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CONDITIONS OF ENTRY AND MEASURES TO PROMOTE COMPETITIVE LOCAL PRODUCTION AND EFFECTIVE UTILIZATION OF MACHINE TOOLS

Issue paper*

Prepared by

the UNIDO Secretariat

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Summary

Entry into the machine-tool industry and identification of measures to promote competitive local production require a clear understanding of the operations of the industry on a world-wide basis. A comparative analysis of the world-wide operations of the industry vis-a-vis that in the developing countries would then facilitate determination of the constraints and opportunities confronted by the latter countries in entering and sustaining their machine-tool industries.

While not all developing countries may wish to engage in production of machine tools, their effective utilization is important for all countries. Of major concern for developing countries are the implications of increasing utilization of numerical control machine tools and other flexible automation equipment in the engineering industries of the industrialized countries. It is important to consider the social impact of these new technologies and the appropriateness of associated organizational innovations in the context of the industrial environment in developing countries.

Greater participation of the private sector in engineering industries requires examination of financing problems and industrial and entrepreneurial policies. New approaches are required to address the financing problems of the sector which could include debt-conversion schemes, as well as leasing arrangements. The specific problems of small and medium scale enterprises merit special attention due to their pre-eminent role in the sector.

Certain industrial processes in engineering industries could have detrimental environmental impacts if adequate precautions are not taken. Enhanced international co-operation, in terms of provision of technical expertise in environmental management, and increased promotion of cleaner production technologies, would alleviate these problems. International organisations and transnational corporations can play a major role in this respect.

Explanatory Notes

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

The following abbreviations are used in this report:

CIM	Computer Integrated Manufacturing
CNC	Computer Numerical Control
FMC	Flexible Manufacturing Cell
FMS	Flexible Manufacturing System
FRG	Federal Republic of Germany
GDR	German Democratic Republic
ISIC	International Standard Industrial Classification
NC	Numerical Control
R&D	Research and Development
U.S.A.	United States of America
USSR	Union of Soviet Socialist Republics

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INTRODUCTION

1. Previous Consultations on the Capital Goods Industry have emphasized the central role of this sector in the industrialization process, and drew attention to the consequences of the gross imbalances in the state of its development between industrialized countries and the majority of developing countries. Development of the capital goods industry was seen as a long term process requiring mastery of a wide range of technologies. Newcomers into the sector faced several barriers ranging from prejudices on the part of foreign trained technical personnel preferring to purchase industrial machinery from industrialized countries, to problems of limited domestic markets and lack of economic and technical infrastructure. The need to formulate integrated development plans for the sector that took into account the technological complexity of capital goods and a country's manufacturing capacity was recognized by the Consultations.

2. Among the large variety of capital goods, machine tools occupy a special position since they are used to manufacture other capital goods. This strategic importance has not always been recognized by developing countries and very few machine-tool plants are found in these countries. Machine tools have undergone major technological changes in recent years, exemplified by the advent of CNC machine tools and flexible manufacturing systems. These developments have direct implications on engineering industries world-wide, and affect both users and producers of machine tools.

I. THE WORLD MACHINE-TOOL INDUSTRY: HOW IT FUNCTIONS

3. With world-wide sales estimated at $ 46,500 1/ million in 1990, the machine-tool industry is small compared to other industrial sectors. Despite its small size, the machine-tool industry plays a strategic role in economic and industrial development. Machine tools are capital goods used to manufacture other capital goods which provide the means of production in all manufacturing activities. The strategic nature of the industry arises from its role as a supplier of continously improved manufacturing technologies, (machines, systems and methods) which is a major factor in the enhancement of overall productivity in industry. The machine-tool industry forms one of the principal nodes 2/ of technological diffusion since new skills and techniques developed in the industry, in response to specific requirements, rapidly diffuse into other manufacturing industries.

4. The machine-tool industry is an established industrial sector which has provided the driving power for industrial development for well over a century. The industry is knowledge-intensive, employing highly skilled design engineers, production technologists and machine operators. It is, however,

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1/ American Machinist, February 1991.
2/ OECD, "Technology and international Competitiveness: an interpretation of the relationships in the machine-tool industry", 1984.

not a high-technology industry. Investments in R&D are relatively low compared to other industrial sectors like semiconductors, computers and pharmaceuticals. The industry uses many technological innovations developed in other industries, notably electronics and increasingly materials science.

