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Some workplace effects of CAD and CAM

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Introduction

Computer-aided design (CAD) and computer-aided manufacturing (CAM) are beginning to make significant inroads into industry.[1] In many enterprises, particularly in the electronics, aerospace, automobile, shipbuilding, mechanical and electrical engineering and machine tool industries, they have now gone beyond the experimental stage and have transformed jobs in design offices and production planning.

A CAD/CAM system has considerable implications for people who have to assimilate the new technology within a short time, and indeed enterprises and their personnel are now going through a more or less difficult and often haphazard adaptation and learning process. There is a growing need for a better understanding of the nature of the impending changes and their social consequences.

It was in the belief that such understanding would be advanced by an assessment of international experience in this field that the ILO launched a comparative study covering eight countries (France, Federal Republic of Germany, Hungary, Japan, Sweden, USSR, United Kingdom and United States) to identify changes taking place in employment, occupational structure and job content, work organisation, working conditions, skill patterns, training and industrial relations as a result of the introduction of CAD/CAM. The main emphasis of the study was on CAD but linkages with CAM were also included. The study was based primarily on national findings and case-study material assembled by experts with the help of a comprehensive open-ended interview guide, but factual evidence from other sources and countries was taken into consideration wherever it was available.

It is too early to try to reach definite conclusions on the subject: experience is still too limited. The data collected showed that many developments are not yet quantifiable and some questions remain open because of contradictory evidence. The CAD systems being used also vary considerably as regards range, capability and capacity and consequently as

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regards their effects on the workforce. Moreover, the long-term effects of increasingly sophisticated CAD/CAM systems with artificial intelligence built into them can hardly be predicted with any certainty even by present users. They will depend to a large extent on the further development and diversification of the systems themselves, and also on how willing undertakings are to invest and take risks in this field. Hence at this stage it is possible only to venture some tentative comments.

Users seem to agree that the main advantage of CAD is not so much that it speeds up the designing and production of drawings – important as that is – but that it serves to do things that would be impossible without a computer, such as rapid production of design variations, direct inclusion of calculations, simulation of functions, very complex designs (e.g. computer chips), and direct transmission of machining data. It also expedites routine work such as detail drawing, information searches, calculations (finite element analysis) and control work. This is due to the fact that the design of a particular item does not go through all the stages of the design process, but is based on existing work or documents held in the data bank. The use of CAD for unique designs without standardised components is therefore inappropriate.

Theoretically, CAD/CAM is introduced in companies because its use makes economic, technical and strategic sense. Since the market demands a wide range and variety of products, manufacturing in small batches is the order of the day; and CAD/CAM helps to satisfy this demand. The direct economic advantages of more efficient design work are fairly minor since in most industries such work accounts for only around 5 per cent of production costs (though in special machine-tool manufacturing the proportion may be as much as 20 to 30 per cent).[2] Technical and strategic reasons, however, constitute a powerful motive for its introduction.

The fact remains that considerable mistakes are made in investment policy if, as reported by one equipment supplier, it is true that about 30 per cent of CAD/CAM installations fail. This leads us to cost-benefit considerations. Here several factors need to be taken into account: the initial development and implementation costs; the change in the plant's overall profitability; labour saving and/or productivity; and the return on investment. This is easier said than done,[3] and for the cases explored under the ILO project only partial cost-benefit data are available. Moreover, many determinants of the efficiency of a CAD/CAM system are not quantifiable, e.g. its ability to provide up-to-date information on the production process; the availability of total process information; high transparency through improved organisation; reduction of paperwork; increased reliability of production; and the possibility of simulation and evaluation at the production planning level. Finally, it should be remarked that the running-in phase of a CAD system is critical and may lead to unforeseen expenses because of malfunctioning. There can be many causes for this, such as inadequate preparation, co-ordination and planning, insufficient time allowed for testing, and the workforce's lack of experience with automated systems.[4] The French study sums up the situation in a nutshell: "In fact, at present the real advantages of CAD/CAM cannot be evaluated in accounting terms, but it definitely improved the competitiveness of enterprises through better quality, increased flexibility and reduced time needed for design and manufacturing."

Productivity gains and employment

Up to now CAD/CAM does not seem to have had any negative impact on employment levels in the design offices and production planning departments of the great majority of user firms despite the high output increases it brings about. It has, instead, enhanced the variety of tasks performed by design offices and encouraged the production of a greater range of drawings, plans and project documentation while improving their quality and increasing the number of possible technical solutions. Thus the employment of designers, draughtsmen and other ancillary staff has remained fairly stable or, under favourable economic conditions, even increased. Shortages of draughtsmen able to work with CAD have even been observed despite high rates of general unemployment. An important reason why firms invest in CAD is to increase the productivity of existing personnel in order to avoid having to recruit scarce qualified manpower. One is even tempted to say that, paradoxically, the more CAD, the better the employment opportunities for designers and draughtsmen. Only the employment of parts (detail) draughtsmen (who are frequently women) and tracers seems to have fallen somewhat. Also, most firms are apparently employing slightly fewer trainees in this field, although this trend is probably due primarily to the latest economic downturn. On the other hand, firms have found it increasingly necessary to recruit staff for the maintenance and development of CAD systems (hardware and software).

Hence the overall employment trend appears to be positive. However, does this reflect only a temporary upsurge during the introductory phase of CAD and relatively favourable economic conditions, or is it a more lasting phenomenon? In general it can be said that job creation is highest where there is high productivity growth, and CAD is an instrument for this. At the company level it can be said that the more advanced the technology being used, the more output per hour and per worker will rise. At the same time, modern processes based on new technologies such as CAD/CAM are labour-saving and consequently may cause job losses if no other factors offset the labour-saving effect.

