UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

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AN INTRODUCTION

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PREFACE

As part of its work on regional policy issues, the Regional and Country Studies Branch carries out policy-oriented studies and provides advisory services in key issues of industrial policy that affects groups of developing countries. These include issues of economic integration, issues in the relationship between technological change and industrial organization and policy issues in international cooperation for industrial development.

An important area of analysis is that of automation in industry. The spread of automation is having a profound impact on the manufacturing sector, both in terms of products and processes. It is associated with equally significant changes in the organization of industrial production. The effects of industrial automation in terms of costs and spread and flexibility, as well as in terms of reduced inputs of labour, are eroding cost advantages enjoyed by developing countries in traditionally labour intensive industries. In fact automation is associated with a general restructuring of world industry, and this finds expression in new and distributed forms of production.

UNIDO, in cooperation with the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria, has carried out a detailed examination of the impact of industrial automation and how it is changing the production process. The analysis examined policies, both at the national and the company level to make recommendations on approaches to automation for consideration by developing countries. The work covers the whole field of industrial automation, but there has been a special concentration on the textiles, clothing and footwear sectors. Financial support for the work has been provided by the Government of Finland.

A major survey of development has been published as "Trends in Industrial Automation", UNIDO/PPD.231(SPEC.). It examines types of automation and their diffusion. It summarises national policy requirements, trends in the costs of automation, the role of design, and education and training needs, together with organisational change. Based on this and other material, the present document has been prepared. It is intended to be a non-technical summary of the implications of automation, addressed to policy-makers, whether at government or enterprise level.

The present document has been prepared by the Regional and Country Studies Branch of UNIDO, in cooperation with Dr. P. Spinadel, Dr. W. Haywood, and Dr. P. Vuorinen as UNIDO consultants.

CONTENTS

1. COMPUTER INTEGRATED MANUFACTURING (CIM) AND DEVELOPING COUNTRIES

A new industrial revolution began with the development and diffusion of organizational changes and modern automation technologies. Although the first impact of this new industrial revolution is already being felt it will become increasingly strong in the years to come. After the middle of the 1970s the demand for mass-produced goods began to decline and many manufacturing industries were forced to produce customized products. The new market requirements called for medium to small batch product series, i.e. for flexibility in production.

The real history of automation in the manufacturing process began in the early 1950s with the introduction of numerical control (NC). This was just at the time when many rising industries in developed countries were concerned about the shrinking workforces. At the same time a number of population development studies, especially in Japan, drew attention to the fact that in the 1990s the increase in young workers would not keep pace with industrial requirements. The studies indicated that industrial automation could solve this problem.

Starting from the application of numerical control at the single machine tool level, the development continued with the integration of more than one machine and auxiliary support devices, such as material handling systems, tool handling systems and so on. The development of industrial robots occurred practically simultaneously with the computer based NC (CNC), but although the first industrial robot was developed in 1961, they only began to become important in later years.

With the introduction of the microprocessor the dependent situation between progress in computerized manufacturing and advances in information technology hardware (storage capacity, data processing time, reliability, cost, etc.) changed considerably and interest became focused on developments in software and communication aspects.

In contrast to traditional automation, in which chains of inflexible, special purpose equipment has to deal with the mass production of relatively homogeneous products, the new automation technology is flexible and applicable to a wide range of machine building operations. Information technology is used from the moment of product conception and development according to market information, up to its final delivery to the customer.

Industrial automation has developed very rapidly and often in a very unstructured way. But, in fact, flexible automation requires a "complete system" idea, beginning at the single production task and extending to the global concept of the plant layout.

Many industries have made studies that show that the benefits obtainable through technological improvements or work rationalization are beginning to taper off. This means that in future only a great technological leap or structural reform will enable a new increase in productivity. The success of this concept, called Computer Integrated Manufacturing (CIM), will depend on the way in which all the separate technologies are connected. The key to CIM and to reaching economic benefits lies in the understanding of the rules of the game between production objectives, technical components and the organizational structure of the industry.

CIM is the concept of a totally automated factory in which all manufacturing processes are integrated and controlled through computerized data linkages. All stages of production, from the design of the product and the ordering of materials through to its manufacture and shipment are included in the concept.

The introduction of CIM issues, like most new developments, has mostly been done in such a way that none of the expected results were reached while other new problems have arisen.

Rapid growth in automation technology and increased attention paid to it in the media have led to a number of misconceptions. CIM is sometimes represented as a panacea, something that can solve all problems. At other times it is put forward as a threat to employment and to the quality of life in general.

CIM is a concept; its application is different in individual cases. It would be better and more accurate to call it Computer and Human Integrated Manufacturing (CHIM).

Introducing CIM should begin with two steps:

Two Preliminary steps before CIM

- **Two steps must be taken into account when introducing CIM technologies:**

1. The first step must always be a thorough study of the enterprise. This study must be made from the top downwards, beginning at the management level and ending on the shop floor.

2. The second step should be the acquisition of decision support software for the management and intermediate levels that will be responsible for the information flow inside the industry, and for support for the medium- and long-term production planning.

Unfortunately, in most cases the first step has been the introduction of automation elements at the lower level, without consideration of future development and the need for communicating with a central system, or in cases where this communication exists, without consideration of the compatibility of the different elements.

Although considerable gains in efficiency can be obtained by the adoption of the new methods for factory organization, planning and scheduling and production control, as well as appropriate subcontracting policy, the reality is different. In fact in the last few years, the developed countries have been involved in correcting mistakes in the chaotic introduction of automation. Most of the industries in developing countries are still involved in this correction. For developing countries, now may be the best moment to try to learn from these errors and perhaps not only avoid widening of the technological gap, but reduce it. The key to this process will be to change the organizational structure of the industry.

The difference between the "best practice" of traditional manufacturing and that of the new is a very substantial improvement in the determinants of market competitiveness. Successful transition requires the adoption of new electronics-based automation technologies. In the short-term, the decisive factor often lies less in replacing machinery and equipment than in perfecting the way in which it is used. This means the introduction of new forms of production and work-organization. Without these prior changes in organization, there is little chance of success with the new automation technologies.

The pace of technological change is rapid and accelerating. Lead times between successive changes have shortened. Decision-makers at national and international levels now place greater emphasis on technology-related issues, and view them in much closer conjunction with other economic policies, including trade policies.

This means that developing countries have to incorporate the technology dimension into the mainstream of economic management and policy-making. In so doing, they have to strike a balance between short-term stabilization and adjustment objectives on the one hand, and longer-term trade and development objectives on the other.

2. BACKGROUND

The predominant mode of production in most developed countries includes large manufacturing enterprises usually producing goods in a continuous flow or process manner. Such companies have sought to exploit the benefits of "economies of scale" as a consequence of what has been termed "Fordist" production methods. This has made production "relatively" cheap.

But it has meant that quick response to customer needs has been difficult. Figures for such production show that up to 95 per cent of the time that material or components are on the shopfloor is spent waiting or being moved. Of the other 5 per cent, three fifths is spent being positioned, loaded or gauged, leaving two fifths (or just 2 per cent of shopfloor time) in which machining takes place.

The importance of organizationally linked adaptation can be gauged from a number of reports that 50 per cent, 60 per cent and even 90 per cent of the benefits of technologies as flexible manufacturing systems (FMS) come from the radical organizational changes which accompany the introduction of such technology.

