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Manning the unmanned factory

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There is a growing body of opinion, supported by case studies and research, that industry is at the threshold of a new era in manufacturing. Many believe that computer-integrated manufacturing (CIM) will transform the world of work beyond recognition. However, there is also much evidence of failures following the introduction of this new technology – even though companies seldom care to advertise their failures. Has the CIM concept the potential for introducing far-reaching qualitative changes in manufacturing? And what can we reasonably expect to happen to the men and women employed there? A preliminary answer to these questions, emphasising the key role of the human factor in the application of the new technology, is attempted here.

The CIM concept [1] seems rational and sensible, and appeals to the tidy mind. It satisfies the quest of the engineer to create order out of chaos. It is reassuring to the manager looking for efficient means of controlling the production process. Why is it then that the realisation of projects runs into so much difficulty in practice? Are expectations set too high? Even allowing for the fact that CIM can be introduced only step by step, that it requires considerable computing power and the mastering of complex system architectures and software developments, and that different production processes need different CIM systems (i.e. they must be tailor-made), it is obvious by now that the practical results achieved so far have not lived up to the initial optimism of many automation equipment and system suppliers, engineering researchers and management strategists. The "factory of the

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[1] There is no generally accepted definition of CIM. It usually denotes computer control of the entire production process from design and manufacturing to product delivery. It comprises computer-aided design (CAD), computer-aided planning (CAP), computer-aided manufacturing (CAM) and computer-aided quality assurance (CAQ). These functions and the subfunctions in each area are parts of a system, are fully integrated through computer networks and have access to a unified data base. CIM is thus essentially a means of organising and controlling the manufacture of components and assemblies as logically and flexibly as possible and of mastering and co-ordinating the corresponding flow of data and information. It aims at optimising the use of equipment, reducing lead time and inventories, and ensuring high product quality and lower unit costs. The synergies created through integration are expected to lead to cost reductions, higher productivity, and rapid adjustment of product quantity and quality, product variations and delivery times to demand in competitive national and international markets. It appears to offer an opportunity to compensate for shorter product life cycles and to eliminate much waste.

future" described by CIM advocates in the engineering profession remains largely a figment of the imagination, despite a few science-fiction-type realisations. And even staunch technocrats readily admit that industry is a long way from realising the full potential of CIM, although partial solutions such as flexible manufacturing systems, automatic materials handling, computer-aided design, and computer numerical control (CNC) of machine tools have made much promising headway. "Islands of automation" have thus been created in many plants, but linking them together is clearly not an easy task. Some CIM systems set up as demonstration or pilot projects illustrate this new approach to manufacturing, but they are usually very costly and isolated experiments removed from the real world of production. The installation of operational CIM systems in industry is in inverse proportion to the talk about it. Should we, therefore, regard CIM as a dead-end, a fading fad or a technocrat's pipe-dream of the manufacturing paradise?

The socio-economic perspective

The CIM concept has evolved in the highly industrialised countries characterised by significant capital accumulation, high labour costs, a solid and wide scientific and technological base, and a well-developed social and economic infrastructure. It owes its birth to rapid advances in computer and information technology. Pilot projects and accompanying research to put the concept into practice in manufacturing have been concentrated in Japan, the United States and some industrially advanced European countries. However, there are considerable differences in the approaches adopted, which tend to be a response to the specific socio-economic situation, the industrial traditions and the factor endowment of the country or enterprise concerned.

The human-centred versus the technocentric approach

The different approaches may be broken down essentially into two: the "technocentric" approach and the "human-centred" approach. No industrial society has a monopoly of one or the other, and they frequently exist side by side, though one or the other may tend to predominate. The following analysis of the main features of these approaches, which does not go into their historical roots, should be seen in this perspective.

In the United States the so-called technocentric approach is found in its purest form. It has often served as a model for enterprises in other countries.[2] It constitutes an attempt gradually to reduce human intervention in the production process to a minimum and to design systems flexible enough to react rapidly to changing market demand for high-quality

[2] W. Wobbe: "Technology, work and employment – New trends in the structural change of society", in *Vocational Training Bulletin* (Berlin (West), European Centre for the Development of Vocational Training), 1987, No. 1; P. Brödner: "Towards an anthropocentric approach in European manufacturing", ibid., loc. cit.

