OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

16071

Distr.
LIMITED

PPD.81
25 May 1988

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

ENGLISH

PRODUCTION AND USE OF MACHINE TOOLS IN SELECTED DEVELOPING COUNTRIES

Milan, Italy, 14-22 October 1987

Report

Sectoral Working Paper Series

No. 67

Sectoral Studies Branch
Industrial Policy and Perspectives Division

V.88-25027
4640T

SECTORAL WORKING PAPERS

In the course of the work on major sectoral studies carried out by UNIDO, Studies and Research Division, several working papers are produced by the secretariat and by outside experts. Selected papers that are believed to be of interest to a wider audience are presented in the Sectoral Working Papers series. These papers are more exploratory and tentative than the sectoral studies. They are therefore subject to revision and modification before being incorporated into the sectoral studies.

This document has been reproduced without formal editing.

The designations employed and the presentation of material in this document do not imply the expression of any opinion whatsoever on the part of the secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Mention of company names and commercial products does not imply the endorsement of UNIDO.

The views expressed in the present document do not necessarily reflect the views of the UNIDO secretariat.

Preface

This document presents the conclusions and recommendations of a seminar on the production and use of machine tools in developing countries organized by UNIDO and UCIMU in Milan, Italy. The document also presents an overview on the issues of developing countries with respect to industrial automation in the capital goods industry which were discussed at the seminar.

The seminar was hosted by the Italian Machine Tools Manufacturers Association (UCIMU) and took place during the 7th International Machine Tool Exhibition (EMO) in Milan, Italy, 14-22 October 1987. It was financed by a special contribution by the Government of Italy. UNIDO expresses its appreciation to the host organization and to the Italian Government for the generous contributions that made this seminar possible.

CONTENTS

Figure

Chart

EXPLANATORY NOTES

References to dollars ($) are to United States dollars, unless otherwise stated.

A comma (,) is used to distinguish thousands and millions

A full stop (.) is used to indicate decimals.

A slash between dates (e.g., 1980/81) indicates a crop year, financial year or academic year.

Use of a hyphen between dates (e.g., 1960-1965) indicates the full period involved, including the beginning and end years.

Metric tons have been used throughout.

The following forms have been used in tables:

Three dots (...) indicate that data are not available or are not separately reported.

A dash (-) indicates that the amount is nil or negligible.

A blank indicates that the item is not applicable.

Totals may not add up precisely because of roundi

Besides the common abbreviations, symbols and terms and those accepted by the International System of Units (SI), the following abbreviations and contractions have been used in this report:

Economic and technical abbreviations

AGV	Automatic guided vehicles
AI	Artificial intelligence
AME	Automated manufacturing equipment
AMH	Automated materials handling
CAD	Computer-aided design
CAM	Computer-aided manufacturing
CECIMO	European Committee for Co-operation of the Machine Tools Industries
CIM	Computer integrated manufacturing
CNC	Computer numerical control
CNCMTs	Computer numerically controlled machine tools
FMC	Flexible manufacturing cell
FMM	Flexible manufacturing module
FMS	Flexible manufacturing systems
GT	Group Technology
IA	Industrial automation
IRs	Industrial robots
ISO	International Standards Organization
LAN	Local area networks
MAP	Manufacturing automation protocol
MIR	Manipulating industrial robot
NC	Numerical control
NICs	Newly industrializing countries
TNCs	Transnational corporations

1. ORGANIZATION OF THE SEMINAR

1.1 Introduction

The UNIDO/UCIMU Seminar on Production and Use of Machine Tools in Selected Developing Countries, was convened at Milan, Italy, during the 7th EMO (International Machine Tool Exhibition), from 14 to 22 October 1987. It was attended by national experts from Argentina, Colombia, Venezuela, Trinidad and Tobago, Turkey, People's Republic of China, Peru, India, Malaysia, Philippines, Sri Lanka, Nepal, Tunisia and Tanzania; international experts of UNIDO from Sweden, France, United Kingdom, Federal Republic of Germany and Belgium; and observers from different enterprises and universities in Italy. The Italian Machine Tools Manufacturers Association, UCIMU, hosted the Seminar and invited as main speaker to the opening session Prof. Gian Maria Gros Pietro of the University of Turin. The list of participants is attached as annex 1.

EMO is the largest and most comprehensive machine tool fair of its kind in the world. Every two years the fair presents the entire range of machine tool technology, equipment, systems, materials, accessories and auxiliary components. It includes also flexible manufacturing systems (FMD); machine division, the latest technological developments in robotics, CAD/CAM - CIM, and all of the technology machine tool producers and users need to know.

Initial contacts between UNIDO and UCIMU for the organization of this Seminar were made in Singapore in November 1986 during the machine tool exhibition METALASIA. At this time UNIDO/SEC had organized a Technical Working Group on Production and Use of Machine Tools in the Engineering Industry of ESCAP Developing Countries (UC/RAS/86/020), jointly with the UNIDO/ESCAP Division of Industry, Technology and Human Settlements, which was also held in Singapore, from 17-21 November 1986.

1.2 Opening session

Mr. Cesare Manfredi, Vice-President of UCIMU, welcomed the participants to the Seminar and wished them a fruitful and pleasant stay in Milan during the 7th EMO. He pointed out the importance of the event in the context of the high intensive technology involved in the machine tool industry. The EMO comprises 1,650 exhibitors from 37 countries representing 98 per cent of the machine tools world production, with a value of around 750 billions Italian Lira ($US 6.3 billions).

He indicated that the joint organization of the Seminar with UNIDO was a matter of pride for UCIMU, and it could open new possibilities for the role of both organizations. In this context, Italian industry could be seen as offering not only tailored technologies, but also instruments to better manage the acquired technologies.

These instruments have been developed by Italian M3T, a society created by UCIMU to meet the demand for vocational training through the supply of teaching instruments, from machines to textbooks necessary to teach trainees how to use correctly Italian machine tools. From the practical point of view, Italian M3T offered a series of teaching modules, which could be adapted to the requirements of the various labour markets and to specific trainee attitudes, so as to get all bodies and companies operating in different economical and manufacturing situations interested in their own training projects, as well as people employed in the mechanical industry.

The original Italian M3T formula has already found concrete application in the People's Republic of China, Brazil, Argentina, Peru, in Bolivia and in other developing countries, and this is seen as a matching of the Italian readiness to share its own technologies with the aspirations towards progress of both peoples and governments in developing countries.

The Head of the Sectoral Studies Branch of UNIDO addressed the participants on behalf of the Director-General of UNIDO. He expressed the appreciation of UNIDO to the Italian Machine Tools Manufacturers Association, UCIMU, for hosting this meeting and particularly to the Italian Government for having financed this Seminar through a special-purpose contribution to the Industrial Development Fund maintained by UNIDO. This is a tangible proof that the Italian Government's commitment to industrial development has made it possible to ensure as broad a participation as possible from the developing regions of the world.

As an organization committed to promoting and accelerating industrial development in the developing countries, the Director General expressed that UNIDO's keen interest in industrial automation and technological innovation in the capital goods sector which are of strategic importance to the economic development of the developing countries. The Seminar had been accordingly designed to familiarize participants from developing countries with the structural transformation of the capital goods industry in industrialized countries that has come about primarily as a result of the new technological developments and industrial automation in the machine tool industry. More specifically, the Seminar offered an analysis of the impact of new technological developments in the machine tool industry, on the basis of which technical assistance programmes related to new technological developments in the capital goods industry could be formulated.

The Director-General indicated that UNIDO was equally confident that this Seminar has been able to establish the investment required for technology transfer in the field of industrial automation and for the establishment of productive structures in developing countries, on the basis of joint ventures between industrialized and developing countries and among developing countries themselves. He described the UNIDO network of Investment Promotion Services, which successfully promoted $US 265.3 million worth of projects in 1986, and over $US 4 billion in the past seven years. UNIDO has investment promotion offices in Cologne, Paris, Seoul, Tokyo, Vienna, Warsaw, Washington and Zurich which provide developing countries with direct access to technological, managerial and financial resources in industrialized countries. Together, these offices allow companies to channel technology packages and technical expertise and a forum in which they can work out licensing and joint venture arrangements. A new office was opened in Milan on Monday, 19 October 1987.

1.3 Election of officers

The Seminar unanimously elected Dr. Jorge Mendez Munevar (Colombia), President of the Colombian Metal Working Manufacturing Association, FEDEMETAL, as Chairman; Mr. C.R. Nagendran (India), Director of HMT International, as Vice-Chairman and Mr. Damodaran (Tanzania), Technical Manager of Cotex Metals and Machinery, as Rapporteur.

1.4 Agenda, programme and organization of work

The Seminar adopted the following agenda:

(a) Opening of the Seminar;
(b) Election of Chairman, Vice-Chairman and Rapporteur;
(c) Adoption of the agenda and organization of the work;
(d) Presentation of the issues;
(e) Discussions of the issues;
(f) Conclusions and recommendations for further action;
(g) Adoption of the report.

The programme adopted in the Seminar is attached as annex 2.

1.5 Documents

The list of documents distributed in the Seminar is attached as annex 3.

1.6 Adoption of the report

The report was adopted by the Seminar on Thursday, 22 October 1988.

2. INTRODUCTORY PRESENTATION:

The situation of the Italian machine tool industry in view of new technological developments, by Prof. Gian Maria Gros Pietro, University of Turin, Italy

The situation of the Italian machine tool industry can be considered as quite favourable. It is characterized by a normalized surplus of foreign trade which has been steadily growing in the long term, while Italy appears as one of the few manufacturing countries able to defend its share of world exports against the rapid growth of Asian countries. This positive assessment of the present situation is strengthened by the consideration that during the last years exports have been concentrating on countries at higher levels of technology.

Indeed, the present state of the Italian industry is the result of the changes made in its product composition. Such changes have lead to a reorganization of industrial facilities, too.

The dominant factor in the technological transformation was the growth of NC techniques and of flexible automation. The introduction of these technologies in the various products has implied an increase of them as a whole, an extension of machining cycles and a rise in the unit cost of machines. For companies, this has resulted in heavier investments and in more problems in finding or training skilled employees.

The new conditions were therefore less favourable for small-sized firms. Some indicators, such as turnover per employee, seem to be better for larger firms, even within the typical limits of a sector which is not intended for mass production.

The choice of new manufacturing solutions has encouraged a change in the demand composition for the different kinds of machines, which was combined with new product policies adopted by manufacturers. The result was an increase of the productive lots of some machines as compared to others. For example, in the field of NC units, the lots of milling machines increased considerably, whilst they decreased for lathes.

For the Italian machine tool industry, 1986 was the third consecutive year of sales growth (6.7 per cent over 1985). However, this positive result is to be ascribed to different patterns of demand components:

- Exports remained practically at the same level as in 1985 in real terms;

- Domestic demand recorded a 20.4 per cent growth at constant prices and 16.5 per cent sales growth at constant prices;

- A brisk domestic market led to an upsurge of imports (28.2 per cent at constant prices).

In 1986 the share of Italian exports in the world market increased from 3.3 per cent in 1985 to 3.5 per cent. Consequently, as a whole, the share of production in the world total increased from 5.0 per cent in 1985 to 5.6 per cent in 1986.

In 1986, Italian machine tools consumption was extremely high (a growth of 20.4 per cent at constant prices over 1985). Orders acquired by Italian machine tools manufacturers on the domestic market increased especially in the first half of the year (growth of 28.5 per cent at constant prices over the same period of 1985). On average, in 1986 domestic orders recorded a 15.9 per cent growth at constant prices over 1985.

The Italian machine tool exports increased at an average annual rate of 12.2 per cent in the period 1980-1986. In the same period, imports recorded an average annual growth rate of 9.2 per cent. This situation is based on the world specialization process within which the Italian industry is quite active.

This is indicated by the analysis of the composition of Italian exports and imports in terms of about 90 types of machines. In the same period 1980-1986 overall export and import indexes increased by 45.9 per cent and 14 per cent respectively. This means that exports and, to a lower extent, imports are progressively focusing on particular types of machines. Analysis of 1986 by main families of machines indicates a despecialization only for non-traditionally operated machines and for gear-making machines. These featured index values below zero because of a deficit of the export-import balance. For all other groups of machines specialization indicator values were positive. More specifically, as regards broaching, boring and forging machines, high specialization was combined with extremely favourable terms of trade. This means that Italian industry holds top segments as far as these products are concerned.

Future prospects are of a further raise in the technological level, above all as far as integrated units, cells and flexible systems are concerned. The present rate of growth of such equipment is indeed very high as compared to a slow increase in the demand for "stand alone" units.

Present trends favour the development of some specific production lines, such as for example robotics. This emerging industry is still dominated by small-sized firms due to the limited trading opportunities. However, some larger businesses are now consolidating in this field. This yields some advantages related to the firm size, but this in any case remains, on the average, smaller than that of manufacturers of machine tools.

As far as the future trends for international trade are concerned, forecasts seem to confirm those of recent years. From the point of view of exports, the main destination will be highly developed countries, whilst imports could mostly involve developing countries, even through the formula of co-operation initiatives with Italian firms.

3. OVERVIEW OF ISSUES FOR DEVELOPING COUNTRIES

Several sectoral studies have pointed out the critical importance of the machine tool industry in capital goods technology. It covers a wide range of equipment for metal cutting and metal forming and varies in technical complexity. In developing countries with no capital goods industry and also in countries with only an embryonic base, products and technology have to be very carefully selected in order to avoid an initial dependence on highly complex technologies which cannot be readily absorbed. Experience in machine tool manufacture shows that in countries where there is an adequate growth of technological infrastructures, technology acquisition through licensing from industrialized countries may be desirable for entry into further stages of technological complexity.