The term innovation is used here to cover both the concept of technological and organizational adaption. Current levels of adaptation have to be related to previous experience and new and original concepts have to be developed. In this process, the knowledge gained and used does not come cheaply. A great deal of the knowledge that is important to the operation and improvement of a given process or product technology is "tacit", that is not easily embodied in a blueprint or operating manual. Much of the knowledge is highly firm specific and results from the interaction of R&D and other functions within the firm.

Innovation should cover not only changes within a firm, but also changes in the relationships between firms. The move is towards a "systemic" form of production. Individual companies operating in this way have become increasingly aware of the importance of establishing close contacts with their suppliers in order to secure the advantages of improved quality, rapid delivery and appropriate prices - though in many ways the last of these is becoming viewed as the least important factor.

The different forms of inter-firm collaboration are also very significantly more closely studied. One example is the relationship between firms and their subcontractors which is extremely important. It involves far more than the arm's length and price-based market interaction, and extends to design quality and supply questions.

Increasingly the "man-machine" interface has emerged as a crucial element for success. Experience from a number of studies has shown the importance that needs to be attached to organizational adaptation throughout the company, and the necessity to involve skilled and well trained personnel in the process of production.

A useful distinction can be drawn between "efficient" and "effective" production systems. The efficient systems represent a traditional (and rather stand-alone) approach to production. The effective systems are the new approach: they reflect not only the automation of production but also the way in which it adapts to meet the needs of a rapidly changing market. They do not necessarily fully replace all the goals of the efficient systems, but they certainly dominate.

EFFICIENT	EFFECTIVE
Conventional layout	Cellular layout
Process Organization	Product Organization
Long runs	Short runs
Large batches	Small Batches
Max. M/c utilization	Quick changeovers
Long lead times	Short lead times
Large stocks	Stocks minimized
Make to forecast	Make to order
Complex controls	Simple controls
High indirects	Lower indirects
High cost and customer insensitive	Lower costs and responsive to customers-JIT

Flexibility is a key theme, both in modern business philosophies and in the practical implementation of automation and other integrated production technologies. It means an ability to change rapidly the production parameters of an enterprise and to be prepared for a continuous change in markets. Changes can be qualitative and quantitave. The response has to be quick and it has to keep costs to a minimum. To a growing extent, large sales are not achieved by increasing production volumes, but by increasing product variety.

Manufacturers look for flexibility in a number of areas:

(a)	in product life - to permit frequent model changes.
(b)	in product range - to permit high levels of product differentiation and to produce to individual customer specifications.
(c)	in volume flexibility - to cope with fluctuating demand levels and match capacity better.
(d)	in routing - to make efficient use of plant, to avoid bottlenecks and consequent delays and to reduce response time.
(e)	in machining operations - to extend the range of tasks and products which can be made on a single piece of equipment and hence improve the utilization of capital.
(f)	in plant life - to permit the same elements of capital investment to be used for a different range of products.

They need a number of different kinds of flexibility:

Machine flexibility	the ease of making the changes required to produce a given set of part/product types.
Process flexibility	the ability to produce a given set of part/product types in different ways, each possibly using different materials.
Product flexibility	the ability to change over to produce a new (set of) part(s)/product(s) economically and quickly.
Routing flexibility	the ability to cope with breakdowns and continue producing a given set of part/product types, e.g. by processing via alternative routes, or using operations that can be performed on more than one machine.
Volume flexibility	the ability to operate a system profitably at different production volumes.
Expansion flexibility	the capability to expand the system in a modular way.
Operation flexibility	the ability to interchange the order of several different operations for each part/product type.
Production flexibility	a wide range choice of part/product types that the system can produce.

One basic feature in all dimensions of flexibility described above is that, in most cases, they contradict the short term efficiency targets. Thus it is never a question of maximizing but of reaching the optimal level of flexibility.

3. A SUMMARY OF AUTOMATION TECHNOLOGIES

3.1 Computer Aided Design (CAD) systems

Design is the way through which innovation is transformed into manufacturing practice. From the point of view of manufacturing, design is the starting point, and is more than just a pre-assembly function. It is the art of product conception itself, beginning with the definition of the future product's objective.

Design is a twofold function which includes the design of the products to be produced, and the design of the manufacturing process itself. However, in the traditional approach, the two design functions are regarded as separate. Either the process (including the machinery, factory layout, division of tasks and the organization for subassembly delivery) has been designed first, and products have to be designed that can actually be manufactured economically in the pre-existing process. Alternatively, products are designed independently, and the whole manufacturing process has to be designed according to the product's characteristics.

For the presentation of geometric objects, different models can be identified. Starting with two-dimensional forms of object presentation, an increased tendency towards three-dimensional presentation (solids) prevails today, due to the limitations of two-dimensional models when integrating new manufacturing methods. Computer-aided design (CAD) systems are thus the (partial) automation of the initial stage of production. At the user interface of a CAD-system the work of designers is supported by several "comfortable" instruments such as a tablet, a light pen or mouse, combined with high resolution screens.

Frequently these CAD systems are connected to host computers, whose functions are reduced to the management of geometric data and piece list information.

CAD systems can be based on various computer configurations, from large, expensive and sophisticated mainframe computers costing US$ 1m or more, through minicomputers costing approximately US$ 100,000 to simple personal computers (PCs) costing as little as US$ 2,000. The capability of such systems does, of course, vary tremendously but as the technology evolves and costs reduce per unit of computing power, the PCs gain in application and popularity.

Users are finding that personal computer-based systems often give them 70 per cent of the benefits for 20 per cent of the cost. This is reason enough for mass acceptance by the market and a whole new market segment has emerged. With an estimated 42,000 units installed globally at the end of March 1985, it is believed that already more than one-third of all CAD seats were based on PCs. The move to personal computers is expected to accelerate quickly now that more powerful machines with better displays are in the process of introduction.

Hardware and software is now available that it is suitable for applications in even very small companies. In the developed countries there is widespread diffusion of CAD in industries such as clothing, footwear, metal manufactures, etc. Since these industries are often the most important onces in developing countries, there is certainly some scope for the application of CAD. It should be noted, however, that a minimum number of product changes per year are thought necessary to make CAD a viable option, and one expert has put the figure at thirty to fifty.

In the final phase of the product cycle, only very minor changes in product design used to take place. At this stage it is more a question of finding new, lower market echelons and cutting production costs as low as possible. In the traditional approach, this was usually the phase when relocating production into low cost countries came into question. Thus, developing countries were not involved in either innovative product design and production process design. Their role in the global division of labour based on the idea of product life cycle was to produce mature products with conventional manufacturing technologies and systems based on the extensive use of cheap labour. CAD can play an important part in changing that role.

3.2 Numerically Controlled (NC) equipment

In conventional production, machines are operated manually according to work plans and drawings. Computer controlled manufacturing works with software programmes. These function as information carriers for job instructions and control measures.

Design (described above) determines the method for machining and assembling work-pieces or piece parts. By translating instructions into a form understandable to controllers of specific machines, robots or conveyers, a continuous flow of information from product development to manufacturing can be established. NC-machines can be regarded as the first components for the introduction of computer aided manufacturing (CAM). In the beginning they used punched tapes for information transfer. To attain more flexible methods of data transfer, CNC (computerized numerically controlled) machines were developed, enabling the direct transfer of machine programmes and their modification or correction at the machine itself.

A more advanced form of machine organization, a DNC (direct numerically controlled system), has a number of advantages when compared with conventional NC/CNC machines, but it also has disproportionate requirements of the control system and software. With a DNC system, several NC/CNC machines are directly controlled by a central computer. This manages NC-programmes and distributes them to single machines. Programmes can be made and altered on this computer.