products. Workers and technicians on the shop-floor are typically seen as unpredictable, troublesome and unreliable elements capable of disturbing the production and information flow, which is best controlled centrally through computers. The "unmanned factory" is the ultimate goal. Only a residual role is assigned to workers, whose skills are supposed to be incorporated gradually and progressively into the machines. The technocentric approach, it is hoped, will halt the continuing erosion of American manufacturing know-how and help industry to regain its lost superiority and competitiveness in world markets. Investment in capital-intensive and sophisticated technology (some have dubbed this the "moonshot" approach) is thus expected to overcome a deep-seated structural problem. Since American manufacturers produce for a vast and homogeneous home market, they can concentrate on large volume products and fairly big batches in component manufacturing. The resulting production process is relatively inflexible even when flexible manufacturing systems and machining cells are used. The central engineering challenge is said to consist in arriving at continuous flow production of large varieties of products and components without much work-in-process, i.e. without idling capital; this would ensure high productivity and adequate returns. Human skills play a minor role in this scenario. Such "scientific management" would be carrying Taylorism or Fordism – originally based on the principle of using vast pools of unskilled and semi-skilled labour – to its ultimate extreme since the increasingly sophisticated machinery is supposed to make human skills dispensable. Traditionally adversarial industrial relations and a low level of worker commitment and loyalty reinforce this attitude. The technical office manned by professional engineers and technicians increasingly becomes the repository of production know-how to the detriment of production workers.

Carried to its extreme this approach has proved not to work very well or to function satisfactorily only at excessively high cost. For instance, it has been found that flexible manufacturing systems installed in the United States have often performed worse than conventional technology. The relevance of the technocentric approach for the future of manufacturing therefore seems questionable.[3] It may prove to be a dead-end because of an essential flaw: there is mounting evidence that proper and continuous operation of the type of flexible automation that is central to CIM systems can be ensured only by highly qualified and motivated workers able to cope with the relatively frequent breakdowns of such complex and sophisticated equipment and with software problems – and there are persistent complaints that the specific skills needed for "high-tech" manufacturing are scarce or simply not available. At any rate, there is generally a long learning and running-in period, with uncertain future returns as a result of excessive reliance on unproven technology.

[3] S. S. Cohen and J. Zysman: "US competitiveness suffers: The emergence of a manufacturing gap", in *Transatlantic Perspectives* (Washington, DC), Autumn 1988.

The Japanese approach to CIM is based on a different rationale. Companies introducing advanced and flexible automation systems can rely on a highly qualified, versatile and loyal workforce. Instead of progressing in the technological field by giant leaps they prefer to make gradual improvements in the production process and in quality, frequently initiated by motivated engineers, technicians and workers on the shop-floor. The wide adoption of the quality circle movement is only one manifestation of this. Emphasis is on product quality and production scheduling (i.e. just-in-time production and electronic ordering of materials and components). Compared with the outstanding manufacturing skills evident in the extensive application of industrial robots, the integration of the information flow through computers is less developed owing to gaps and difficulties in software development. The most flexible element in the system is, in fact, the people who make it work. Moreover, most companies operating such systems tend to serve large local and export markets and therefore produce fairly large series, although the flexibility of the equipment is more fully utilised than in American manufacturing thanks to a highly qualified workforce. The strength of this approach, which is facilitated by a co-operative industrial relations climate, is apparent in diversified high-quality mass production.

Manufacturers catering for relatively small, heterogeneous or specialised domestic or export markets demanding high-quality components and customised products, as is largely the case in Europe, have been inclined to rely on another strategy in introducing CIM. Owing to the high investments required and the often limited capital base, they usually opt for a cautious, pragmatic and gradual approach rather than adopting the whole panoply of CIM at once. The centrepiece of manufacturing has remained, by and large, the skilled and highly skilled craftsman and technician. Although Taylorism made some inroads in European manufacturing, particularly in the automobile and consumer durables industries, it never replaced skill-based production in medium- and small-scale enterprises in the capital goods sector where an extreme division of labour is not feasible. Enterprises competing in narrow markets have always had to be flexible and innovative to survive. The new computerised flexible and integrated automation equipment is primarily seen as an improved tool in the hands of a skilled and versatile workforce serving to enhance existing know-how and to permit greater flexibility, higher productivity, better product quality and shorter delivery times. It is not regarded as a solution for all production problems, but as an effective prop in gaining a market share. Such enterprises also tend to make a sustained effort to retrain their staff. Moreover, the lesser emphasis on division of work allows them to assign broader responsibilities to the workers according to their qualifications and consequently permits more flexible forms of managerial control and work organisation, including teamwork and imaginative applications of CIM using available skills.[4]

[4] H.-J. Warnecke: *CIM in Europe* (Stuttgart, 1987), unpublished manuscript.