The introduction of flexible automation devices in the engineering industry of the industrialized countries constitutes a revolutionary technological breakthrough. It is the most important technological transformation in the capital goods sector since the introduction of electricity and the steam engine. This technological breakthrough occurred after a long period of relative stability with regard to production technology in the capital goods sector. In the next few decades, the consequences of flexible automation for the productive organization of production, competitiveness and employment will be considerable.

The most important microelectronics based technologies in the capital goods sector are:

- Computer numerically controlled machine tools (CNCMTs);
- Computer-aided design (CAD) systems;
- Industrial robots (IRs);
- Flexible manufacturing systems (FMS).

The technological transformation is taking place mainly in industrialized countries. However, the four technologies listed above are also spreading to the more advanced developing countries, although at a slower rate.

This transformation certainly has important implications for the majority of the developing countries since they are part of the same international techno-economic system as the industrialized countries. Those developing countries to which the flexible automation technologies have not been diffused at all are also affected. This technological transformation certainly affects the gap between developed and developing countries, as well as the magnitude and structure of production costs in various types of countries. Therefore, it also has consequences for the relative competitiveness of firms in various countries, for the international division of labour, subcontracting and other aspects of the international location of production. It is within this context that the developing countries have to formulate their industrial and technology policies. These developments will affect all countries, irrespective of whether they introduce the advanced technologies in their own economy or not.

The electronics-based automation technologies have not been widely spread among developing countries, being mainly limited to the most advanced developing countries. There are, however, certain differences between the four technologies from the point of view of their diffusion. CNCMTs is the technology which has been diffused to the largest extent in the most advanced developing countries. In spite of this, the growth in investments in CNCMTs in these countries is not large enough for them to catch up with the industrialized countries. The use of industrial robots has been very limited in developing countries partly because robots mainly save on unskilled labour and at the same time require new engineering skills. FMS is largely nonexistent in developing countries, mainly because it is an immature and very complex process technology. CAS systems have been diffused in the most advanced developing countries, e.g. the Republic of Korea and Brazil. However, CAD could spread quite rapidly in developing countries thanks to the very recent and very substantial decrease in cost, related to the emergence of personal computer-based CAD systems. Developing countries may be able to use CAD for catching-up in the field of design, since the CAD software embodies accumulated design and drafting experience. Such experience is at present a scarce resource in most developing countries.

The discussions in the Seminar addressed issues in the use and production of machine tools and CNC machine tools, CAD/CAM systems, industrial robots and FMS in the engineering industries of developing countries and especially:

(a) The need for machine tools and CNC machine tools by the engineering industries of the developing countries concerned, as well as technical assistance needs.

(b) The technical requirements for introducing the most recent technology in machine tools, and in particular the CNC ones in relation to the level of technology in selected developing countries.

(c) Possible investment requirements to transfer technology and initiate production in selected developing countries, through co-operation agreements between industrialized and developing countries and among developing countries themselves.

3.1 <u>The diffusion of flexible automation technologies in the capital goods industry in the OECD countries: implications for developing countries and their possible responses, by Prof. Charles Edquist, University of Linköping, Sweden</u>

The ongoing introduction of flexible automation devices in the engineering industry of the industrialized countries constitutes a revolutionary technological breakthrough. It is the most important technological transformation in the capital goods sector since the introduction of electricity and the steam engine. This technological breakthrough occurred after a long period of relative stability with regard to production technology in the capital goods sector. In the next few decades, the consequences of flexible automation for productivity, organization of production, competitiveness and employment will be comprehensive.

The most important microelectronics based technologies in the capital goods sector are:

- Computer numerically controlled machine tools (CNCMTs);
- Computer aided design (CAD) systems;
- Industrial robots (IRs); and
- Flexible manufacturing systems (FMS).

These four technologies are together often called flexible automation technologies. They are the main elements of the "factory of the future" in the engineering industry. The first three of them are well known and need not be described here. FMS, however, can take many forms. A flexible manufacturing module (FMM) consists of a stand-alone CNCMT, material handling equipment (e.g. a robot or a pallet changer) and some kind of monitoring system. A flexible manufacturing cell (FMC) usually consists of a number of machine tools and material handling devices. A flexible manufacturing system (FMS) proper, often contains several automated machine tools, FMMS and FMCs. These are interlinked by an automatic workpiece flow system which enables the simultaneous machining of different workpieces which pass through the system along different routes.[1]

The technological transformation mentioned is mainly taking place in the OECD countries. However, the four technologies listed above are also spreading to the more advanced developing countries - although at a slower speed.

The process of automation in the industrialized countries has reduced the input of labour per unit of output - and thereby often the total cost of production. The factor saving bias differs between the four technologies. In some cases, the automation technologies may even be capital saving. CNCMTs and CAD may also be skill saving. CNCMTs save on skilled labour in the form of operators of conventional machine tools. However, at the same time, other skills are needed, e.g. those for programming, setting, maintaining and repairing the CNCMTs. (The repair and maintenance task has become more complex. However, the amount of repair and maintenance work per unit of output may have decreased at the same time, since one CNCMT replaces several conventional machine tools.) CAD software contains accumulated knowledge. At the same time, new skills are needed to operate, maintain and repair the CAD units. Hence, these technologies save on some skills, but others are needed instead. On the whole, however, both CNCMTs and CAD are skill saving in the sense that the mass of skills needed per unit of output is reduced.

The technological transformation in question has important implications for the majority of the developing countries, since they are a part of the same international techno-economic systems as the OECD countries. (This includes, of course, also those developing countries to which the flexible automation technologies have not been diffused at all. They will be also affected.) The transformation affects the technological gap between developed and developing countries, as well as the magnitude and structure of production costs in various types of countries. Therefore, it also has consequences for the relative competitiveness of firms in various countries, for the international division of labour, subcontracting and other aspects of the international location of production. It is also within the international techno-economic context mentioned which the developing countries have to formulate their industrial and technological policies.

1/ What follows is partly based on a forthcoming book by Charles Edquist and Staffan Jacobson entitled "Flexible Automation - The Diffusion of New Engineering Technology", to be published by Basil Blackwell, Oxford, in January 1988. A large number of tables on the diffusion of flexible automation techniques emanating from this book were included in the presentation, but they are not reproduced in this summary.

The electronics-based automation technologies have not been diffused to the same extent in developing countries as in the OECD ones. This diffusion has largely been limited to the most advanced developing countries. There are, however, certain differences in this respect between the four technologies, and CNCMTs is the technology which has been diffused to the largest extent. In spite of this, the growth in the investment in CNCMTs in the NICs is not large enough for them to catch up with the OECD countries. The diffusion of industrial robots has been very limited in developing countries, partly due to the fact that robots mainly save on unskilled labour and require new engineering skills at the same time. FMS is largely nonexistent in developing countries, mainly because it is an immature and very complex process technology. On the other hand, CAD systems have recently been diffused very rapidly in many developing countries. CAD has a large potential for being diffused quite rapidly in developing countries thanks to the very recent and very substantial decrease in their cost, which is related to the emergence of personal computer based CAD systems. (In some developing countries pirate copies of PC-based CAD software can be bought for a few dollars.) Developing countries may be able to use CAD for leap-frogging in the field of design, since CAD software embodies accumulated design and draughting experience. Such experience is currently a scarce resource in most developing countries, which is indicated by their heavy reliance on foreign technical licenses.

However, our knowledge is inadequate and, for example, the actual or potential consequence of flexible automation for the international division of labour and location of production are not known. Still, there are reasons to believe that automation, in many cases, is a threat to further industrialization of developing countries and even sometimes to their present production of capital goods, because of the cost reduction of the new technologies. In other cases, however, these technologies probably provide new opportunities for developing countries, which they should try to exploit. (The use of PC-based CAD - mentioned above - is an example of such an opportunity. Another one is CNCMTs to increase the quality and precision of the parts produced. A third possible one for some developing countries is the use of flexible manufacturing cells (FMCs) as an alternative to transfer lines, i.e. fixed automation.)

On the whole, it is not known in which specific respects the new technologies provide threats and opportunities for developing countries. For this reason, research is needed. Since the impact of the four techniques differ between themselves as well as between products for the production of which they are used, the research should be product specific. The studies should focus upon the economic impact of flexible automation on the production of specific engineering products in various kinds of developing countries as well as in industrialized ones - i.e. an analysis of the global techno-economic context must be included. (A study programme along these lines was presented by the Sectoral Studies Branch of UNIDO in March 1986: "The Impact on Developing Countries of Flexible Automation in the Capital Goods Industry", Vienna, 25 March 1986.) Such product specific studies would illuminate the issues raised above (threats, opportunities, production costs, relative competitiveness, subcontracting, etc.). They would thus provide a basis for decisions about which products and product groups developing countries could and should avoid producing and, hence, continue to import. The studies could also identify the needs of the firms for assistance from governments and international organizations.

About 40-60 per cent of all investments in machine tools is now in CNC machine tools in the leading OECD countries. In many firms conventional machine tools are no longer even considered as an alternative. CNC machine tools have several advantages over conventional machine tools (productivity, flexibility, accuracy, lead time etc.). Another advantage is the fact - mentioned above - that less skills per unit of output are needed when CNC machine tools are used than when conventional machine tools are used. This makes the arguments for using CNC machine tools in developing countries even stronger, since there is a shortage of skills in most developing countries. For these reasons many firms in developing countries have a strong interest in using CNCMTs.

For most developing countries there are no reasons at present to begin the prodution of flexible automation technologies. On the other hand, the arguments presented above mean that governments in these countries should support and facilitate the use and diffusion of CNC machine tools and CAD in their countries. (The alternative is to specialize in producing items which are not affected by flexible automation.) However, there are also important obstacles to the diffusion of flexible automation technologies in developing countries.2/

A social carrier of a technique is a social entity which chooses and implements a technique; it "carries" it into the society. It is defined in the following way. For a certain technique to be chosen and implemented in a specific context or situation, the technique must, of course, actually exist somewhere in the world, i.e. it must be "on the shelf". But some additional conditions must also be fulfilled:

(1) A social entity must exist that has a subjective interest in choosing and implementing the technique;

(2) This entity must be organized to be able to make a decision and also be able to organize the use of the technique properly;

(3) It must have the necessary social, economic and political power to materialize its interest, i.e. to be able to implement the technique chosen;

(4) The social entity must have information about the existence of the technique and functionally similar ones;

(5) It must have access to the technique in question;

(6) Finally, it must have, or be able to acquire, the necessary knowledge about how to handle, i.e. to operate, maintain and repair the technique.

If all the six conditions listed above are fulfilled, the social entity is a social carrier of a technique. The carrier may be, for example, a private company, an agricultural co-operative or a government agency. Every

---

2/ The following discussion of obstacles is based upon the concept of "Social carriers of techniques" which has previously been used in Charles Edquist: "Capitalism, Socialism and Technology - A Comparative Study of Cuba and Jamaica", Zed Books, London, 1985.

technique must have a social carrier in order to be chosen and implemented. If the six conditions are simultaneously fulfilled, the technique will actually be introduced and used. In other words, the six conditions are not only necessary but, taken together, they are also sufficient for implementation to take place.

The relevant actors may have no interest in flexible automation. In a market economy, this normally means that they do not see any possibilities of increasing profits through automation, which often has to do with relative factor prices. For example, since unskilled labour is cheap in developing countries, firms may have no profit interest in introducing robots. If the interest condition is unfulfilled there will be, of course, no automation.

The introduction of flexible automation may require considerable changes in the organization of production. This is particularly true for flexible manufacturing systems. Organizational or managerial rigidity may therefore be an important obstacle to diffusion.

Lack of power of actors to introduce flexible automation devices may be a result of government restrictions or of union resistance. Therefore, government attitudes to new technologies and the involvement of unions and workers in the process of technical change are very important in this context. The most efficient means to overcome union resistance is to try to keep the general rate of unemployment low and to create mechanisms for transferring workers displaced into new jobs, perhaps after relevant retraining.

Lack of information is a substantial obstacle to diffusion of flexible automation in developing countries. Often the users do not have enough information about the new technologies and about the advantages attached to using them. This is particularly so for small- and medium-sized companies. Governments and international organizations can intervene in various ways to facilitate the diffusion of information about CNC machine tools and their advantages. For example, information systems can be established and demonstration facilities can be provided. This is particularly important in relation to small- and medium-sized firms.

Lack of access to flexible automation technologies may be caused by financial constraints, import restrictions and political embargoes. One special case of access problems is when domestic production of flexible automation technologies are fostered in small developing countries by the use of import restrictions and other policy instruments. If minimum efficient scale of production cannot be attained, this often leads to a very high cost of the machines which retards diffusion considerably. On the other hand, governments may be helpful in facilitating access, e.g. by providing credits or arranging for leasing of machinery.

Lack of knowledge is probably the most important obstacle to diffusion of flexible automation technologies in developing countries. It is a question of knowledge about how to:

- implement,
- maintain, and
- repair

the technologies. Consultants are most useful in the implementation phase. Training is needed for the other stages. The fact that training is needed in spite of the skill saving nature of the use of CNC machine tools is a result of the need for certain new kinds of skills for the use of CNC machine tools - in particular skills to set and programme the machines. This need is even more pronounced for robots and flexible manufacturing systems.

However, obstacles to diffusion of flexible automation technologies may also be a result of the non-existence of strong enough domestic productive actors. Such actors may be national private firms, public firms or co-operatives - the form does not matter. However, the subsidiaries of transnational corporations cannot be primarily relied upon. The reason is simply that they do not have any interest in building up a technological capability as such in developing countries. If they contribute to the generation of some technological capability, it is only a spin-off of their interest to use the market, labour or raw material in the developing country in their process of profit generation for the transnational corporation as a whole.