Case studies have provided numerous examples of rationalisation. Increases of output per draughtsman range between 200 and 6,000 per cent, depending on the specific application, with averages of between 200 and 500 per cent. Vendors of CAD/CAM even claim that output may increase by 6,500 per cent, but their estimates should be regarded with caution since they tend to be self-serving. Vendors invariably underestimate time scales and often overestimate software capabilities. The British study reports a wide range of figures for increased drawing production efficiency – in general about 300 per cent depending on the tasks.[5] The productivity gains in original design reported in other studies[6] range from 200 to 2,700 per cent. In secondary design or modifications of drawings gains of between 2,000 and 100,000 per cent are quoted. The British study states that "these productivity ratios depend critically on a change in the organisation of the design process and particularly on a change in the nature of the work". It is surprising that the corresponding labour-saving effects are nowhere near so high. How can this discrepancy be explained?

The British study notes that "it is important not to make too much of productivity gains data since [they are] difficult to collect and compare". Few firms specify how the gains are measured. Moreover, they depend very much on the way in which the drawing office and design process are organised. Most turnkey CAD systems come from American suppliers, yet the hierarchy in drawing offices in the United States usually includes a large number of junior draughtsmen in contrast to the typical European firm which leans rather towards team-work, i.e. greater involvement of all the team members in the design process. Hence claims of productivity gains based on American experience and practice may be irrelevant to European conditions.

Furthermore, productivity gains may refer only to the time spent on drawing and designing. A design engineer may spend three-quarters of his time on non-drawing activities such as thinking, discussing, reading, consulting, and a draughtsman about half of his time. High gains in productivity may be possible for only a small proportion of a company's operations.

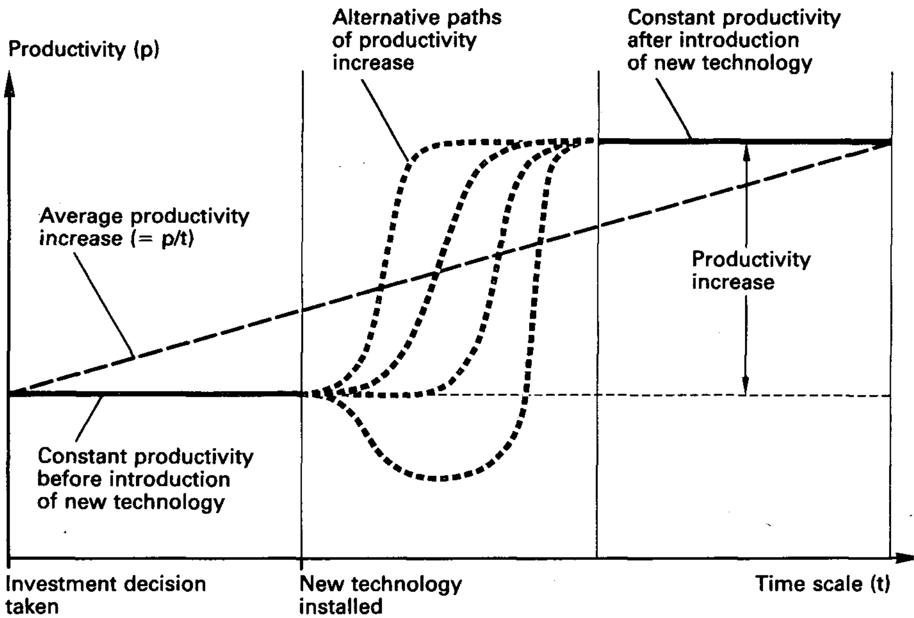
In many cases the subjectivity and often doubtful validity of claimed productivity increases from CAD are due to the fact that such gains are frequently used to justify the investment involved. That such justification is often spurious in practice is borne out in some of the case studies: for example, one pump manufacturer in the United Kingdom described the outlay of £85,000 on a CAD system as "largely an act of faith. The potential financial gains were subject to so many intangibles that no one took them too seriously."

Such remarks give pause for thought. Productivity figures are only an indication of the potential impact of CAD on employment and workplaces, and much depends on how they are interpreted and who supplies them (users, suppliers, consultants, planners, trade unions, employers).

The process of introducing and developing a CAD/CAM system is a very complex one and entails other economic and organisational changes. Let us look briefly at a few of the factors that need to be borne in mind in trying to assess the possible labour-saving effects.

First of all, care has to be taken to avoid a pitfall in the interpretation of productivity figures. Sudden jumps in productivity cannot be regarded as annual changes. The figures for productivity increases usually refer to the

Distribution of productivity increases over time



time span between a situation characterised by the traditional kind of work and one where the work is done with the help of the new technology. The length of this time span varies and will be considered later. More important still, it is very unlikely that new technological advances will occur each year, allowing a succession of spectacular productivity jumps. Seen in a longer perspective they are exceptional events. This means that productivity should be measured over the whole period starting with the planning and running-in time of the new technology (about two years or more as will be shown below) and continuing with the time after its introduction during which no further productivity-increasing measures are taken (see the figure).

The British study mentions time spans from nine months to two and more years for reaching a constant higher level of productivity of the sort advertised by system vendors. American research confirms that the time needed to achieve effective functioning of CAD systems tends to be underestimated. The American study estimates a pay-off time of three years for the system investigated. In the Federal Republic of Germany the time span for running-in and learning about CAD was also two to four years. The USSR study considers that a pay-off time of some years is needed for a CAD system and that its costs are difficult to justify in advance.