NCMTs are now relatively low cost compared with ten years ago and they are widespread. In the developed countries there are skilled personnel to use them. Information links between manufacturers and their customers and suppliers are improving, in general, with the result that the machines are more in line with actual requirements.

All the projections suggest a very rapid NCMT diffusion during the period 1990-2000. This can be explained by the significant reduction of NCMT prices relative to those of conventional machines in the 1980s. The price ratio between conventional and NC lathes has reduced dramatically from the mid-1970s to the mid-1980s. The price ratio drops to three or four to one for lathes and to about three to one for boring machines in the mid-1980s. Given the higher productivity of NC machine tools (four times greater), NCMT implementation has become economically justified since the mid-1980s.

The rationale for the introduction of NCMT is that it allows a one off or small batch production (< 50 parts) to be changed into a more flow line process. In general, by far the largest share of production in manufacturing is in batch sizes of less than 50.

Because of their one consequence of this has been very low utilization of conventional machine tools. NCMTs clearly have a major role to play - the future. An average component will actually be having cutting operations performed on it for only about 1 per cent or 2 per cent of the time in the workshop. The potential of NCMTs may be realized through a combination of computerized machining and planning functions, allied to effective organizational control, e.g. Just-in-Time (JIT) parts control.

A productivity increase factor of 2 or 3 to 1 was found in the transition from conventional machines to NCMT; and from 2.5 to 6.5 to 1 in moving from using conventional machines to the adoption of Flexible Manufacturing Systems.

R&D in the field of NCMTs aims at simplification and easy use. Emphasis is also given to designing a product that can easily be manufactured at a low cost, i.e. through a reduction in the number of components in the machine. In manufacturing NCMTs, a large volume of output is required. A few firms produce their own CNC units. The main barriers to entry are economies of scale, access to a large marketing network, and design skills.

NCMTs for turning, boring, drilling and milling functions can be said to be mature technologies. By the latter half of the 1970s they had already moved to the stage in their product cycle where standardization and mass production were essential. Today, the main innovative efforts lie in system building.

The mature character of the technologies is reflected in the diffusion of NCMTs to smaller firms also. In Japan, firms with fewer than 300 employees have accounted for the majority of sales for some time. In terms of stock, data from the USA in 1983 revealed that 40 per cent of the number of NCMTs installed are in firms with less than 100 employees. In the period 1978-83, these firms accounted for 47 per cent of the market for NCMTs in the USA. Adding to this market share approximately 15 per cent from the group of firms with 100-300 employees, the share of "medium and small firms" in the market for NCMTs would be about the same as that in Japan in 1980. Hence, in the USA also the small- and medium-sized firms have accounted for the bulk of the market for some time.

In Japan, sales of NCMT to large firms increased by a factor of approximately 6 between 1970 and 1981. But sales to small firms (<300 employees) rose by a factor of almost 21, clearly a reflection of the Japanese suppliers' technology policy and the long established network of formal contacts which have been established between large and small firms, and buyers/suppliers.

3.3 Robotics

There is no readily accepted international definition of exactly what a robot is. For many years even simple pick and place equipment was considered to be a part of the robot "family", especially in Japan. However, a gradual consensus is emerging and the definition adopted by the British Robotics Association (BRA) is probably becoming accepted as the standard: An industrial robot is a reprogrammable device designed to both manipulate and transport parts, tools, or specialized manufacturing implements through variable programmed motions for the performance of specific manufacturing tasks.

The main drawback of first generation robots is that they cannot obtain information concerning their work environment. They therefore require well-structured environments involving expensive and inflexible fixtures and parts-orientation devices. In addition they must also be programmed on line, i.e., taught a particular sequence of movements on the shop floor.

As a result, product-specific fixtures, grippers, and parts-feeders may account for between a half and two-thirds of the total cost of a first-generation system. Second-generation robots are more expensive, but in principle at least the cost of such fixtures should be significantly reduced, and they promise the ability to be programmed off-line, allowing better computer integration. However, serious technical obstacles still exist:

(a)	Sensors are still relatively expensive and require considerable computational power to translate signals into appropriate action;
(b)	Information from sensors cannot readily be fed into robot or process control systems;
(c)	There is still no single interface standard. Compliance with Manufacturing Automation Protocol (MAP) is still the exception rather than the rule, and in any case MAP does not deal with software compatibility;
(d)	On-line programming languages are still used extensively, but are unsuitable for CIM;
(e)	Current off-line languages cannot exploit CAD databases in real time, and are unable to incorporate sensor input or the effect of tool compliance;
(f)	The absolute positional accuracy of existing robots still results in deviations between the geometric model used off-line and actual conditions on the shop floor.

Consequently, existing sensor-based, second-generation robotic applications are expensive and application-specific, rather than cheaper and more flexible than their first-generation counterparts. For example. the use of machine vision usually requires the use of special light sources, high optical-contrast between parts and environment, accurate positioning of cameras and parts, and dedicated programming. Flexibility is sacrificed to ensure system robustness and reliability.

Trends in the use of robotics technology are towards increasing diffusion across sectors, firm sizes and applications. Assembly automation is set to become a much larger user in the medium-term future. Indeed, since the development of the SCARA (Selective Compliance Assembly Robot Arm) robots in Japan for general purpose assembly tasks this area has experienced the most rapid growth, both in Japan and in other countries. Future diffusion to other sectors and to smaller firms will depend critically on improvement in the flexibility of robots - since this will increasingly enable them to be cost-justified on the basis of factors other than labour cost. Robots remain, at present, relatively unintelligent and insensitive tools. They are not yet capable of the necessary judgement and adaptation for carrying out the majority of tasks in manufacturing. This is particularly a problem in clothing where the characteristics of the materials present major problems for robotics.

Among key technological developments currently being explored are:

Direct drive robots, in which motors are directly connected to arm joints rather than via gears and transmissions.
Advanced sensors, especially in image processing for vision systems.
Improved, more sensitive grippers.
Artificial intelligence based programming so that robots can "learn" from their own mistakes.
Off-line programming with CAD-Systems and data base linkages.

However, the adoption of robots will be a function of the size and scale of the user. Companies with large volumes of investment capital and employing considerable numbers of people are the ones likely to invest in IRs. Developing countries, in general, do not have many companies operating on this scale.

3.4 Flexible Manufacturing Systems (FMS)/Flexible Manufacturing Cells (FMCs)

Developments in the NC-techniques sector have been mainly concentrated on the machining (cutting) sector, resulting in the introduction of flexible manufacturing systems (FMS).

Today, many researchers consider that FMS is an approach to a particular set of manufacturing problems rather than a single technological configuration.

Although the idea of FMS was created almost twenty years ago, it only started to be of significant interest to the research community in the early 1980's.

FMS cannot be regarded as a new technology which can be installed and operated in the same way as traditional machine tools, aiming at a reduction of labour costs. FMS is rather a new philosophy. It uses computerized methods to "transfer" the advantages of industrial scale production to -lot or job-production also. The key word "flexibility" characterizes the ability of the system to be automatically adaptable to different manufacturing conditions (to produce different products) with minimal set-up times.

FMS vendors are simplifying and standardizing them to make them more marketable to potential users.

Current trends favour simpler systems, the setting-up of which do not present so many problems. The stage of prototypes is passing, being followed by a period of industrial applications. However it will take another few years before the full cycle of this new generation of workshops, mainly based on standard and modules, can be evaluated.

As with most other technologies, FMS have been installed first in large companies in specific industrial sectors, e.g., automobiles, aerospace, agricultural/earthmoving equipment, etc. The early FMS were not particularly flexible, or even economic, though systems are now becoming more rational due to longer periods of planning, a greater concentration on training for the people who run them, and more realistic goals being set.

