Uhandisi Journal Vol. 21 No. 3, December 1997 pp. 24-35

Fundamental Issues in CAD/CAM System Selection, Training and Management

E. Z. Opiyo and B. A. T. Kundi
Department of Mechanical Engineering, University of Dar es Salaam,
P. O. Box 35131, Dar es salaam, Tanzania.

ABSTRACT

An increase in the use of computers in engineering design and production has resulted in a rise in numbers of both general purpose and application-oriented Computer Aided Design and Manufacturing (CAD/CAM) software and hardware products. As CAD/CAM system selection, training and management is often costly, a structured approach to system selection and a planned and comprehensive training and management is apparent. This paper presents a methodology for CAD/CAM system selection and addresses key issues in CAD/CAM training and management in the form of the actions to be taken and factors to be considered. Such factors and actions, when appropriately considered or taken, should help users in making effective selection and management of their CAD/CAM system and guide users towards better and adequate training that would improve the benefits of CAD/CAM.

INTRODUCTION

The definition and scope of Computer Aided Design/Computer Aided Manufacturing (CAD/CAM), Computer Integrated Manufacturing (CIM), Computer Aided Engineering (CAE) and related disciplines associated with the use of a computer as a working tool or component is very broad and is not agreed even among the practitioners. Consequently, it can be confusing. Even when addressed to production machines and systems, definition and scope has considerable breadth. The widest definition covers any use of any type of computer in a manufacturing environment [1], but it is very important to divorce Computer Aided Design (CAD) from an exclusively traditional view of manufacturing, because it is increasingly used in other professions such as architecture, fashion design and entertainment. Computer graphics, however, are invariably used to represent what is being designed.

Recently, discussions about modern manufacturing have been dominated by the paradigm of CAD/CAM and CIM [2,3] and there is evidence of an increase in use of CAD/CAM systems to improve efficiency and reduce costs in production systems. As a result of the increased popularity of CAD/CAM systems, the number of design and manufacturing software products available on the market is also increasing, and the list of the packages to choose from is comprehensive. The CAD/CAM market has always been in a state of flux since it began and new hardware configurations and software concepts are continuously developed [4,5]. Many organizations have embarked on implementation of CAD/CAM without paying attention to such aspects as proper selection of software, adequate training and satisfactory management. Despite the fact that the existence of alternative software products is beneficial to users, it is not usually easy to decide which software product to choose. Many organizations tend to choose CAD/CAM systems without establishing formal criteria or thorough examination of the available software packages on the market. Instead, they often base their decisions on highly visible attributes such as documentation or look and feel, rather than on quality and support of a specific method. Whilst for the selection of a suitable CAD/CAM system, adequate CAD/CAM training and satisfactory management can result in significantly improved productivity and reduced manufacturing costs, the choice of an inadequate system, insufficient CAD/CAM training and poor CAD/CAM management can result in the loss of the actual purchase costs and in the costly disruption of design and manufacturing processes.

This paper presents a structured approach for CAD/CAM implementation. It provides basic elements to be considered in the selection of a CAD/CAM system, CAD/CAM training and management of CAD/CAM systems. A proposed methodology for CAD/CAM system selection is also described. This methodology comprises the main stages to be followed, from determination of a need to purchase a CAD/CAM system, selection criteria, specifications for purchasing and management aspects.

METHODOLOGY FOR SELECTING CAD/CAM SYSTEM

Practical experience obtained in working with CAD/CAM systems, experience in software development, literature survey and expert judgement formed the basis for establishing a methodology for CAD/CAM hardware

and software selection proposed in this paper. Fig. 1 shows a global overview of the proposed methodology while Fig. 2 shows the stages to be followed in the selection of a CAD/CAM system. There are many factors and issues to consider when selecting a CAD/CAM system. Of paramount importance is the relevance of each consideration to the user's particular needs and proposed level of investment. A user has to do needs analysis (i.e. what he/she thinks are his/her needs) and draw up his/her appropriate functional specifications (i.e. requirements for software and hardware).