5. A distinction is made between metalcutting and metalforming machine tools.* On a world-wide basis, metalcutting machine tools account for about 75 per cent of the market demand the remaining 25 per cent being for metalforming machine tools. Machine tools were primarily manually-operated up to the early 1970s. The invention of the microprocessor led to the development of CNC machine tools. This development altered the "boundaries" of the machine-tool industry. Prior to the introduction of CNC technology, the machine-tool industry was a clear sub-sector of the non-electrical machinery industry (ISIC 382). The machine-tool industry can now be considered as a subsector of the mechatronics sector, which is a combination of mechanical engineering and electronics. 3/

6. There are some 3000 types of machine tools differing in their production technologies and design features. This diversity has made it necessary for machine-tool firms to specialize in well-defined, narrow product lines catering for particular markets. One study 4/ has identified about 100 strategically different machine-tool business segments differentiated according to:

(a) degree of specialization of the machine tool: a conventional lathe has universal application while some machine tools are tailor made for a specific application;

(b) production volume: a machining centre is well adapted to the production of small batches of differentiated products while transfer lines are used in large volume production; and

(c) market potential: larger firms producing for large markets will have a competitive advantage over smaller firms.

7. The machine-tool industry is dominated by small- and medium-sized enterprises, especially in the industrialized market economies. The industry has been ideal for entrepreneurial engineers and machinists who have established production units on the basis of skills rather than heavy financial resources. However, these producers buy-in many components and rely heavily on sub-contractors. The value of bought-in components and subcontracting services, as a percentage of total production inputs, typically ranges from 40 per cent in Europe to 60 per cent in Japan. This heavy reliance on subcontracting services has led to geographical concentrations of the industry.

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* Only metalworking machine tools are considered.

3/ Mick McLean, "Mechatronics development in Japan and Europe," Frances Pinter, 1983.

4/ Boston Consulting Group, "Strategic study of the machine-tool industry,", 1985.

8. The high level of subcontracting arrangements in Japan has had distinct advantages, including higher efficiencies measured in terms of output per employee as compared to other countries, with lesser use of subcontractors. The machine-tool builders in Japan are mainly involved in assembly of bought-in components, wiring and final adjustments. Production is limited to the most important pieces, such as spindles and sometimes heavy castings. All other components, including ball bearings, electric motors, cables and electronic controls are purchased from subcontractors. In addition, subcontractors provide services such as heat treatment, casting, surface treatment, gear-making and machining.

9. Among the determinants for competitive advantage of a national machine-tool industry, the following appear most important:

(a) Factor conditions: the industry relies on highly skilled labour in mechanical engineering and increasingly electronics. Thus availability of such skilled personnel is one of the most important factors contributing to success in the machine-tool industry.

(b) Demand conditions: the characteristics of the domestic and regional demand for machine tools determines the growth and technological level of the machine-tool industry. Thus, the structure, size, and technological level of the engineering industries play a crucial role in shaping the machine-tool industry. Among engineering industries, the automotive and aerospace industries often have the most stringent requirements and hence their presence tends to stimulate technological innovations in the machine-tool industry.

(c) Supporting industries: the presence of a subcontracting network of supporting industries is important for development of the machine-tool industry.

(d) Firm strategy, structure and competition: larger firms have advantages for those market segments which allow long runs of production. Smaller firms tend to concentrate in niche markets. In all cases, a competitive environment is essential for success.

10. Government policies and measures directly contribute to shaping the competitive advantage of a national machine-tool industry. Thus, by providing appropriate training facilities, the factor conditions are promoted. Governments can shape demand conditions through public procurement policies and establishment of standards and regulations. Governments may also take measures for the promotion of supporting industries and for influencing firm strategies through tax and trade policies.