The assessment also has to take into account the geographical distribution of firms where the new technology is introduced. Firms that install CAD will experience high productivity gains and possibly redundancies, firms that do not will remain at the same level as before. The average labour-saving effect for all firms in a region may be moderate or negligible, depending on the proportion that install such new technology within a given period of time. Since case studies usually investigate firms where a change is introduced but neglect those where nothing of the sort happens, results compiled on the basis of such studies tend to show extremes which, though they may be real, cannot be said to be typical for a whole industry, region or economy.

Moreover, it is necessary to distinguish the effects of CAD from those of other technologies, business cycles, organisational changes and other factors both internal and external to the company concerned.

The Federal German study compares case-study results with the general unemployment figures for draughtsmen to show that employment depends on other influences besides CAD:

The time series concerning the unemployment of draughtsmen in the Federal Republic of Germany . . . goes up and down with possibly a slight growth trend. . . . This trend [should be seen in relation to] the trend of the time series for total unemployment. From 1980 to 1983 the increase of unemployment for all occupations was much higher than that of draughtsmen. . . . Since 1983-84 . . . the rate and the number of unemployed draughtsmen decreased while total unemployment increased to 10.5 per cent in 1985. . . . [It can hardly be concluded] that CAD causes unemployment of draughtsmen. Job losses of draughtsmen are evidently more related to economic ups and downs than to anything else.

The French study offers a partial explanation: "The time gained through automation of simple and routine procedures is partly offset or absorbed by trying out several solutions of a given design problem and variations of a new model." [7]

The British study adds a caveat and hints why productivity gains may not result in redundancies:

Management may have the problem of conflicting interests to resolve; for example . . . most systems are justified on the basis of productivity gains – yet many union agreements explicitly contain "no redundancy" clauses. This reduces the scope for finding productivity improvements significantly, although in some cases it was still possible to achieve gains by cutting down on the numbers of contract draughtsmen used. [There seem to be] three major causes for draughtsman unemployment: declining business, continuing lack of innovativeness in the industry and the productivity gains offered by CAD.

However, firms seemed to be reluctant to attribute redundancies to CAD, and instead blamed overall decline in business for fear of creating workforce resistance to CAD technology.

The British study goes on to quote a previous survey which fundamentally corroborates the Federal German findings:

As Senker and Arnold point out, it is extremely difficult to relate employment directly to technology. Their study [8] shows that overall draughtsman employment in the UK has been declining steadily since 1967 (when it stood at 80,000 as opposed to 54,000 in 1980) but the proportion employed as a total of all engineering employment has declined more steeply, with a reduction of around 30 per cent up to 1978. However, far from relating this to the introduction of new technology they suggest that the main reason for this decline was a lack of innovative activity in the mechanical engineering sector which led to an overall lack of competitiveness.

Moreover, as a UN/ECE report[9] argues:

The effect of CAD systems seems to be an increase of the capacity and capability of the design departments and not a reduction in employment. . . . For CAM, as for CAD, the impact on employment has not been dramatic, as most of the changes consist rather of increases in versatility. Some typically unpleasant jobs have, however, been eliminated: welding, painting and underbody protection.

Despite these generally reassuring findings, the fact remains that whereas previous technological change in pre- and post-war periods mostly had a labour-saving effect, the new technology entering the market now saves both *labour and capital*. It also helps to reduce the consumption of raw materials. In the past job losses were partly offset by increased labour demand for the production of capital goods. That compensation effect may no longer work because even the labour-saving machinery is now produced by labour-saving processes.

Further empirical work is needed to find an explanation for the demonstrated huge productivity increases and the only very moderate labour-saving effects and job losses attributable to technology at the industrial sector level or the level of the whole economy.

Factors that offset the labour-saving effects

Are we therefore to deny the existence of negative employment effects? Is there any proof that they have not occurred in the expected way? Are we perhaps only witnessing the beginning of a new trend and hence are still unable to pinpoint accurate indicators? How long do we have to wait until the advance of new technology produces the feared results? Are there similarities with the effects of technical change in the past? Can a precedent be found of technology that produced both labour- and capital-saving effects?

These are questions to which we should try to find at least tentative answers. Some of them are in the tradition of the technology debate that has been going on since the time of Say and Adam Smith and has continued with Schumpeter, Köhler, Leontief and others.

Various case studies give numerous hints about some of the factors that, from the employer's point of view, may offset the labour-saving effects, such as time lags, "hidden" extra costs, upgrading of the quality of work, innovations and growth-initiating effects.

Time lags appear to be a fairly typical phenomenon. The expected effect does not materialise at once and meanwhile economic factors, changes in the business organisation or other environmental influences alter the situation and invalidate initial assumptions. According to the British study, there are "underestimations of the time needed to achieve effective functioning, overestimations of the utilisation rate likely to be achieved, underestimations of the need to make adaptive adjustments or underestimations of the task involved in securing acceptance of the change by labour".

Delays tend to occur in the following areas:

- system selection and specification (e.g. a total of three years may be needed to make the investment decision and select a system);
- system introduction;
- collective bargaining;
- establishing a work organisation and support system;
- drawing office/design process organisation.