Users have also been made aware of the fact that there are many intangible benefits of FMS. For instance, FMS can raise quality levels and shorten lead times. This may alter existing or potential customers' perceptions of the company and thus increase orders. The more tangible benefits include reduced costs, increased equipment utilization rates, reduced inventory and work in progress, etc.

There are, however, costs associated with the technology, e.g., increased training outlay, (although this is actually an investment in the future), increased costs in fixtures, jigs, tools, greater planning, system maintenance, etc. In many instances, because the cost of a system is high compared with a conventional workshop, this involves multiple shift working.

Benefits of FMS use by company size

Size of firm (no. of employees)	Lead time (per cent)	Work in progress (per cent)	Machine utilization (per cent)
1-500	-66	-66	+45
501-1000	-76	-63	+50
1000+	-86	-70	+55
United Kingdom: average (50 firms)	-74	-68	+52
Sweden: average (20 firms)	-69	-60	+74

Successful FMS/FMCs use often entails dramatic changes in the way that companies operate. This may involve the breaking down of hierarchical or structural distinctions between jobs, the devolving of authority and responsibility back to shopfloor workers, much tighter links into suppliers and customers, and the adoption of a total quality approach to manufacturing.

The main component of growth up to the mid-1990s will be of rather simple and customized systems. It is likely that as more of the software, organizational and integration problems are resolved in the late 1990s, rather more sophisticated systems will again emerge.

The potential of FMS are of the following order of magnitude as compared with conventional systems:

(a)	Labour costs: savings of 30 per cent or more;
(b)	Material costs: savings of 13-15 per cent;
(c)	Inventory and work in progress: reductions of 50 per cent or more;
(d)	Lead time: very substantial reductions, on average of 40 per cent. Examples of reductions in lead time from 15 to 2 days or even from 16 days to 16 hours;
(e)	Machine utilization: average increase of 30 per cent;
(f)	Number of machines: examples include reductions from 31 to 6 machines and from 80 to 12 machines. However, requirements for ancillary equipment - e.g. AGVs, robots etc. - are increased;
(g)	Floor space: reductions of more than 50 per cent;
(h)	Total production costs: reductions of 14-27 per cent; and
(i)	Operating profits: increases of 112-310 per cent.

While machining systems will probably remain the main focus of FMS, increasingly attention will centre on assembly FMS which are likely to become widespread in the first decade of the next century.

FMS is now diffusing broadly through industrial sectors and this will continue to occur as the "philosophy" of FMS spreads. This will be as relevant to the clothing, textiles and footwear industries, as it will to engineering, furniture making, injection moulding, foundries, etc.

First the NICs and then other developing countries - including those East European countries experiencing market pressures in and from the OECD countries - will adopt higher levels of FMS.

3.5 General automation

Automation strategy should not start from technology but from business strategy.

The main questions are:

What are the targets the firm wants to reach?
Which of these can be reached by organizational changes?
What could be the role of automation technology?
What are the costs and benefits of technology introduction?
What other changes are necessary to reap most benefits from the technology?

The response to these questions has often been in terms of organizational change. In large concerns this has meant a radical decentralization of power and move away from the existing organizational hierarchies. Diverse business areas are now dealt with by establishing independent companies often with only common ownership and very general strategic management under the umbrella of the giant enterprise. Factories and other functional units have gained more independence in strategic target formulation, decision making and practical operations.

After reorganization, relationships between different divisions, units and other parts of the concern are determined in a more equal, cooperative way based on substantial factors and common long term development targets, not on orders and control from central management. The independent units have, of course, full freedom to develop their external relations with other firms and organizations outside the enterprise.

They are responsible to the central enterprise management only in terms of very general business results.

The main aims of these changes are:

(a) to gain more flexibility at the enterprise level in order to reallocate resources rapidly from one area to another;
(b) to create a cooperative organization of independent units that are all able to react rapidly to market and technology changes;
(c) to motivate management and personnel in the units to more innovative and committed activity.

Such networks of independent units working in long term cooperation are not created only within companies. Even more important are networks between firms and concerns. Networks are an outcome of a trend, where firms - instead of horizontal diversification or vertical integration - concentrate on the core business where their key skills are. Supportive functions and even parts of the main activities are to a growing extent discontinued as part of the firms' activities. Instead, they are acquired through various contracts and other arrangements from outside sources. Through these contracts enterprises create a network of strategic alliances with other companies.

Strategic alliances are created in all directions from the enterprise:

1.	Backwards in the production chain: to a growing extent, intermediates are obtained through long term subcontracting, where the partners are linked to each other such as by continuous technological development in both products and processes.
2.	Forwards in the production chain: finishing, marketing and other functions following the core activities are subcontracted in the same way as obtaining intermediates. Technological links are involved here as well.
3.	To supportive and complementary functions: many supportive services are acquired through alliance creating contracts. This is especially typical for research and development functions but also for more common business services involving assets of medium specificity. This kind of horizontal strategic alliances - e.g. using the same trade marks in marketing - are also created with companies whose product variety can be used to complement the firm's product range.
4.	To competitors: strategic alliances between competitors are - with the growing complexity of technology and markets - becoming more and more common. The most typical are alliances on basic research, but marketing alliances (eg. as market cooperation limited to some regions) between competitors are not unusual either.

By splitting up the rigid, integrated hierarchical concern model and replacing it with a business organization based on strategic alliances, the enterprise gains more overall flexibility. It also enhances its abilities both to get information from all its interfaces and to react more rapidly to the changes. Individual - independent or autonomous - parts within the network can react faster to changes than - hierarchically commanded - parts of a rigid concern. Again, it is easier to change partners and create new linkages within the network than within a closed concern structure. Today, networks are often the most economic solution to the "buy or make" question.

From the small firm's point of view, creating networking relations is even more important than for large concerns. Even a technologically competent firm is powerless alone without the necessary connections and linkages to all outside interfaces. This is especially true for companies in technologically developed sectors, where firm resources and internal skills are inadequate even for many vital activities.

There are two basic pressures for change particularly in the small- to medium-sized batch area (an area in which approximately 70 per cent of all manufacturing companies find themselves located, i.e., with average batch sizes of less than 50 parts).

First, internal pressures. There is a wide range of traditional problems which are endemic in many firms, a few of which are listed below:

High inventory levels tying up large amounts of capital;
Low machine utilization;
Poor delivery performance;
Poor production control.

Second, external pressures. These mean that increasingly companies must respond quickly to customer requirements, and display "agility" in reacting to markets increasingly resemble the fashion industry in changing customer consumer tastes.

These require:

Shorter lead times for delivery purposes;
High and consistent quality in the product;
Meeting increasingly customized markets.

What is called for here is more flexibility and responsiveness -- factors that might be called "improved manufacturing agility".

(a)	New production technologies reduce interruptions in the production process and make quality control more reliable.
(b)	New technologies facilitate organizational changes which increase productivity; eg some service/assembly activities may be passed to customers or deliverers.
(c)	New technologies offer possibilities to take advantage of increasing returns to scale either by allowing the production of larger lots, or by favouring concentration.
(d)	In many sectors, automation promotes flexibility through which firms can obtain economies of scale through economies of scope.
(e)	New technologies reinforce dynamic competition, and thus lead to process innovations in sectors unable to gain competitiveness by product innovations.

4. SELECTING TECHNOLOGY

Selecting the right technology is not enough. The "environment" also needs attention if the technology choice is to be effective. Frequently there is inadequate concentration on the infrastructural framework which supports the use of new technologies.