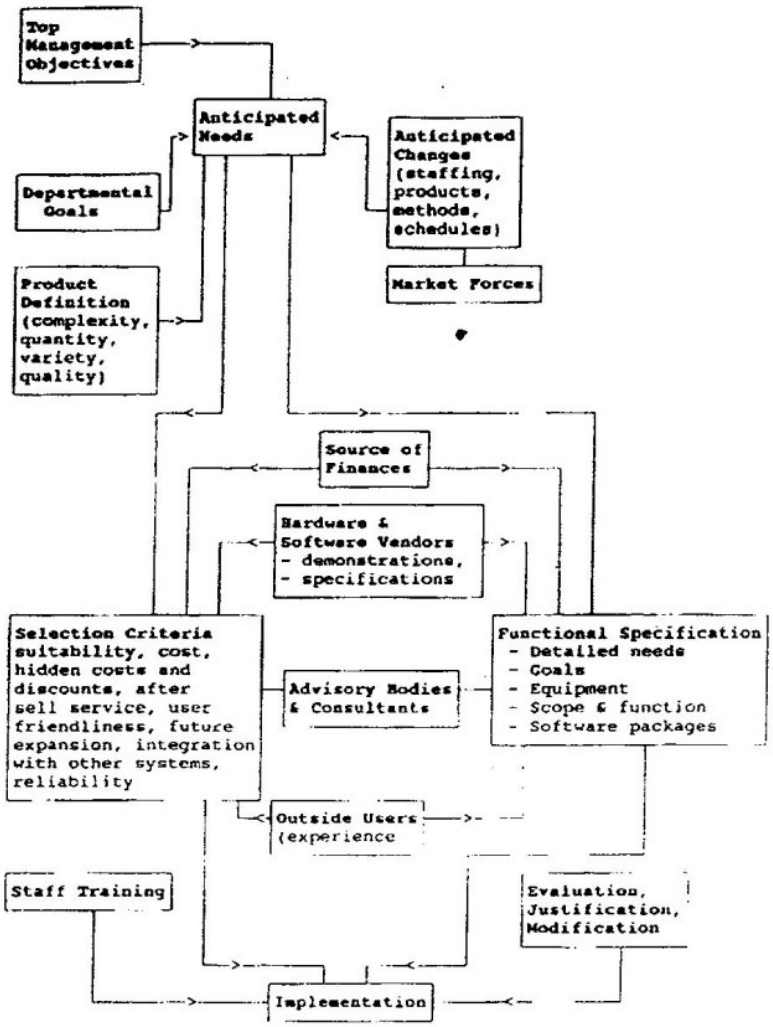

Fig. 1 Methodology for selecting CAD/CAM system

The user has to consider on-going changes in technology, the systems available (i.e. now and around the corner), financial sources and constraints,

advice from consultants and the experience of other users. Once the user is clear of what he/she wants from a CAD/CAM system, he/she can look more closely at the market, devising his/her own specific selection criteria. These criteria relate to the same information sources used to devise the functional specifications.