Moreover, cost effects are not uncommon and may cause disagreeable surprises. Unexpected or "hidden" extra costs arise from updating and maintaining equipment; special facilities and accommodation (e.g. air-conditioning, special furniture); and training, retraining and learning on the job. These various factors point, of course, to the risk involved in installing CAD, which needs to be calculated with care and yet is a frequently neglected aspect of technology management.

There are also reasons to believe that the new possibilities and methods of drawing and design by CAD enhance existing jobs or create new or additional fields of industrial work, including:

- new complex products, which can only be designed by three-dimensional modelling;
- improved products, by designing several variants and optimising them;
- flexible designing, by using macros (i.e. standardised geometrical elements) for several variants of the same model;
- simulation of production processes in various industries (e.g. plastics) in order to find an optimal design of product, tools and production process;
- standardisation, which generally has stimulated the growth of industries: enterprises often owe their existence to the introduction of standards because a division of labour among different producers and/or regions becomes possible and generates new production and new markets (e.g. software production and marketing, markets for special suppliers); moreover, training independent of suppliers becomes feasible;
- training measures which, based on standards or not, impart qualifications needed for further development; training systems are expanded; and the needed build-up of the training infrastructure creates new jobs.

In general, compensation effects work indirectly and sometimes produce new jobs in wholly unexpected fields. There are signs that this will happen with CAD as the amount of data grows and more and more files, storage systems and data banks are set up. The data "traffic" becomes denser. Tighter and more complex networks evolve. As a result there is a need for a data handling technology, interface technology, data control and assurance devices, data administration, systems maintenance, and data protection systems. Considerable exchange of experience is generated through journals, meetings and workshops.

A host of new jobs is created in this process. However, it is impossible at present to foresee all the new products and services that will come into existence or how existing occupations will be influenced and what new ones will emerge.

Effects on the occupational structure

As regards the occupational structure, the main effects of the introduction of CAD appear to be that:

(a) the proportion of parts (detail) draughtsmen tends to decline while fully qualified draughtsmen and designers strengthen their position;

(b) the recruitment of supporting staff for hardware and software maintenance and development (e.g. system analysts, mathematicians, parts programmers, computer operators) increases. These occupations may be new in design offices but, with the exception of the parts programmer, are not new occupations as such;

(c) in technical and design offices where strict hierarchical divisions prevail instead of a more integrated, team-work approach, the lower categories (e.g. junior draughtsmen) are threatened by redundancy;

(d) the content of occupations in design and production planning tends to change through job enrichment while many "new" occupations are specialisations of existing ones, e.g. CAD co-ordination and data teleprocessing programming. Some functions such as tracing and filing disappear;

(e) there is a tendency for design office staff to be recruited at a higher educational level than in the past (e.g. technical engineering diploma for design positions instead of secondary school diploma or draughtsman apprenticeship certificate) and the use of CAD tends to enhance their status;

(f) CAD is generally considered a new and efficient tool since it relieves its users of much routine work, but the consequent change in working practices is not very significant since there is no change in the sequence of tasks, the same basic knowledge requirements prevail and CAD software generally uses the same working procedures with which draughtsmen are familiar from the drawing board. A basic understanding of computer technology is generally considered to be just an additional knowledge requirement.

It has also been observed that in some cases designers have taken over tasks of detail draughtsmen since the computer permits these tasks to be executed rapidly and in conjunction with the design process. It is, however, not sure whether this is a permanent phenomenon or only a special circumstance in the introductory phase of CAD when only a limited number of design office staff are involved in the new system.

Little can be said at present about what effect the linking of CAD and CAM has on the occupational structure. It seems likely that numerous middle management functions in supervision and control will disappear or will be taken over by the computer. While this will enhance the role of top management, at the same time much decision-making will have to be delegated to lower hierarchical levels, constituting a job enrichment for skilled workers, engineers, technicians, designers and draughtsmen. In fact, all levels will, in principle, have access to a common data base. This presupposes more communication among team members, but fewer hierarchical levels in management. At this stage it is, however, too early to say which specific managerial jobs will fall by the wayside.

It is also likely that many ancillary functions of an administrative nature will be transferred to the computer. To what extent this means occupational change and job losses needs to be investigated further.

Whether or not new specialised occupations will emerge permanently depends to a large extent on work organisation, i.e. the choices made by management in dividing new tasks among staff in design offices and production planning, and on how far the objectives of job enrichment and enlargement are pursued. Moreover, the different education and training systems influence the division of labour to a considerable extent through the quantity and quality of graduates released on the labour market.

Changes in work organisation

Generally, it can be said that CAD tends to strengthen team-work in the execution of projects but to weaken the supervisory function and the hierarchical division of work. This seems to be a direct consequence of the way the system works, including the interactive dialogue at the terminal and the use of a common data base. Also, most CAD stations are used by several team members who must agree on appropriate arrangements and work schedules. The computer memory becomes the cumulative repository of most technical and design data and knowledge concerning specific projects, which necessitates co-operation and co-ordination among team members. The other side of the coin seems to be diminished control over one's own work and what has been called the "expropriation" of individual know-how as it is transferred to the common data base. This could lead to strained relations among team members.

There are considerable differences in the extent to which CAD is used in design offices, i.e. in the time spent on the terminal. In general, CAD work takes up between 30 and 60 per cent of the working time of design office staff. Depending on whether CAD is used as an exclusive instrument (e.g. chip and wiring diagram design) or as a complementary one absorbing many routine tasks (frequent in machine-tool design), different forms of management and work procedures may be required in design offices.

The supervisory function is relaxed because CAD considerably reduces the error rate in design and improves design quality. Working relationships often improve because supervisors have less occasion to point out errors.