Impact on employment

There is encouraging evidence that by and large the aggregate level of employment in industrial societies is not greatly affected by the introduction of new technologies. The long-term trend of declining manufacturing employment observed in industrialised countries is certainly continuing, owing partly to technological innovations that eliminate unskilled work (and may also accentuate labour market segmentation). However, on the whole, job displacement and redeployment of workers in the innovation and rationalisation process appear to balance out, and where technological change is accompanied by strong economic growth, expanding markets and new investments, it even tends to induce positive employment effects through the revitalisation of the economy. Japan's technology drive and growth pattern are a case in point. However, it would certainly be vain to pin exaggerated hopes on the spin-off effects of CIM and other advanced technologies in creating employment. "Reindustrialisation through high technology" is certainly a misleading concept.[5] Only a very small proportion of the labour force in the highly industrialised countries – roughly 2 to 5 per cent – are engaged in this advanced sector and, if past trends and experience are any guide, the proportion will rise only slowly in future, if at all.

The managerial and organisational perspective

CIM: The end of chaos or its beginning?

Management attitudes about how to cope with CIM vary. In part they mirror the national idiosyncracies and different industrial backgrounds evoked above. Thus the technocentric approach results in management strategies that neglect or underrate the human factor in production. This tendency is frequently aggravated by short-term profit considerations, which are one of the major stumbling blocks to sound technology planning and management. The introduction of CIM requires long-term strategic thinking. From the managerial point of view it is essentially an organisational quandary: how to create order out of potential chaos. Equipment needs to be carefully selected and compatibility ensured. However, the fundamental problem is how to reshape existing production processes, alter organisational boundaries and make them permeable. This requires redesigning the information and data flow to foster decentralised decision-making. The difficulties involved in accomplishing this in existing organisations should not be underestimated.

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[5] Wobbe, op. cit.; K.-H. Ebel and E. Ulrich: *The computer in design and manufacturing – Servant or master? Social and labour effects of computer-aided design/computer-aided manufacturing (CAD/CAM)* (Geneva, ILO, 1987), Sectoral Activities Programme working paper, pp. 19 ff.

At the same time, the introduction of CIM may well act as an antidote to poor management practices. This is where the human factor comes in. Industrial case studies and experience accumulated so far clearly indicate that a pragmatic management approach that advances step by step, builds up the skills, responsibility and motivation of the workforce, invests in the people who are to operate the system and relies on the human factor to make it flexible, has consistently paid off best.

The conviction that this is really the case seems to be lacking in many management circles, otherwise a more systematic and consistent effort would be made to enhance the human factor. At all events, it has been found that in general CIM is not introduced primarily to "humanise" work. The motives and expectations of management have to do mostly with inventory reduction, greater transparency of the organisation, reduction of lead time, closer adherence to deadlines, saving of personnel, greater marketing flexibility, increased capacity use, higher product quality or the need to keep up with technological developments – all leading to higher productivity. Better working conditions tend to be a secondary consideration and to be regarded as a rather accidental by-product.[6] In fact, working conditions may even be neglected or grow worse, particularly where automated machinery is used to impose an accelerated pace of work, where only residual tasks are entrusted to workers or where the new tasks created by computerisation involve a higher degree of stress.

A new management style

A management style that allows production personnel greater autonomy may well mean a break with established principles and thus be seen as a threat to vested interests and the power structure in an organisation. Although it is not surprising that as a rule everything is done to avoid such clashes, it is in fact possible to switch to new technology without making fundamental organisational changes, and to keep established divisions and hierarchies in place. However, information technologies can also be used, where vested interests oppose restructuring, to institutionalise and even reinforce ineffective and counterproductive management practices such as excessive centralisation of decision-making or abusive monitoring of individuals. This is, of course, costly and leads to mediocre results while prolonging the life of organisational dinosaurs.

The successful introduction of CIM requires a clear strategy that has the backing of both senior management and the rank and file. Obviously nothing much can be done without the consistent support of top management; however, the stumbling block may prove to be middle management who stand to lose part of their influence when established hierarchies are dismantled and all needed information is available directly "on-line" to all

[6] Ebel and Ulrich, op. cit., pp. 53-57.

participants in the production process. This shows the need for top-level technology management, a function frequently neglected because legal, financial and marketing aspects tend to dominate decision-making at the top. It is not enough to let middle management acquire new technology and then to resort to crisis management at the top when bottlenecks occur in the organisation or the middle managers lack the necessary skills for handling the technology.