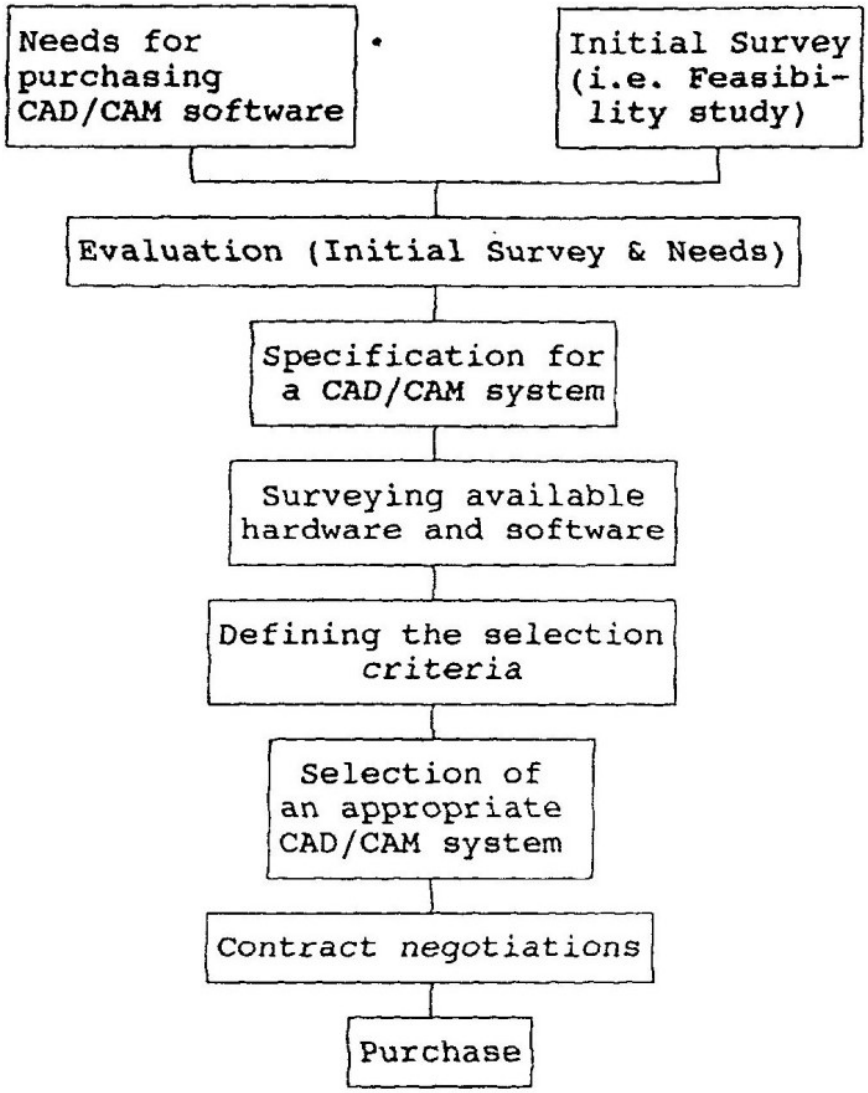

Fig. 2 Stages of CAD/CAM system selection

The needs analysis includes consideration of the major objectives of introducing CAD/CAM, potential problems, manner of information flow between all departments, possible future changes, and advice from consultants to evaluate the potential benefits in specific situation. On the

functional specification details, the user must ask questions like: What is the throughput of drawings? How active is the life of each drawing? To what extent do drawings incorporate standard parts, symbols, similar designs or symmetrical items? Are such features as scaling, nesting, automatic parts listing or using parametric symbols important? What proportion of the time does the draftsman actually spend drawing, as opposed to amending drawings, listing parts, etc.? Does the user want the new system to draw on an existing database? If so, will it be compatible? Are programming facilities for routine design, analysis and manufacturing required? Is there a need for centralized, distributed or stand alone systems? How will the equipment meet the identified needs? Where will the equipment be housed?

The selection criteria help to ascertain that the system is clearly costed (e.g. are there extra charges for software, plotters, etc.?), will be cost effective in both short and long terms (e.g., costing may include such non recurrent cost as the cost of feasibility study, such recurrent costs as shift work premiums, computer 'down time', and heating and lighting for the extended day, fulfil detailed needs (e.g. one terminal can usually accommodate two operators), is ergonomically viable to accommodate the particular ways in which the draftsman like to work and does not tire the eyes (e.g. Is the screen size suitable? - normally 15" screens are adequate, 19" are popular, micro's tend to use 13" screens, but even 26" screens are also available), Is it easy to learn and use (i.e., Is it user friendly?) and has clear documentation (i.e. Is the operating manual easy to follow?).

Other questions the user should ask himself/herself are: Will the system improve productivity? Can the system be modified by the supplier as and when needed (e.g., can the user change the input device or any different device for the latest model)?, Is the system expandable to suit the changing needs (e.g., can memory or terminals, etc. be added)?, Is the system unique (i.e. are there other systems around from which users can glean other users experience)?, Does the system has peripheral equipment which exactly matches users needs (e.g., if the price includes a plotter, Is the size suitable? Can the user get both 2D and 3D representation as hard copy?. Does the user want to 'spool' i.e. to operate peripherals simultaneously, such as plotting, printing parts lists and creating drawings?), Can the system be housed in a suitable environment? (important considerations for centralized systems include, drawing office lighting and sound proofing, air

conditioning, room temperature and humidity, safety legislation, site access and transportation, power supplies which are 'dedicated and clean' from interference, Does the system has a symbols library which can be easily edited and extended?, Does the system take up back-up copies suited to throughput (e.g., Is the tape or floppy disc sufficient or does it require another hard disc pack?, how often will the user secure copies? How will the user store backup copies?), Can the system be integrated with other manufacturing processes such as part programming?, Can the system offset the costs of introducing it by bringing into the organization work which was previously sub-contracted? Does the system carry supplier-based training? If so, how many personnel are offered free training? What fees are payable for additional personnel? What training fees are payable on later enhancements? Can personnel gain hands on experience before system is finally selected? Where is the training course held? Does the system incorporate colour monitor only where necessary?