The combined use of CAD and CAM is clearly progressing in enterprises, but perhaps not as fast as the abundant technical literature on the subject would have us believe. Many managerial, organisational and technical difficulties are apparently encountered in this respect. The standards and software necessary for such integration are emerging only gradually. Difficulties are also encountered in overcoming conflicting views and vested interests, which may even lead to haphazard and ill-considered investments.

Changes in work organisation produced by CAD frequently come slowly, if at all. The various case studies indicate that the CAD centre tends to remain a "pilot exercise" isolated from the rest of the plant despite the lip-service generally paid to the need for integration.

Adaptability of CAD

The introduction of a particular technology does not predetermine any specific type of work organisation. The same is true for the occupational structure, skill levels and working conditions.

So far it is uncertain whether CAD is instrumental in changing the work organisation of an enterprise. No clear cause-and-effect relationship has been found. The matter is complex since many different influences may converge to trigger changes in the organisational pattern. In the American study, for instance, it was reported that during the implementation phase of CAD collective bargaining resulted in a change of the entry level of workers and in the pay structure. However, these changes were due to general economic conditions and were not a direct consequence of automation. Their effects on organisation were marginal.

Another review of research findings [10] comes to the conclusion that so far CAD users have observed no changes in the centralisation of decision-making. CAD in fact offers increased possibilities both of centralising and of decentralising; and indeed some enterprises may centralise some functions and decentralise others. The choice depends more on the company's management philosophy than on the technical features of CAD systems.

The general experience suggests that organisational patterns change little, if at all, when CAD is introduced. Despite some redistribution of tasks, established hierarchies and existing organisational separations prove surprisingly resistant. It remains an open question whether the progressive linking of CAD and CAM will have more radical effects. It is, for instance, conceivable that the design office will take over the production planning functions of the technical (methods) office while the manufacturing departments will assume the residual functions of the technical office, e.g. the specification of tools required. This may happen once computer systems start working to stored rules and specifications, which would make engineers and technicians on work preparation jobs redundant. So far, however, this has apparently hardly ever occurred.

Noting the centrifugal forces at work in enterprises, the French study observes that "the organisational heritage [of a firm] with its clearly established and regulated separation of functions having their inherent distinct logic may be stronger than any tendencies towards integration". In fact, CAD confined to the design office does not rock the boat. However, the linking of CAD and CAM may well bring about a higher degree of integration. This may prove to be the crux of the matter. CAD/CAM may not be compatible with existing configurations of power and dividing lines in organisations and may thus fall victim to internal power struggles.

Here some thought needs to be given to the integration of the human factor into the new design environment. How flexible is the CAD technology in accommodating human needs and what features can be designed into the system to make it user-friendly? To what extent do technology dependencies exist and in what areas? How adaptable is the new working environment? While we rule out absolute technological determinism, nevertheless a number of investigations into changes in work organisation, working conditions, skill and training requirements indicate various degrees of technological dependency and adaptability in different fields pertaining to the new working environment. There is obviously much room for manoeuvre in the distribution of tasks among the various workplaces and in the organisation of working hours, for example, but much less in the sequence of operations involved in handling machinery.

Working time arrangements

The most notable departure from past practice has been the introduction of shift work in design offices in an attempt to recover the high capital cost of CAD equipment and software through fuller capacity utilisation. A variety of flexible working time arrangements have also been introduced which, if properly organised, can have advantages for both the enterprise and the staff and result in an improvement in working conditions.

The introduction of shift work, which requires design staff to work "unsocial" hours, obviously does not facilitate the acceptance of CAD, particularly when carried to extremes as in the three eight-hour shift or multi-shift systems of the kind frequently used in American companies. In Europe only double shifts have been found, except in one enterprise in Italy using a multi-shift system. However, the pressure to increase the utilisation of CAD/CAM equipment may ease as the cost of computers and interactive terminals drops and larger capacity central memories speed up the response time (although this may be hampered by rising software costs). In other words, if investment costs fall substantially, a reversal of the trend towards more shift work is possible. Some firms already rule out shift work because they consider that the stand-by costs, i.e. additional costs for service maintenance, computer time and other infrastructure, would be too high.

Work stress and job satisfaction

It has also been found that, at least during the transitional phase, work stress tends to increase, which is hardly surprising. Curiously enough, most stress is apparently caused by the fairly long response time of certain systems and computers or by breakdowns. Sometimes it is inflexible software that causes irritation. However, this may be a passing phenomenon that will be overcome by more sophisticated and better designed software and hardware. At any rate, once users of a CAD system are fully familiar with it they generally do not wish to return to the drawing board despite often high work intensity at the terminal and the need for great concentration. They consider such work more interesting and challenging than work with traditional methods. This higher job satisfaction is reported fairly consistently. However, CAD users have also remarked that screen work has something of a "hypnotic" effect which leads to mental exhaustion. Some say that they feel completely drained after working for long hours with a system that exerts a kind of "horrible fascination" as the dialogue with the computer drives the operator on at a fast pace.