Some commentators have in fact traced existing problems to the lack of managerial competence.[7] Managers' knowledge of advanced manufacturing systems is frequently limited even when they have received a technical education or are professional engineers. Owing to the fast advances being made in manufacturing technology, and especially information technology, the professional knowledge and experience that managers have acquired rapidly become obsolete unless they are constantly exposed to shop-floor experience. Consequently, potential users of automation equipment, often fearing that they will not be able to muster and constantly update the know-how needed for operating the equipment, fall back on outside consultants and equipment suppliers. They naturally tread carefully in unknown territory and avoid incalculable risks.

Managers are also under pressure to justify the high capital expenditure required for implementing CIM. By the standards of a short-term return-on-investment (ROI) approach, the financial feasibility of most CIM projects is doubtful despite the hypothetical long-term economic advantages outlined above. In fact, there are no generally agreed methods for making reliable cost-benefit analyses of CIM, and the cost of full-scale CIM implementation is often considered to be prohibitive, especially when the cost of tailoring the system to the enterprise's specific uses is added to the cost of the equipment. It is also feared that CIM will be inefficient to use and expensive to maintain because technical change will constantly require the replacement of parts of the system, by definition not an easy job in an integrated package. To this should be added that in present flexible manufacturing systems fixed costs constitute about 70 per cent of the total outlay. This is one indication of the high risks that management takes when installing CIM.

There is, of course, the other side of the coin: the risks are balanced by opportunities if the expected economic benefits of CIM materialise. Moreover, in the years ahead the capital outlay required is bound to decrease as cheaper systems come on the market. It has also been estimated that CIM plants could break even at 30 to 35 per cent of capacity utilisation as against 65 to 70 per cent in the case of conventional plants.

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[7] R. Hodson and J. Hagan: "Skills and job commitment in high technology industries in the US", in *New Technology, Work and Employment* (Oxford), Autumn 1988.

Introducing CIM : A strategic decision

Costs are not the only element to be considered in making the strategic decision to introduce CIM. A responsible and forward-looking management may well conclude that the company cannot afford to be left behind in the technology race and that it must meet research and development expenditures for process technology and investment in CIM in order to remain competitive in the long run. Clearly, much depends on the specific situation of the enterprise. If it is decided to introduce CIM, management's essential task in implementing the system is to overcome organisational resistance to the change, from the shop-floor up through all layers of the organisation. To streamline an organisation and make it suitable for CIM may be a considerable challenge but may well be worth the effort. The findings of a number of surveys concur on this point: manufacturers who have introduced advanced manufacturing systems attribute between 40 and 70 per cent of the total improvement achieved to organisational changes. In other words, the main benefit does not necessarily stem from sophisticated and integrated technology itself but from the reform of management and production practices and from a more transparent and efficient organisation.[8]

The human and social perspective

The indispensable human factor

If we accept that a technocentric approach to CIM would be inefficient and counterproductive it follows that we must recognise the key role of the human factor. The difficult part is to assign a really effective function to the people involved, to help them master the production process and utilise to the full their knowledge, capabilities and skills.

It is important to look at the potential weaknesses and strengths of the human factor in a CIM environment. Human beings involved in the production process are apt to make mistakes, particularly when they are under physical or psychological stress. Noise or bad lighting can lead to fatigue. The rate of error also grows with information overload. Survey findings show that 70 to 90 per cent of the failures of technical systems are due to faulty human intervention or system design. Human beings do not always concentrate fully on their work: they sometimes come to wrong conclusions or fail to act when they should. Their behaviour at work can be unpredictable. Should the human being therefore be banished from the production process?

There is clearly a wide range of tasks and functions that are best done by machines, industrial robots and computers. The improvement of sensors and

[8] B. Haywood and J. Bessant: *The integration of production processes at firm level*, Brighton Polytechnic research paper (Brighton, 1987).

actuators makes robots and other production equipment more versatile, rapid and exact than human beings. Some jobs can be done far more efficiently and reliably by information systems and computers. This is particularly the case of routine functions such as data collection and statistical analysis as well as many surveying and control functions that serve as the basis for automatic process and quality control in production. Hence the execution of an increasing number of specialised functions can no doubt be transferred to machines and computers. We are therefore faced with a growing complexity of such technical systems.