The evaluation scheme is planned before the project is implemented. The scheme monitors the implementation of the new system and it also assesses the benefits and drawbacks. Feedback information ensure smooth operation. The scheme also provides data to justify capital outlay and growth.

The human aspects must also be given consideration. Staff may become unduly worried about the possible effects on their established working arrangements. It is therefore expedient to keep staff constantly informed on full implications of any changes, e.g., staggered start and finish, shift working, re-deployment, acceptance of sub-contracting work from outside and union involvement.

It is also useful to, for instance, locate the CAD equipment in the drawing office to promote co-operation and cohesion with on-going traditional methods, install furniture suited to changed working conditions, etc.

Training

CAD/CAM users usually look for improved productivity and efficiency far beyond that achieved with the conventional manual methods. However, without adequate training the benefits envisaged from the implementation of CAD/CAM system may never be fully realized and only very localized benefits will accrue. Regrettably, in most proposals for a project involving

capital expenditure on computer based equipment, the first item to be reduced in value or totally removed is often the training budget [6]. This is perhaps true with CAD/CAM projects because managements usually erroneously feels that a lot of risk is already being taken by spending a significant amount of money on CAD/CAM hardware and software and that there is little point in increasing the risk by spending even more money on something as intangible as training. It is therefore important to educate managements to understand why training is so necessary and do anything possible to include training item in CAD/CAM projects. Better training would improve the benefits of CAD/CAM [7]. People who need training in CAD/CAM may come under one of the following groups: companies installing CAD/CAM systems for the first time; existing users moving to a new system; existing users updating to a new version of the software; existing users recruiting new staff; contract staff who wish to improve knowledge of a particular system; or existing users who want their staff be more familiar and effective with existing CAD/CAM software package.

The types of training required for a successful implementation of CAD/CAM systems include basic user training, awareness training, system management training, advanced application user training and managers/supervisors training. Awareness and manager/supervisor training can be obtained from a variety of sources, including exhibitions, journals, courses, seminars and consultants while training can be given as a series of courses matching the steadily progressive ability of the user. Direct users of CAD/CAM systems such as draftsmen, designers and production engineers must obtain basic user training and/or advanced application user training, while managers and supervisors of direct users (inside and outside engineering departments) and the top-management will also need to be trained. Without their understanding, commitment and support, it is unlikely that the implementation of CAD/CAM will be successful. Furthermore, everybody concerned by CAD/CAM (inside and outside engineering departments) and all indirect users in such areas as purchasing and marketing must receive awareness training. Sources of CAD/CAM training include internal trainers, CAD/CAM system vendors, CAD/CAM training companies, CAD/CAM training package vendors, CAD/CAM consultants and educational institutions.

Broadly speaking, advanced training courses can be classified as: manufacturing management/systems (Computer Integrated Manufacturing

- (CIM)/Manufacturing Systems Engineering - (MSE); applied computing in manufacturing (CAD/CAM) and computer science (Computer Aided Engineering - CAE/Software Engineering - SE). When choosing an advanced training course, it is important to start by identifying the main theme, but it is essential to investigate the course contents and structure more carefully. Particular skill and knowledge requirement vary among employers, but fortunately the basics are highly portable both within and between companies. The basics include having a good knowledge of software engineering and a facility in at least one modern programming language, data structures and database management, computer graphics, artificial intelligence, computer hardware and networking, operating system, and modern manufacturing environment (which includes usage of robotics, flexible manufacturing systems; numerically controlled machines, and Programmable Logic Controllers - PLCs). In order to get the best out of software packages, it is necessary to have a sound working knowledge of software engineering with at least one higher level programming language e.g., C++, etc. This enables the user to explore full capabilities of packages and to customize them for efficient operation in a particular application or environment. The knowledge of data structures and database management is very important because management of vast amount of CAD/CAM information from a variety of sources needs to be handled by database software, and knowledge of how these tools are used and structured is vital. Computer graphics, with enhancements such as 'animation' and 'surfacing' is central to modern CAD and has its own skill requirements while artificial intelligence is now having an impact on design and manufacturing. CAD/CAM applications software runs under the overall supervision of a large management or housekeeping program known as an operating system. Some CAD/CAM applications software may use some functionality provided by the operating system and an understanding of the characteristics and usage of at least one system is therefore a vital element to a CAD/CAM practitioner. Although the skills of a computer scientist are not essential in CAD/CAM, a better understanding of the major lines of computer hardware development greatly increases opportunities. Also the methods of exploiting distributed computing (networking) resources and the operation of the networks that connect them should be understood. Finally, because there is still a real danger of the inappropriate choice of CAD/CAM software and hardware systems, which can actually compromise rather than improve a company's performance, study of methods of evaluating the operation of a company, along side performance

evaluation of competing CAD/CAM systems is also vital skill for a CAD/CAM practitioner.

