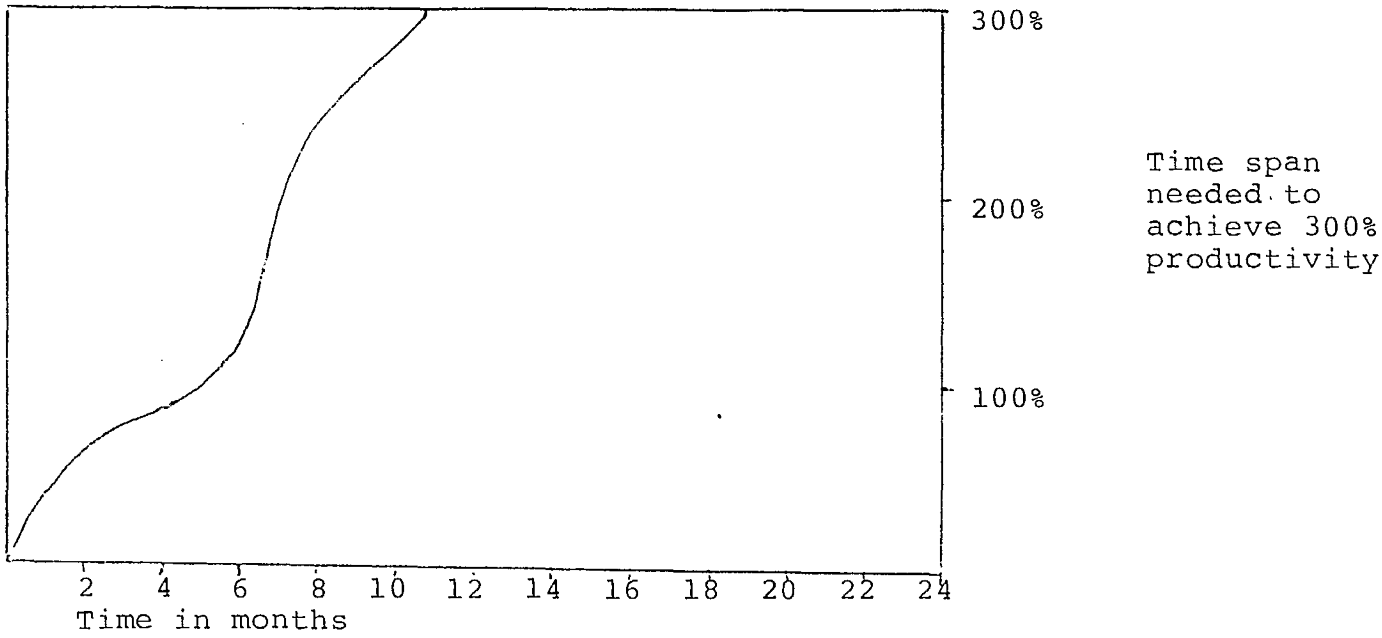
For engineering purposes, the system is used for both the design and analysis of the project in addition to the production of engineering drawings. There are many system management activities that have a great effect on the increases in productivity rates.

A good draftsman can usually produce an engineering drawing in the same time that is necessary to create a data file and produce a plot on the interactive graphics system. However, a great saving in time can be accomplished when this data file is used to create a drawing of a very similar subject as the file can be reviewed, modified and then automatically plotted.

Similarly a full and comprehensive use of available software can greatly accelerate design time, and provide accurate and systematic data for subsequent analysis. Productivity gains with regard to these applications are as follows:



Time Span Needed to Achieve



The above graphics illustrate several important points:

1. The increase in productivity is absolutely dependent upon the application. In Electrical Applications, over 75% of the responding companies had productivity rates of 5-1; in Mapping, the majority of companies had gains of 4-1 with a maximum (10%) of 10-1; in Engineering, 85% of companies had over 3-1 gains with a maximum (15%) of 6-1: and in manufacturing, 70% of the companies had more than a 3-1 gain with a maximum (10%) of only 5-1.
2. In Electrical applications, it takes an average of 8 months to reach a productivity gain of 300%, whereas in Manufacturing, this level takes approximately 3 times as long, or 24 months. In both mapping and the engineering fields, 12 months are needed to reach 300% productivity.

These differences in time needed to increase productivity are dependent upon the ability of the system to address the user's problem and the ability of the operator to address the system. In the mapping area, a great deal of time is spent in data entry, whereas in manufacturing the operator is creating three dimensional geometry or programming N.C. tool paths. Thus the manpower requirements are different for each application, and each level within that application.

For those companies whose applications do not correspond to the above categorization, "productivity" is of no importance. Examples are found in Aerospace Research and Development applications where interactive graphics systems can be used for experimental simulations and development of satellite and space craft dynamics technologies. The systems are essential in displaying visual images which will be much more accessible to scientists and lay people alike. They are programmed by the scientists themselves and their aids who are not necessarily computer personnel.

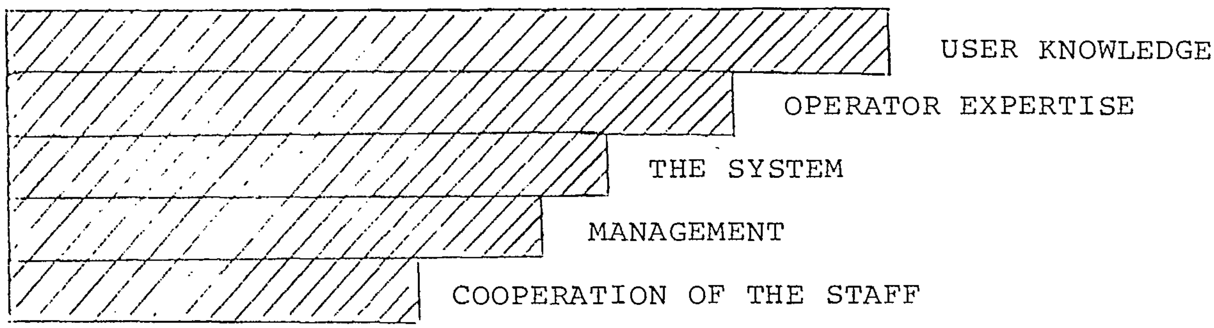
<u>What is the Role of the Operator in the Overall Productivity of a CAD Installation?</u>

94% of the respondents stated that their companies were satisfied with the results produced on the system, the remaining 6%, whose companies were not satisfied, usually had a very slow startup period and have not yet made full use of the system capabilities. There are several reasons for this: personnel, management, and the acquisition of the wrong system are just a few of the possible problems.

In a drafting or mapping situation, most of the staff are unfamiliar with computer technology, and must be retrained. Management personnel have often stated that the attitude of the operators is a very important consideration and that the inevitable 'culture shock' must be handled in a positive rather than authoritarian manner.

In response to the question "upon what are your productivity rates dependent?", the companies questioned answered that the prime consideration was User knowledge, the amount of knowedge on both the users problem and the ability to address this problem to the system. If an operator doesn't know his job, i.e. architecture, mechanical drafting, electrical or structural, the system is not going to help him.

Factors Affecting the CAD Installations' Success



The second most important factor is the ability of the operator to use the system to solve the problem. For many electrical and mapping applications, a high school graduate with a mind for details is sufficient to perform straight digitizing functions. In the engineering and manufacturing areas. a knowledge of design and analysis functions or any understanding of N.C. programming would be a necessity. In both cases, the interactive graphics system is simply a tool, but the calculational and computational abilities of the software would require a more intimate understanding with relation to the difficulty of application.

The system is the next largest consideration. Because of the quantity of manhours needed for software programming, turnkey suppliers have, generally speaking, focused their activities in specified areas. The choice of a system is often an involved and laborious process and a good choice cannot be guaranteed. Many companies have found that, due to the nature of their specific applications, projects may take two months or more to complete. Benchmarks, under these circumstances, can be very difficult.

Although management was not seen as the most important factor when considering productivity, it is certainly very important to have management personnel who are interested in computers, and sensitive to the new problems that are facing the staff. Still, the ability of management to split the problem into areas that can all access the same data base is not of as much importance as having operators who know what they are doing once their work has been defined.

Several questions have, however, been raised concerning individual work scope and jurisdiction. There will be a natural dilution of activities as the systems become an integral part of the working space, but certain professional barriers have been raised, and these must be studied, and if need be, lowered. These decisions will need to be made by the management and will eventually affect the system's productivity to a great degree.

Finally, cooperation was seen to be the least important factor to consider when studying productivity. The ability of existing staff to communicate and solve their system problems is not seen as a large factor, but is important to the smooth running of a CAD installation. If the staff have a problem, the time taken to resolve it is greatly reduced if they are able to approach others on staff who have perhaps encountered a similar difficulty and then if no help is available, to approach the Vending company for their opinion or possible help.

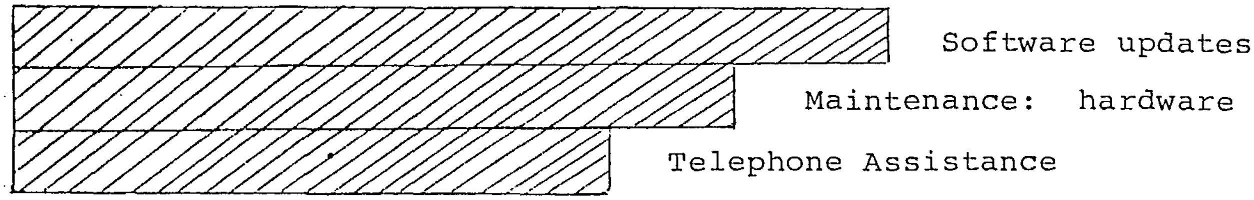
It is obvious from the above responses that the CAD operator is the most important factor in the productivity of a CAD unit. His knowledge of the area of application plus the ability to address this to the system is of primary importance.

What is the role of the vendor in the start-up of a system?

Contact with the Vendor

Most companies find that they are in constant contact with the vendor for several reasons.

Areas of Contact with the Vendor



The gaining sophistication of the user community is the major reason that software updates provide the most contact between users and vendors. While users are exploring their own specific branches of the technology, vendors are facing the increasingly demanding task of providing necessary software. Advances within the larger companies have to be written in house to keep up with operator demands, while smaller companies either purchase advanced software packages from the vendors, or from their fellow users.