Standing in contrast to the reports of higher job satisfaction are the findings of a Swiss study which noted that some design office staff trained in CAD preferred to return to conventional drawing and design work because they were dissatisfied with the new tasks and the level of abstraction demanded.[11]

Display terminal work can result in eye strain and back and neck problems.[12] However, the extent of such complaints depends on whether ergonomic factors were taken into account in the design of the equipment and on the amount of time spent at the terminals. In this respect much progress has been made in recent years and screen displays, particularly in colour, now tend to cause less eye strain. Modern workstations are usually well designed and easy to operate. The inadequacy of much software has become the subject of research, and a new scientific discipline – "cognitive ergonomics" – is emerging with the aim of overcoming the stressful factors involved in its use, which have become a major problem. As already noted, CAD may also cause a sense of lack of control over the work process as personal planning of work is reduced and an element of rigidity – some say more rigour – is introduced into the design office. Moreover, CAD systems make it possible to exercise greater supervision over performance, a possibility that may or may not be used according to the company's management ethics. There is also considerable fear – often on the part of experienced designers – that CAD may dampen creativity as designers and draughtsmen come to rely excessively on macros stored in data banks.

It is well known that monotony of work also causes stress. CAD work, even routine tasks, is generally still looked upon as quite new and challenging. The newness will no doubt wear off with time, so the present high level of job satisfaction is unlikely to last. This is more than mere speculation since it is what has happened in the case of other technologies which have lost the charm of novelty and whose negative aspects have become a source of irritation.

Some research findings [13] suggest that job satisfaction will not change in response to CAD technology as such. It may, however, deteriorate if the introduction of CAD leads to workplace changes such as reduced autonomy or less communication with fellow workers. In other words, whether job satisfaction is positively or negatively affected depends largely on job design. Since job content is not exclusively determined by CAD technology, there remains considerable scope for designing attractive and rewarding jobs.

Another fear is that prolonged work at CAD workstations could cause social isolation of design staff. That fear was not borne out by the case studies except where workstations were physically separated from the design office, probably because in general only a limited amount of time is spent at the stations. Evidence to the contrary was found in Switzerland, however, where it was reported that "user interviews clearly testify to a reduction of social contacts".[14]

Effects on remuneration

In the case studies there is little evidence that jobs were upgraded or downgraded or that a change in pay occurred following the introduction of CAD. (The USSR case study is a notable exception where it is stated that CAD increased the bonuses of design staff.) Nevertheless, this lack of evidence hardly means that no improvement has taken place. It is not uncommon for companies to increase pay as staff acquire new skills in order to retain them; they may also do so in order to attract new employees or to compensate for inconveniences caused by staggered working hours, shift work, etc. In design offices salaries are frequently paid on the basis of individually established contracts and fringe benefits so that it is difficult to obtain accurate information on the subject. However, it has been reported in the United Kingdom [15] that staff working with CAD/CAM have overtaken all other occupational categories in the salary scales of the electronics industry.

The case studies showed that overtime is a widespread practice in design offices since there is always some urgent deadline to be met. However, it was not possible to ascertain the pay implications in any detail.

New skill requirements and training

The main new skill requirements for staff working with CAD systems appear to be "computer literacy" and higher mathematical and analytical skills, especially a good understanding of the principles of analytical geometry and the application of co-ordinate systems, together with an open mind and a high degree of accuracy and attention to detail. The younger generation of design office staff usually have already had some exposure to computers during their education and training and consequently find it easier to cope with CAD systems than the older generation of draughtsmen for whom adaptation problems have been observed in most of the cases studied. Traditional draughtsman skills nevertheless appear to retain their validity and importance – at least for the time being – since the main tasks remain unchanged. Because they are relieved of much routine work draughtsmen and designers should have more time for creative work, but in practice existing software and rules and macros stored in data banks may seriously limit their options. Design freedom is increasingly constrained because the building up of new geometrical forms by means of CAD is relatively time-consuming and expensive and the main economic advantage of the system lies in the possibility of reusing macros. Excessive standardisation may tend to make innovation in design difficult as increasingly only variations of existing components and products are produced. The integration of new materials and production methods into CAD/CAM may become a problem and companies might even lose their competitive edge because of such lack of design innovation.

The successful introduction of CAD obviously depends on adequate training being given to all staff assigned to the new tasks. So far, however, in all the countries studied makeshift arrangements seem to prevail over a systematic approach.

Many CAD users feel that the training provided is inadequate. Frequently companies rely heavily on a somewhat superficial theoretical initiation followed by on-the-job learning. This could be accelerated by means of better teaching materials which should be in the trainee's mother tongue – not always the case at present – and systematic instruction. There is obviously much uncertainty about training requirements for the various CAD jobs. Often the suppliers of equipment provide the training, which tends to limit the skills acquired in this way to one type of equipment and software. The duration of the training ranges from short (one to three weeks) initiation courses to much longer comprehensive courses. The length and type of training depend largely on the previous qualifications of the trainees. Draughtsmen have likened CAD training to learning a new language; and indeed they often have to cope with more than one programming language. CAD systems and their software are constantly being updated, and this entails regular further training for system users. Usually such further training is given within enterprises and financed by them, except in the USSR where the ministry concerned is responsible.

Training institutions are beginning to take up the challenge and to include CAD in the syllabus. However, training regulations so far seldom reflect CAD requirements and generally recognised trade tests in this field do not seem to be available yet.

Training is also a way of preventing underqualified draughtsmen from becoming redundant and is usually the solution chosen by enterprises when introducing CAD. Hence it is rather surprising that many older employees are unwilling to undergo retraining. Age is not an obstacle in itself; there are examples of very successful retraining of older draughtsmen once their initial resistance has been overcome. Moreover, their experience is usually highly valued. The methods (or lack of methods) used for introducing CAD may well be responsible for the misgivings felt by older employees.