Management

CAD/CAM management is a very important issue for every state-of-the-art CAD/CAM environment. By definition, the concept of CAD/CAM management addresses a set of functions which build, maintain, display, manage and enforce relationships among data and CAD/CAM tools [6]. Different people at different levels of the company implementing CAD/CAM are responsible for managing various activities concerning CAD/CAM. However, in implementation of CAD/CAM, it will be necessary soon after starting the implementation process to select CAD/CAM director, CAD/CAM manager and CAD/CAM support team. These are responsible for system selection, installation and providing an efficient day-to-day service for both short and long term implementation strategies. It may also be helpful to set up a CAD/CAM steering committee which will play a role of seeing that CAD/CAM meet user requirements. Generally, the whole administration should keep in close contact with the users and listen to their experience with the system. The feedback is very important in solving problems associated with the system usage. For the CAD/CAM manager and all members of the CAD/CAM support team to provide service to users, they should have detailed knowledge of the system and know how to operate it and how to carry out application tasks with it. The CAD/CAM support team members will need to be trained to operate the system, to maintain it, to optimize its performance, and to give assistance to users. However, it should be noted that much of the required system management knowledge will not come from the formal course, but from individual learning, often acquired on-line while solving problems with the system.

There is no single organizational structure that can always be considered as the best for all companies implementing CAD/CAM. This is because there are always differences between companies in different industrial sectors which result from the relative importance of the product development function. Even in same industrial sector, the particular organizational form chosen may vary between companies involved in jobbing, batch or mass production, but as a rule of thumb, the best criteria for judging an organizational form is whether the results as stipulated in the objectives of the CAD/CAM project are being met. However, certain

general remarks can be made about suitable structure of organization for CAD/CAM and in many CAD/CAM installations the responsibility for management of the system rest with the engineering personnel. Fig. 3 shows a generic structure for CAD/CAM administration.

The major objective of the CAD/CAM organization is to use engineering information more effectively, thus ensuring the customer requirements are met. An organization that is too rigid will prevent the company from changing to meet the changing environment while an organization that inhibits the free flow of information will also obstruct attempts to be receptive to customer requirements.

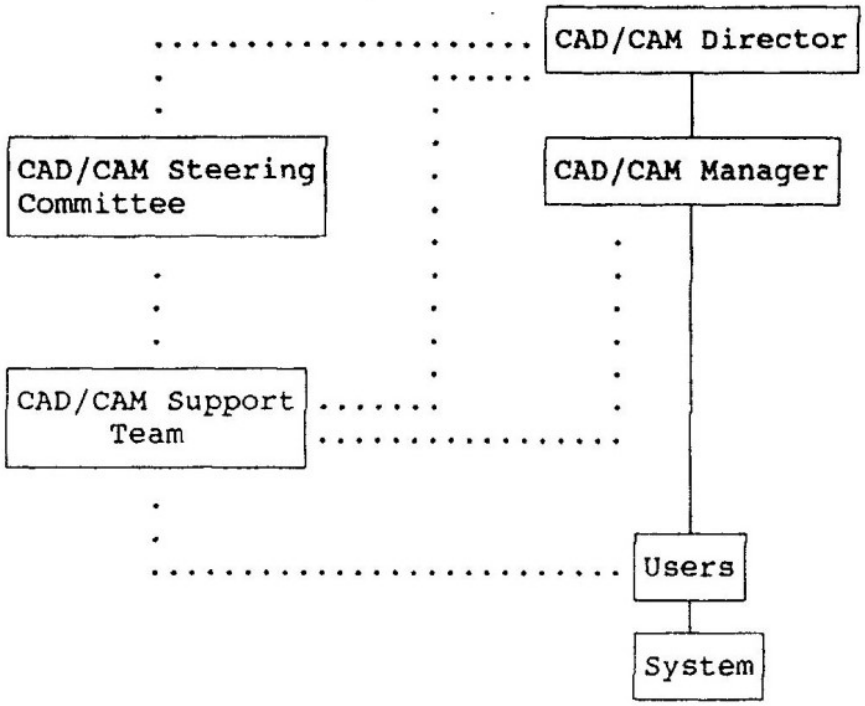

Fig. 3 A generic structure for CAD/CAM administration

DISCUSSION

Issues to be considered between the moment that an engineering design and production company decides to invest in CAD/CAM and the moment that the top management decides on a specific solution for implementation have been presented. Often companies may take several years before it becomes clear that the investment has paid off, but if the top management understands and carefully consider from the very beginning of the CAD/