With regard to maintenance and hardware, many companies found that they are pleasantly surprised by the durability of their systems. Although minor repairs are frequent, most of the vendors have good maintenance contracts, and are quite reliable.

After the initial six months on the system, the necessity for training, demonstrations and "telephone" assistance drops off radically. The existing staff take control of the system and it is up to them to make it work.

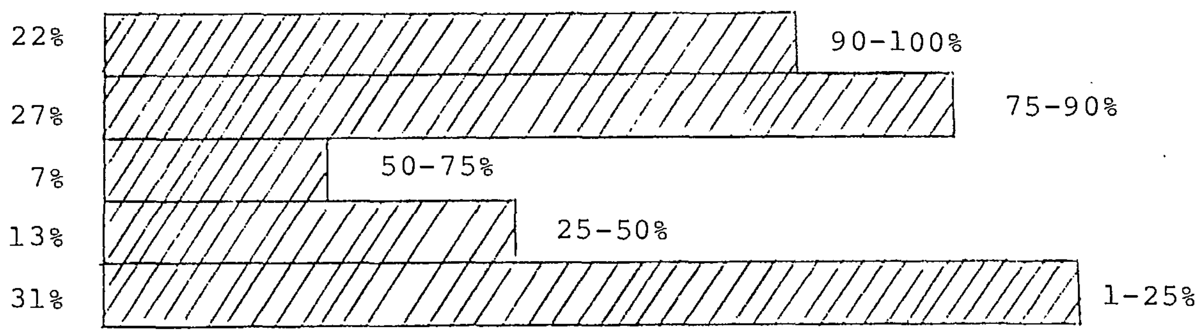
MANPOWER REQUIREMENTS OF A CAD SYSTEM

To identify the manpower requirements of a CAD installation it is first necessary to examine the staff of existing successful CAD installations.

CAD technology is a relatively recent development, and the CAD staff, who are correspondingly new to the field, are generally unstable as a unit. Employers are not always informed about salaries and updates of job positions, and consequently lose their trained staff to other installations at a higher rate than the more stable positions would.

What Percentage of the Staff have Remained after the Implementation of the System?

Staff Turnover



Percentage of present staff after the Implementation of the system

Staff Turnover

Of the companies who responded to the questionnaire, very few (22%) of the outlets had over 90% of their present staff before the installation of the system. Less than half of the companies surveyed (49%) had over 75% of their present staff, and 31% had less than 25% of their present staff. This would indicate that a large percentage of users have had to hire a substantial amount of new staff to operate and maintain their CAD facility.

When positions are available, 60% of the companies surveyed advertized in local newspapers, and only 30% advertized in company journals. These figures would necessarily relate to the relative size of the companies involved, but still suggests that companies have been looking for staff from outside of their traditional framework. Many of the larger companies stated that they usually took their CAD staff from within the company, but were not sure if this was a result of present economic conditions or whether they would hire elsewhere if they could hire freely. Surprisingly, only 14% of the companies surveyed had a staff turnover of more than 10 percent last year. This could be due to several factors: 1. the present economic condition tends to decrease personnel turnover in most areas, and makes employees settle for working conditions that they may find otherwise unfavourable, 2: once the computer installations have been working smoothly for six months to a year, both the staff and the management are more aware of their capabilities, and are satisfied with their working conditions.

Salaries

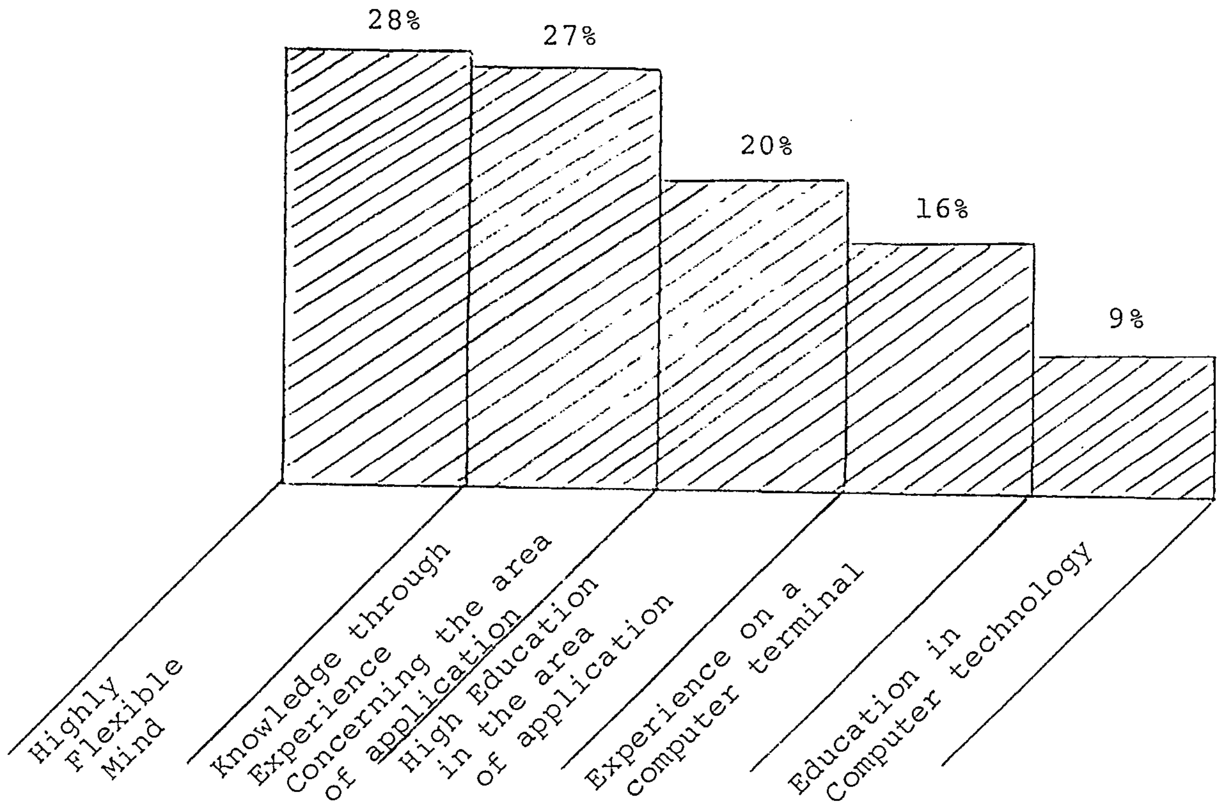
Most companies found that their staff left due to higher salary offers from other companies or installations. Because the drafting design and manufacturing staff are still expected to make the same aesthetic judgements in addition to being able to utilize the computer and being aware of updates and software releases, most operators feel that they should be paid at least 10% more for their services. It is usually the individual's preference to transfer onto the system, and he/or she usually feels that he should receive some remuneration for his extra effort. "Keenness" is one of the most important factors in a speedy startoff time, and monetary gain is certainly an added stimulous.

One company questionned observed that although it may be true that anyone can use the system and be productive, levels of productivity are important. For 25% more pay, a person can be three times as valuable to the company.

This observation relates to a fairly sophisticated application, where the user required a good overall understanding of his subject area and application. Certainly the repetitive applications where little job satisfaction can be expected would have less qualified personnel.

Once the systems had been up and the job position re-evaluated, it is to the company's advantage to keep the trained staff, as others will take considerable time to get up to speed.

WHAT MAKES A SUCCESSFUL CAD OPERATOR



What Factors Contribute to the Productivity of a CAD Operator

It is generally agreed that the two most important considerations are a highly flexible mind, and a knowledge through experience on the subject of application. Education in the area of application is the next largest consideration, and experience on a computer terminal is of importance though not critical. An education in computer science is of minimal importance to the operator as he is usually expected to use the system as a tool in the completion of his own projects.

Most companies, especially the smaller sites, expect their staff to perform computer related tasks, but these are usually simple procedures that are part of a repetitive system that has been set up by the system manager.

System Management

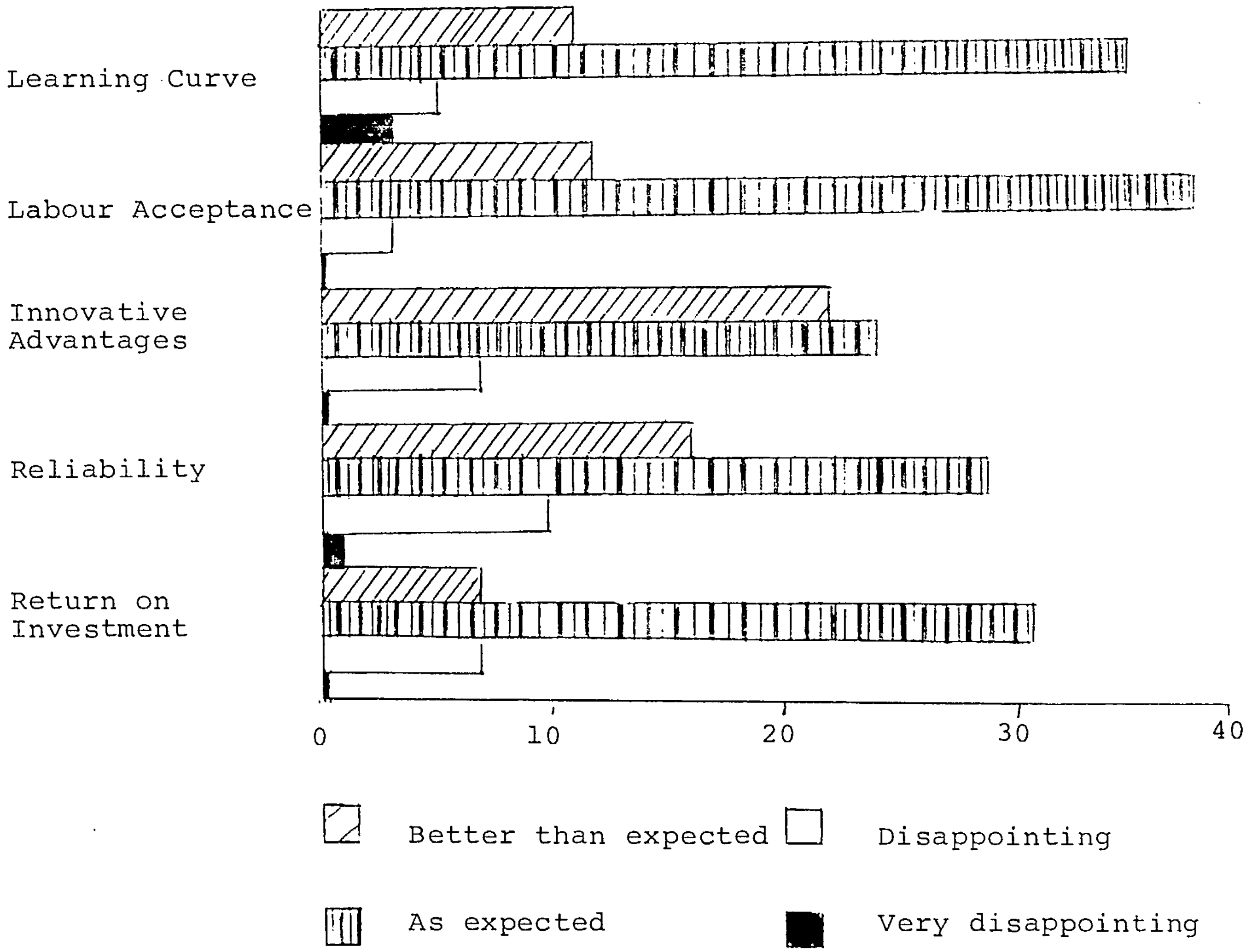
The system manager should have a computer background, and should be able to set up archiving, accounting and software routines to help the operators with their work. In conjunction with management, the system manager is a key person in the implementation of a CAD system to help train and inform the operators on the use of their terminal time to complete their given tasks.