Therefore, domestic actors which are strong enough must be created and built up if they do not already exist. Government intervention policies to achieve this have been successfully pursued in countries as different as Cuba and the Republic of Korea. The mode of intervention may be different: from creating public firms, over inducing land owners and trade capitalists to diversify into industrial production, to supporting the growth of small private firms within this sector.

Whether the domestic actors are "strong enough" cannot be judged in absolute terms. It must be seen in relation to foreign productive actors, e.g. subsidiaries of TNCs. The latter are always "strong" in a developing country's context. Hence, if all foreign investors interested are accepted - and even given subsidies and other incentives - there will be no profitable investment opportunities left for domestic actors, and no strong group of national actors can thereby emerge. Therefore, foreign direct investors must not be allowed to capture all or most investment opportunities and dominate the industry in developing countries. Historically, Japan and the Republic of Korea have been restrictive in accepting direct foreign investments. Brazil is following a similar policy with regard to the informatics industry in the mid-1980s.

However, a restrictive policy with regard to direct foreign investments does not exclude technology imports to developing countries. On the contrary, the domestic productive actors must be, more or less, dependent upon foreign technology, at least in the technologically advanced sectors of industry. Restrictions with regard to direct foreign investments in developing countries does not imply that they should try to reinvent the chip. Keeping decision-making power at home can be combined with technology imports through licenses, joint ventures, migrations, etc. In addition, the domestic actors fostered must reach international competitiveness in forms of quality and production cost in the long run. The infant industry argument does not imply the acceptance of permanent infants. It implies that domestic firms shall - e.g. through government policies - be protected against competition from the global market, but only for some limited period of time. Hence, when domestic actors which are strong enough have been created, the state must force them to become efficient. One way to achieve this is to open up the country to foreign competition in a gradual and planned manner.

In order to avoid the creation of costly permanent infants, the protection against global competition must not mean an excessively large or extended deviation from the rules prevailing on the international market.

3.2 Possibilities for technological upgrading of the machine tool industry in developing countries, by E.J. Wightman, United Kingdom[3]

The lecture was centered on three main topics:

- The use of computers in the manufacturing process to improve accuracy, quality, cost and response to market needs;

- The criteria necessary to progress from the manufacture and use of manual machine tools to computer controlled machines, including flexible manufacturing systems;

- The requirements for implementation of a modernization programme for the machine tool industry in developing countries.

On the last point, classical arguments for the increased cost of a CNC machine have tended to be based on a comparison of the cycle times for machining a component on a CNC machine and on a traditional machine. Such arguments have tended to overlook several important factors:

(a) For small-batch production, the setting time of the machine tends to predominate; a CNC turning lathe, for example, with versatile standard tooling, can be set up in a matter of minutes, whereas setting up a traditional turning lathe takes much longer;

(b) A CNC machine can run for 24 hours a day and it can machine components repeatedly within tolerances of a few 100ths of a millimeter, thus eliminating the need for subsequent inspection;

(c) The actual productive time may be two or three times greater than that of a conventional machine of similar capacity, and when this kind of comparison is made, the new generation of CNC machines on offer today are competitively priced.

One of the most useful concepts in manufacturing technology in recent years is that of group technology and attendant cell manufacturing. In traditional machining processes based on conventional machines, turning operations are confined to rows of turning lathes, drilling operations to rows of drilling machines, and so on, with the result that substantial batches have to be manufactured at any one time to justify the costs of scheduling and tooling. Stocks of material and work in progress therefore tended to be high. The adoption of group technology and cell manufacturing, where components are classified into types, and where machines are permanently allocated to the exclusive manufacture of these types of component, has enabled work in progress to be kept to a minimum.

An important point of difference between a conventional NC machine and a CNC machine is that, with the latter, the part programme may be modified on the machine to optimize cutting conditions. The operator, therefore, returns to the scene as a key figure and may exercise judgement and discretion as required.

3/ For further details on this lecture see UNIDO, Technological requirements for the machine tools industry in developing countries, Sectoral Working Paper Series No. 51, UNIDO/IS.642, 1986.

One may conclude that CNC machines and group technology complement one another to such a degree that they become mutually dependent, because CNC machines solve the prove-out problems associated with conventional NC machines and thus enable quicker change-over from one component type to another to be made and even smaller batches to be manufactured economically, leading to the introduction of flexible machining systems (FMS).

The question is now to identify the difference in constructing manually and numerically controlled machines. In the case of the manually operated machines, they are characterized by their inherent simplicity, e.g. rigid structure, usually cast iron, incorporating a constant speed main-drive motor with gearbox for speed selection and manually operated lead screw for actuating the tool slides.

The modern CNC machine tool, on the other hand, while appearing to be superficially similar in configuration and physically using a similar rigid structure, is radically different in the drives and control area because of the complete dependence on electric actuation. The main-drive motor is a sophisticated D.C. or A.C. variable speed drive, the multi-range gearbox is reduced to two speed or eliminated entirely and the axes are powered by variable speed D.C. or A.C. drive motors driving precision ball screws to eliminate backlash. As one machine tool builder remarked cynically, machine tool builders are little more than assemblers of bought out specialized equipment nowadays, in contrast to the labour intensive and skill dependent manufacturer of twenty years ago.

The basic configuration of machine tools has remained unchanged whereas control system technology has developed very rapidly, particularly in the last ten years. This prompts two questions:

(a) How many of the existing conventional machines can be updated for this new role?

(b) What constraints need to be overcome in technical terms?

The short answer to these questions is regrettably that very few of the traditional manually operated machines of today may be converted: little more than semi-automated systems can be achieved for relieving the operator of the physical effort required to operate them.

Confronted with these trends, what can developing countries do? In principle, they have several choices, each demanding progresssively more effort. The choices include the following:

(a) Employ such advanced machines in CNC machining centres to set new standards for quality and productivity in existing production;

(b) Progressively update existing machine tools to utilize the latest technology;

(c) Plan to manufacture machines embodying CNC systems.

3.2.1 Technology levels

There is a number of specialist skills comprising in advanced manufacturing system capability, from mechanical design, electrical design, instrumentation, computer interfacing, computer software, systems analysis and co-ordination. In the case of a machine tool design incorporating any form of control system it is not only necessary to know how a machine may be automated. but why the automation should be applied in a particular way. Thus management skills for multi-disciplined technological projects are the first acquisition essential to the success of the proposed venture into moving up market in the machine tool industry.

3.2.2 Criteria for upgrading

The need to upgrade is motivated by fundamental survival issues:

- Productivity;
- Quality;
- Competition.

It could be said that it is more important to begin using advanced CNC machine tools than to begin making them. This is because

(a) The necessary infrastructure for using CNC machine tools has to be developed before they can in turn be manufactured;

(b) Production methods have to be chaged to those based on new CNC technology;

(c) Computer tools have to be introduced in production;

(d) Training at all levels is a major and demanding requirement.

It is recommended that, because of the complexity of modern machine tools and their dependence on computer technology both for control and production management, a formal project management structure be set up to implement the planned improvements. This project management team should report to a government working party comprising representatives from finance, industry and education.

The project brief should include:

(a) Feasibility studies for the use of CNC machine tools and/or justification for local manufacturers;

(b) Project proposals for demonstration and/or training centres to develop the infrastructure;

(c) Structured training programmes for all levels of personnel from managing director, accountants, managers to operators;

(d) Capital assistance for pilot schemes.

3.3 CAD/CAM systems drawbacks and opportunities for developing countries,[4] by Erik Bohez, Asian Institute of Technology, Thailand

3.3.1 Definitions

CAD/CAM is an acronym for computer-aided design/computer-aided manufacturing. The term CAD/CAM refers to the integration of computers into the manufacturing processes to improve productivity. Business computers crunch numbers and data, CAD/CAM systems store, retrieve, manipulate and display graphical information.

Traditionally, a design is created by rubbing graphite on paper and refined by the use of an eraser. In a CAD/CAM system, an engineer interacts with the system to develop product design in detail, monitoring his work constantly on a TV-like graphics display. By issuing commands to the system, and responding to the system prompts, the engineer creates his design - manipulating, modifying, refining - all without ever having to draw a line on paper or recreate an existing design element. Once he is satisfied with the design, he can command the system to make a "hard copy", or generate a computer tape to guide CNC machine tools in manufacturing and testing the part. Figure 1 shows the broad categories of CAD/CAM activity which can be applied for the manufacturing industries.

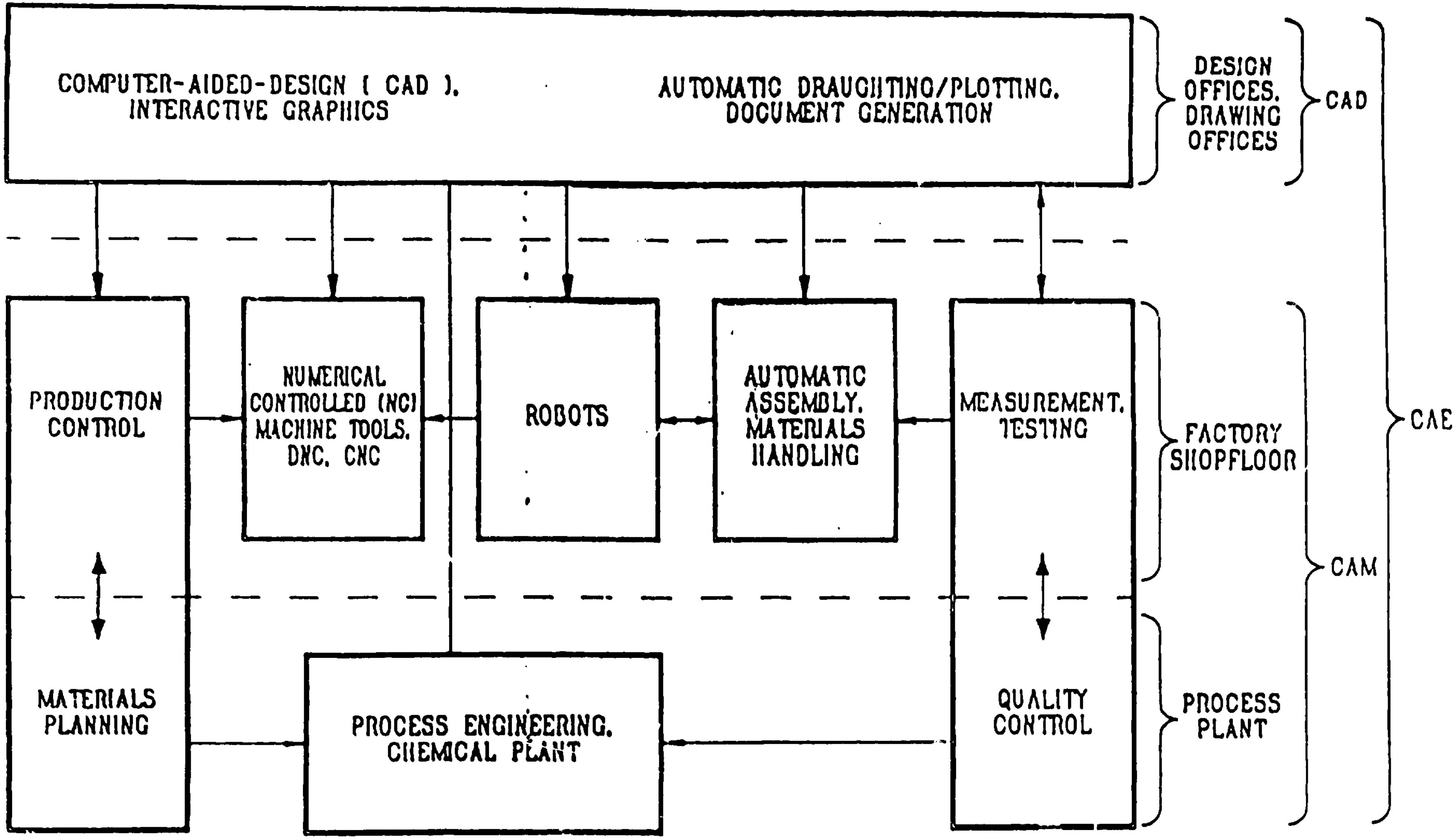
3.3.2 Early developments

CAD/CAM began with the development of interactive graphics in the early 1960s. One of the earliest developments in interactive graphics was the Sketchpad Project at the Massachusetts Institute of Technology. Data was entered via a hand-held lightpen, and as the computer sensed the position of the lightpen on a CRT display scope, the co-ordinate data were stored in its memory. By specifying points on the scope and executing simple computer commands, the user could quickly generate straight lines, circles, arcs and other geometries. With this technique, the user could easily produce an entire diagram on the display screen. And the data base of co-ordinates stored in the computer could subsequently be used to manipulate the display image, produce hard-copy drawing, or be entered as an input to some form of geometric analysis. A feature that made interactive graphics so appealing was that the communication with the computer was carried on in real time. Feedback from the computer was almost instantaneous, permitting the interaction to take place almost in a conversational mode.

Several interactive graphics systems were developed in the 1960s. Their use, however, was restricted mostly to very large companies such as General Motors and Boeing that developed their own in-house systems using expensive mainframe computers. By the early 1970s, interactive graphics could be performed on less-expensive minicomputers. Initially, these interactive graphics systems performed little more than simple automated drafting. But as computer hardware became more powerful and software was refined, the capabilities of graphics systems expanded dramatically. These systems now permit the user perform a much wider range of geometric manipulations and sophisticated analysis.

4/ In addition to the lecture by Erik Bohez this section is based on a forthcoming UNIDO reference guide on CAD/CAM systems in developing countries prepared by TECHNONET-Asia.