The kinds of infrastructural failures include:

Inadequate levels of formal education;
Low emphasis on vocational training;
Poorly maintained or non-existent logistical systems, e.g., transport, communications;
Low emphasis on management skills;
Poorly developed buyer/supplier relationships;
Restrictive trade and technology policies.

The role of individual technologies varies according to the type of change that is sought. In the following table the main stages of factory automation development are categorized according to the aim of change, actions needed and the main technology.

Stage	Aim	Action	Elemental technology
1.	Improvement of productivity at the level of working machine and the working process.	Automation in individual work and working machine.	NCMT: automated selection and exchange of tools, automated loading and unloading of work, automated replacement of palettes, machining center abnormality and surveillance system.
2.	Improvement of productivity at the level of processing system and the parts.	Automation in the group of working machines and in part of indirect work.	FMCs, FMS: Processing information, distinctive automated processing system, roller conveyor, unmanned transport vehicle between the FMCs, automated control of jigs and tolls, FMCs group control system.
3.	Improvement of productivity at the level of the factory.	Coupling with CAD/CAM, distribution system such as the automated warehouse, development and manufacturing, and control and manufacturing.	FMS: Automated whole process control surveillance and control system, automated warehouse system, unmanned factory transport system, factory communication system.
4.	Improvement of productivity at the level of the factory head office and including manufacturing.	Coupling with marketing information and developing design and manufacturing activity, unified control of goods and information, and unification of control information and engineering information.	FMS, CIM: Communications network, LAN, MAP data base system, comprehensive management control technology.

During normal operations, the control systems of a factory have to receive a lot of digitized information (starting from the level of sensors up to the level of complete data sheets). For a fully automated system, this data flow must be multi-directional, providing the whole company (from the senior management through the departments of sales and distribution, handling, warehousing, material purchasing, product design and development, and so on down to the machine operator on the shop floor), with the necessary information and all needed parts, tools and materials, at the appropriate place and at the appropriate time.

Because of the need to make compatible all languages and protocols used for the industry, by using bridges, gates and converters, the idea of establishing a universal communication protocol arose. The first step in this direction was the publication of the Open System Interconnecting (OSI) model by the International Standardization Organization (ISO) in 1978. This ISO-OSI model has been almost universally accepted as a pattern for local area network (LAN) developments in both the factory and the office.

The second step was completed with the development of a specification based on the existing ISO-OSI seven layer model as a framework for many established and emerging networking standards. This development was called the Manufacturing Automation Protocol (MAP). At the same time, a working group in Europe began to develop the CNMA protocol which differs only by a few points from the MAP ideas.

MAP may be described as enabling technology which specifies only standard protocols to facilitate the connection between equipment from many different vendors on a network without the need for customer-developed communications hardware and software. This situation gives the manufacturers a choice of appropriate manufacturing equipment vendors, without worrying about compatibility.

The MAP or the CNMA standardization work allows multivendor communication between different hardware elements, but it does not represent a complete solution. A lot of work has to be done at the higher levels, where the applications communicate with one another. It is very important to have a normalized communication so that one application software can communicate with another and exchange information at the programme level, and not only through a "file transfer management system".

5. SKILLS FOR TECHNOLOGICAL DEVELOPMENT

Acquiring the relevant skills for technological development is a complicated matter. The roots are in the national education system and the curricula. However, the theoretical and basic qualifications while necessary are not sufficient in themselves. Most skills needed are of a more practical nature and highly specific in relation to the technology, organization and firm in question. To acquire these skills there is a need for specific training courses, apprenticeships, and learning by doing, in addition to the basic education requirements.

Clearly, recent high technology research and development (R&D) in most industrialized countries has prompted both fundamental and incremental innovations which have offered new opportunities for companies - both the suppliers and users of such equipment. Those technologies, such as flexible automation, computers, and robotics require somewhat different levels and types of skill in the people using them than did their more traditional equipment predecessors.

Cooperative research programmes alone are insufficient to transform the innovative performance of technically backward industries and firms. More is needed, specifically the development of sufficient expertise within these firms to utilize the results of externally performed research. Where such expertise is lacking, cooperative research organizations often have been unsuccessful in industry. The difficulties inherent in the provision of research on a contractual or arm's-length basis can undercut the effectiveness of these organizations to industries with little or no in-house R&D activity.

There are many business targets that can be reached by using automation technologies and many strategic options that can take advantage of automation. However, very often widespread applications of programmable automation are associated with a business strategy called flexible specialization. New automation offers the best technical possibilities for realizing the strategy, and the advantages of the technologies are often best exploited through the strategy. Flexible specialization is often seen as the key element in the new "post Fordist" manufacturing strategy challenging traditional manufacturing thinking based on Taylorist and/or Fordist ideas on business, on manufacturing organization and on relations between machinery and human skills.

Among the core ideas of flexible specialization are the following:

1.	Specialization is a basic condition for flexibility. A company has to decrease both its horizontal diversification and its vertical integration. For a large company this often means a tight commitment to the traditionally strongest business area; for a smaller firm it means the need to define a very clear main business area and target all operations into this field.
2.	The basic difference between flexible and conventional (rigid) specialization is the emphasis on quality. This means that quality thinking has to spread throughout the company. The Japanese Total Quality Control-ideology is a good example of this.
3.	Within the chosen area of specialization the company will operate very flexibly. Product variety will be increased within the decreased product area. This often implies an effort to develop customized products, where the provision of a total service package - selling design, installation, training and maintenance as a part of the physical product - becomes an important dimension of competition.
4.	When the company is manufacturing customized products to order, the timing and precision of delivery become very important. The company may focus on competing with very short delivery times - with quick service products - or it may build a competitive strategy on the long term quick response principle, on the ability to adapt rapidly to market changes.

For large firms, the shift to a strategy of flexibility is in the first instance market driven. Changes in the market compel the introduction of more flexibility into a previously rigid production process.

For small- and medium-sized firms, the technology push (the possibilities of gaining economies of scale through economies of scope) is more central. For them the introduction of flexible automation may even mean decreased flexibility, but increased competitivity in the field previously dominated by large firms. Those firms that have least difficulty in changing direction also have a higher percentage of skilled workers.

In order to make new technology efficient and profitable, it is essential not only to make good use of old vocational skills, but also to add new ones. The old skilis are needed in order to understand the process and materials - something which becomes increasingly important as the process of change becomes more important. But it is also necessary to learn new skills, such as how to programme the equipment. When production becomes automated on a large scale, as in the process industry for example, the process operators need to understand not only the process and how it is controlled but also how the computer controls the controls.

This contradiction is not leading to a polarization in the skills of the labour force in the traditional sense. At least not in the skills of the young labour force: the polarization line goes within different segments of the labour market, and partly between age and educational groups. The older employers within more traditional industries and old fashioned firms are the losers; youngsters with high education - and active to a growing extent within the modern segments of economy - are the winners.

Flexible companies do not have much use for traditional workers who tend to do what they are asked to do and work mainly for the wage. This kind of traditional wage labourer attitude and motivation to work is not enough for modern manufacturing firms. Many characteristics traditionally typical of entrepreneurs and independent professionals are to a growing extent also expected from shop floor workers. Modern manufacturing firms with advanced flexible technologies are looking for employees that are:

1.	Deeply committed to their work.
2.	Fitting in with the culture of the firm and its customers.
3.	Capable of continuous flexible reorganization in their own workplace.
4.	Motivated and receptive to continuous training in new tasks.