Job Satisfaction

Many of the operators interviewed stated that they find the constant updates, revisions and even the problems exhilarating, and that they couldn't go back to manual drafting and design work. Usually there are waiting lists of people who would like training on the system.

Having worked with the system for over a year, most companies are satisfied with the performance of the equipment and the acceptance of it by the staff.

Satisfaction According to Responses



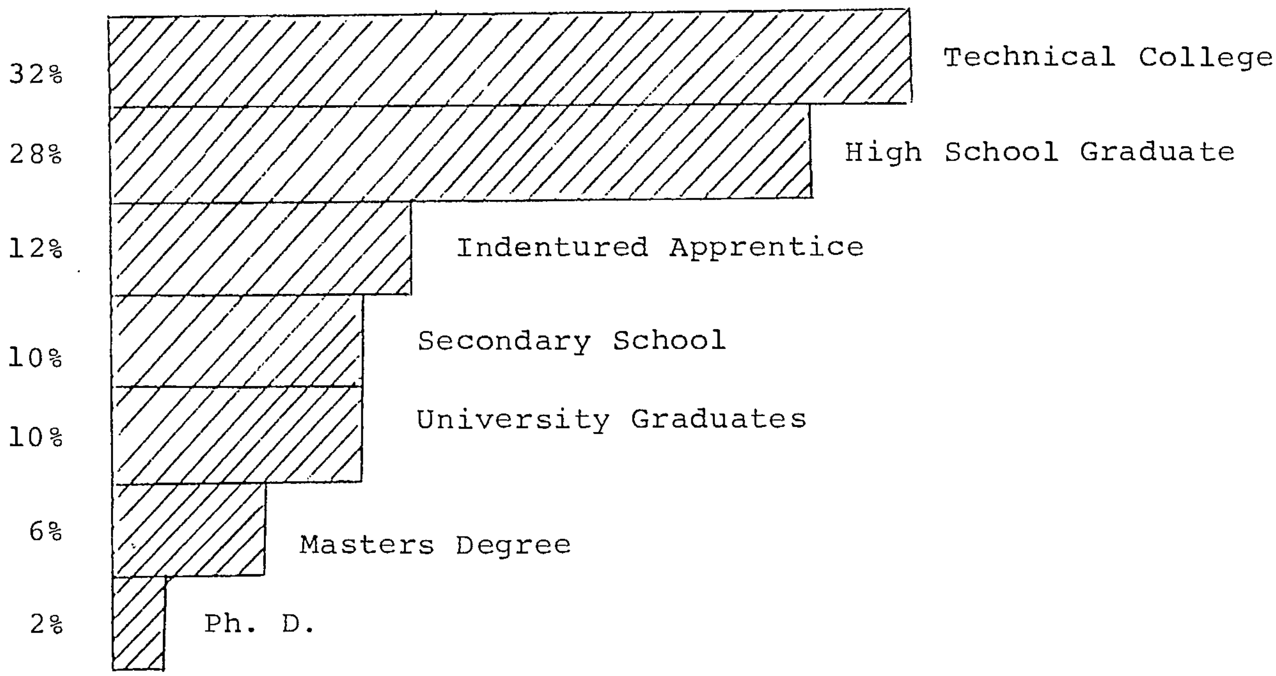
BACKGROUND OF CAD STAFF

Education

The CAD staff usually work either 37½ hours or 40 hours per week. The amount of this time that is spent on the graphics terminal depends upon the application. 46% of the operators spend their entire work week on the terminal, while the remaining 54% only use the terminal when necessary; anywhere from 7½ to 35 hours per week.

The background of an operator or designer depends upon the requirements of the application.

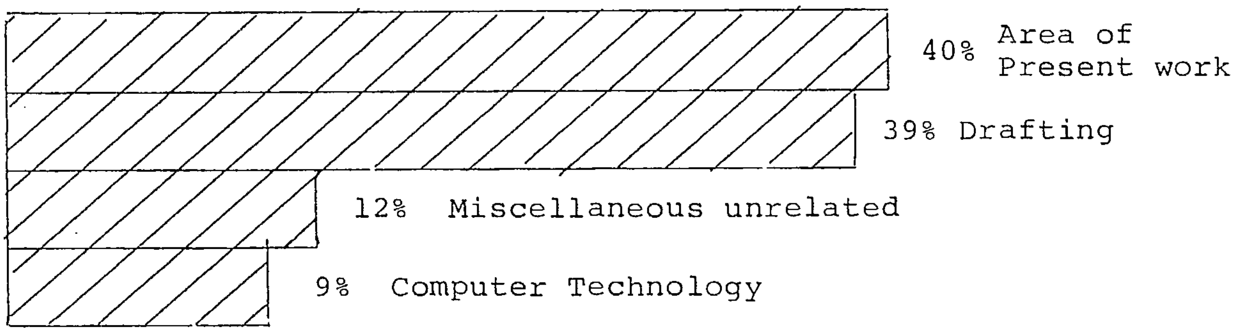
EDUCATION OF CAD OPERATORS



Many companies believe that anyone can be taught to use a graphics system. This is true to a certain degree. For simple data entry and basic constructions, high school graduates can suffice. For more intricate operations, however, a higher education is necessary.

When an interactive graphics system is introduced to a work site, system management procedures for documentation, memory management and user interfaces for efficient time utilization will need to be introduced. Once a system has been developed, however, these functions are not of high priority and can be done by people who are relatively unfamiliar with computer technology.

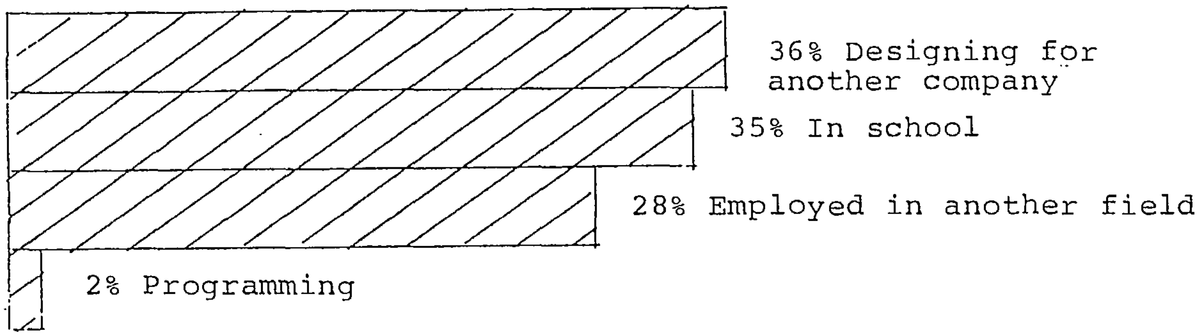
Education with Relation to Present Position



40% of the companies surveyed were educated in the area that they are presently working in, i.e. Engineering graduates are doing engineering work, Geophysicists are producing maps and topographical surveys, etc. 39% of the respondents had people who were trained as general draftsmen, 12% were trained in unlrelated fields from clothing design to biology, and only 9% of those who responded had training in computer technology.

Experience

Activity of Employee Previous to the Present Position



35% of the operators interviewed were in school before their present position. 36% were designing for another company and 28% were in another unrelated job. Only one percent of the present CAD operators were programming.

Many of the CAD personnel interviewed said that most of the operators on the system were younger than 40 years old. This could be for several reasons. Most drafting people would prefer to avoid computers as a primary impulse, and many are determined to "retire on the board". Either by accident, by choice or by very subtle hiring policies, younger people are introduced to the system before the senior personnel.