Figure 1. Broad categories of CAD/CAM activity



For the more sophisticated drafting packages, a user can temporarily "erase" portions of a complex model from the screen to see the area under construction more clearly, then the deleted area can be recalled later to complete the model. Likewise, portions of the model may be enlarged to view and add minute details accurately. And the model may be moved and rotated on the screen for the user to view at any angle. When the design is complete, the system may automatically add dimensions and labels. After the part geometry is defined with a complete model, the user can have the computer calculate properties such as weight, volume, surface area, moment of intertia, or centre of gravity. A finite element package may be used to determine the stress, deflections and other structural characteristics. After the analysis, the display screen may show colour-coded stress plots, the deflected shape of a part subjected to a given load, or even an animated mode shape showing how the structure might vibrate and deform during operation.

As a result, with a CAD/CAM system, designers can view complex forms from various angles at the push of a button instead of having to construct costly, time-consuming physical models and mockups. Changes can be made quickly and inexpensively at the keyboard or data tablet without requiring alteration of drawing or physical models. In addition, computer displays can produce realistic simulations of product operations before any hardware is produced.

After the design is completed, the resulting geometric data stored in computer memory may be used to produce numerical control instructions of making the part on automated machine tools. Formerly, the preparation of NC instructions was performed manually by experienced programmers. The programme was then tested on the machine and refined several times before the part was machined properly. Many of these tedious and costly operations are now reduced with CAD/CAM systems. NC instructions can now be produced automatically for a range of part types, and tool paths simulated on the display screen to verify and refine the programme more quickly.

3.3.3 Benefits

The most obvious benefit of CAD/CAM is increased engineering productivity. This is probably the single consideration that influences most potential users to invest the high capital outlay for implementing a CAD/CAM system. Initially, productivity may decline somewhat due to learning and familiarization with the system. The overall productivity increase during the first year operation is typically 2 to 1. Succeeding years may show further productivity increases as high as 20 to 1 depending on the application. A 3 to 1 or 4 to 1 increase is a common norm for most well-established CAD/CAM systems. In a typical mechanical design application, a 2 to 1 productivity increase is usually sufficient to justify the installation of a CAD/CAM system.

Another benefit of CAD/CAM is the increased analytical capability placed at the fingertips of a user. This allows rigorous product analysis that would otherwise be quite impossible to perform manually. Reduced product and development cost is a direct result of increased engineering productivity. In many applications, computer simulation of an entire mechanical system or product is possible. In this way, functional characteristics such as vibration, noise, stress distribution, etc., can be analyzed with the system instead of having to build costly prototypes.

Perhaps, the greatest and the most subtle benefit of using CAD/CAM is enhanced creativity of the user. It is a direct result of a compatability between the human mind and interactive graphics. This is attributed to the ability of the brain to grasp graphical data quickly - a picture is worth a thousand words.

3.3.4 CAD/CAM justification

The introduction of CAD/CAM into a company very often entails reorganization of its structure and may initially involve huge capital outlays not only for the system hardware and software but also for staff additions, special training required, etc. This section looks into some of the direct and indirect monetary savings or cost benefits while indirect benefits could mean improved product quality, enhanced product safety and a number of other implicit and intangible benefits.

(a) Improved product quality

The quality of a product is very often judged by its performance or function, its reliability, maintainability and safety. With powerful CAD/CAM packages, a problem can often be analyzed more thoroughly and accurately. Any possible fault or potential dangers can be identified at a much earlier stage. For example, the vibration, deflection and motion of a structure under stress can be simulated with a CAD/CAM system. Individual modes can be created and weakness identified. Previously, this could not have been possible as a large number of prototypes has to be made, which is both time-consuming and expensive. McDermott, a leading offshore engineering company, simulates the launching of a large offshore platform on a CAD/CAM system before the actual installation as any mistake at the site will cost millions of dollars as well as numerous human lives.

(b) Shorter project span times

Today, project lead-time can have considerable impact on a product's competitiveness and marketability. Current CAD/CAM techniques can have a significant impact on reducing project span time. Reduced project span time can mean considerable monetary savings through a number of ways such as lower interest payments on borrowed funds for a project, more efficient use of manpower through better scheduling, reduction of unnecessary data and lower computer run costs. Shorter span time for a project may very well be the basis for winning a contract which, in turn, could represent millions of dollars of business.

In test or research and development environments, CAD/CAM systems permit tuning of trial parameters in real time. Input trials of parameters at a graphic console can be processed in seconds and the output viewed on the display. The quick assessment potential for each set of parameters, and the immediate visualization of the effects of changes, would eliminate tedious manual data reduction, completion time on calibration from one day to several months, eliminate many superfluous computer runs and lessen the need for much expensive test data.

(c) Reduced labour hours

A significant amount of paper work can be reduced through the use of a CAD/CAM system. In a manufacturing environment, documents such as routing sheets, tool lists, bills of material list, machine loading capacity charts, production scheduling, etc., can now all be handled by a system. Tedious calculations on areas, volumes, moments of inertia, mass centre, etc., can be achieved in seconds without having to spend hours of labour. Reduced labour hours would mean a shorter project time as described previously. The productivity is increased and more contracts can be signed without additional manpower.

(d) Power of a CAD/CAM system

It may be an overstatement to say that many problems can be solved only through CAD/CAM technology. However, the statement is essentially true and CAD/CAM readily lends itself to improved techniques. For example, in applications involving the layout of piping, ducting and wirings, it is previously almost impossible to check for all possible interferences. This is generally the case since objects which are three-dimensional in nature cannot be studied efficiently from conventional two-dimensional drawings. There is no easy way to visualize clearances and interferences in a 2 D mode. Present day 2 D/3 D systems provide the needed flexibility of analysis and presentation.

In NC machining, a cutter path can be simulated to check for interferences, and optimized cutting parameters such as feed speed can be generated automatically.

One of the important features of CAD CAM is geometric modelling, the representation of part size and shape in computer memory. The modelling technique is extremely useful as many design and manufacturing functions use it as a starting point.

The most powerful method for analyzing a structure on a computer is reckoned to be the finite element technique. This method determines characteristics such as deflections and stresses in a structure otherwise too complex for rigorous mathematical treatise. A CAD/CAM system is virtually indispensible for such applications and with the graphics post-processing power, the data generated can be converted into visual form for quick interpretation.

(e) Reduced data handling and better management information

Interfacing of various programmes on a CAD/CAM system greatly reduces the repeated manual handling of both input and output data. Centralized control of planning data further reduces the dependency on the planner's skills in a manufacturing environment. It is now possible to capture years of experience on a computer memory.

(f) Enhance user's knowledge

Users of CAD/CAM systems not only perform their jobs more efficiently but they also derive greater job knowledge in the process. This expended purview, in turn, has many benefits to the user. Improved knowledge and awareness of applications and of the interaction of applications offer some hope for coming to grips with today's expanding technical complexity.

The freedom of the human mind to concentrate on the more essential parameters of a project, made possible by CAD/CAM, offers a major potential for increased productivity and better solutions to complex problems. This value is, however, too abstract and difficult to quantify.

(g) Cost effectiveness

Direct cost effectiveness may be easier to qualify in terms of dollars and cents. If a case can be made clearly that a CAD/CAM system produces cost reduction, then all the other areas mentioned earlier on are like frostings n the cake. Cost reduction in this sense is the most conservative approach but it is certainly a benefit that the non-technical management and financial people can readily understand. For a more conservative organization, it may be justifiable enough for a CAD/CAM acquisition.

The initial design phase is very important. The designer has a very high cost responsibility which is difficult to quantify, but it can easily be shown qualitatively: a design that is not cost-effective will have a very important impact on the cost of tooling, material and production. A designer can select between a mass-production technique and a small batch production technique. His decision has to be based on as much information as possible at the moment of design. This information may cover marketing study results, new techniques, new materials etc. It is clear that the designer should have good design tools to reduce the risk of a non cost effective design, and a CAD system here offers a large advantage over manual design methods. A good CAD/CAM system reduces the non creative design task by automating routine work, such as calculations of strength, weights, volumes and generation of parts list.

3.3.5 CAD/CAM in developing countries

There are thus a number of considerations with respect to the link between design and production, as far as developing countries are concerned. In general, industrialized nations do not transfer their design know-how to developing countries, they mostly transfer the production alone, because of cost of labour considerations. Another important reason can be to have access to the local market under "locally assembled" rules. Design know-how itself used to be something accumulated over a very long period mostly by a process of trial and error rather than by a formal scientific effort. The term appropriate technology was used often in the context of design know-how transfer to developing countries. This was because labour intensive production in the traditional sense could easily be transferred to low labour cost countries. Design is also a labour intensive process but is not so easily transferred, because it needs highly skilled and specialized staff and there are strategic considerations attached to it.

In countries with high design capacity the tendency was obviously to make the design process more efficient, which led to the development of CAD systems. Separately, production was optimized by the use of NC, which could cope with increasing complexity and rising labour costs. Once the concepts were demonstrated, the advantages were obvious.

The somewhat paradoxical result of the present situation is that there are definite advantages for developing countries who are at only an initial stage in design. They can immediately adopt and integrate the new design tools without having to go through all the stages which were gone through by countries more advanced in this field.

In general, CAD and CAM systems are profoundly changing the design and manufacturing process. Computer-aided design (CAD) is essentially the application of computer technology to assist in conceptualizing, designing, drafting, analyzing and documenting designs, while computer-aided manufacturing (CAM) is the application of computers in converting design information into the actual products. A link between CAD and CAM can significantly improve productivity. This link is realized by using the same geometrical data base for the design and for the manufacturing data. This integration of CAD and CAM is a very complex task, and it is only recently that CAD software vendors offer this kind of integration, with a missing link to be implemented by the customer or by the NC hardware vendor.

Initially numerically controlled (NC) machine tools were programmed by coding instructions on a paper tape. Now they are programmed on the terminal screen of the machine controller. The code itself is little changed but it is different for each type of NC or CNC (computer numerically controlled) machine, the latter being a machine tool with a micro programmed microprocessor controller.

The basic need for a mature CAD/CAM system is a common data base and a means of communicating with all its current and future users. This makes the use of a process standard a virtual necessity. One concept or philosophy that is coming back into use is group technology (GT). Group Technology can be defined as the bringing together and organizing of common parts, principles, problems and tasks to improve productivity.

The first step for establishing a GT programme is to develop a classification system for determining families of parts. It includes the coding of parts based on the similarities of the parts, grouping the parts into production families based on similarities in their production so that the parts in a particular "family" can then be processed together; and finally the grouping of various machines together to produce a particular family of parts.

The ultimate convergence of new production technologies takes place in computer integrated manufacturing (CIM). Material requirements planning, pattern recognition system, use of artificial intelligence, robotics, can all find their place here. Most CIM technology is currently being developed in the United States, yet its most innovative implementation has thus far been in Japan and Western Europe. For example, Japan Fujitsu Fanuc operates a factory for producing robotic parts; it is almost entirely unmanned during night shifts.

The objective of CIM is to develop a cohesive digital data base that integrates manufacturing design and business functions. Information is sent on demand and as needed to the largest number as possible of intra- and inter-disciplinary groups within the production system.

3.4 State-of-the-art in robotics and FMS in the industrialized countries, by A. Laffaille, Director, AFRI, France

3.4.1 Introduction

The evolution of manufacturing technology from the mid-19th century until the end of the 1960s can be broadly characterized as exploiting economies of mechanization, specialization, standardization and scale. On an aggregate level, the productivity of workers was enormously increased by mechanization, subdividing and rationalizing complex, non repetitive tasks into a sequence of simpler repetitive ones, higher precision, and higher operating rates of machine tools, mass production of truly interchangeable standard parts, use of dedicated automatic machines to maximize parts output rates and mechanical assistance for handling and assembly. Labour productivity improvements from the 19th century to the 1950s vary from one product to another, but in many cases the overall improvement was several orders of magnitude. Metal cutting rates, for example, increased by over 100 times between 1890 and 1970.

In the last decade, the manufacturing industries of almost every country are being affected through increasing cost pressures, low productivity growth and stagnant demand. Several large industrial sectors are facing severe adjustment pressures as a result of this weak demand and of international competition. Nevertheless, while faced with low profit levels and cash flow problems, many manufacturing industries are increasingly investing in new automated manufacturing equipment, in order to increase their productivity and thus their international competitiveness.

Based on developments in semiconductor technology and also in new machining technology and concepts, the increasing automation of capital equipment is leading to significant changes in concepts of manufacturing. The rapid development of techniques of automatic control in manufacturing processes, the integration of computers in real time directly with machines and the integration of machines through industrial robots, has led to the application of these new manufacturing concepts to a wide range of industries, and it will continue to do so.

Three main questions arise from developments in industrial automation:

(a) The first question is a commercial one: given the range of automation choices for manufacturing, the problem is to determine what approach is best suited to market conditions for the industry in question.

(b) The second question is in the realm of political and industrial economy: if, from a national strategy point of view governments are encouraging in various degrees, the domestic production of industrial robots and other automated manufacturing equipment (AME), the decision-maker has to be aware of the fundamental characteristics of these industries.

(c) Thirdly, there are socio-organizational issues: indeed, the patterns of industrial automation diffusion in the industrialized countries reveals that the factors inhibiting the spread of automation are more organizational than technological. So any policy to strengthen capital goods industries through industrial automation has to take account of its impact on work structure.

3.4.2 Recent technological developments and trends

As remarked above, up to the end of the 1960s, productivity improvements were mainly based on economies of scale. However, by 1970, the potential for such increases was far more modest in most cases. Today, consumer markets are characterized by shorter product life cycles, segmentation and improved quality, further reducing the scope for economies of scale. The new automated manufacturing equipment and methods are designed to satisfy these market constraints. Economies of scale will have decreasing influence in coming decades, whereas economies of scope (i.e. capital sharing facilities by increased flexibility) will have an increasing influence. What follows is a brief survey of their present and expected future features.