As such systems become more complex, however, they also tend to be less fail-safe. In fact, they break down frequently, and the cost of such breakdowns is high. They can be perfected or repaired but this requires skilled human intervention and means that the workers responsible for the operation have to make choices and decisions that no technical system can make for them. Quick intervention based on experience and a knowledge of the system's limits is often required. Despite their shortcomings, human beings are thus indispensable for an optimal and efficient use of automated equipment. The qualified, motivated and experienced worker familiar with the system can cope with uncertainty and assess situations, find and interpret faults rapidly and correct them. Judgement backed up by technical knowledge and experience, understanding of the system and common sense is a human quality that cannot be replaced by computers or artificial intelligence in the foreseeable future. In CIM systems machines and computers may well take over most routine and physical tasks but they do not relieve the people involved from thinking, critical decision-making and responsibility.

The design of CIM systems

Since the human factor cannot be replaced it is essential to design and plan CIM systems in such a way that those working on them can do their job in the best possible conditions and can effectively apply their empirical knowledge. This means, first of all, that they must not be made totally and helplessly dependent on the system. Such dependence could have serious consequences when system errors cannot be corrected in good time. It also limits initiative, improvisation and creativity, and fosters blind reliance on routine which in turn makes the systems, and consequently the enterprise, vulnerable. Overdependence on systems and machines has not only caused disasters in nuclear and chemical industries but has also produced perhaps less spectacular, but none the less very costly, failures in automated production. Workers employed in "human-centred" CIM systems should be able to intervene in the production process in order to optimise it. This means that the system must allow shop-floor programming of CNC equipment on the basis of indications provided by and discussed with the design office. The implementation of such organisational principles presupposes the availability of appropriate man/machine interfaces and software. An example is a portable electronic sketch pad which designers can use to discuss their ideas with shop-floor personnel, thus helping to overcome their notorious divorce – accentuated by computer-aided design – from the realities and constraints of the production process.[9]

Another problem that has to be borne in mind is that there tends to be a greater physical distance between the personnel operating or supervising the equipment and the production process itself. Much visual and manual control has been replaced by sensors that transmit data to screens and data bases. The worker has before him control data at his workstation, but loses direct touch with the production process which often can only be monitored from a control room. It has been found that such distances from the process may make quick reaction and the correction or compensation of system faults more difficult because warnings emitted by the system can be misinterpreted or neglected and workers lose the "feeling" for the process. This means that the process must be designed transparently so that it is comprehensible and sufficiently accessible to the worker, without creating hazards, to allow him to make the required intervention. Some research conducted on the empirical knowledge of machines and materials that experienced skilled workers possess indicates that they develop a feeling, almost a sixth sense, that tells them what is wrong with a machine and how it works best. This capacity is precious and its importance for the smooth running of advanced manufacturing systems should not be underestimated.[10]

In the technocentric approach to CIM there is clearly a tendency to incorporate most production knowledge into the computer and expert systems without giving workers sufficient opportunity to exercise skills – skills that may then waste away from lack of use. This can make production systems very unwieldy and vulnerable. It can also erode the human knowledge base of the enterprise to such an extent as to put its future in jeopardy.

Moreover, there are signs that the technocentric approach may lead to the disaffection of the workforce. Research findings in the United States suggest that workers in high technology industries are less satisfied than other manufacturing workers because of more rigid rules, stricter discipline and closer supervision and monitoring.[11] Such disaffection has been noted particularly in the case of production workers who feel threatened by de-skilling. Management frequently tends to leave the trouble-shooting and maintenance and repair of advanced systems to specialised services and not to the operators of the equipment, and this neglect of shop-floor skills has led

[9] Paper presented by M. Cooley to a conference on vocational training as an investment in the future, Essen, 2-3 May 1988, cited in *BFZ Info* (Essen), 1988, No. 3, pp. 4-5.

[10] F. Böhle and B. Milkan: *Vom Handrad zum Bildschirm – Eine Untersuchung zur sinnlichen Erfahrung im Arbeitsprozess* (Munich, Campus Verlag, forthcoming).

[11] Hodson and Hagan, op. cit.

to a great increase in production down-time.[12] The obvious solution is to entrust as much responsibility for maintenance as possible to suitably qualified workers on the shop-floor.

The practical problems of taking all these aspects into account in designing CIM systems and of making optimal use of the human factor must not be underestimated even where such human-centred systems are recognised as superior. Though by no means easy to organise, a multidisciplinary approach is needed: managers and engineers responsible for designing the system should associate ergonomists, training specialists and social scientists in the work. There are few tried methods of proceeding since the technocentric approach, which neglects ergonomics and social concerns, has prevailed up to now. Moreover, engineers and ergonomists often tend to be at cross-purposes. This is certainly a field that requires further study.[13]

Skill requirements for CIM

The foregoing observations imply that there should be a rise in the level of skills of shop-floor workers, despite the fact that some of their present skills will become obsolete and trends towards the division of labour will be reversed. CIM requires versatile craftsmen and technicians, computer and software experts, mechanical and communications engineers and, in general, people who understand production methods and the system and are capable of handling a great deal of technical information and of taking decisions on the spot. These requirements go far beyond simple machine-tending. There is little room in CIM for unskilled workers such as assemblers, labourers, machine loaders and transport workers. CIM also renders redundant clerical workers engaged in ordering parts and materials and scheduling the workload of machines.