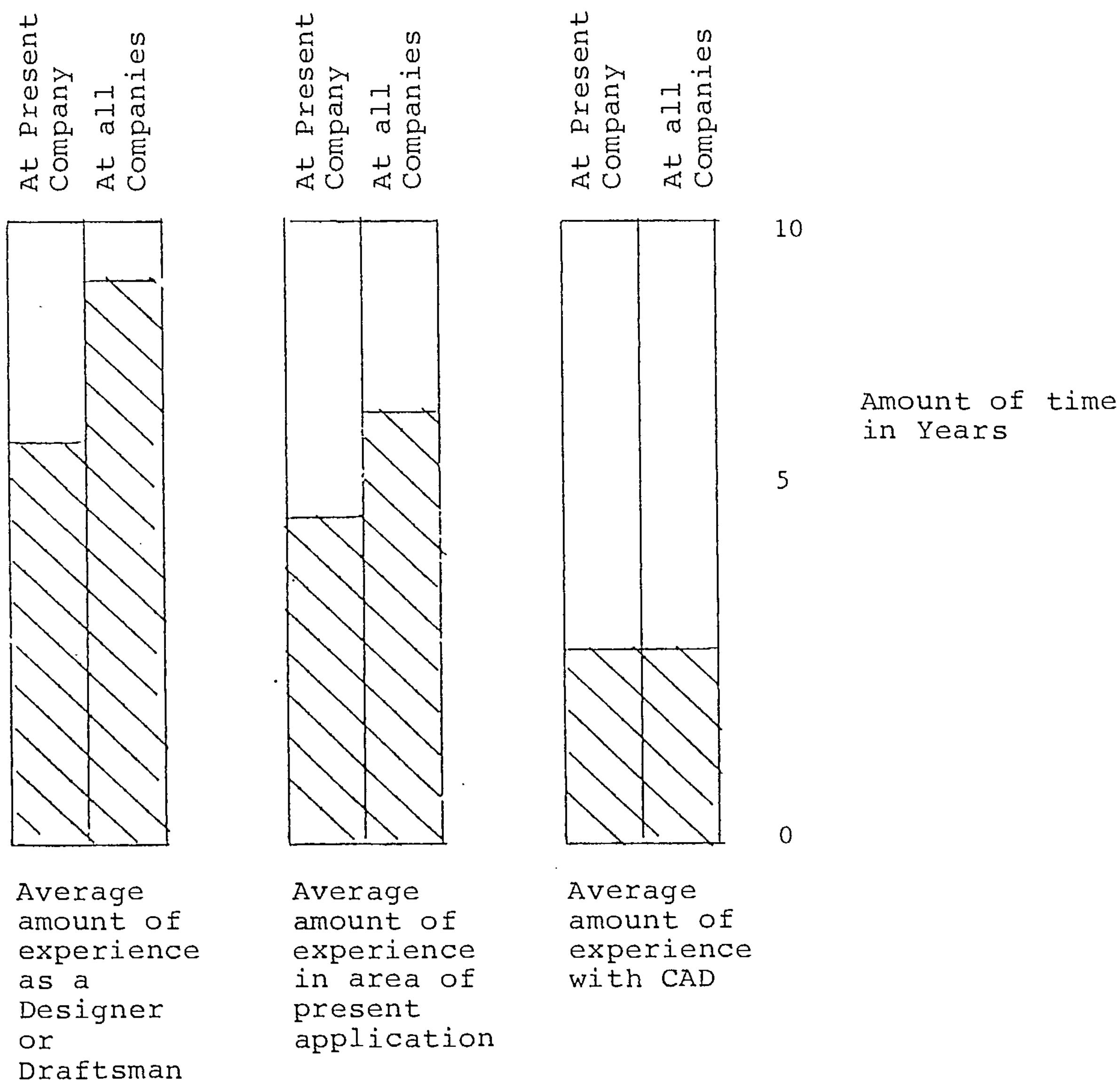
Progressive computer and electronics companies whose evolution and productivity are inextricably linked with the use of CAD also have a generally lower average age. In Mitel, as an example, the average age is 28, whereas General Electric and more established companies usually have an average age of 40-45. This would suggest that the generation that has grown up with television, radio and, recently, video games is less prone to the "culture shock" than those generations that were more removed, on a day to day basis, from the advent of electronic technologies.

Of 125 CAD Operators questionned, the typical incumbent had spent an average of 5.25 years in design or drafting at the company where he was presently employed. The average overall years of employment was 9.325.

With regard to experience in the field of application, the average CAD operator had worked 3.75 years at his present company and 7.0 years in his area of application overall.

The average length of experience on CAD systems in general was 2.53 years, and average 2.5 years at the present company.

<u>Overall Employment Record</u>



The above graphics illustrate several interesting points:

1. The average length of employment is less than 10 years, suggesting that the operators are in general relatively young.
2. A person who had been using a computer interactive graphics terminal for 2½ years by mid 1982, could be considered an "old hand" or very well experienced.
3. The average CAD operator has had less than 7 years experience in his area of application.

With regard to the manpower requirements of a CAD installation, the above information suggests that the incumbent need not have extensive education in computer technology. Knowledge of the subject area is important for the more complex applications where the system is viewed as a sophisticated tool. For less specialized applications, the incumbent need have little education or experience to be useful for basic data entry. Computers are not hard to learn.

TIME NEEDED TO LEARN TO USE A CAD SYSTEM

To determine the amount and type of training required, it is necessary to identify the amount of time needed to learn to use a CAD system.

In learning to use an interactive graphics system, the amount of time needed to approach the summit of one's capabilities depends once again upon the application.

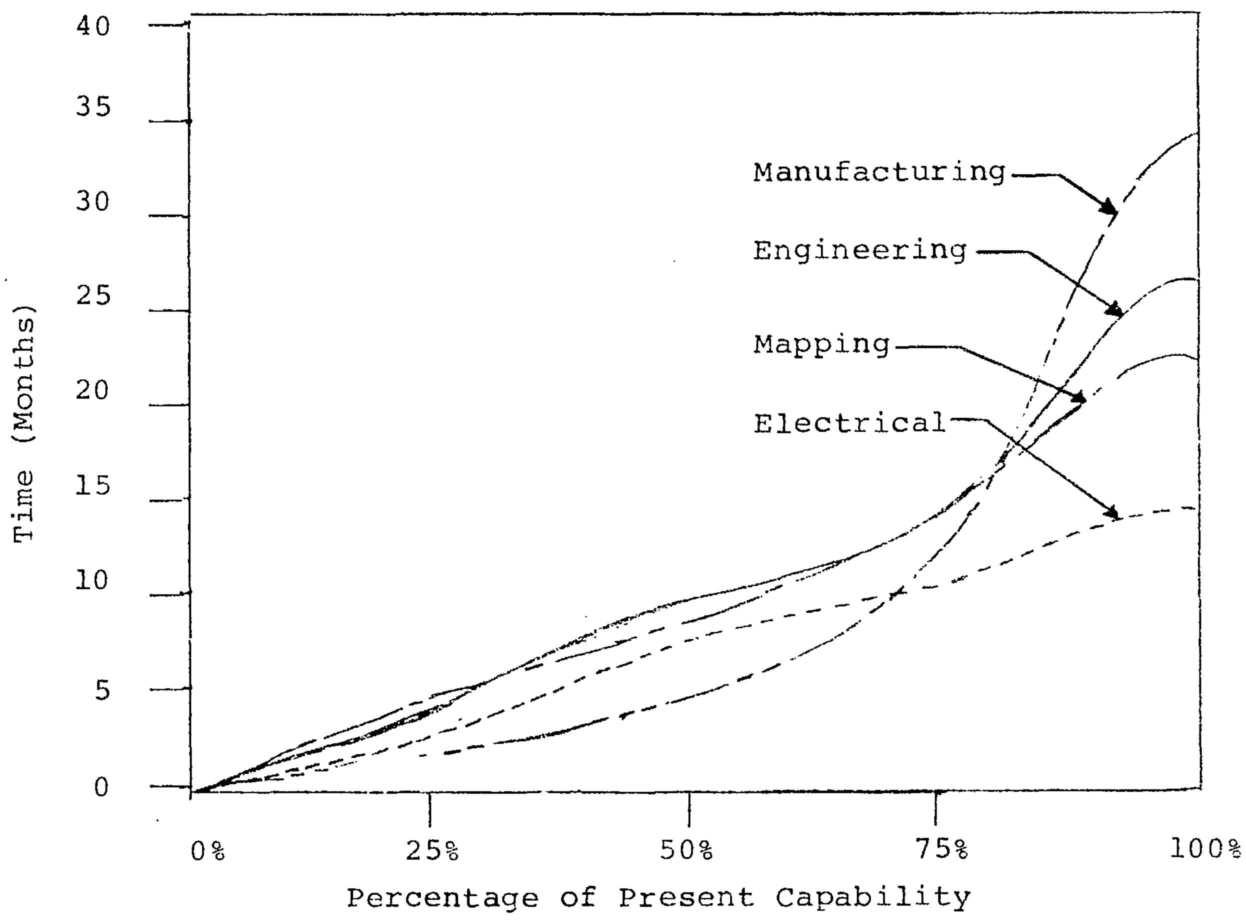
For simple data entry, a person with typing or word-processing experience should be 'up to speed' within a week. For more complex applications, for personnel with no computer-related background, 12-14 weeks are necessary to become familiar with the command strings and their applications. For sophisticated software applications, it could take a year or more for an operator to reach his/her maximum potential.

The following graph illustrates that operators performing manufacturing applications take the most time to reach their maximum capability, where electrical applications take just more than 1/3 of that time to be 100% productive. Mapping and Engineering applications are much similar in their time span for reaching operator efficiency.

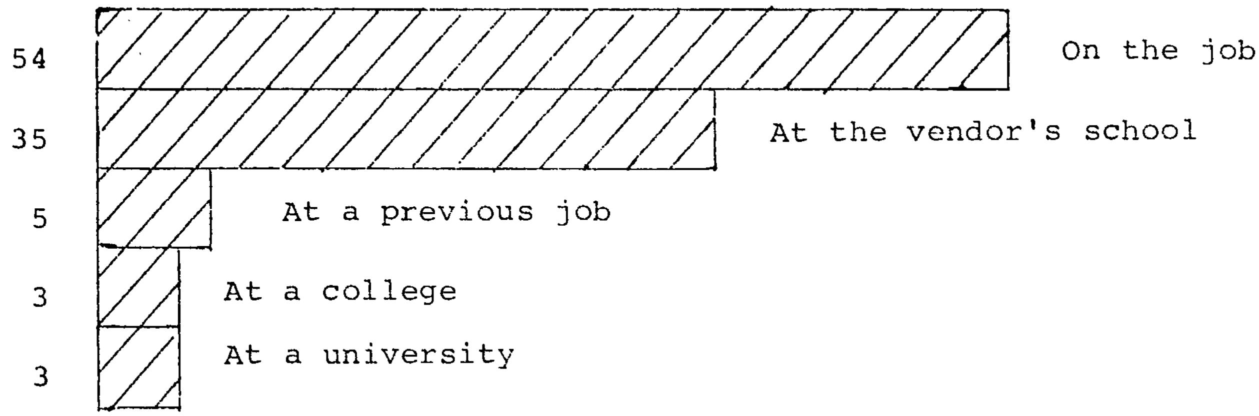
One of the major constraints in Quebec and for other French-speaking operations is a lack of documentation in French. Most of the command strings are directed towards English usage, the manuals are generally in English, and the files for aiding the operator in his correct usage of the commands are also in English. A limited comprehension of English will severely limit a person's ability to grasp basic system concepts.