This does not mean, however, that directly relevant qualifications - knowing what to do in order to reach a certain, preset result - are less important. For example, in metal manufacturing machining jobs both new and traditional productive skills are needed.

Traditional machining skills are required, even though they are not usually needed every day, in at least three contexts:

(a)	The operator has to master the basics of manual machining in order to know how the objects to be machined behave during machining, to know what kind of machining is possible with various materials and what is not;
(b)	Traditional skills are also needed in unusual/crisis situations where the machinery has to be operated manually;
(c)	When production requirements override the flexibility of the system; not all components and parts can be manufactured with modern technologies (e.g. individual objects with parameters very different to other components), and may require manual machining with older equipment.

In addition to the traditional manual skills, new qualifications specific to numerically controlled equipment are required. Some of these - e.g. programming - can be allocated to external personnel. However, experience in flexible production has shown that both programming and manufacturing results are usually better if the programmer is also a user of the system.

Consequently, the skill needs in flexible production using advanced automation are as a rule more complex and demanding than in traditional, manual manufacturing. In principle, it is possible to apply more traditional divisions of labour where tasks with new skill needs are separated from basic operative tasks. Many organizational solutions are possible, as discussed above. However, in production with teams consisting of extensively trained, qualified workers with good motivation and high commitment to work, the results are usually better in terms, for example. of undisturbed machine utilization and better quality products than when using a workforce with a more hierarchical division of skills and tasks.

In conclusion, it would appear that wider diffusion of advanced, flexible manufacturing is linked to a new model of organizational thinking based on a highly skilled work force. The following issues are typical:

1.	The enterprise has to be seen as a human, collective organization; one that allows continuous personal development in work.
2.	A new conception of authority is needed that stresses the responsibility rather than the superiority of managers. This approach means a continuous dialogue within the company and also means the acceptance of trade unions as partners in the enterprise.
3.	Rigid structures are replaced by "operational teams". The decentralized approach allows a wide autonomy.

Organizational renewal based on wide use of human skills requires, of course, good training and education. This involves all levels of education: the national systems for basic, vocational, higher and further/adult education as well as firm, sector and technology specific training for new technologies.

Japan is an interesting case of long-term technological development largely based on extensive investment in training and education. The absolute number of young people acquiring secondary and higher levels of education in Japan is among the highest in the world. The scale and quality of industrial training carried out mainly at enterprise level is also high. This second feature goes back to earlier efforts to assimilate foreign technology. Some large Japanese firms already had extensive high level technical training before the First World War.

The combination of a high level of general education and scientific culture with thorough practical training and frequent up-dating in industry is the basis for flexibility and adaptability in the work-force and high-quality standards. The Japanese system of industrial training is distinguished further by its close integration with product and process innovation. The aim is to acquaint those affected by technical change with the problems that are likely to arise, and give them some understanding of the relationship between various operations in the firm. This again greatly facilitates the horizontal flow of information. Thus the "systems" approach is inculcated at all levels of the work-force and not only at top management level.

The Japanese example highlights the importance of not only extensive and high quality education, but also the need to have training closely linked to industry. In this sense, the German system of vocational training is also a good example. Germany is another country - in addition to Japan and the Nordic countries - where the skill-based model of flexible automation is applied to a growing extent.

The German system of vocational education is based on apprenticeship contracts, where the trainees learn the work itself in an industrial firm and then acquire theoretical learning in a school environment. The advantage of this system is the live contact with real industrial work and the interaction of theoretical and practical learning.

(a)	Theoretical learning without real connexion to practical applications is often not learned well enough and will be lost;
(b)	Vocational trainees often lose motivation if the education is too much like studying in a school atmosphere.

The planning of education in such a way that it can answer the needs of future working life becomes critical for all countries trying to reach higher levels of technological development. This is true for both the secondary vocational education and for higher scientific and technological education.

Recently, adult education, further education and retraining have been given major emphasis. The concept of "continuous education" or "lifelong education" is widely seen as a basic theme in all education and training development. Important considerations on education and training in relation to flexible automation are:

Mastering technical change implies, to a large extent, mastering the generation of skills and knowledge, i.e. vocational education and training.
The key role of vocational education and training is closely connected with the organization of work. The organizational requirements in generating and utilizing skills are more important than the technical requirements.
Mastering technical change through improving skills raises the problem not only of individual but also collective skills. Differentiated specialist skills have to be integrated. This requires an organization and a strategy based on team work, cooperation and changing task description.
For smaller firms, supportive networks should be developed to make training, specialist human resources, consultancy, development, marketing and other services more available to them.
This is required in order to assist them in turning their asset of organizational flexibility to more effective use in the prevailing context of technical change. Relations between companies and with their environment are increasingly characterized by greater interdependence.
Further training appears as a new, strategically important element in companies. It poses acute problems to small- and medium-sized companies which need support networks.

6. GUIDELINES

The use of Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Flexible Manufacturing Systems (FMS), Automated Guided Vehicles (AGVs) and Robotics are only a few of the technologies which have been intended to upgrade production potential in order to meet increased competition.

There are also organizational factors in the effective implementation of new technology:

(a)	Low risk, low cost changes in production methods, such as group technology or just-in-time systems may bring significant benefits more rapidly than high risk technological investments such as FMS. For small- to medium-sized firms this may represent a more viable option than full scale technology-based factory renewal.
(b)	Strategy for change: It could be that the "island of automation" approach is the correct one, or organizational change, or quantum leaps in technology, or simultaneous organization and technology changes. Options and consequences need to be examined very thoroughly. Perhaps more attention should be paid to simulation exercises geared towards a post-installation analysis of existing systems.
(c)	Functional structures and hierarchies need to be adapted. Traditional Tayloristic approaches may be less than appropriate for integrated tasks and the skills that will be required in the future. In particular, in the developed countries there is considerable discussion of devolving power and autonomy back to the shopfloor, using skilled labour as a key integrative interface.
(d)	A consequence of traditional patterns of organization has been long vertical hierarchies in firms. This is likely to be increasingly challenged by the needs of integrated technologies. The trend towards flatter and less structurally functional occupations is being accelerated. This is a result of the introduction of information technology and the organizational changes that this brings, with both vertical and horizontal movement occurring.
(e)	Companies need to achieve closer links with perhaps a more limited number of suppliers, i.e., the so-called "preferential supplier" relationship. Many benefits come from this organizational readjustment which involves improved product quality, reduced units costs, and improved delivery performances. Traditional linkages between suppliers and users have focused on price negotiation, but evidence suggest that a radical change in this pattern is required. The use of electronics-based technologies for interactions between suppliers, manufacturers and customers should be increased.
(f)	Although there is growing evidence regarding the problems posed by integrated technologies and the need for organizational adaptation, there has been relatively little work done in this field. Factors such as education and training, job design, and organizational development interventions need much more attention, since these will prove to be increasingly important factors if developing countries wish to improve their adoption of new technologies, and with them their competitive position. A decision not to adopt more effective means of production means a decision to remain reliant on the sale of primary products or low value added manufactures.

6.1 Things to avoid

Over reliance on traditional advantages

For developing countries, things will be very difficult in the future if reliance is placed merely on low cost labour as a competitive advantage. Other strategies are also needed.

Raw materials, agriculture and basic, low value-added products are a traditional form of development and advantage and these can, and do, provide stepping stones to further development. Yet they are not enough in themselves. At some point countries must transcend these modes of development and focus on manufactured products with high quality characteristics, perhaps aimed at niche markets, but certainly based upon long-term, well thought out policies of development.