Middle-level managerial jobs are also bound to decrease or undergo changes in CIM systems because of the general dissemination and free flow of information. There tend to be fewer hierarchical levels and demarcation lines, and fewer co-ordinating tasks. The emphasis is on planning, anticipating problems, less formal communications, teamwork and interaction, and much less on giving instructions. Excessive monitoring of workers (which is technically possible) is best avoided because it can antagonise the very people needed to man the systems. There is a new world for team leadership in CIM which requires from managers a subtle combination of human, conceptual and technical skills.[14]

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[12] P. Chabert and P. Laperrousaz: "Modernisation – Attention aux idées reçues!", in *L'Usine nouvelle* (Paris), 21 Jan. 1988.

[13] J. M. Corbett: "Human centred advanced manufacturing systems: From rhetoric to reality", in *INFO Pack No. 4* (Karlsruhe, Committee on Social Effects of Automation, International Federation of Automatic Control), Mar. 1989.

[14] O. L. Crocker and R. Guelker: "The effects of robotics on the workplace", in *Personnel* (New York), Sep. 1988.

New types of work organisation

As many specialised jobs are abolished because of the reduced division of labour, work organisation tends towards the group pattern. Relatively autonomous groups are organised and their members perform complementary tasks; they must be versatile enough to handle a variety of jobs in order to keep the system running smoothly, and have the ability to co-operate and to communicate beyond narrow technical boundaries. They are given some autonomy in the choice of tasks and in planning their work. In this way existing qualifications can be used more efficiently and mutual coaching takes place. Such teamwork, if properly organised, results in greater job satisfaction.

However, this sort of participative work organisation is by no means an automatic outcome of introducing CIM. Management must consciously seek to overcome outdated, demotivating and unsuitable hierarchical forms of organisation, and this means shedding old power relationships, which is often a painful process fraught with pitfalls. Those who have a vested interest in maintaining the status quo are usually in a strong position. However, it should be some comfort to management deciding to base CIM on group technology that this type of production is usually less capital-intensive than full-scale CIM since it is less computerised and requires less costly software; the fact that many decisions are taken on the shop-floor also helps to make it flexible. Moreover, existing qualifications of the workforce can normally be used and few new ones are required. There is also a reduction of throughput time.[15]

Hazards in the new working environment

Although the new job requirements in CIM systems are gradually becoming better known, there is still much uncertainty about the new occupational safety and health hazards they may pose. It stands to reason that physical risks are diminished because fewer workers are in direct contact with production equipment and most production takes place without direct human intervention. On the other hand, the pace of work is usually faster and the amount of shift work greater, both factors that tend to increase fatigue and the risk of accidents. It has been found that work at computer terminals can be very stressful, particularly in the case of computer-aided design. There also tends to be more social isolation, with all of its detrimental effects.

A potentially very serious problem is that an increasing number of psychosomatic disorders appear to be caused by work with the new automated systems. Workers confronted with the expensive and complex equipment often do not feel up to the task assigned to them and have a sense

[15] Brödner, op. cit.

of being powerless to intervene in the production process though they are responsible for running it. The combination of great responsibility and insufficient qualifications to master the job at hand or to intervene can be extremely stressful. The stress may be aggravated by frequent breakdowns which have to be repaired quickly. A state of constant stress can lead to nervous and physical disorders and is said to affect a disproportionate number of workers in advanced manufacturing systems. While training and ergonomically designed workplaces may help to solve the problem, it can be averted more easily if system designers ensure from the outset that excessive demands are not placed on system users and maintenance staff. At the same time, however, they should not go to the opposite extreme and make jobs undemanding and monotonous, a factor that also causes stress.

Another cause for concern is the fact that work with CIM is more sedentary than traditional production work and requires more brainpower than muscle. As machines and robots take over materials and components handling, physical activity is greatly reduced and this too can be a serious threat to health. Countermeasures may well be needed.