For most operators, a person can be of use to a company within three to four weeks. Within one week, an operator should have enough system knowledge to perform basic operations, and do primary functions. The operator is usually supplied with increasingly difficult tasks, until he has reached his maximum capability. The reading of manuals and related texts has a great influence on the operator's scope and final performance. The amount of time necessary to reach full proficiency on an interactive graphics system is related to both the quantity of software necessary to perform essential operations, and the amount of knowledge that the operator has concerning his own area of application.

Time Needed to Reach Maximum Capability



Where Was the Operator Trained



Training Received according to Replies

54% of the companies questionned had operators trained at the work site. 35% sent their staff to a vendor location, and only 11% had hired staff who received training elsewhere.

Mechanical Failures

One of the problems encountered with a new installation is the unfamiliarity of the operators with computer equipment. Draftsmen, geologists and designers are often not experienced with basic computer functions and encounter a multiplicity of annoying mechanical failure within the first few months of system use. Once a primary level of familiarity is reached, an operator should have little more difficulty on a terminal than he/she would have with the family car.

TRAINING

Once a Computer Aided Design system has been installed, it is up to the personnel to make that system productive, and it is the responsibility of management to make the most of available personnel.

A thorough understanding of computer functions is not a necessary prerequisite of a competent computer operator, but there should be someone on staff, preferably a systems manager, who will oversee the development of programs, software, etc. and encourage the design/drafting personnel to take full advantage of the available computational abilities of the system.

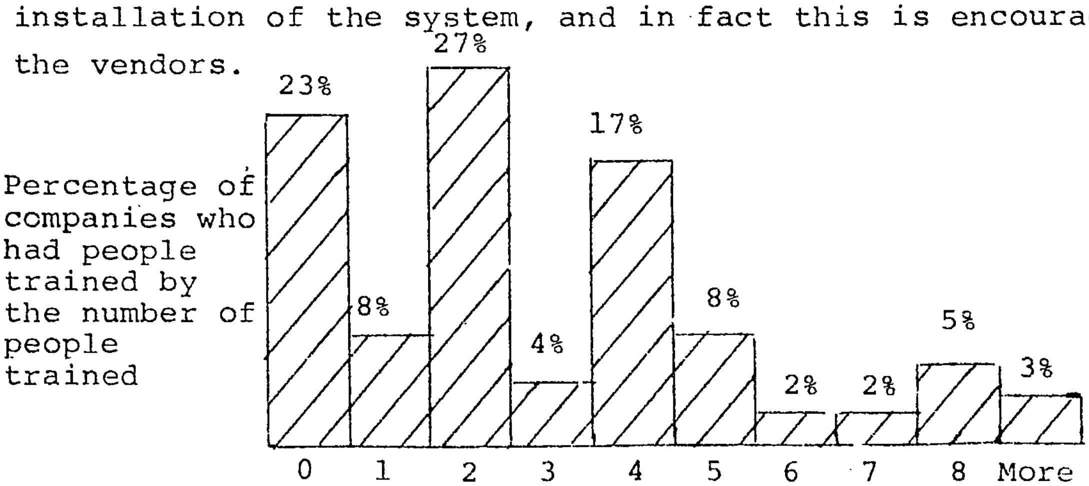
The participants will require guidance and information, especially those who have received no formal training.

Vendor Training

Up until 1981, there was no public training available for interactive graphics equipment. The turnkey vendors provided one or two week introductory courses for those who had purchased systems. These courses were often included in the purchase price. As it was virtually impossible to hire people with a CAD background, computer experience was not a necessary requirement for most drafting and mapping personnel.

Pretrained Staff

Many companies sent their personnel to be trained before the installation of the system, and in fact this is encouraged by the vendors.



The Percentage of Companies who sent their Personnel to be trained before the system was Installed

The Importance of Forethought

It is to the vendor's advantage to have the system perform for the client in the way that they have promised. Without staff who know how to use it, this would be impossible.

Only 11% of the participating companies had hired CAD personnel who were already trained on a graphics system either in school or at another location.

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All but two companies have sent one or more people to be trained at the vendor's school at the same time.

Most of the participating CAD sites agreed that training for staff at the vendor's school is critical in the rapid integration of the system, but becomes obsolete once the sites have their own trained personnel.

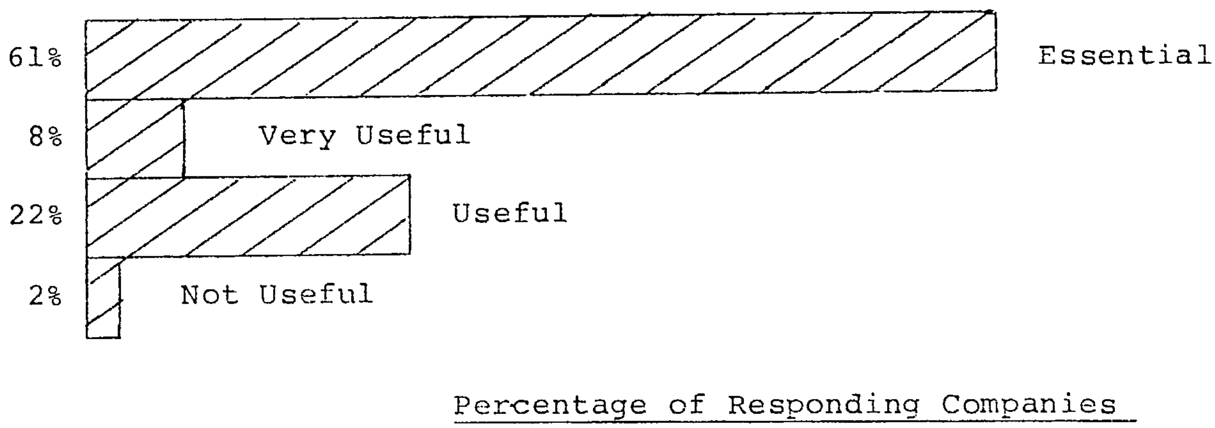
Due to the wide variety of CAD users, vendor training is aimed at a universal understanding of the system capabilities, and cannot address the users' applications in any detailed manner. The vendors cannot know as much about the users' problems as the user does himself. After the successful implementation of a system, the existing staff develop short cuts and routines that are unique to their type of application. Training by existing in-house staff is thus more useful to the company as it allows the trainee the benefit of instructors who have experience both on the system and with the problems that he or she will be required to address, instead of the necessarily generalized instruction offered by the vendor.

A Solid Technical Base

New staff can adapt to operating CAD/CAM systems once the system has been in use for some time because they have so many people to refer questions to. Companies who have no trained staff have a much more difficult time making the same quality of individual productive. In many areas a "user base" is a major consideration in the acquisition of a system. As the primary stages are difficult, it is an advantage to have local companies who use the same system and can help each other out with simple routine problems, even competitors belonging to user groups that are mutually beneficial. These groups supplement the growing technical bases in each respective company.

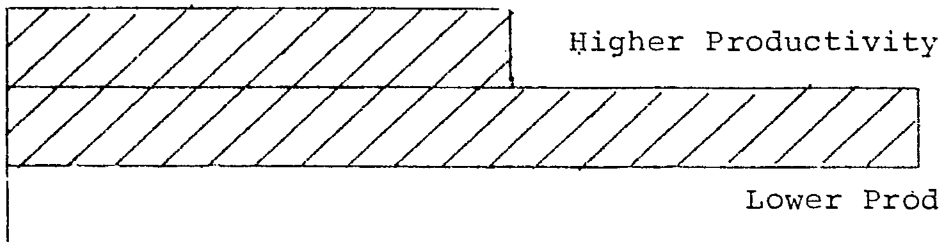
The Expense of Vendor Training

Of those who received vendor training, only 28% of the available training was found in Canada. 80% of the training received was supplied by the vendor, but travel expense costs still averaged at $1,200.00 per person a week. Those who participated, however, generally agreed that the vendor training was useful, or often essential.



Value of Vendor Training

44% of the participating CAD sites felt that the training cost was reasonable, 16% found training to be expensive and 24% found it to be extremely expensive. 16% were undecided.



Value of Employees Who
Have Vendor Training

Performance of those operators who received training as opposed to those who didn't.

78% of companies found that, after the elementary stages of learning there was no difference between the operators who received CAD training, and those who didn't. The advantage was in the time necessary to get up to speed if there was little experience among the existing staff.

Most companies agreed that the final productivity of an operator has little to do with his training, but will certainly accelerate the time necessary to reach his/her peak efficiency.