11. World production of machine tools in dollars has increased from $8,000 million in 1968 to $46,500 million in 1990. The increase has, however, not been uniform over this period. In fact, machine-tool production is considerably more cyclical than that for other industrial sectors. The demand

for machine tools is strongly linked to the demand for capital goods which are themselves dependent on investment trends. It has been observed that in periods when production capacities were fully utilized, a 10 per cent variation in the demand for consumer goods brought about a 40 per cent variation in the demand for capital goods. 5/

12. Table 1 depicts the geographical distribution of machine-tool production for the years 1980, 1985 and 1989 on a regional basis. Western Europe retained the leading position over this period. The biggest changes occurred in both North America, where the share of world production dropped from 18.7% in 1980 to 8.7% in 1989 and in Asia, where the corresponding figures show an increase from 17.9% to 30.3%. The latter case is mainly due to the rise of Japan and some East Asian countries.

13. Table 2 lists the main machine-tool producing countries in 1990 and their estimated shares of the world market. Machine-tool production is heavily concentrated among a few industrialized countries. The 1990 top five producers were Japan, Germany (former FRG), USSR, Italy and Switzerland. These five countries accounted for 67 per cent of world production for that year. This concentration of production is, however, lower than that for related industries, such as those for electronics and automotive. In the electronics industry, the top five producers accounted for 79 per cent of world production in 1988. For the automotive industry, the corresponding figure was 76 per cent.

14. Significant shifts in production have occurred among the leading producers in industrialized countries. Among factors which have contributed to the declining performance of the machine-tool industry in some of these countries, the following may be cited:

(a) lack of export orientation;

(b) domestic demand conditions that did not stimulate technological innovations;

(c) reluctance on the part of producers to adopt new innovations;

(d) poor relationships between local producers and users of machine tools. In particular, some main producers failed to appreciate the changing needs of small- and medium-scale engineering enterprises;

(e) lack of interface standards between numerical control units from different vendors.

5/ B. Real, "Technical Change and Economic Policy - The Machine-Tool Industry", OECD, 1980.

15. On the other hand, countries which increased their shares of world production of machine tool' had positive atributes with regard to the above factors and their industries were characterized by:

(a) shop-floor work organizations which emphasized flexibility in production even prior to the introduction of flexible automation technologies;

(b) investments by major users in the production of machine tools for their captive needs as well as external sales. Strong user-producer bonds were thus forged;

(c) pre-eminence in the art of precision machining and production of electronics products;

(d) industrial policies which recognized the strategic importance of the machine-tool industry and hence gave the necessary incentives for entrepreneurs to enter the sector.

16. Consumption of machine tools is a rough indicator of a country's rate of industrialization. In 1988, western industrialized countries accounted for 63 per cent of world machine-tool consumption. The corresponding share for the USSR and Eastern Europe was 28 per cent, while that for developing countries stood at 9 per cent.

17. There is a strong correlation between machine-tool consumption and investment trends in the engineering industries where there is a need for modernization and/or creation of additional capacities. With the increasing use of CNC machine tools, software costs represent an increasing share of consumption in the industry.

18. In 1968, one-third of machine tools produced world-wide were traded internationally. Twenty years later, this ratio had reached almost 50 per cent. This trend points to the fact that international trade plays a very important role in the machine-tool industry. The machine-tool industry has become globalized and success in the industry requires effective exporting in the international market. In fact, trade ratios (defined as the ratio of the sum of imports and exports to production) can be as high as 300 per cent for some producers. This implies a high level of import penetration. The combination of export orientation and import penetration is further testimony to the high degree of market specialization in this industry.

19. Exports to developing countries rose from US$ 2515 million in 1980 to US$3453 million in 1987. Western Europe is the largest supplier of machine tools to developing countries, accounting for 46 per cent of all machine-tool imports by developing countries in 1987.

20. In contrast to the high trade orientation, the internationalization of capital in the machine-tool industry has been very limited, with most foreign investments being made in industrialized countries. Thus, leading American and European machine-tool firms have invested mainly in each other's region.

Overseas production by Japanese machine-tool manufacturers has been a competitive strategy in keeping with the export drive measures adopted by that country. Japan has set up machine-tool plants in the U.S.A. and Europe to cater for the needs of, inter alia, their own newly installed automotive plants in those countries.