A further cause of fatigue and stress is the poor design of much computer software. Much of it is not user-friendly and is ill adapted to actual workplace requirements. This can make man/machine interaction very difficult. "Cognitive" ergonomics addresses these problems. However, this is a relatively new science and improvements in software design that take into account research findings are only slowly forthcoming.

System designers, who usually have an exclusively technical or scientific background, tend to overlook such considerations when planning the installations. However, it is then that preventive measures must be taken. The increase this implies in planning and investment costs is insignificant compared with the cost of rectifying ergonomic mistakes once a system is installed.[16] The principal objective here should be the creation of humane working conditions, for only workers who are treated first and foremost as responsible human beings will be prepared to commit themselves to company goals. A definition of humane work that is apposite to the new technology is the following:

> Work is called humane if it does not damage the psycho-physical health of the worker, does not . . . impair his psycho-social well-being, meets his requirements and qualifications, allows him to exercise individual and/or collective control over working conditions and systems of work, and is able to contribute to the development of his personality in activating his potential and furthering his competences.[17]

[16] Wobbe, op. cit.

[17] T. Martin, E. Ulich and H.-J. Warnecke: "Appropriate automation for flexible manufacture", in R. Isermann (ed.): *Preprints*, 10th World Congress on Automatic Control, Munich, July 1987 (Laxenburg, Austria, International Federation of Automatic Control, 1987), Vol. 5, pp. 291-305.

The preparation of the workforce for CIM

If people are the key to successful CIM, obviously much hinges on their preparation for the new systems. In all industrialised countries there is a shortage of professional, technical and managerial personnel able and qualified to mastermind the implementation of CIM. There is no easy solution to the problem. But one way of tackling it is through the systematic training and further training of the workforce based on a strategy specifically designed for the purpose and endorsed by management and workers' representatives. Such training needs to be carried out mainly by the enterprises themselves in co-operation with system suppliers, since CIM systems are tailor-made to the particular requirements of enterprises and training institutes rarely have the necessary expertise in leading-edge technology.

Another path lies in the widest possible use of expert advice at the planning stage of CIM and an open discussion of alternatives among all those concerned – including the workers' representatives who far too often at present find themselves faced with a *fait accompli*. A thorough discussion of the economic, technical, organisational, and manpower requirements and of the objectives of a proposed innovation would facilitate an informed assessment of the social consequences and the negotiation of working conditions. In introducing CIM both management and the workforce are usually moving into uncharted territory and ought to recognise the fact.

The impact of CIM on industrial relations

In the real world the transition to CIM systems, even when they are well planned and prepared, will rarely be accomplished without creating tension or conflict. The workforce has good reason to be worried since there is ample evidence to show that its interests may not be taken sufficiently into account or may simply be neglected. Far too often technology is placed before people to cope with as they can, without having been properly trained to handle it or given a say in its choice. Small wonder that systems fail. Workers fear pay losses as a result of reduced overtime, redundancy, fewer promotion prospects and lower manning levels, de-skilling, greater stress, more intensive shift work, individual performance monitoring by the computer system, and the strain of having to adjust to unfamiliar working patterns.

By applying a strategy that puts people first and seeks genuine consultation at all levels, such fears can be overcome. The positive aspects of introducing advanced systems and the new opportunities they offer will be more readily accepted; these include safer and physically less taxing jobs, enhanced learning and training opportunities, greater responsibility and more interesting assignments, better remuneration, generally better working conditions or greater job security in a more competitive enterprise. The use of new systems can also bring down the rate of absenteeism. Innovations can, in fact, exert a beneficial influence on industrial relations if more emphasis is placed on consultation at all levels and less play is given to "the arrogant expertise of technologists".

The positive aspects can carry the day only in an atmosphere of social dialogue and good will at the enterprise level. Adversarial industrial relations might easily spell the failure of CIM projects. Their success presupposes reconciling the interests of management and workers and introducing flexibility in work rules. Dialogue between the social partners is thus essential for achieving product and process innovation and higher productivity and flexibility in manufacturing. There is evidence that in an adversarial climate of industrial relations management tends to resort to an excessive division of labour as a means of restricting the influence of unions. In such circumstances management avoids entrusting blue-collar workers with more autonomy and control (e.g. the programming of NC tools) in order to circumvent rules in collective bargaining agreements providing for the upgrading of workers who are assigned greater responsibilities. This situation has the perverse effect that unionisation – whenever it leads to restrictive and inflexible work rules – inhibits skill acquisition by blue-collar workers and their upgrading.[18]