Price factors are not the only and not even the major issues behind success; management design and engineering skills often play a more critical role in explaining differences in performance. Sustained manufactures exporting cannot be achieved based only on short-run cost advantages. The role of product quality has increased and is to a growing extent ranked above price factors in market competition.

Avoid short-term programmes that bring a "spurious" competitiveness based on factors such as low interest loans, tax benefits and so on. The programme must be based on technological changes and better working conditions through a better distribution of the benefits.

Introduction of new automation technologies should not be a target

Introducing new manufacturing technologies should neither be a target as such nor should it be considered independently of organizational changes.

Automation in itself is no business target. The introduction of new manufacturing technologies is always based on business considerations, such as raising productivity and efficiency, or increasing production volumes. The diffusion of conventional automation was mainly based on the aims of reducing production costs - especially labour costs - and increasing the technical reliability of the production process. In the case of programmable, flexible automation these objectives still remain, but the need to automate is essentially based on other targets.

The fully automated factory should not be a target

The division introduced by the Taylorist doctrine of scientific management states that planning takes place before production and is outside the production process both organizationally and as an activity. Within the production process the supervisor takes care of the practical organization; the worker only has to fill the gaps in the system. In some cases, manpower planning is confined mainly to minimizing the labour requirements.

This has been the fundamental approach also in respect of complex automation technologies. The basic target has been to create a fully automatic factory, with no or only a minimum of human intervention. Experience has, however, resulted in a questioning of this approach. With growing technological complexity, the number of unforeseeable situations and problems increases. The systems simply can not be preplanned. With growing flexibility the need for user interventions becomes even more important and there are ever fewer possibilities of planning a complete range of human tasks in advance.

Do not copy! Study and adapt to your own situation

It is important that developing countries take account of local conditions, size of markets, labour relations, degree of skills, logistical systems, financial and monetary institutions, etc., and that they do not attempt to follow blindly an industrialized country or Japanese model of development.

Machine purchase should be a consequence, not a prerequisite

Merely buying a new technology is no guarantee that it will be utilized effectively if both implicit and explicit knowledge are insufficiently developed. Any consideration of a production system must take into account not merely the machines but also the people who have to manage and operate them. Thus the man/machine interface becomes increasingly important in full competitive terms. Do not simplify the problem by a "machine purchase", this will never be a solution but will only present a bigger problem.

Productivity increase is not a direct consequence of automation

Much of the improvement in performance in companies in developed countries has stemmed from organizational or institutional changes preceding the technological changes, or at least alongside them.

The ability to link the whole chain of a company's activities from design through materials processing, manufacture, packaging and transfer has increased dramatically - but is still in its early stages. Nonetheless, its potential in manufacturing currently appears unlimited.

Product innovation through process innovation

There is a distinction between "product" and "process" innovation. The former presents considerable difficulties for developing countries. The latter presents considerable potential. In many instances, organizational or institutional innovations may provide substantial improvements for such countries, and probably at much less cost than a simple reliance on new technology.

Robots can wait

Robots have developed quite considerably over the years but are still relatively inefficient and expensive for the modes and scales of production carried out in most developing countries.

Since this is a technology which is largely labour replacing, it is probably the least relevant of the four technologies from a developing country perspective. In addition to being expensive, robots require considerable computational power. Sensors are not yet highly developed, there are few interface standards, off-line languages cannot exploit CAD databases, and positional accuracy can be somewhat off target.

The technology has been applied in fairly specific industrial sectors, such as motor vehicles, mechanical engineering and, in a more general context, in fairly large companies.

Inhibiting factors in the diffusion of robotics, even in developed countries, include:

- shortages of trained personnel to maintain or support the technology;
- only large firms can afford multi-purchases thus justifying robots economically;
- payback normally involves at least two shifts' work per day.

The Japanese are the pioneers par excellence of flexible automation. This is not due to superior robot or related technology, but to faster implementation of the new production techniques backed up by new organizational methods.

The road to FMS/FMCs is a long and difficult one

For the introduction of FMS/FMCs, detailed pre-installation work is required. This may take up to a two year period of feasibility studies if the wrong choice of configuration and operation is to be avoided. All the interfaces need to be assessed in an integrated approach to production and a high level of management and workshop personnel is needed. They should include:

- a high level project leader - preferably one of the three or four most senior persons in the company, who must have a knowledge of the industrial process;
- a top level methods expert;
- a planner with production/management expertise;
- a senior representative of the buying department with strong links to the equipment supply industry;
- a production planning and inventory control expert;
- a senior representative of the personnel department;
- last, but certainly not least, a top level manufacturing engineer.

Clearly, if such a grouping of personnel is required for implementing FMS/FMCs in the most developed countries, considerable barriers - though not insurmountable ones - are raised for developing countries.

Avoid confrontations

Automation as a whole will lead to a gradual transformation of employment structures and there will be consistent changes in skill requirements both in existing jobs and industries and, in particular, in the new jobs and industries being created. This calls for considerable analysis and planning in developing countries, and perhaps the development of not merely a skilled workforce, but a multi-skilled one.

Avoid confrontation between capital and labour by creating awareness programmes with trade union leaders, progressive entrepreneurs and government officials.

6.2 Areas to examine

Optimize the influence of changes

Introduce advances that could act as a generator or motor for the industrial system and ensure a multiplier effect in industrial productivity. This requires a good understanding of how industry works and what its linkages are.

Maximize the direct and indirect benefits in local society.

Design for manufacturing

Many significant changes have to take place within product design. Among the main points are:

A reduction in the number of parts which compose the product.
An increase in the number of standardized parts.
Modular design which makes it easier to test, to build and to offer a broad product mix and yet to have low inventories and short delivery time.
Jigless production, i.e., avoiding jigs and fixtures as much as possible in order to reduce set up times (or using jigs and fixtures with uncomplicated set-ups).
Taking into consideration the machine capabilities and the potential problems related to the use of certain parts or methods for assembling parts.
Using software that helps designers to evaluate the manufacturability of the design.

Design is, in fact, a kind of industrial creation. From the point of view of manufacturing, design is the starting point and is more than just a pre-assembly function. It is the art of product conception itself, beginning with the definition of the future product's objective. Design has to be integrated into research. It impinges on the whole management of the firm, its internal organization, communications and compartmentization of different services.

The advent of information technology has created a radical transformation of production possibilities which has provided the opportunity to integrate manufacturing processes in a way no earlier technologies have offered.

Discussions on technology policy and the experience of developed countries stress the importance of infrastructure for technological development. The importance of logistical systems on the one hand and human skills on the other are critical for developments in manufacturing technologies. Logistical infrastructures are physical conditions for setting up modern production facilities and human skills are critical factors for using them.

6.3 Things to do

Create national and regional information centres

There is a specific need to spread information on the use and possibilities of new technologies. This could be done through, for example, establishing specific "information technology centres" with differing targets, e.g., CAD centres. There are many possible alternative forms for this kind of centre but it is important that it is in close contact and cooperation with educational and training institutes as well as with firms.

Encourage bilateral transfer and communication between industries and universities.

Create a regional information system to promote contacts between the existing institutions and projects.

Provide support for the provision of information and advisory services regarding specific technologies. In both economic and technical terms CAD and NCMT are technologies appropriate for diffusion.

Provide support for consultancy services and feasibility studies on appropriate technologies.

Use the power of the demonstration effect

Demonstration sites allow the technologies to be seen in action, and people to gain hands-on experience.

Use practical demonstrations of new technologies (Video, PC, etc.).

Narrow the gap between industry and educational institutions

A considerably greater concentration on education, skills and training is needed at all levels. There is clear evidence from the experiences of the developed countries that this was the starting point of a "virtuous circle" of success.