There is a great variety of CAD training schemes. The training may be provided by equipment suppliers; by training staff of the user firm; by vocational schools or technical colleges; by the user firm and vocational schools ("dual training", e.g. in apprenticeship); by external consultants; or through correspondence courses.[16]

In the countries reviewed the level and depth of CAD courses also vary considerably. Short introductory courses in CAD are normally organised for numerical control (NC) programmers, application programmers, technologists, managers and members of works councils, while more comprehensive and in-depth training is given for designers, draughtsmen, CAD/NC programmers and system operators. Some case studies emphasise the importance of familiarising the managerial staff with the systems so that they will not feel inadequate to the situation or surpassed by junior staff members; otherwise they might prove to be a stumbling-block to the introduction of CAD/CAM. Moreover, as the American study notes, the availability of CAD/CAM equipment on the shop-floor pushes the decision-making authority to lower levels: "This could bring higher levels of satisfaction, greater motivation, and faster decisions. Yet, it carries the danger of being threatening to middle managers who see this as being an infringement on their power."

CAD implies additional qualifications for well-defined traditional occupations in the industrial hierarchy. It seems to have little influence on the career prospects of individuals and the country studies provide no evidence of management having devised specially designed career paths for CAD/CAM specialists. CAD knowledge possibly gives a boost to job security and income but not necessarily to occupational advancement, although it may well improve the promotion prospects of designers, draughtsmen and technicians within the framework of established career patterns in design and technical offices.

Occasionally, the skill requirements for CAD/CAM are summed up in very general terms, probably because they cannot easily be singled out. Thus, an expert inquiry[17] found that a good CAD user must be intellectually agile, must be strongly motivated and must acquire much practical experience with the system in use. Another description stresses "knowledge of the system in a larger production, technological, business, economic and industrial policy context" as well as knowledge about production processes, planning and work organisation. This stands to reason since CAD is meant to have an integrating function in manufacturing.

One should probably not overstate the further training requirements. As the French study points out, "CAD/CAM qualifications require supplementary training which entails relatively little cost. They are rapidly acquired by design office staff who already possess essential professional know-how." Following adequate training, proficiency in the use of CAD systems is generally reached after about one year's work with them.

Industrial relations and the new technology

CAD/CAM has begun to transform vital parts of the manufacturing process and hence the world of work. It has had some impact on collective bargaining (e.g. works agreements have been concluded on shift work, flexible working hours and work with visual display units), but the attitude of the trade union movement so far remains somewhat ambivalent. As a rule technological change is accepted by the overwhelming majority of union members (e.g. 85 per cent in Switzerland[18]) as a necessity for enterprises to survive in a highly competitive environment, and unions seek benefits for their members from the introduction of the new technology (e.g. shorter hours, better conditions of work and higher pay) through collective bargaining. On the other hand, they fear redundancies and job losses as well as deskilling of occupations and subsequent income losses for their members. There is also some concern that work with visual display units may adversely affect users' health. The unions therefore insist on consultation prior to the introduction of the new technology.

CAD may have attracted less attention from the unions than changes on the shop-floor (e.g. robotisation) because of the fairly low level of unionisation among design office workers. Moreover, union representatives frequently lack technical knowledge of CAD systems. Unions also view with suspicion the trend towards flexible working arrangements and individual contracts. Changes in that attitude are slow to come despite the fact that the proportion of white-collar workers in industry is constantly growing. There is, however, an increasing awareness that the unions must defend the interests of these workers and organise them more effectively if they do not want to risk losing influence in the world of work.

The more enlightened managers are fully aware of the need for consultation in the transition to CAD/CAM as a kind of insurance policy to make the system work. Employee involvement and participation from the outset can pay off handsomely. The absence of consultation, on the other hand, is often punished by passive resistance and the subsequent failure of the system.

While the scope for consultation and participation is therefore great, it also has its limits. It is often genuinely hampered by lack of knowledge about the new systems on the part of both management and workers. To some extent trial and error is inevitable.

There is one very specific problem that may have to be tackled in negotiations. As already noted, several studies have referred to the "expropriation" by CAD systems of personal know-how and consequent deskilling which may prompt a negative reaction on the part of their users, such as a refusal to pass data on to the system. It is the responsibility of designers and draughtsmen to store problem solutions in the CAD data banks, which then become accessible to co-workers. While this may facilitate co-operation and have a synergetic effect, it can also be resented as preying upon the competence, skills and performance of workers who are in competition with each other and want to protect their jobs. Such resentment may destroy whatever team spirit existed under the traditional systems. A remark in the French study is revealing: "In the design office [of an automobile manufacturer] a CAD system is used at only 20 per cent of its capacity because of repeated software modifications and the lukewarm reaction of the designers who are afraid of deskilling." This problem is so serious that proposals have been made to declare an individual's design and engineering knowledge private property requiring suitable protection. Here it should be remarked that "know-how expropriation" does not extend to the practical knowledge and experience of designers and draughtsmen: that cannot be transferred to the computer nor matched by it – at least not yet.

Future developments and conclusions

It is safe to say that the integration of CAD and CAM will be carried further through the networking of high-speed workstations, the use of compatible hardware and appropriate systems architecture, and the creation of suitable software. The aim is totally paperless information transfer from design to machining and assembly. This integration process is multidirectional and will embrace the entire product design process, production planning and tooling. The use of product modelling techniques combined with artificial intelligence techniques will give systems some analytical capacity and improve the means of displaying and conveying information within enterprises.