(a) Automated manufacturing equipment: present situation

Here we consider two important subject areas: industrial robots and flexible manufacturing systems (FMS).

Industrial robots

According to the ISO definition a "manipulating industrial robot (MIR)" commonly called "industrial robot (IR)" is an "automatically controlled, reprogrammable, multi-purpose manipulative machine with several degrees of freedom, which may be either fixed in place or mobile, for use in industrial automation application".

Thus an IR is a CNC manipulator whose main features are:

- Its ability to move its end effector along 6 degrees of freedom;
- Its working volume;
- Its ability, if equipped with a tool changer, to execute sequentially at the same working station several operations during the same work cycle;
- Its possible use of external sensors - often optical - the outputs of which give its control unit a knowledge of its environment and changes in or evolutions of this environment.

One of the characteristics of an IR is that according to the sophistication of its control system, it can operate:

- Either in a blind, purely repetitive, but always accurate way;
- Or in a repetitive way, but according to real time information on its end effector. The motions of the end effector and/or the forces exerted by the end effector can be adapted to the current state of the environment;
- Or in a more autonomous way with only one goal.

The flexibility of use of an industrial robot can be considered at two levels:

- The control level;
- The end effector level.

Industrial robots can be thought of as mechanisms that duplicate human ability in movement and adaptability, especially in a well defined limited space such as a shop floor.

The main fields of application of IR may be divided into four, depending on its mechanical structure, its size, and the type of its end effector:

- Manipulation;
- Machining;
- Assembly;
- Test and inspection.

Flexible manufacturing systems (FMS)

"A flexible manufacturing system (FMS) is an integrated computer controlled complex of numerically controlled machine tools, automated material and tool handling devices and automated measuring and testing equipment that, with a minimum of manual intervention and short change over time, can process any product belonging to a certain specified family of products within its stated capability and to a predetermined schedule".[5] So, in short,

---

5/ Definition established by the CECIMO working party on standardization.

an FMS is a production unit capable of producing a range of discrete products with a minimum of manual intervention. FMS is mainly used for drilling, milling, testing, storage and retrieval. An essential feature is an automated materials handling (AMH) system. This stores and moves products and materials under computer control. The first application for AMH is to shuttle workpieces between the stations of an FMS. The second major one is automated storage and retrieval systems. Such systems allow more accurate inventory records.

FMS works according to the following scheme: using NC programmes and often also, using computer-aided process planning, workers develop the sequence of production steps for each part that FMS produces. Then, based on inventory orders and computer simulations of how the FMS could run most effectively, the FMS managers establish a schedule for the parts that the FMS will produce on a given day. Next, operators feed the materials for each part into the system, typically by clamping a block of metal into a special carrier that serves both as a fixture to hold the part in place while it is being machined, and as pallet for transporting the workpiece. Once loaded, the FMS essentially takes over: IRs, conveyors, AGVs or other automated materials handling devices transport the workpiece from workstation to workstation, according to the process plan. If a tool is not working, the FMS can reroute the part to other tools that can substitute.

Machine tools are not the only workstations in an FMS; other possible stations include washing or heat-treatment machines, automatic inspection devices, and machines for grinding, sheet metal working, plastic handling and assembly.

The amount of flexibility necessary to deserve the label "flexible" is arguable. However, in the current state of the technology, a system that cannot produce at least 20 different parts is not flexible.

The essential features that constitute a workable "part family" for FMS are:

- A common shape;
- Size;
- Material;
- Tolerance.

For a manufacturer with an appropriate part family and volume to use an FMS, the technology offers substantial advantages over stand-alone machine tools. In an ideal FMS arrangement, the company's expensive machine tools are working at near full capacity. Turn around time for manufacture of a part is reduced dramatically and computer simulations of the FMS helps determine optimal routing paths.

Most systems have some redundancy in processing capabilities and thus can automatically reroute parts around a machine tool that is down. Because of these time savings, work-in-process inventory can be drastically reduced. The company can also decrease its inventory of finished parts, since it can rely on FMS to produce needed parts on demand.

Finally, FMS can reduce the "economic order quantity" for a given part, the batch size necessary to justify set up costs. When a part has been produced once on a FMS, the set up costs for later batches are minimal because the process plans are already established and stored in memory, and the materials handling is automatic. Theoretically, a FMS could produce a batch of one part almost as cheaply as it could produce one of 1,000, in terms of unit cost. However, in practice there are unavoidable set up costs for a part, and a one-part batch is uneconomical. Nevertheless, the FMS's capability to lower the economic size of order is particularly useful in an economy in which manufacturers encounter increased demand for product customization and for smaller batch sizes.

The chief problems related to FMS arise from its complexity and cost. Several months and even years of planning are needed for such a system, and installing and maintaining an FMS is likely to require a higher degree of technical expertise than manufacturers may have available. Finally, because FMS is a system of interdependent tools, reliability problems tend to be magnified.

(b) AME: technological issues and forecasts

The possibilities for application of existing programmable automation tools are already extensive. But the technologies continue to develop rapidly, with emphasis in five areas:

- Increasing the power of the technologies, i.e. their speed, accuracy, reliability and efficiency;
- Increasing their versatility, the range of problems to which the technologies can be applied;
- Increasing the ease of use, so that they require less operator time and training, can perform more complex operations, and can be adapted to new applications more quickly;
- Increasing what is commonly called the intelligence of the system, so that they can offer advice to the operator and respond to complex situations in the manufacturing environment; and
- Increasing the ease of integration of programmable automation devices so that they can be comprehensively co-ordinated and their data bases intimately linked.

Industrial robots

In part because robotics is a complex and interdisciplinary technology, there are many discrete areas of research and possible directions for extension of capabilities:

- Improved positioning accuracy for the robot's wrist;
- Increased "grace, dexterity and speed". Work on lighter structures is likely to lead to the use of composite fibre materials;
- Software methods for programming robots are becoming easier and more efficient; the trend is towards more "user-friendly" and interactive high level languages which could suit every brand of robot.

Flexible manufacturing systems

FMS for the machining of prismatic parts are becoming more prevalent and are a relatively established technology. FMS for rotational parts are now available, while the range of other possible applications for FMS - grinding, sheet metal working, or assembly - are at early stages of development.

Many of the chief R&D problems for FMS involve logistics: the design and layout for the FMS and computer strategies that can handle sophisticated combinations of powerful machine tools. In addition, there is a need for more sophistication in simulation systems for the FMS, so that their efficiency can be optimized.

There is a variety of enhancements to FMS hardware; these include automatic delivery and changing of cutting tools and systems for automatic fixturing and defixturing of material to be processed. There is a trend towards the increased use of automatic guided vehicles (AGVs) in FMS.

Besides perfecting AGVs with respect to control system, speed, mobility and sensor interactions, it is likely that they will be used for carrying robots between workstations, or that, while transporting workpieces and tools, they will perform certain operations such as quality control, cleaning, etc.

Improving the reliability and versatility of material handling systems is also an important need for FMS. However, the level of sophistication of material handling technology often does not match that of other programmable automation technologies and the automatic material handling system may be the "weak link" of FMS.

Sensors

Many programmable automation devices are limited in their capabilities because they are "unaware" of their environment; they do not "know" what they are doing exactly where the parts are, or whether something is wrong in the manufacturing system. A minor adjustment or observation which would be easy and obvious for a human is nearly impossible with most current manipulators.

Many machines have internal sensors - e.g. IR and machine tools have sensors which provide feedback on the positions and speeds of their joints - but here we are concerned with those sensing devices that can acquire information about the environment and can be used in conjunction with robot systems or other CAM equipment, such as CNC machine tools, or AMH handling systems, of which such sensors are an integral part.

There are roughly three ways to use sensors:

- Inspection, in which parts or products are examined and evaluated according to pre-established criteria;
- Identification or pattern recognition, in which part, products or other objects are recognized and then classified for further processings;
- Guidance and control, in which sensors provide feedback to IRs or other CAM machines on their tool environment, or on the state of the part under process.

The simplest sensors provide binary information. At a moderate level of complexity, the information sensed is analogue.

At the most sophisticated end of the sensing techniques, visual and touch sensors deal with information that is not only analogue but also needs substantial processing to be useful.

Artificial intelligence

It would not be right to close a subchapter on current technological issues without mentioning, at least briefly, the subject of artificial intelligence and one of its most powerful tools, the expert system.

The purpose of AI is to design machines which can perform tasks generally regarded as requiring intelligence. It may be a key to automate parts of the manufacturing process previously thought to be too complex for automation.

So far, AI techniques have successfully been used for image processing mainly in robotics applications, where a simplified aspect of AI techniques is an important factor of the adaptive control of the IRs.

Standards, interfaces and communication networks

The need for standards in both languages and interfaces is strong and consistent throughout programmable automation technologies.

Without standards it is very difficult to combine equipment from different vendors, and it is still more difficult to proceed incrementally towards a more integrated system.

The demand for standardization in languages is particularly strong from users of automation devices, because of the increased confusion and need for additional training that result from the profileration of different programming languages.

Furthermore, standards for interfaces between computerized devices will greatly facilitate integrated AME systems. The recent development of standards for "local area networks" (LAN) helps define the hardware connections for linking devices together, as well as the "protocols" that ensure that different systems can interpret each others messages conveyed by this data exchange system. Such a "nerve system" must take into consideration the different levels of control and the kind of information it is necessary to communicate, and must also be open to further developments of the manufacturing system.

The most efficient way to overcome this problem of data exchange is probably to follow a strict policy of implementing a well known communication system such as MAP (manufacturing automation protocol).

From this rapid technological survey regarding AME, integration and flexibility appear as being the key features of the emerging manufacturing standard. Flexibility refers to reprogrammability of AME and FMS, and integration to accurate and reliable means and methods of co-ordinating the complex process required in present manufacturing. These two features reinforce each other to improve manufacturing systems efficiency.

3.4.3 The industrial economy of industrial automation: the case of robotics

It is not intended here to write the history of industrial automation since the beginning of the 1960s, nor to analyze for its own sake the development of industrial automation in the industrialized countries. But, since industrial automation markets are strongly international, any decision-maker must be aware of the emerging trends.

CAD, IR, NC machine tools, flexible manufacturing systems and other industrial automation equipment and systems are supplied by industries that are currently more or less separate. Of the principal industrial automation industries, the NC industry is the oldest and largest, dating from the 1950s.

Only the robotics industry is under considerationhere, since it is assumed that information and reports on the machine tool industry are easily available to illustrate the present levels of international competition.

At the end of 1984, four main trends could be discerned:

- Accelerating technological improvement;
- Opening of United States and European markets;
- Beginning of IR mass production;
- Launch of price competition.

In 1987, the following are the main trends:

(a) Prices competition: a static warfare

IR average prices are presently decelerating. Three facts explain this first trend:

- Increase of low cost light robotics share;
- Launch of new low-cost designed IR;
- Suppliers prices strategies oriented more to maintain prices in nominal money than to drastically cut them.

Price competition did not take place because:

- Suppliers, after losing a good deal of money in 1981 and 1982, prefer to strengthen their profits margins;
- Competition occurs more in the field of commercial networks and post-sales services than in that of prices;
- Yen revaluation prevents aggressive prices strategies from Japanese suppliers.

Nevertheless, with the development of IR mass production, price cuts in the near future are likely.

(b) IR manufacturing: from craft methods to automated production

If the 1986 low market profile postponed IR suppliers' investments, automated IR manufacturing remains an underlying trend: longer production ranges, production equipment flexibility allowing manufacturing automation, and the necessary lowering of production costs all point to the emergence of this trend.

(c) World wide markets

Since 1982, new commercial and/or industrial agreements are announced every month. Licensing, outsourcing, mergers and takeovers, limited equity investments and joint ventures are common and usually occur between firms from different countries.

(d) Technological evolution

More and more innovations, designed in research laboratories, are now industrialized. Nevertheless, their diffusion remains very slow. Off-line programming, high level languages, local area networks amount to only 1 per cent of turnover. Also the technological competition remains sharp, and relates to:

- The establishment of a high level language standard; for instance, IBM promotes its standard, called AML2, while GMF promotes KAREL, another high level language;

- The design of new programmable controllers;
- The compatibility with the communication interface network, called MAP (manufacturing automation protocol) proposed by General Motors.

(e) Increasing role of "system houses"

With IR diffusion to small- and medium-sized firms, system house companies are playing an increasing role in robotics markets in meeting the above needs.

This is partly because for both simple and complex applications, pre- and post-sale support and service are increasingly considered essential by both vendors and users, and system houses, as intermediaries and integrators, can contribute to meeting this demand. One indicator that service and support have been inadequate is the fact that buyers occasionally abandoned robots, a situation which has not occured with CAD systems and other types of programmable automation.

A good deal of pre-sale support-planning, training, facilities preparation, etc. is often needed, for two reasons; IR has yet to be viewed as the only alternative for certain tools; and there are no single, correct approaches to applying robots in given situations. Because IR technology is still developing, and because users often adopt their first IR as a preliminary to broader process changes, post-sale support - software updates, services contracts - is also important.

(f) Increase of minimum production capability size

At the beginning of the 1970s, a two hundred units annual production was sufficient to be an IR supplier. Today, the required production level to be profitable is much higher. Markets leaders manufacture about 1,500/2,000 units a year and have goals for the 1990s of a 5,000 units production level. The increasing gap between the leaders' production volumes and those of other firms ones is disturbing for the latter.

Finally, during recent years, the trends foreseen for the industry grew stronger. And if technological diffusion and prices evolution proved less than expected, this has not affected the underlying trend towards an oligopolistic structure in the robotics industry.