A large degree of consensus and co-operation is indeed necessary if CIM systems are to work smoothly, though this does not exclude a resolute defence of the workers' rights and interests. It must not be forgotten that highly skilled workers and technicians in integrated manufacturing are in a strong position and cannot easily be replaced. Enterprises installing CIM depend on the quality and commitment of their workforce; qualified personnel are needed to maintain the complex and costly equipment and keep the system working. Moreover, advanced manufacturing systems are vulnerable to strikes by a small proportion of the workforce, and responsible management will therefore be well advised to seek the social dialogue and collective agreements needed to provide a proper framework for their operation. An unorganised workforce kept in check by management prerogatives and arbitrariness, subdued by authoritarian supervision and anti-union policies, could easily jeopardise the success of CIM. Industrial relations based on mutual confidence and respect will be far more conducive to success.[19]

However, it should also be borne in mind that as hierarchical structures change and as middle management is threatened by CIM the role of unions and workers' representatives in enterprises may be weakened. Autonomous groups of highly qualified staff may be able to exert a more direct influence

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[18] M. R. Kelley: "Unionization and job design under programmable automation", in *Industrial Relations* (Berkeley), Spring 1989.

[19] F.-J. Kador: "Das Soziale in High-tech-Unternehmen", in *Der Arbeitgeber* (Cologne), 1988, No. 3/40.

on the determination of their working conditions and thus feel less in need of union representation and intermediaries in their dealings with management.

In enterprises introducing a CIM system, social dialogue obviously cannot be limited to questions of remuneration and benefits. At any rate, payment-by-results systems may well have to be redesigned since the success of the CIM system and higher productivity depend essentially on the reduction of down-time of the automated equipment and not on the output of individual machine operators. The dialogue will have to embrace questions related to the implementation of the new technology, such as more flexible working time arrangements, adjusting working conditions to teamwork and redeployment.

Outlook

At present there is little chance of reconciling divergent views on CIM. Many of its advantages or faults are in the eye of the beholder. However, it is definitely not the panacea that some seem to see in it for all problems encountered in production. The promised land of total manufacturing integration is still far away, although an increasing number of enterprises appear to be engaged in an evolutionary process towards it.

At all events, the introduction of CIM is a risky undertaking. If it is to be successful the firm's manufacturing organisation and product range have to be reviewed and rationalised. The pace of transition will depend on the knowledge, qualifications and abilities of the planning and operating staff.

CIM is a leading-edge technology and its introduction requires long-term strategies, much research and development and, possibly, forgoing immediate financial benefits. The most essential element in such a strategy is the preparation of the workforce for the impending changes. This requires consultation at all levels and a systematic training effort. To neglect the further training of staff is inevitably very costly in terms of machine down-time and scrap production.

All experience gained so far speaks in favour of a cautious and gradual approach in order not to overstretch the assimilating and learning capacity of the workforce with the negative results which that implies. The fact remains that the trend towards more manufacturing integration is bound to continue and scientific advances will continue to offer solutions to outstanding technical problems. CIM is most likely to fail where it tries to supplant essential human qualities. The subjugation of people to machines and technical systems is proving more and more counterproductive. Instead, a type of work organisation is needed that enables and motivates people to use their theoretical and empirical knowledge and skills in mastering advanced means of production and operating them efficiently. CIM will be only as good as the people in charge of it.

Are we heading in the wrong direction? Evidence suggests that the difficulties and complexities of introducing CIM on a large scale were initially underestimated. The technocentric approach aiming at the "unmanned factory" is now questioned for a very good reason: so far it has failed to produce the expected results. This is having a sobering effect on the unconditional technocrats. There is probably not just one type of "factory of the future" but many alternative solutions to manufacturing problems.

Will CIM really spell the end of Taylorism? It is definitely too early to pronounce its methods dead and buried. Taylorism will continue to subsist in mass production alongside dedicated automation and machinery and so will the corresponding hierarchical structures. However, mass production and market dominance of mass-produced goods are declining in many manufacturing activities. The markets demand differentiated, diversified and customised products, entailing a need for small-batch production. The flexible automation offered by CIM can, if properly conceived, do the job.

Integrated manufacturing systems are very vulnerable to disruption. Running them efficiently and, so far as possible, round the clock presupposes harmonious industrial relations, since work stoppages, go-slows or other types of resistance stemming from demotivating working conditions can cause major losses. The success of CIM, therefore, presupposes mutual understanding and co-operation between management and the workforce and its representatives. While the introduction of even well-designed CIM systems is bound to cause tensions, it also offers new opportunities for enhancing dialogue and breaking down barriers between the social partners – a chance not to be missed.