This development will be helped along by the expected drop in investment costs for CAD systems. The culmination will be fully computer-integrated manufacturing (CIM) which today is more a concept than a reality. It would be wise not to underestimate the time needed for the conversion of industry. The process will be gradual, with much trial and error, and may take ten to 20 years. It presupposes that the present shortcomings of CAD/CAM, such as the lack of standardisation of functions, terminal interfaces and data interfaces as well as the proliferation of machine languages, are overcome. And, finally, the technical feasibility of systems and the ultimate decision to invest in them are not the same thing.

The human factor will clearly be the key element in the implementation of CIM. Indeed, management commitment to motivating people through job enrichment and training is essential if the expected return on investment in advanced technology is to materialise.

It is of course conceivable that the fairly minor impact of CAD/CAM on employment and work organisation observed so far will give way to more profound changes as CAD and CAM are progressively integrated. Things are in a state of flux and there is much experimentation. However, the process of integration is a fairly slow one and no immediate dramatic effects are anticipated. At present, in fact, there are increasing signs of skill shortages, particularly in engineering design, that could prove serious enough to diminish the competitiveness of firms and act as a brake on a sustained economic recovery.

The evidence reviewed here suggests that only a highly qualified and motivated workforce can implement this new technology successfully and economically. Many of the difficulties encountered in the introduction of CAD/CAM and ultimately CIM are of a transitory nature. They are due to the fact that the new technology must be integrated into existing organisations with established internal divisions and employing people trained in more traditional systems and skills to which they cling. Once apprenticeship and technician and engineering training systems catch up with CAD/CAM it will be easier for industry to man its CAD/CAM equipment with properly qualified staff. But industry will still be called upon to make a continuous training effort since the new technology is constantly changing. Care must be taken to create a working environment, conditions of work and an industrial climate that will permit a smooth transition over which man remains the master. It is the task not only of governments but also of employers and workers and their organisations to facilitate the process so that the results may benefit all members of society.

Notes

[1] The Comité européen de coopération des industries de la machine-outil (CECIMO) Working Party on Standardisation has proposed the following definitions:
CAD: "A CAD system is a system which incorporates one or more computers for carrying out some of the calculations and actions involved in the design process."
CAM: "A CAM system is a system which incorporates one or more computers for carrying out some of the tasks involved in the organisation, scheduling and control of the operations involved in the manufacture of the product. Where machining is involved, a CAM system will usually involve CNC [computer numerical control] machine tools and means for producing part programmes for them and it may also involve a central computer for scheduling, planning and control of the operation of the system. It may involve a DNC [direct numerical control] system using either the central computer or a separate computer, as well as computer control of stores, orders, etc."

CAD/CAM: "A CAD/CAM system is a system in which computers are used to carry out some of the tasks involved in designing and manufacturing a product. In particular, computers are often used to produce part programmes for the CNC machines in the system directly from the design data." (See UN/ECE: *Recent trends in flexible manufacturing* (New York, 1986), p. 18.)

[2] Ch. Muggli and W. D. Zinkl: *CAD in der Maschinenindustrie und im Architekturbüro* (Zurich, Verlag der Fachvereine, 1985), p. 42.

[3] J. D. Reinking: "Quantifizierung der Produktivitätssteigerung beim Einsatz von CAD-Systemen", in *VDI-Z* (Dusseldorf), Sep. 1986, No. 18, pp. 714-716.

[4] UN/ECE: *Software for industrial automation*; doc. ENG.AUT/AC.12/R.2/Add. 6 (Geneva, 1986).

[5] Detailed study of 34 user firms by E. Arnold and P. Senker: *Designing the future: The implications of CAD interactive graphics for employment and skills in the British engineering industry*, Occasional paper 9 (Watford, Engineering Industry Training Board, 1982).

[6] R. Kaplinsky: *Computer-aided design* (London, Frances Pinter, 1980), cited in the study on the United Kingdom.

[7] For a fuller discussion see S. Watanabe: "Labour-saving versus work-amplifying effects of micro-electronics", in *International Labour Review*, May-June 1986, pp. 243-259.

[8] Arnold and Senker, op. cit., p. 46.

[9] UN/ECE: *Techno-economic aspects of the international division of labour in the automotive industry* (New York, 1983), p. 183.

[10] A. Majchrzak et al.: *Human aspects of computer-aided design* (Philadelphia and London, Taylor and Francis, 1987), pp. 183-185.

[11] Muggli and Zinkl, op. cit., p. 88.

[12] For recent discussions of these and other hazards associated with the use of visual display units, including possible radiation risks, see Fe Josefina F. Dy: *Visual display units: Job content and stress in office work* (Geneva, ILO, 1985) and R. Kaplinsky: *Micro-electronics and employment revisited: A review* (Geneva, ILO, 1987), pp. 134-137.

[13] Majchrzak et al., op. cit., p. 196.

[14] Muggli and Zinkl, op. cit., p. 95.

[15] Kramer Westfield, reported in *Financial Times* (London), 6 Aug. 1986.

[16] C. Berger: "Anwendung von CAD/CAM-Technik erfordert zielgerichtete Qualifizierungsmassnahmen", in *Berufsbildung* (Berlin), 1986, No. 3, pp. 149-152.

[17] U. Riehm: "Wandel der Arbeitsweise in der Konstruktion. Neue Anforderungen und Weiterbildung beim CAD-Einsatz im Maschinenbau", in *VDI-Z*, Dec. 1985, No. 23/24, pp. 990-994.

[18] "L'opinion des membres, les travailleurs syndiqués et les nouvelles technologies", in *Revue syndicale suisse* (Berne), 1986, No. 1, pp. 24 ff.