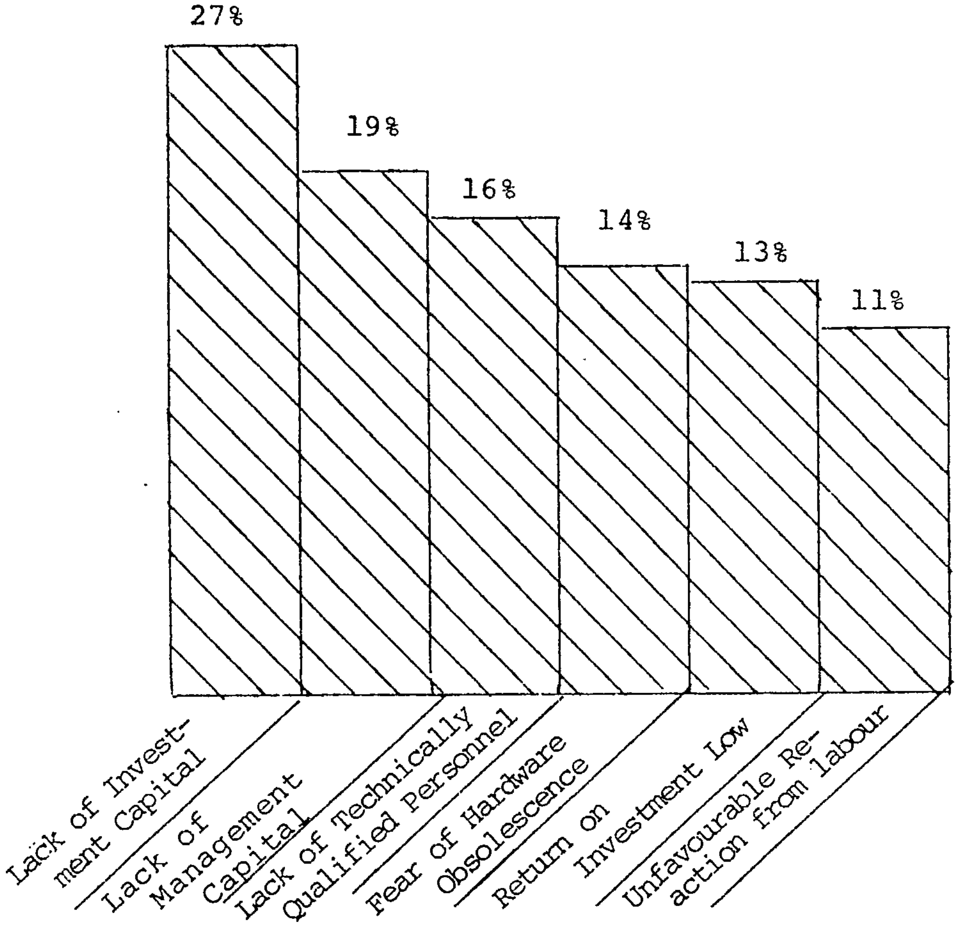
Most CAD operators learn to do simple computer routines such as back-ups, simple software development and programming as a matter of course during their work. These routines make operating a system more challenging and save frustration on the job site.

Unions are unfortunately, making job scope and jurisdiction in these areas a problem.

Those companies who took advantage of vendor training prior to the installation of the system found that their start-up time was generally quite minimal. Such companies as General Electric, Cobourg, Canadian Institute of Metalworking and Mitel, trained key staff prior to the installation of their systems, continued to train staff after they received their system, and are still in the process of building up experienced teams that can guide others as they come into the organization. The productivity of these companies is proportionate to the systematic influx of energy needed to build a solid technical base.

WHAT CONSTRAINTS WILL HINDER THE USE OF CAD TECHNOLOGY

The following graph illustrates the areas that have been identified by industry as the most serious constraints to the implementation of CAD in business:



Serious Constraints to the Increased Use of CAD

Lack of Capital

Lack of investment capital is seen as the most serious constraint facing an increased use of CAD in industry in the near future. Hopefully, this is a temporary situation and will not be the case in a few years. Several companies who use CAD in Alberta were not hesitant to blame recent Federal Government decisions for "putting the lid" on CAD development in the West. Many other companies across Canada stated that they would also have expanded their CAD installations considerably if not for the present economic position.

Management Understanding

Secondly, there seems to be a lack of management understanding of both CAD capabilities and the most productive use of CAD personnel within a facility. Because they are concerned and preoccupied with other activites, top management is often out of touch with the CAD installation and, through a lack of communication, is known to make decisions which negatively affect the CAD installations staff or system management. In other cases, top management has an idea of the value of interactive graphics, but on a middle management level there is much confusion. Too many decisions are being made that affect the working conditions of the operators without allowing the operators to expand their understanding and ultimately their productive abilities on the system.

The "older generation" are getting a reputation for rejecting CAD technology without a proper examination of its capabilities, but this is not necessarily the rule.

Lack of Technically Qualified Personnel

16% of the responding companies felt that a lack of technically qualified personnel would be a serious constraint. Depending on the application, it is often the technical personnel who push for a system in the first place, while management are the ones who need convincing.

A lack of trained personnel in some areas is no longer an issue. As an example of the change in this area, a recent (August 1982) advertisement for CAD personnel in Alberta received 143 applications, 26 of which were from experienced CAD personnel. (This influx of personnel is due to the extensive lay offs in Alberta, and will hopefully be a temporary situation as well). Many drafting and design personnel are realizing the imminent doom of their drafting boards, and are pursuing CAD independently, which will supply even more trained personnel for industry.

Hardware Obsolescence

Considerable weight was given to the fear of hardware obsolescence. With the cost of a 3 dimensional turnkey system averaging at $500,000.00, this is a very real consideration for smaller companies. A time-sharing or rental system would provide an answer to these fears, but these are not readily available and not highly regarded for security and maintenance reasons.

Return on Investment

A low return on investment was sited as another major constraint and for many companies is the deciding factor. For strictly drafting purposes, a qualified draftsman can sometimes beat the system timewise, and the system could not be justified. Figures for productivity gains, while available, are sometimes questionnable and often the application is unique and won't fit a conventional application's time limitations.

For many sites, however, where the system is a major ingredient in the company, it is difficult to quantify the amount of return on investment.

Once viable figures are available from users concerning a wide variety of applications, the return on investment should be a more concrete consideration.

The labour force was not seen to be a problem in most areas as far as drafting applications are concerned, many companies are finding that the personnel are anxious to become involved with the system and see it as a real challenge. Engineering and design staff are also generally enthusiastic.

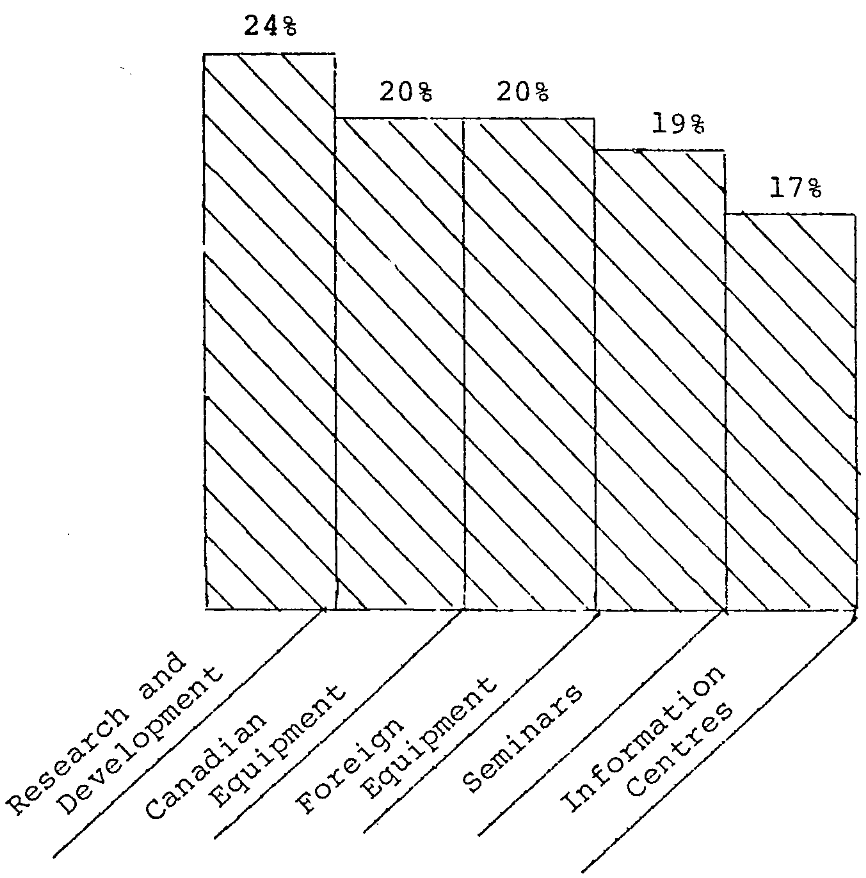
The attitude of the Users

The success of an interactive graphics set-up depends primarily on the attitude of the people who are going to use it. The labour force on both the organized and individual levels are responding to CAD in a very favourable way.

GOVERNMENT INCENTIVES

In many cases, government incentives can help to overcome some of the obvious constraints, and help both the large and the smaller industries to become involved with Computer Aided Design technologies.

What Government Incentives Industry would like to see



Research and Development was identified as the most favoured government incentive. Several companies stated that a very serious constraint was the inability of the vendor company to keep up with the user requirements in software. With the increased use of Computer Aided Design internationally advanced software developments are one of the major requirements if Canada is to remain competitive in the world market.

With relation to tax incentives for the acquisition of CAD equipment, most larger companies would purchase a system whether there was available funding or not. They would, of course, take advantage of available funding, but would not use funding as a prerequisite for purchase.

Smaller companies are more influenced by available tax incentives, and would probably buy a system sooner if funding were available. Lack of funding would not be an ultimate deterent, but would simply delay the process.

As Canadian Computer Aided Design equipment is not really competitive for most applications, there is relatively little conviction to buy a Canadian product. Due to obvious cost and maintenance advantages, many companies would buy a Canadian system if it did the job, but performance is still the major consideration.

For a general understanding of 'state-of-the-art' technologies, it is essential that management and design staff attend technology transfer sessions such as seminars and conferences. Due to present economic conditions, an added tax incentive would make attendance more available to those who require it.