CAM implementation process the economics of introducing CAD/CAM system, i.e., that the implementation process is a long term-activity with long term payback, it may be decided to terminate the selection process before the anticipated results of the overall selection process are achieved. A feasibility study carried out right at the beginning of the selection process can reduce the danger of making wrong decisions, e.g., by making clear to management that not only there will be no payback for a long time, but the process of selecting a solution is also lengthy and costly. Feasibility study should be done quickly, thus saving time and money. In order to gain the company management respect, it is often advised that the feasibility study have to be carried out by someone who is both expert and neutral, preferably from outside the company.

Training and education in the necessary computer skills for all cadres of employee is an essential prerequisite for successful implementation of a CAD/CAM system. CAD/CAM affects many people, including the top organization management, direct users such as engineers, drafters and supervisors and indirect users e.g. purchasing and marketing personnel. The question of who should be trained first is often linked to the question of which applications and which projects should be the first to be carried out. Starting a CAD/CAM implementation process with insufficient regard for the needs of the organization's skills base is likely to result in frustration and eventual failure because of the gap between awareness and capability. On the other hand, people require access to training for their careers to develop in accordance with their aspirations. These aspirations are dependent on company strategy. If certain group of people within an organization are rewarded well for the possession of certain knowledge, then the attainment of this knowledge must surely become an aspiration within that company. In terms of CAD/CAM specifically, there is a widely recognized under-utilization of the major investments made in hardware and software [6], hence people who can increase utilization of such resources are much sought after. People's aspirations (both individual and company) determines training needs. Training is best done if it is goal-directed, and by backward chaining from goals one should arrive at needs.

CONCLUSIONS

A methodology for CAD/CAM system selection has been presented and important issues that must be considered between the moment that a

company decides to invest in CAD/CAM and the moment that the management approves the implementation of a specific solution have been presented. It is believed that this methodology can be of practical use for any manufacturing company or educational institution planning to purchase CAD/CAM software and hardware. Although these guidelines are proposed for selection of CAD/CAM systems, they can also be used for selection of other engineering design and manufacturing application software and hardware systems. On training, it must be understood and agreed that training is expensive, is necessary and should continue long after initial system installation. It is also important to give refresher courses after a certain period, say, yearly, but the course contents must be updated to take into account the latest developments in CAD/CAM technologies.

REFERENCES

1. Shaw, T., (), Design Aid, Guiness Publishing Ltd., 1991, pp. 11.
2. Stahre, J.., Evaluating Human - Machine Interaction Problems in Advanced Manufacturing, Computer Integrated Manufacturing Systems Journal. Vol. 8. No. 2,1995, pp 143-150.
3. Uden, L., Design and Evaluation of Human Centered CIM systems, Computer Integrated Manufacturing Systems Journal, Vol. 8. No. 2, 1995. pp 83-92.
4. Hlupic, R. and Paul. J. R., Methodological Approach to Manufacturing Simulation Software Selection', Computer Integrated Manufacturing Systems Journal, Vol. 8. No.3, 1996, pp 49-55.
5. Singhal, K., Fine. C. H., Meredith, J. and Suri, R., . Research and Models for Automated Manufacturing, Interfaces, Computer Aided Design Journal. Vol. 17 No. 6, 1987, pp 5-14.
6. Stark, J., Managing CAD/CAM - Implementation, Organization and Integration, McGraw-Hill International Editions, Industrial Engineering Series.
7. Peacock, D., Newton. R., Santos, L., Opiyo, E. Z.., Klamantis, C., Rashid, T., and Ford. M. P., Generic Specification for a Multi-Media CAD/CAM Training Package, CAD/CAM Group Project Research Report. Cranfield University, 1991.

The manuscript was received on 24th May 1997 and accepted for publication, after corrections, on 29th December 1997