(g) Patterns in supply strategies

In the United States market, where competition is keener than elsewhere, a double trend can be discerned:

- A falling back of the traditional firms relative to others;
- The rise of new firms, such as GMF, the market share of which has increased very rapidly.

The Japanese market, with more than 200 vendors, is dominated by some large firms: MATSUSHITA, FANUC, TOSHIBA, etc.

On the European market, the leader is the Swedish group ASEA, with 30 per cent of the market. The other firms are the German company KUKA (15 per cent), COMAU, a FIAT subsidiary (8 per cent) and RENAULT AUTOMATION (6 per cent).

Four patterns can be seen:

- Specialized market niche strategies: some firms design and develop specific automated devices, for markets which are today very narrow ones but are expected to become profitable (personal robots, service robots for cleaning, agriculture, mining, etc.);
- Functional package strategies: these consist of selling not only a wide range of IR, but also a range of robotic turnkey systems for industrial applications;
- Standard IR mass production strategies;
- Industrial automation system strategies: the robot is here viewed as a peripheral device of the control system. In this case, suppliers aim at selling computer integrated manufacturing systems, including IR.

Even if a firm is in a position to follow a mixed strategy, any decision-maker will have to choose from among those four patterns. The final result will depend on finance resources, technological capabilities and market access.

3.4.4 Industrial automation: another way of working

Industrial automation (IA) had to help companies to produce better and cheaper: IA can improve product quality by raising consistency and control in production. It can be used to produce an increased range of products because of its programmability. These features can make IA economical in production of much smaller quantities than hard automation, which is largely restricted to large quantity or mass production.

In spite of these potential benefits, the way in which IA is applied is often quite inappropriate. Indeed, IA is viewed as a panacea for problems in manufacturing. In fact, IA is an important and powerful set of tools. And this misunderstanding in the industrialized countries about what industrial automation really means is one of the main reasons for the slow and uneven growth seen in markets for automation. Another reason is the present unfavourable economic conditions for investment.

Currently there is an under-assessment of the interconnections of technological, social and economics concerns surrounding the spread of industrial automation in manufacturing. The key impacts of industrial automation on work structure need to be better understood. The analysis of the industrialized countries' experience is very fruitful.

Among the broader work environment issues, one could mention organization and nature of work, occupational safety and health, labour-management relations, changing skill levels and training.

Only the first three issues will be discussed. Concerning changing skill levels, one has to appreciate that the ways in which work is organized and jobs are designed will determine both the skills needed to do a particular job and the overall level of skills required in a workplace using industrial automation. In general, industrial automation gives rise to a greater need for conceptual skills (e.g. programming) and a lesser need for motor skills (e.g. machining) than are required for conventional equipment.

(a) Organization and nature of work

The ways in which work is organized together with the specific design features of industrial automation technology, will together affect the work environment. In the short term, the new and emerging technologies will be adapted to traditional structures of work organization; over the long term, the structures themselves will change to reflect the characteristics of the new technologies. While it is too early to predict exactly how these changes will develop, the experience to date may offer some insights.

One of the most vivid examples of how organization of work in automated manufacturing can affect the quality of the work environment comes from the allocation of programming in a NC shop. The introduction of NC machinery is usually accompanied by the development of a new programming department and a new division of labour. The planning of work becomes more centralized and is moved off the shop floor, so that planning and execution become increasingly separated. From the point of view of management, this results in increased efficiency and control over the production process. However, whether or not production workers are permitted to edit programmes on the shop floor, or in general engaged in planning, can determine whether their jobs are routine and relatively boring or involve, instead, an element of challenge and decision-making. The assignment of work is a function of managerial choice.

It is generally agreed that there is nothing inherent in automated technology that makes one particular form of work organization essential. Industrial automation gives opportunities for enlarging the scope of jobs. With appropriate training, workers could be involved in a greater variety of tasks by rotating jobs; however, this would require co-operation between labour and management in agreeing to increased flexibility in work rules. Another opportunity for workers to perform a wide range of tasks rather than narrow, fragmented ones, is the application of group technology, through the use of manufacturing cells producing families of parts grouped on the basis of similar shapes and/or processing requirements.

The flexibility of industrial automation provides the potential to achieve a better balance between the economic considerations that determine technological choices and the social consequences of those choices in the workplace. There are cases where organizational and technological changes have been combined successfully to yield dramatic improvements in productivity and effectiveness. While these changes were generally motivated by factors other than the improvement of the work environment, organizing work in ways that improve the work environment should result in economic pay-offs as well through better worker morale and productivity.

Many of the concerns about the introduction of industrial automation revolve around the changes it will bring about in the organization and nature of work. The choices made by those who design and manage automated systems will have a profound effect on how these systems influence the work environment.

(b) Occupational safety and health

The various forms of industrial automation have both positive and negative effects on the safety and health of workers. In general, the introduction of industrial automation tends to have a favourable impact on the work environment, although some new physical hazards associated with the lack of immediate worker control over system operations may emerge. However, industrial automation will create new situations, or perpetuate old ones, that may have negative psychological effects on the work force.

Overall, the potential physical hazards appear to be more amenable to solution than some of the psychological ones because they are more easily recognized and are less subject to the subtleties of individual personalities. The relief of such symptoms as boredom and stress is more challenging because they are not as well measured or understood, they affect different people in different ways, and they are often complicated by other factors not directly related to the workplace. In addition, a commitment to alleviating monotony and stress in the workplace usually involves major changes in the way work is structured, which can pose problems for both managers and other workers.

A breakdown is a common event on the shop floor which illustrates the difficulties in correctly assess these safety and occupational considerations. While they are technological in nature, the pressure to meet quotas in spite of equipment failure is organizational. This situation is not unique to industrial automation, but the problem is exacerbated by a system designed in such a way that equipment cannot be pulled to one side for repair and by the complexity and automatic nature of the equipment. In addition, the high capital cost of the equipment increases the desire to use it to the fullest extent. This may entail operating the line faster to make up for time when the machine is down, in order to meet production goals.

(c) Labour-management relations

The effects of industrial automation on the work environment will be determined in part by management's motivations for automating and by the nature of labour-management relations. Management might decide to introduce industrial automation for a variety of reasons, such as:

- To improve productivity;
- To reduce costs;
- To standardize production methods;
- To enable the use of workers with fewer skills;
- To encrease control over the pace and quality of production, and
- To get on the technological bandwagon.

Who makes the decision in the organization will also have an important effect on the results. Research suggests that managers often lack the background to assess the technological options, while staff familiar with the new technologies are less able to appreciate associated strategic dimensions.

Once the decision is made, the strategies employed by management for introducing industrial automation are crucial in determining its impacts. Prior experience seems to be an important factor in how an organization copes with additional automation. Also, the introduction of new technology may be facilitated by good intra-company communications and a "participative" management style. Where the knowledge and expertise of workers is included in the decision-making surrounding new technology, and where information is shared, the implementation problems may be reduced.

As was said above, the nature of labour-management relations will affect the implementation of new technology and its consequences for the work environment. Co-operation between employers, workers and society in determining the design, implementation and pace of change would tend to minimize the potential negative effects of technological innovation. Such co-operation, however, will require mutual trust among the parties involved.

In response to changing worker expectations, management has increasingly been forced to pay greater attention to the needs of its work force, beyond the traditional ones of fair wages and benefits. This trend has been growing since the 1960s and 1970s, and is not limited either to new technology or industrial automation. In addition to such provisions as profit-sharing and job security, workers have been demanding a greater say in matters that directly affect their workplace; where management has begun to tap into this knowledge and experience they have often discovered a new source of support and insights.

Any discussion of restructuring work in automated environments in ways that would enhance the workplace needs to be framed in the context of how the work rule issue evolves. Management's ability to take innovative approaches to implementing industrial automation may be constrained by work rules that are outmoded and difficult to change. In return for increased flexibility in deploying workers, management may need to be more responsive in such matters as increased labour involvement in decisions concerning the implementation of new technology or job security.

To summarize, a number of factors determine the impacts of industrial automation on the work environment, such as how the technologies are designed and applied, the strategies employed to introduce them and management's goals for automating. In general, the introduction of industrial automation tends to improve the work environment. However, it has the potential to create new situations that are stressful or monotonous, resulting in negative psychological effects on the work force. Industrial automation offers a wide range of choices concerning its use - choices that, if made well, will help to ensure that industrial automation is applied in ways that will maximize its potential for affecting the workplace positively. But the persistent mismatch between commercially available technologies and the willingness and ability of users to implement them remains one of the major stakes for manufacturing today.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The diffusion of automation technologies will profoundly influence industrial production in general and the capital goods industry in particular. This impact is already significant and will gradually reach further subsectors and industrial processes. Since all countries belong to the same economic environment, this means that industrial automation technologies will influence to an increasing extent the industry in developing countries, including those that have no plans to automate industrial production for the foreseeable future. In some ways, this process causes a threat to the developing countries since the industrialized countries, through their ability to develop and apply advanced technologies, will be able to re-establish the competitive advantages in areas where developing countries have been able to compete successfully so far and even become exporters, such as textiles. But the use of industrial automation technologies also offers new opportunities to developing countries, since it is a substitute for skilled labour and managerial capabilities which might be scarce in developing countries. It will be possible through a well conceived industrial automation policy to find adequate response to the international market development. The opportunities for the use of CNC machine tools for small enterprises in developing countries need to be considered for each part of the engineering sector.

CNC machine tools are more productive than manual machines which will lead to labour savings at the machine level. However, there would be an increased need for support staff such as programmers and specialist service engineers. Through its macro impact, e.g. the opening of new markets for industrial products, even more substantive benefits could be reaped which would enhance the economy as a whole. This might be brought about by the removal of present barriers to expansion such as poor quality, lack of precision and long lead times. On the other hand, failure to introduce modern technologies might endanger market gains already made by developing countries.

Consequently, developing countries must try to find adequate and feasible responses in good time to the challenges offered by industrial automation. They must make a profound assessment of their own capacities and capabilities. They must define clearly their priorities and formulate dynamic strategies in the light of future trends. Such strategies can also include a review of product lines less likely to be influenced by further automation.

On the basis of the assessment, priorities and strategies that are defined, a technological policy related to an industrial automation strategy must be elaborated. It is essential that a clear-cut distinction be made between the application of new technologies and the production of the corresponding hardware and software. It should be recognized that widespread diffusion might lead to indigenous production later.

A number of stages of industrial automation technologies have been defined in earlier UNIDO work. In the following notes the main conclusions of the work of the Seminar are summarized:

4.1.1 CNC machine tools

CNC is necessary to achieve the standards of accuracy now required internationally by the engineering industries. Experience of established users has shown that the effective use of CNC requires an infrastructure in terms of programming capability, application of cutting technology, and production control.

The manufacture of CNC machine tools is more dependent on the assembly of multidisciplinary components and systems, such as computer control and axis drives, than traditional machine tool manufacture which was oriented around mechanical manufacture. The manufacture of CNC machine tools should only be contemplated following a successful introduction and use of CNC in engineering or other industrial sectors. The examples of countries such as the People's Republic of China, India and the Republic of Korea show successful experiences in this direction. While the use of CNC represents an ideal objective, it is recognized that financial and organizational constraints may preclude their immediate introduction. When introducing CNC machine tools, care should also be taken to make effective use also of the existing machines base.

Progression from manual machine tools to CNC is illustrated in chart 1. A first possible step is the addition of a digital read-out system to a machine. This alone might allow for substantial increases in accuracy and productivity. Later enhancements would involve the retrofitting of CNC systems to earlier NC machine tools. It would be impractical to convert existing manual machines to CNC without major re-engineering of the machine tool structure.

4.1.2 CAD and CAM

A timely introduction of computer-aided design (CAD) and computer-aided manufacturing (CAM) methods can play a crucial role for developing countries by enabling them to cope with continually rising standards of quality, diversity, flexibility and service.

CAD/CAM systems can reduce the overall time of the production cycle (from design to manufacture) by 2/3. Manual programming of a CNC machine can be very difficult and even impossible without computer tools, such as high-level languages and CAD systems, and the advanced use of CNC machines and cells also needs CAD/CAM.