There is a need to:

1.	Considerably expand the system of vocational education in the most important fields of the economy.
2.	Update technical facilities for teaching, especially for teaching computer-related subjects. The general level of computer literacy - even familiarity with computers - is all too low to meet the needs of the modern economy; and trainers are often poorly qualified.
3.	Narrow the gap between industry and educational institutions. This could be done for example by introducing elements of the Central European dual education system to vocational education. In this case students would be alternating between school and factory; practical training would be given in the factory and theoretical teaching explaining the things learned by doing in the school.
4.	University students involved in management and technology studies should spend more time in industrial firms during their studies as should, in general, all students. They should also be given the opportunity to learn at first hand about the latest developments through training abroad wherever possible.
5.	There should be more publicly aided systems for training the personnel of firms. This could be done by either opening the training institutes of large firms to other companies, or by establishing cooperative training centres perhaps jointly funded by private companies and the public sector. This kind of training centre could operate with the technology demonstration centres proposed in the previous chapter. This kind of model - based on cooperation between public authorities, local companies and technology suppliers - has proved to be rather successful, for example, in Sweden.

Develop training programmes at all levels

The more complicated the production technologies installed, the more modifications, alterations and adjustments in the technology as well as experience in operation are needed before the optimal level of operation is reached. In the case of FMS, this often takes years after the installation. Thus, in technology transfer the recipient organization has to be capable of developing further the acquired technology. In this, local capability development is a crucial condition for continuous and accumulating technological change.

CAD+NCMTs = a good combination for developing countries

As with CAD, the utilization of NCMTs is imperative for industrial development. These innovations result in improved quality in the product, improved delivery performance, savings in materials, and can also compensate for scarce skills. The increased productivity they create also justifies them economically.

Some combination of CAD and NCMT tools would prove a valuable, indeed indispensable, form of manufacturing. Production based on these two technologies would help developing countries to produce higher quality goods, more rapidly, at lower cost, and using indigenous design capabilities; and could lead to broader industrial development, in an expanding range of industries.

Short-term thinking = short-time living

Long-term strategies have to be adopted and in many instances for developing countries this will take decades rather than a few years. The precedents are clear: Germany, Japan, Sweden, just three countries which are now successful in international terms have spent decades putting in place social systems which have created skilled, educated workforces capable of moving along consensus lines to highly developed economies. This provided the catalyst or "virtuous circle" for success. Changes in learning and skills are essential and this is only possible with a fully developed educational system at all levels, including vocational and adult education.

Thus, a concept of skill based production where continuous training and flexible automation are combined needs a total approach. In conclusion, the approach has to include:

1.	The development of coordinated skills;
2.	Design and re-design for manufacture;
3.	A joint technological/organizational approach to change;
4.	Closely coordinated buyer/supplier relationships;
5.	Allocating to the computer what it is best at;
6.	To allocate people to do what they are best at.

The USA, Japan and Germany achieved their success - over a very long period of time - by building powerful infrastructures with highly developed educational, social and logistical underpinning. All developing countries should be aware of the degree of effort and time that lay behind this trend towards world competitive success.

Set up industry clubs

To provide, as far as possible, a long-term programme of support in order to eliminate uncertainty on the part of industrialists though not so long that these programmes create over-dependence on the part of companies.

To encourage inter-firm collaboration both in an engineering sense and in a modern buyer/supplier sense. In addition to this, to help create stronger links between educational and technology research institutes and the bodies they are intended to serve, i.e., the manufacturing industry.

Help in organizational adaptation. In many companies visited in the case study countries, management expe:tise was weak and based on traditional structures. The whole system of managerial control and organizational structures needs to be modernized by less hierarchical or functional activities and by the adoption of Just-in-Time (JIT), Total Quality Management (TQM), etc.

Companies need direct aid in getting information on production technology developments and making technology acquisition decisions. This could be arranged for example through sectoral research institutes, branch organizations or parastatal holding companies employing personnel specialized in information gathering, and creating contacts to sources of technological information abroad. The specialists should carry out contract tasks to individual firms, to help them both in creating contacts to technology suppliers and in technology contract issues.

Quite similar aid is needed by firms in technology assimilation and adoption matters. In this case, however, the need is for highly specialized knowledge on production technologies and for long term support, which starts before the actual implementation of new technologies and continues until the new system has been totally incorporated into the everyday activities of the firm.

As for the importance of this idea of an Industry Club, some characteristics are:

(a)	Independence of the product, i.e. the system must be capable of adapting itself to the manufacture of different types of products with very modifications.
(b)	Independence of the hardware and software being used: The system should be independent from software and hardware elements with which it interacts. This means that at the system level only resources with determined economic and temporary characteristics and not determined elements will exist. This requires a definition of clear interfaces simple enough to be able to communicate with elements from different suppliers without too much extra effort.
(c)	Practically demonstrable: The system must be in a position to manufacture some kind of product. After studying the specific needs of the market, a product must be selected which is flexible enough to be easily produced in different types and different variations of this types.
(d)	Flexible software: The software must be easily expandable to allow for a step-by-step introduction into the industry. Its design must therefore be modular.
(e)	Flexible hardware: The system to be controlled must be easily expandable.

6.4 Future developments

Look at future developments in the robotics sector

Given the forms of production most developing countries possess, and their surplus of low cost labour, robots are not amongst the most useful forms of automation which could be applicable -- and we do not believe this is likely to change in the short term.

However, robots can be fairly extensively utilized even in the NICs and, as industrial development grows and technology reaches a more mature state, robotics may become more extensively used providing the industrial structure allows for this, e.g., the size of companies and the sectors they operate within.

Expect cross-advantages from the introduction of a technology

The most important savings in automation investments have often come from the rationalization, simplification and integration of production planning. But organizational changes bring new complexities into the picture. For example, in implementing FMS the production arrangements are changed in many dimensions. FMS will not necessarily perform all the tasks previously done by the old machinery. However, where the need arises, such tasks can be relocated in other departments in the factory. Correspondingly, FMS are quite likely to get tasks from other units in the factory as well. Thus it is rather difficult to calculate the overall labour effects, even at the level of one system. At the whole factory level, the effects are even more complex.

Follow the employment effects of advanced production technologies

In the short run, introducing flexible automation and other new production technologies can have either negative or positive employment effects, depending on the economic situation of the firm and the country and on the way technology is implemented and managed.

In the long run, reticence to introduce modern production technology can only cause negative employment effects. It is a relatively common conviction that automation will lead to a gradual transformation of employment structures at the national level. There are several trends involved. In occupational terms, the basic tendency seems to be a shift from manual to mental work - an increase in indirect production/support work tasks and a decrease in direct, physical work. This is documented by both national and individual enterprise employment data. In terms of occupations, there has been a general shift from industrial occupations to services and, further, to information occupations.

Automation is causing changes in skill requirements both in existing work and, in particular, in the new jobs created. Productive qualifications - practical skills - have to be complemented by more theoretical skills, technological and scientific knowledge. Even in practical terms, multidisciplinary skills are required to a growing extent.

There seems to be a circular relationship between skills and use of automation: with better skilled people, new organizational forms can be applied and technologies used more effectively. Then again, by developing team cooperation and through learning by using technologies, skills are developed further, the technological system can be refined and new benefits reaped.

Education and training	Skilled workers	Organizational renewal	Better use of automation	Higher skill needed

The introduction of CAD can also have widespread effects on occupation, as follows:

(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. systems 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 specializations of existing ones, e.g. CAD coordination 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.