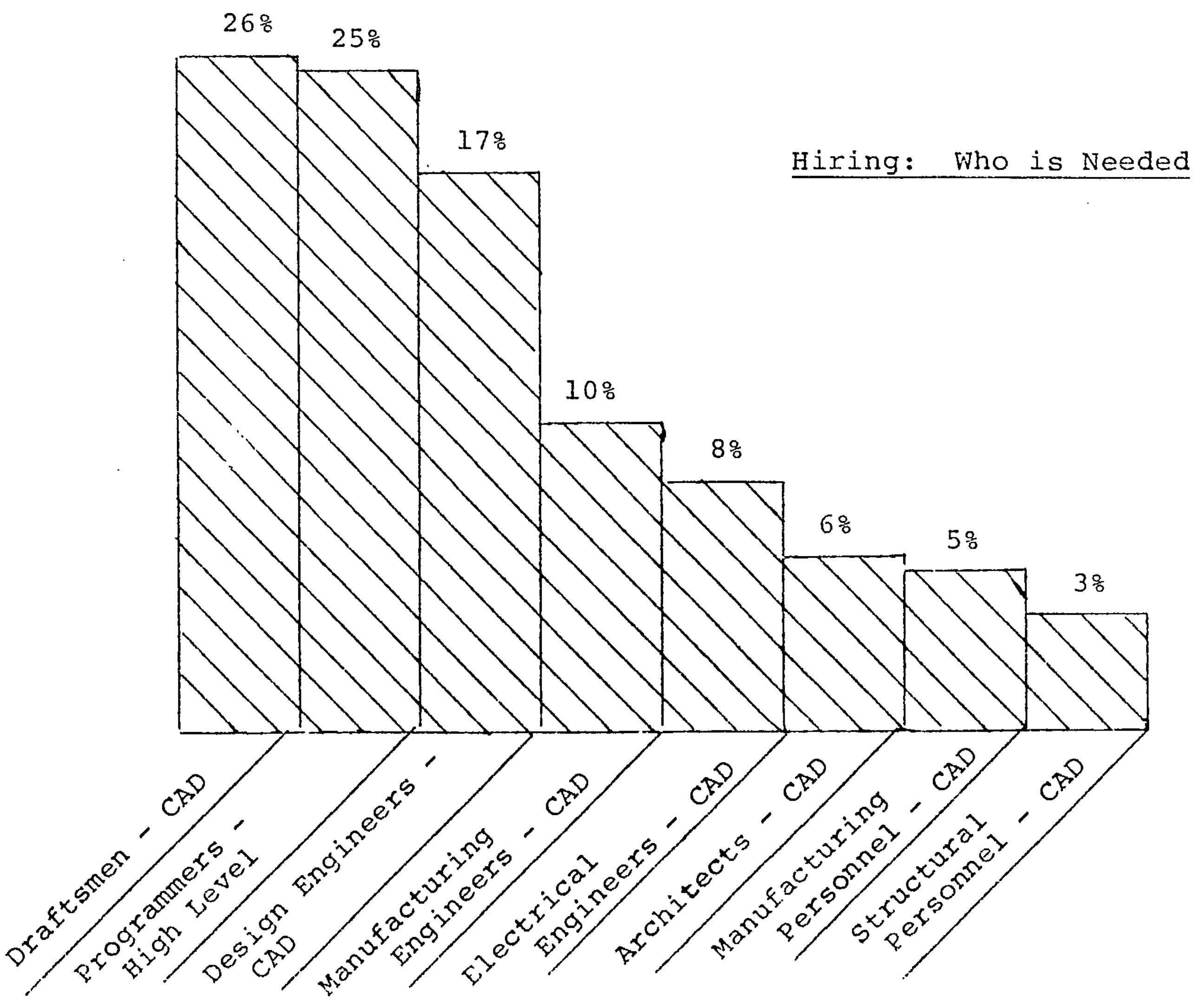
In addition, attendance at seminars and conferences would aid Canadian companies in avoiding "reinventing-the-wheel". The use of Group Technology in reducing costs for research and development of projects that do not need to be done privately for reasons of genuine uniqueness and genuine confidentiality, is a good way to avoid non-productive and repetitive spending. Only through attendance at seminars and conferences will companies be aware of advancements related to their own field.

The provision of an information centre with training facilities for CAD/CAM technologies is the least favoured of government incentives. There is a general feeling that the money to create such a centre would be better spent by industries who could acquire CAD systems and learn to make them productive independently. With colleges receiving CAD equipment and independent service bureaus already supplying many of the required services, there doesn't seem to be a need for an information center at this time.

PROVIDING TECHNICALLY QUALIFIED PERSONNEL

Once a system is installed, it is the responsibility of company management to make that installation productive, and it is the responsibility of Canadian Educational facilities to provide both the people and the resources to fill the personnel needs of industry.

Because computer technology is a relatively new field, many industries have had difficulty hiring trained and/or experienced personnel. It has been established that industry is not in need of "computer" personnel to operate the system, but could make use of personnel trained in their particular area of application, but with a familiarity to computer aided design/or drafting technologies.



Drafting personnel with CAD experience are the most difficult people to hire. A knowledge of drafting conventions is the most important prerequisite, with experience in applying these procedures on an interactive graphics terminal being of secondary importance.

Higher level programmers were sited as the second most difficult group to hire. During the 70's computer programming was not a popular course, and few people graduated in that area. In the 80's, however, approximately 20% of the total university student population are engaged in computer courses, and this shortage should be alleviated shortly.

Design Engineers, Manufacturing Engineers and Electrical Engineers with computer design experience were identified as all being difficult to hire.

As stated earlier, economic conditions have greatly influenced both the hiring policies of most companies and the expectations of employees. Colleges and Universities are offering a multiplicity of both part-time and full-time courses when both experienced personnel and students can learn how to use a computer graphics system while working,or at school. Many individuals are taking such courses to upgrade their abilities.

In a drafting, an engineering or an electrical curriculum, most people feel that CAD courses should be offered as an elective, i.e. not mandatory. Although a highly sophisticated instrument, a CAD system is nonetheless only a tool, and should be treated as such in education.

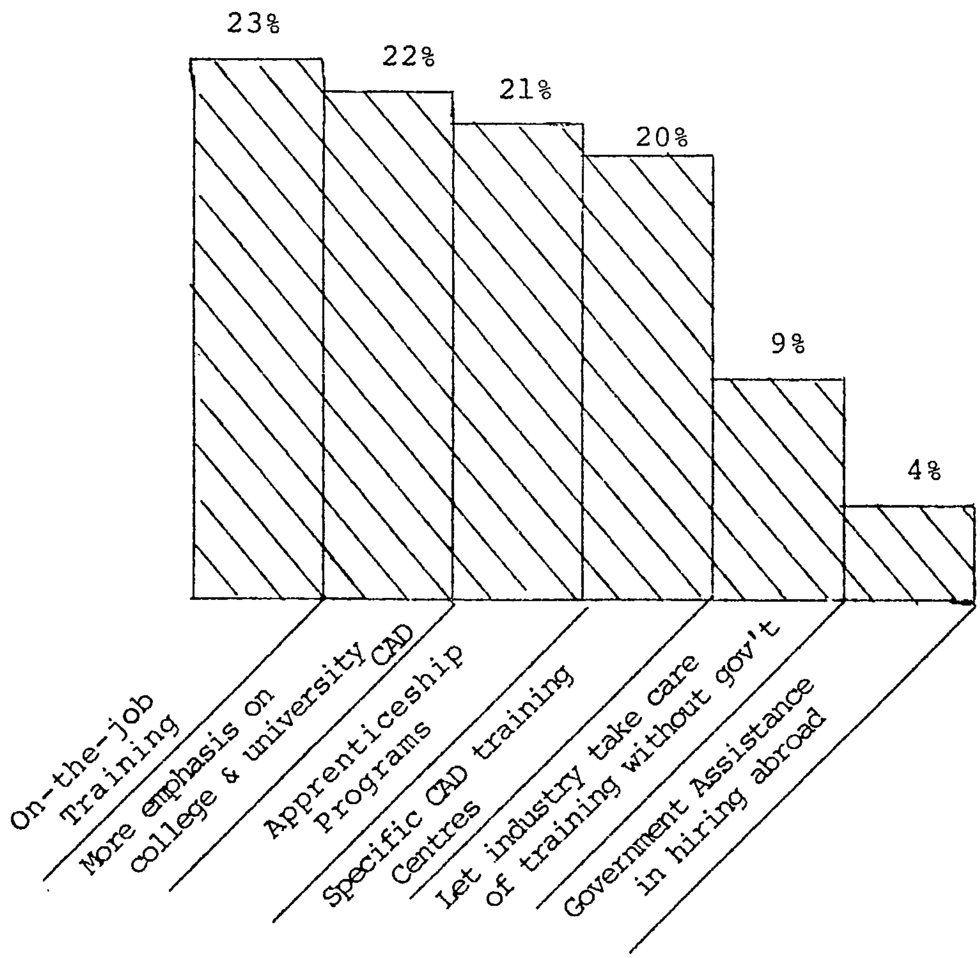
A large part of learning to use a computer graphics terminal is the inevitable 'culture shock' for those who have been trained or have experience in another discipline. Pure and simple computer courses would overcome this type of problem in a short time.

With relation to manufacturing personnel there is still a major problem as far as NC training is concerned. The best programmers are still by and large of British extract as the apprenticeship training programs there are still generally superior to ours.

For general data entry for mapping or electrical purposes, many companies are having little trouble hiring personnel. In Calgary, it takes approximately three hours to fill a vacant position.

It has been established that companies that are new to CAD should train key staff members prior to the installation of a system and continue to train people immediately after its implementation. Certain government programs are available to help companies to become productive through training and retraining of staff. For those who are hiring new staff, an experienced person can make a significant difference in the speedy integration and smooth continuation of a CAD installation. There are several ways to ensure needed personnel, and the following graph illustrates industry preferences for government aid in this area.

Needed Training



Most companies feel that on-the-job training programs and CAD/CAM courses at the college and university level are the best way to increase skilled labour in industry.

Ontario is promoting on-the-job training through a series of job-sponsoring programs. In this way, skilled workers are produced, and industry doesn't lose any revenue due to unproductive labour during the training period.

Several colleges and universities are also offering co-op programs where the student attends classes for several months, then applies this knowledge at a work site, while earning money to complete his/her education. This system aids the employer by supplying inexpensive labour and allows the management to perform a thorough screening of perspective personnel.

As mentioned above, several colleges and universities are in the process of acquiring CAD systems for training, and this should also provide more skilled labour. As the systems are provided with government money, these installations should be made available to industry and students alike.

Apprenticeship programs, especially with regard to Numerical Control equipment, were identified as another worthy consideration. There is no substitute for two or three years of actual hands-on experience for a programmer or operator who wants to familiarize himself with shop procedures. These programs again provide industry with relatively inexpensive labour and production while promoting a higher quality employee. Several colleges are sponsoring apprenticeship programs but while quite good, facilities are limited.

20% of the responses favoured centres for specific CAD/CAM training. As the construction of CAD/CAM information centres was the least favoured response to the question concerning government sponsorship, this would seem to indicate a desire for a centralized source of information concerning existing college, university and apprenticeship programs. As courses are being offered by several institutions on a variety of equipment, a source or library of CAD/CAM related courses would be a tremendous advantage, and a much more efficient use of existing resources than a complex designed and constructed specifically for this purpose.