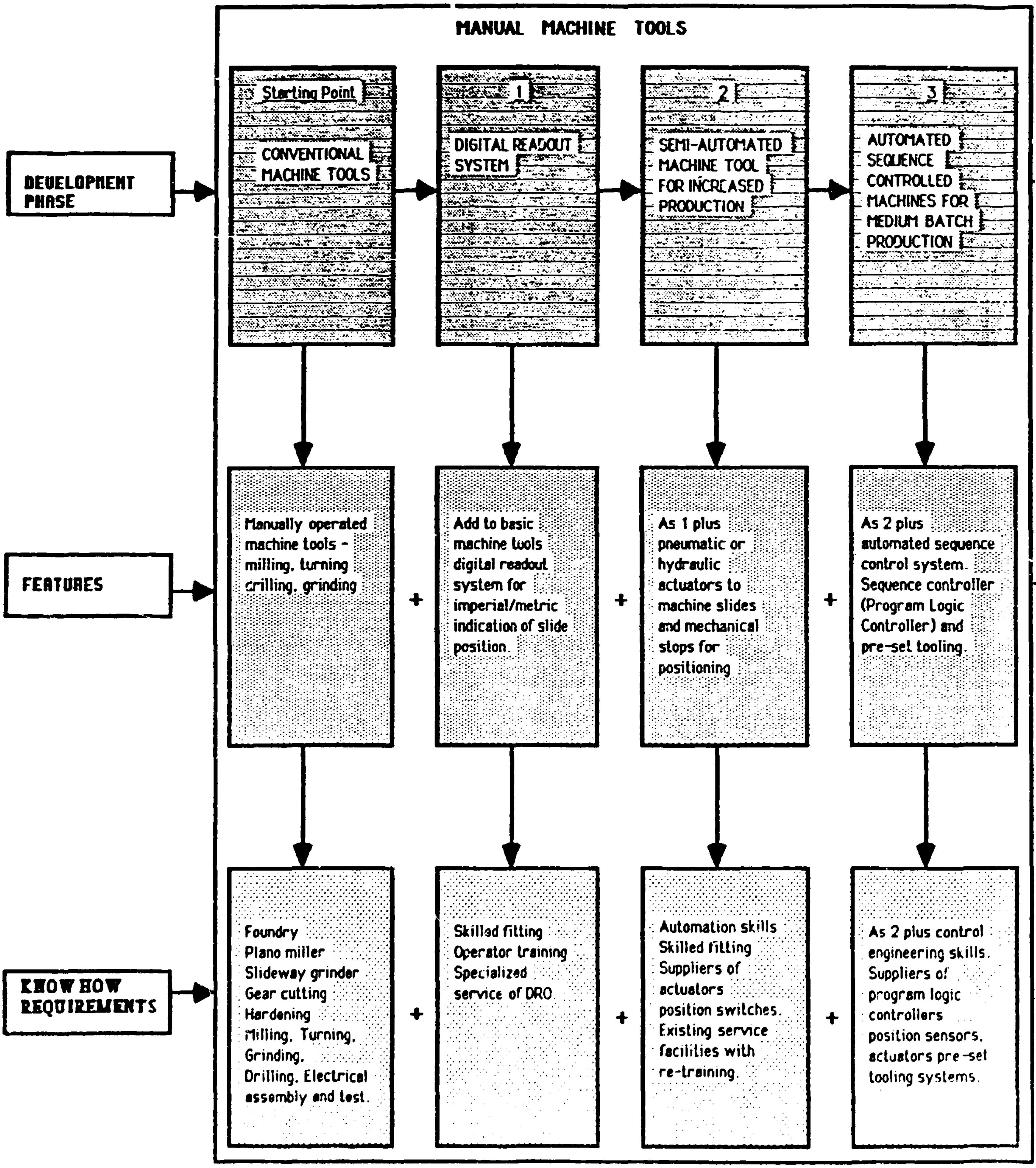
A wide range of CAD and CAM systems is available, using mainframes, minicomputers, and microcomputers. Developing countries need advice and guidance to evaluate, select and install these CAD/CAM systems. Regional and national centres could provide such guidance, and eventually play a more advanced role which included software development and engineering.

4.1.3 Industrial robots

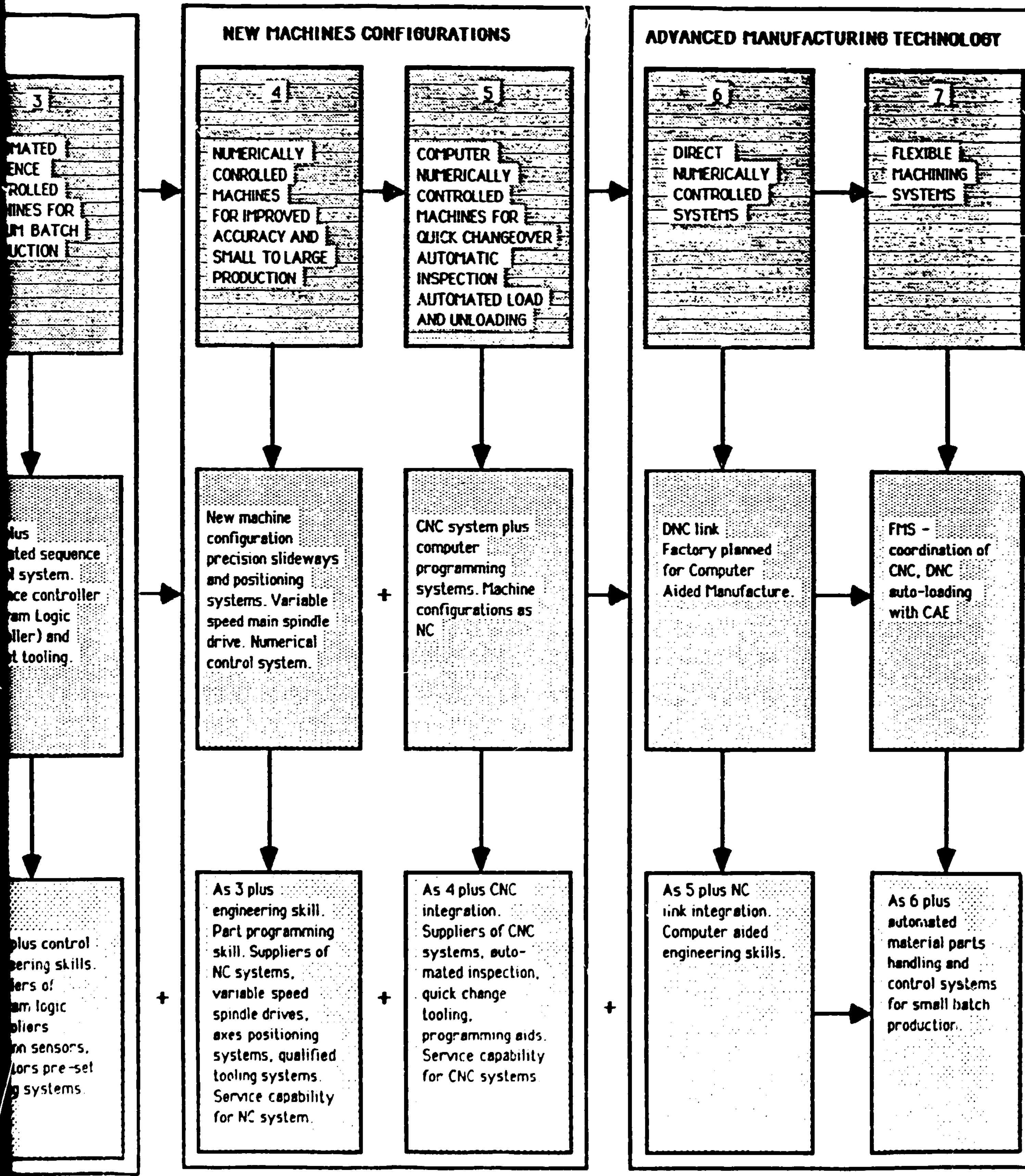
Several tasks have been identified in manufacturing processes which require the use of robots irrespective of whether a country is developed or in a transitional stage. These are:

- Hazardous operations such as paint spraying;
- Repetitive precision work such as welding assemblies, including spot welding of fabrications;
- Assembly of precision parts such as microchips.

Chart 1. Progression from Manual Machine Tools to Flexible Machining Syst
A SEVEN POINT PLAN



ining Systems



Within the family of machines comprising industrial robots two major categories have been identified:

- Programmable robots requiring computer control;
- Automated handling devices for repetitive mechanical functions, e.g. loading and unloading of heavy components into and out of machines.

Whereas the use of simple automated handling devices would be beneficial for certain applications in developing countries, the most advanced computer controlled robots should not be contemplated without first developing the basic infrastructure of CNC machine tools.

4.1.4 FMS

The application of FMS for manufacture must be discussed in the context of both flexible machining cells and machining systems. The former have stand alone general purpose machines which can make a variety of parts, while flexible manufacturing systems tend to be developed for making families of related parts and involve several machines linked together by robot loading, automatic tool changing and computer control. So far, these systems have not been widely diffused in industrialized countries, but they are recognized as a trend to be noted for future educational programmes for the application of computers in automated manufacturing systems.

The process of automation in the production of capital goods has reduced the input of labour per unit and therefore the total cost of production. This fact will have a substantial impact on the competitive advantages of developing countries, since industrial output will be more knowledge-intensive than labour-intensive. In the international context, this will lead to a new international division of labour. Developing countries with no clear response to the changes in the environment will be the losers in this radical structural change which will be specially important in the production of capital goods. This requires, on one hand, that information be readily available for private entrepreneurs as well as for government officials and, on the other, that research on the future impact of new technologies in the capital goods industries be undertaken.

The production of capital goods should therefore be undertaken in the framework of a clear strategy for the production and diffusion of industrial automation technologies. The strategy formulation should examine the impact at specific branch levels and should include cost/benefit analysis. The strategy should stimulate specialization in those sectors where developing countries would have new opportunities, as for example software production for the industrial automation sector of the country.

Against this background, it can be concluded that an awareness programme, covering the different stages of industrial automation is a prerequisite before developing countries adopt modern production automation techniques. An important part of this awareness programme should be the development of human resources, especially managerial and entrepreneurial capabilities. The programme must address different levels:

- National policy makers and planners;
- Enterprise directors and entrepreneurs;
- Factory level management;
- Shop floor personnel at the operator level.

One central part of the programme would include demonstration centres comprising a cell with one or two CNC machines and an inspection station linked by automatic handling equipment (such as a robot). The cell could be surrounded by suitable offices containing office based computing systems for functions such as:

- Production control;
- Process planning;
- CAD/CAM;
- Purchasing;
- Inspection;
- Accounts.

Discussions and later visits to the Fair confirm that suitable equipment is now available to set up such facilities.

In some cases regional and subregional centres may be contemplated. They should build on already existing facilities, and they could undertake training of new managerial/shop floor personnel in operation, maintenance, programming and application engineering.

4.2 Recommendations and continued work

Based on the presentation of issues, the discussions with the international experts and the above conclusions, the participants at the Seminar recommended to UNIDO:

(1) To continue the systematic analysis of the impact of the industrial automation in the capital goods industry in developing countries, in line with the approach emerging at the Seminar and as presented in different documents elaborated by UNIDO on this topic.

(2) The systematic analysis should be reflected in the formulation of the UNIDO programme on industrial automation in the capital goods industry of developing countries. The programme should have the following elements:

(a) Development objectives

To foster development of the capital goods industry in developing countries through an adequate and programmed introduction of industrial automation technologies. This requires the formulation of a technology policy to create the necessary domestic capacities in the form of human resources and managerial capabilities through e.g. training and demonstration and other high technology centres as vantage points for an industrial automation policy in the capital goods industry.

(b) Immediate objectives

To guarantee the achievement of the development objectives the following immediate objectives should be also reached:

(i) To set up a capacity in UNIDO to give direct technical assistance and specialized professional services to enterprises in developing countries, which decide to introduce automation technologies, particularly the CNC machine tools, CAD and CAM systems.

(ii) To provide decision-makers in enterprises at different levels of the public and private sector with the necessary information for a rational automation policy through:

- Knowledge of the technological requirements for upgrading the capital goods industry to improve the use of installed capacity and increase productivity;
- Knowledge of the impact of industrial automation on specific branches of the capital goods industries with particular emphasis on the implications for training of human resources, management skills and know-how requirements.

(c) Implementation of the programme

The programme should be implemented in the following steps:

Step 1:

An immediate measure to be taken would be to select priority areas. Tentatively, such priority areas could be:

(i) Market studies to define the sectors most likely to benefit from automation programmes as well as studies of the impact of such programmes on the national economy and on the traditional financial, educational and social structure;

(ii) Explore the possibilities to set up and finance awareness centres along the lines, described above, for training, promotion and consulting;

(iii) Specific projects arising from the awareness programmes to develop human resources, notably managerial capacities, but also measures to sensitize policy-makers, users and service industries;

(iv) Re-orient national capital goods projects to benefit fully from industrial automation technologies.

Step 2:

The priority activities should be undertaken according to national capacities and facilities that are already available in developing countries. It is therefore necessary to identify those areas which can be extended and expanded into fully fledged regional or subregional projects by means of pooling of country resources as well as through outside technical assistance.

The participants undertook to bring the outcome of the present Seminar to the attention of the competent authorities in their countries and to promote as wide a dissemination of the results as possible. They also recommended a determined implementation of the recommendations drawn up in the UNIDO/ESCAP Technical Working Group held in Singapore in 1986 and of the meeting in Bogotá, Colombia, in 1987 as well as of the present Seminar. For possible further activities it was recommended to arrange workshops and seminars to coincide with engineering/capital goods/machine tool exhibitions, when possible.

In the course of the Seminar a large number of contacts between various participants and enterprises participating in the EMO were taken, some leading to the initiation of negotiations for co-operation agreements. Technical assistance requirements and investment possibilities in line with the main results of the Seminar were elaborated in detail[6/] and submitted to the UNIDO secretariat for appropriate action. In particular, the participants expressed their interest in a possible joint UNIDO/UCIMU programme in the machine tools area and asked the two organizations to explore the possibilities to extend the Italian M3T programme of UCIMU to other developing countries where UNIDO is providing technical assistance to the machine tools, metal working or capital goods industry.

6/ Lists of project concepts and investments profiles are attached to this report as annexes 4 and 5, respectively.

ANNEX 1

List of participants

1. Participants

Roberto Almaraz
AAF MHA
Vice-Presidente
Alsina 1609, 6to piso, oficina 33
Buenos Aires — Telex: 21658
Argentina — Tel.: 46-9298

Omer Anlagan
EMEK Holding A.S.
Director R & D
Mesrutiyet cad n. 2 kat 9
Bakanliklar
Ankara — Telex: 42897 EMHO TR
Turkey — Tel.: (90)41172142

D.M.J. Caldera
National Engineering Research and Development Centre
Mech. Engineer
Engineering
Industrial Estate Ekala Jaela — Cable: Resden
Sri Lanka — Tel.: 536434 536384

Venatan Damodaran
COTEX Metals and Machinery
Tech. Manager
Tool Room Engineer
Box 34F COTEX DSM — Telex: 41209
Tanzania — Tel.: 37283

Jose Geraldo De Lima
UNIDO
Chief Technical Adviser
Naval Architect
PNUD A.A. 091369
Bogotá D.E.
Colombia — Tel.: 2346272

Jaime Gianella
UNIDO
Project Director
UNDP
Avenida Central 634
Lima 27
Perú — Tel.: 419135

Cao Gui Bin
Sector expert
Department for International Relations
Ministry of Foreign Economic Relations and Trade
People's Republic of China

Xu Jiaxiang
China's Mission to UNIDO
First Secretary
Untere Donaustrasse 41
1020 Vienna
Austria — Tel.: 269389

Abelardo Lago
Asociación Argentina de Fabricantes de
Máquinas Herramienta
Alsina 1607, 6to piso, oficina 33
Buenos Aires — Telex: 21658
Argentina — Tel.: 46-9298

Stanley Lau
Integrated Corporate Services
Consultant
30 Leotaud lands
Arima
Trinidad and Tobago — Tel.: 647-3939

Jorge Mendez
Federación de Industrias Metalúrgicas de Colombia
Presidente
Calle 35 4-81
Bogotá
Colombia — Tel.: 2323600

C.R. Nagendran
HMT International
Director
17 Ali Asker Road — Telex: 0845-663, 0845-8074
Bangalore 560052 — Cable: HMTINTEL
India — Tel.: 27832

Chauch Noury
CETIME
President-General Manager
22 Av. d'Afrique
El Nenzah V Tunis Cimes 30949
Tunisia — Tel.: 235312

Héctor E. Pasi
CIMHER INTI
Director Técnico
Casilla de Correo 157
1650 San Martin
Argentina — Tel.: 755-6161

See Siew Inn
Malaysian Industrial Development Authority
Deputy Director Engineering
3-6 floor Wisma
Damansara Heights — Telex: MA-30752
Kuala Lumpur 50720 — Cable: MIDAMAL
Malaysia — Tel.: 03-2543633

Indu S. Thapa
Ministry of Industry
Project Director
HMG-NEPAL
Tripure Swar
Katmandu
Nepal — Tel.: 2-15030

Getulio Tirado
ONUDI - CONDIBIECA
Project Manager
Edificio Torreoni, p. 5
Calle Veracruz
Las Mercedes
Caracas
Venezuela — Tel.: 920033-9791551

Constante Ventura
Metals Industry Research and Development Center
Executive Director
P.O.BOX 1440 MCPO — Telex: 45596 MIRDEC PM
Philippines — Tel.: 822-0431

Liang Xunzuan
Machine Tool Bureau of China
State Commission of Machinery Industry
Director
Sanlihe road, Scomi Building
Bejing
People's Republic of China — Telex: 22341 SCOMI CN

2. Consultants

Prof. Erik Bohez
Asian Institute of Technology
AIT GPO Box 2754 — Telex: 84276 TH
Bangkok — Cable: AIT-BANGKOK
Thailand — Tel.: 529-0100-13

Prof. Charles Edquist
University of Linköping
Researcher
Department of Technology and Social Change
S-58183 Linköping — Telex: 50122
Sweden — Tel.: 46-13-282260

Gian Maria Gros Pietro
CERIS CNR
Director
University Professor
via Avogadro 8
Torino 10121
Italy — Tel.: 011-515953

A. Lafaille
AFRI
Director
4, place Jussien T66
75252 Paris Cedex 05
France
Telex: 200145
Tel.: 1-43546939

E.J. Wightman
Wightman Associates
180 Myton road
Warwick CV34 6PS
United Kingdom
Tel.: 0-926-492983

3. UNIDO

Bengt O. Karlsson
Head, Sectoral Studies Branch
UNIDO
P.O. Box 300
A-1400 Vienna
Austria

Swamy Rao
Senior Industrial Advisor
Engineering Branch
UNIDO
P.O. Box 300
A-1400 Vienna
Austria

Leonardo Pineda-Serna
Industrial Development Officer
Industrial Planning Branch/Sectoral Studies Branch
UNIDO
P.O. Box 300
A-1400 Vienna
Austria

Geofrey Mariki
Industrial Development Officer
System of Consultations Division
UNIDO
P.O. Box 300
A-1400 Vienna
Austria

4. Observers

G. Bosi
JOBS SPA
Via Marcolini 13
29100 Piacenza
Italy
Telex: 531396 JOBS I

Maria Teresa Carelli
Docente Universitaria
Corso Moncalieri 450
10133 Torino
Italy — Tel.: 011/6611476

Antonio FARESE
BLM
President Ass.
Via Salveregina 30
22063 Cantu Como — Telex: 380204
Italy — Tel.: 031/707911, 031/704555

Francesco Leone
CERIS/CNR
Assistente
Via Avogadro 8
0121 Torino
Italy — Tel.: 011/515953

Leticia Lago
Asociación Argentina de Fabricantes de Máquinas Herramientas
Alsina 1607
Buenos Aires — Telex: 21648
Argentina — Tel.: 46-9298

ANNEX 2

Programme

BLOCK A: Technological aspects

Thursday, 15 October 1987

8.30 - 10.00	Registration of participants
10.00	Opening ceremony
10.30	Coffee break
10.45	Election of Chairman, Vice-Chairman and Rapporteur
11.00	Present situation of the machine tools industry in Italy from the perspective of new technological developments. - Prof. G.M. Gros Pietro, University of Turin, Italy
12.30	Lunch
14.00	Technological developments in the machine tools industry in OECD countries - Prof. C. Edquist, University of Linköping, Sweden
15.00	Discussions
15.45	Coffee break
16.00	Present situation of the machine tools industry in developing countries. Results of UNIDO studies - Mr. L. Pineda-Serna UNIDO, Industrial Planning Branch
16.45	Discussions
17.30	Closing of session

Friday, 16 October 1987

9.00	Possibilities for technological upgrading of machine tools industry in developing countries - Mr. E. Wightman, international consultant to UNIDO, United Kingdom
10.00	Discussions
10.45	Coffee break
11.00	State-of-the-art of CAD/CAM systems and perspectives for developing countries - Mr. E. Bohez, Asian Institute of Technology, Bangkok

12.00	Discussions
12.45	Lunch
14.15	State-of-the-art of robotics and flexible manufacturing systems (FMS) and perspectives for developing countries - Mr. A. Laffaille, Association Française de Robitique Industrielle France
15.00	Dicussions
15.30	Coffee break
15.45	ROUND TABLE: Impact of industrial automation in the production of capital goods in developing countries
17.30	Closing session

Saturday, 17 October 1987

Guided visit to the 7th EMO Milan Fairground

Sunday, 18 October 1987

No official programme

Monday, 19 October 1987

9.00	UNIDO activities in the machine tools industry - Technical Assistance Programme, Mr. Swamy-Rao, UNIDO, Engineering Branch - System of Consultations Division, Mr. C. Mariki - Sectoral Studies in the capital goods industry, Mr. B.O. Karlsson, Head, UNIDO, Sectoral Studies Branch
10.00	Coffee break
10.15	Closing session Block A - Mr. D.L. Siazon, Jr., Director-General of UNIDO

BLOCK B: Investment promotion

Monday, 19 October 1987

10.45	Opening of Block B - Mr. S. Zampetti, Investment Promotion Office in Milan
11.30	Programme for Block B will be made available to participants. Start of discussions
17.00	Official opening of the Investment Promotion Office in Milan - Mr. D.L. Siazon, Jr., Director-General of UNIDO

Tuesday, 20 October 1987

Continuation of discussions on investment promotion

Wednesday, 21 October 1987

Visit to factories near Milan

Thursday, 22 October 1987

9.00	Submission of draft final report of the Seminar
10.30	Coffee break
10.45	General evaluation of the Seminar, suggested follow-up actions
11.30	Closing session of the Seminar

UNIDO/UCIMU Visit programme

Monday, 19 October 1987

Firm	Stand	Interested countries	Hour
BAKVER	6A - B01	Brazil, Venezuela, P.R. of China, Rep. of Korea, Malaysia	11.00 a.m.
OMAG	4 - A24	All	11.45 a.m.
ROSA	12 - B05	All	12.30 a.m.
FICEP	4 - D12	P.R. of China, Rep. of Korea, Thailand, Malaysia, Philippines	2.30 p.m.
VIGEL	7 - B03	All	3.30 p.m.
COLGAR	4 - E12	All	4.30 p.m.

Tuesday, 20 October 1987

Firm	Stand	Interested countries	Hour
GERNETTI	20 - B16	Rep. of Korea, P.R. of China	9.30 a.m.
S.A.F.O.P.	5 - A02	P.R. of China, Rep. of Korea, Thailand	10.30 a.m.
VARINELLI	5 - C03	Argentina, Rep. of Korea	11.30 a.m.
INNSE	4 - D02	Argentina, Brazil, P.R. of China, Rep. of Korea, India	2.00 p.m.
BLN	20 - A02	All	3.00 p.m.
DUPLOMATIC	15 - G06	All	4.00 p.m.
TACCHELLA	12 - B01	Asia	5.00 p.m.

Wednesday, 21 October 1987

9.30 a.m. Visit to RIVA CALZONI Factory - Via Stendhal - Milan
Contact: Mr. Comi

Dinner in the Sala Cavalieri inside the Fairgrounds

2.30 p.m. Visit to DUPLOMATIC Faactory - Via Alba 18 - Busto Arsizio (VA)
Contact: Mr. Rossignoli

The participants will be collected at Hotel COLLEONI (Agrate Brianza) at 8.15 a.m. and then taken back in the evening.

UCIMU'S representative: Ing. P.L. Zenevre

ANNEX 3

List of documents

UNIDO, Selected Aspects of Microelectronics Technology and Applications: Custom and Semi-Custom Integrated Circuits, Technology Trends Series No. 1, UNIDO/IS.631, 1986

UNIDO, Selected Aspects of Microelectronics Technology and Applications: Numerically Controlled Machine Tools. Technology Trends Series No. 2, UNIDO/IS.632, 1986

UNIDO, The Machine Tool Industry in the ASEAN Region: Options and Strategies. Main issues at regional level. Sectoral Working Paper Series, No. 49, Volume I, UNIDO/IS.634, 1986

UNIDO, The Machine Tool Industry in the ASEAN Region: Options and Strategies. Analysis by Country, Sectoral Working Paper Series, No. 49, Volume II, UNIDO/IS.634/Add. 1, 1986

UNIDO, Final Report of the UNIDO/ESCAP Technical Working Group on Production and Use of Machine Tools in the Engineering Industry of ESCAP Developing Countries, Singapore, 17-21 November 1986, Sectoral Working Paper Series No. 55, PPD.17, 1986

UNIDO, Implicaciones de la nueva revolución industrial: nuevas tecnologias de información y su impacto sobre las estrategias de industrialización, Serie de Documentos de Trabajo Sectoriales Núm. 53, PPD.4, 1986

UNIDO, Informe final de la Reunión del Grupo Técnico ONUDI/JUNAC para la formulación de un programa de trabajo en microelectrónica en las industrias de bienes de capital de los paises del grupo Andino, Paipa, Colombia 8-12 Marzo 1987, PPD.36, 1987

UNIDO, Industrial Automation in the Production of Capital Goods. Issues for Developing Countries, Sectoral Working Paper Series No. 61, PPD.44, 1987

UNIDO, Technological Requirements for the Machine Tool Industry in Developing Countries, Sectoral Working Paper Series No. 51, UNIDO/IS.642, 1986

UNIDO, Technological Perspectives in the Machine Tool Industry and their Implications for Developing Countries, Development and Transfer of Technology Series, No. 19, UNIDO/ID.312, 1085

ANNEX 4

Project proposals for technical assistance to developing countries emanating from the discussions in the Seminar

Argentina

Upgrading the capabilities of an existing research centre in: CAD/CAM, design & operation of CNC machine tools, industrial robots & flexible manufacturing systems

People's Republic of China

Malaysia

Assistance in upgrading country industry by the development of common industrial engineering and supporting services, including training

Promotion of CNC machine tools utilization within the machine tool sector

Workshop on NC, CNC application in metalworking industries in Asia

Nepal

Prototype development and machine tool design training centre -
1st phase: Pre-feasibility study or feasibility study
2nd phase: if funds feasible, then assistance in establishing the centre

Philippines

Common facilities for metal working in selected regional centres

Common facilities for metal working co-operatives in selected regional centres

Sri Lanka

Development of numerical controlled machine tool utilization

Tanzania

Expansion and modernizing the existing tool room of Cotex metals and machinery

Trinidad and Tobago

Computer-aided design and CNCMT manufacture of spares for plants & equipments

Turkey

Development of low cost CNC systems for Turkey

India

Establishment of an international CNC technologu training facility to meet the input requirements of all developing countries

ANNEX 5

Investment profiles

People's Republic of China

CPR/827	CNC horizontal boring and milling machines
CPR/828	High precision hard alloy dies and tool machining
CPR/829	CNC gear hobbing machines
CPR/830	Mould and dies
CPR/831	CNC lathe and mill tur centre
CPR/833	CNC control system of machine tools
CPR/835	Injection moulding and extruding machines
CPR/836	Milling machines tool/machining centre
CPR/839	Rubber recycling machines
CPR/853	Mould copper pipes for billt and round continous casting machines

Tanzania

TAN/001/MI	Modernizing the existing tool room
TAN/002/MI	Two wheelers and mopeds manufacturing plants

Tunisia

TUN/001/MI	Printed circuits and electronics devices
TUN/002/MI	Moulds and sheat tools

Indonesia

IND/241/V/87-6	Manufacture of precision jigs and fixtures

Argentina

ARG/001/MI	Turri new machine tool factories in Argentina for manufacturing CNC lathe and machine centres

Trinidad and Tobago

US/INT/87-061	Manufacture of spares and replacement parts for machinery