9% of industry responses favoured letting industry take care of the training of skilled workers without government assistance, and 4% favoured government assistance in hiring abroad. Many hostile responses were also received with regard to the above proposal.

ADDITIONAL CONSIDERATIONS

Several other factors must be considered with regard to the training and retraining of CAD staff. Many companies are taking advantage of available government funding for retraining of staff, and these programs must be tailored to fit the needs of the participating companies.

The most important factor when considering the acquisition of a large computer system for an educational facility is the proximity of businesses who have that particular system, and can thus take advantage of extension courses for the working people. There is no point in training a person on a Computer Vision system when they will be required to operate a Calma.

There should be an overall plan for integrating the colleges in each Province to CAD; some rationale for postsecondary education. In the area of high-technology, industry retraining of staff is just as important as the training of people who have just graduated from high school. Planning should take into consideration local needs, the priorities of participating students, and the employment opportunities of each specific area. As millions of dollars have already been spent on the acquisition of CAD equipment, these priorities should be determined now.

Secondly, retraining must be sold to the participant who often has family ties and responsibilities that influence his decision to engage in after work classes. In the present economic climate, many employees are willing to undergo retraining at any time to keep their positions, but a good working relationship between the colleges and industry will make the most of available equipment and manpower.

An example of a productive interaction of colleges and industry is Sir Sandford Fleming in Peterborough and its program to retrain staff from Canadian General Electric, Peterborough. A three-level diploma course has been produced for those people who are interested in retraining. Diplomas are available on three levels both as an incentive for the staff, and as a method of discrimination for the employer.

There is also a difficulty in any high technology training with providing instructors who are up-to-date on a particular system or application. Who is training who? The colleges and universities must be keeping up to date on advancements in CAD technology to retain any credibility. A sabbatical system of perhaps three months actually operating a system and eight months of instruction would perhaps complement education's long-term goals.

To date, government funding has not significantly impacted on training or retraining programs within the larger companies, as they are in the habit of training whatever staff are required. Evidence of this attitude are the very successful apprenticeship programs that General Electric have been running for years.

Larger companies will, however, take advantage of training when it is available, and will hopefully make use of CAD courses as they become available.

In contrast, training for smaller companies with more limited budgets could be of fundamental benefit in the implementation of an interactive graphics system. Retraining programs can make the difference between an initial 2 people receiving training or six people receiving training thereby creating a much more solid technical base.

A CASE STUDY AT THE CANADIAN INSTITUTE OF METALWORKING

In February 1981, CIM took possession of a Calma Interactive Graphics System complete with two work stations, one alphanumeric terminal, one Calcomp 960 plotter, and one tectronix copier. Over a year later, another work station was added.

Since the installation of the system, eleven staff members have been trained to use it and have spent a substantial part of their time working on the terminals. Of these eleven people, only four were with the company before the installation of the system, and only eight are now remaining in the company. Of the three people who left, one returned to university to obtain another degree in the same field, one went to a competitive company and one left to enter an unrelated field.

Of the people who were hired after the installation of the system, one person had experience on CAD systems but no experience in the particular area of application, three had experience in the area of application but none on CAD, and one had experience with graphics but not with computers. All of these people were 28 years old or younger, and all were either college or university graduates. Only one of these people received training from the vendor, the others were trained on site.

The amount of time necessary to learn to use the system depended on both the experience and education of the individual, and the amount of system software that the individual must be aware of to complete his given task.

Illustration (a) is a graph indicating the participant's background, experience with metalworking technology, experience with CAD, experience at CIM, function on the system and pay level. Illustration (b) indicates the amount of time that the individual needed to become proficient on the system.

<u>CAD Students at CIM</u>

Over a period of 18 months, nearly 200 individuals received basic training on an interactive graphics system at CIM. The course was one week in duration, or ten evening sessions. It provided the student with the basic concepts involved in the design/drafting procedures plus hands on experience with a graphics terminal.

Students were drawn from many facets of society, 59% were from a manufacturing environment, 20% were teachers at either a college or university in either computer science, drafting, engineering or manufacturing, 17% were students ranging from high school through university and 4% were from fields totally unrelated to manufacturing such as advertising.

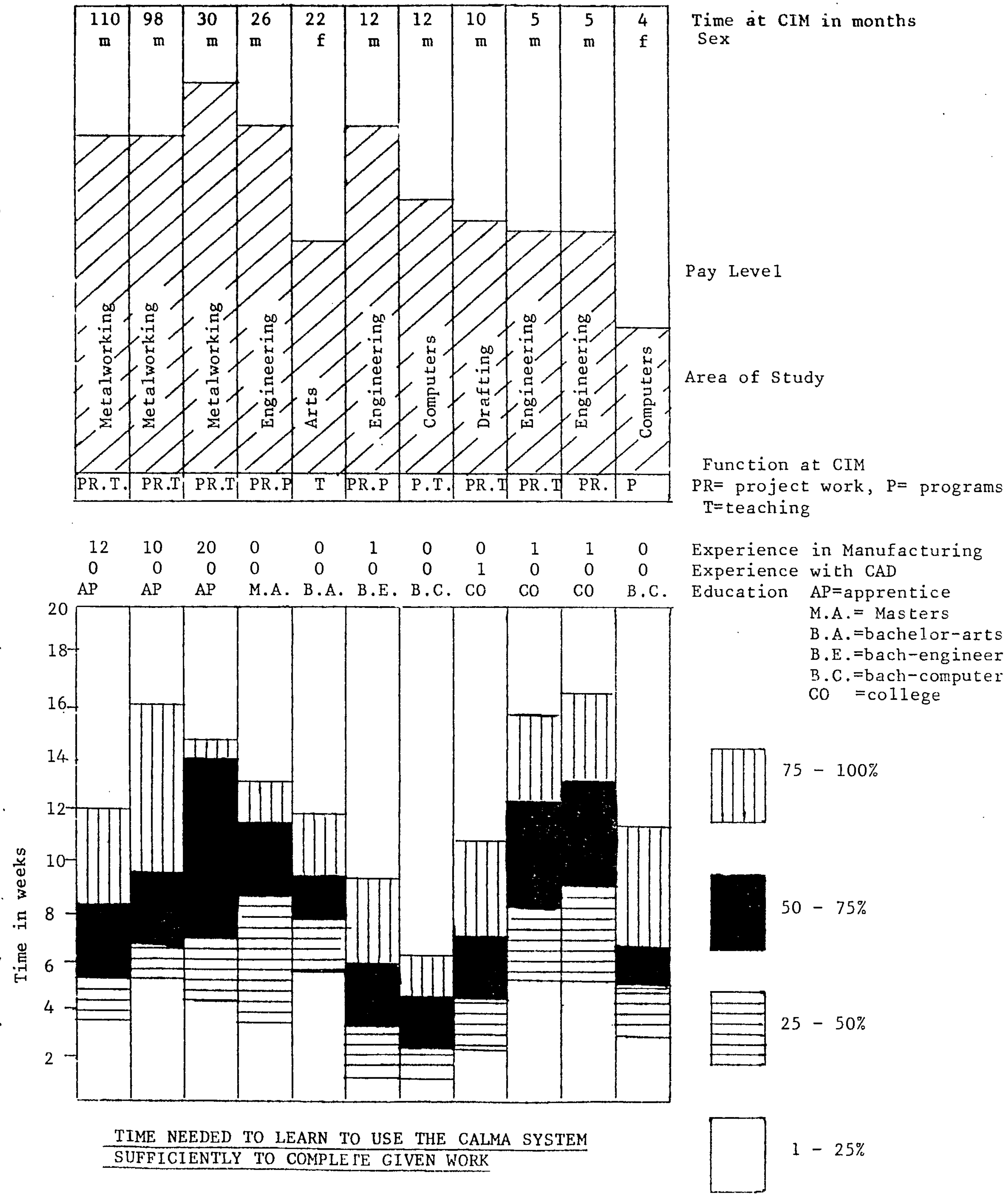
From experience with these students several conclusions can be drawn.

1. Typing is definitely an asset, as much of the learning time is spent trying to locate the keys on the keyboard. A familiarity with a word-processing, desk-top or personal computer is also an asset in that basic ocmputer data entry is also a large part of the learning process.
2. In dealing with the three dimensional objects, the student must be able to conceptualize in 3D, then be able to make this concept a concrete image on the display screen by means of identifyable coordinates. There are people - perhaps as many as 10% - who simply cannot do this. Examples or wire frame models are effectual and necessary teaching aids in this regard.
3. For the initial week, two to four students per terminal are suggested for an exchange of information. Past this point, a limit of one or perhaps two people per terminal is suggested. The learning curve is directly dependent upon the amount of time spent actually using the terminal.
4. Younger students seem to catch on much more quickly than the older students, possibly due to their increased use and awareness of electronic equipment - video games, television, etc.

5. It is suggested that any post-secondary institute purchasing a CAD system for teaching purposes arrange with the vendor a good supply of styluses; electronic tablets, digitizers or other costly terminal equipment as these tend to malfunction regularly during student use.
6. Of the students who participated in CIM's training programs, only 5% were returning to a working environment that contained an interactive graphics system similar to the one that they had been trained on at CIM. This suggests that 95% of the students were taking the course to expand their knowledge of the subject area. Of these people approximately 31% were not currently employed in any area related to an industry that would be using CAD.
7. Several of our students were not fluent in English, and had, as expected, much greater difficulty in grasping the basic concepts. As the student must make use of extensive documentation, it is imperative that they have a good working knowledge of the English language.
8. Due to the fact that the student must be able to digest a substantial amount of terminology in a very short period of time, it is suggested that the student be sent information (an introductory pamphlet or booklet) prior to the commencement of the course.

In general, CIM has found that most people find the course interesting and informative and have little difficulty adjusting to the computer after their first introduction to it. Many people who are presently employed in a drafting or map making capacity are apprehensive of the long term implications of the system, but are impressed with the system's capabilities and their own increased productivity.

C.I.M. STAFF



TIME NEEDED TO LEARN TO USE THE CALMA SYSTEM
SUFFICIENTLY TO COMPLETE GIVEN WORK

TECHNOLOGICAL INNOVATION STUDIES PROGRAM

PROGRAMME DES ÉTUDES SUR LES INNOVATIONS TECHNIQUES

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