21. Foreign investments in developing countries have been limited to a few cases in Latin America and Asia. Germany (former FRG) has been a forerunner in establishing joint venture firms in Latin America, while some Japanese firms have relocated their production of conventional machine tools to other Asian countries.

II. MACHINE-TOOL PRODUCTION IN DEVELOPING COUNTRIES

22. The share of developing countries in production of machine tools is very limited. In 1988 this share stood at only 9 per cent 6/. It is possible to distinguish four categories of developing countries with regard to the status of the machine-tool industry in those countries:

(a) countries with little or no manufacturing capacity for machine tools;

(b) countries with the capability to manufacture machine tools but which have not yet entered the sector;

(c) countries manufacturing conventional machine tools and planning to enter into production of NC machine tools; and

(d) countries that produce conventional and NC machine tools and aspire to consolidate their positions.

23. One fundamental pre-requisite for successful entry into the machine-tool industry is the presence of dynamic engineering industries. Engineering industries are important for two main reasons: on the demand side, they constitute the major market for machine tools, and on the supply side, they provide the necessary supporting industries, which facilitate subcontracting arrangements in the production of machine tools. However, the structure of engineering industries is also important. In countries with little or no manufacturing capacity for machine tools, the engineering industries are embryonic and consist mainly of manufacturers of metal products (ISIC Division 381). Fabrication of most metal products requires mainly simple metalforming machine tools, drills and grinders. In these countries, metalcutting machine tools are used primarily in repair and maintenance workshops and for educational purposes. Establishment of machine-tool production facilities may not be feasible except for some countries where production of simple drills and grinders may be initiated depending on other factor conditions.

6/ World Machine-Tool Industry (UNIDO ID/WG.514/), 1991.

24. In the more advanced developing countries, engineering industries are often more developed and, in some cases, may include production of non-electrical machinery (ISIC Division 382) and transport equipment (ISIC Division 384). In these same countries it may be possible to sustain a viable machine-tool industry. Table 3 presents data on the production output (and structure) of engineering industries and machine-tool production in selected developing countries. Analysis of this data shows that machine tool production takes place mainly in those countries with value-added production of their engineering industries in excess of US$1000 million. Some production is however also registered in a few developing countries with much smaller value-added outputs of their engineering industries. In some of these latter group of countries, regional or sub-regional markets may justify existence of machine-tool plants.

III. CONSTRAINTS AND OPPORTUNITES FOR THE DEVELOPMENT OF THE MACHINE-TOOL INDUSTRY IN DEVELOPING COUNTRIES

25. Increased participation of developing countries in machine tools production has to take into account, not only of the strategic nature of the industry, but also the anticipated economic returns (in terms of value-added, foreign exchange savings, employment generation and domestic resource costs), as well as the prospects of being internationally competitive within a reasonably short period of gestation.

26. Entry into the industry should also be based on a comprehensive evaluation of the economic and technical constraints that are likely to be faced. Appropriate strategies to resolve those constraints should then be developed. Among the factors that often act as barriers to entry into the machine-tool industry and sustenance of competitive production, the following should be recognized:

(a) Lack of sufficient domestic market. The domestic market for machine tools is directly related to the state of development of engineering industries, including their sub-sectoral structure and sophistication. Major users of machine tools are the non-electrical machinery, transport equipment and electrical machinery sub-sectors. However a large domestic market may offer only static efficiency to the machine-tool industry. The quality of this domestic demand is equally important in creating dynamic efficiencies by exerting pressure on producers to upgrade their production lines. It should also be pointed out that, while the domestic market for many developing countries may be too limited, there are often unexploited opportunities in sub-regional and regional markets. Through co-operation it is possible to develop viable machine-tool production facilities to serve sub-regional and regional markets. Important initiatives that have been taken in this respect include the capital goods integration agreement between Argentina and Brazil and the agreement to promote joint projects between Morocco and Tunisia. Furthermore, the trend towards specialization in the production of NC machine tools in the

industrialized countries offers new export market opportunities for conventional machine tools that could be exploited by those developing countries able to attain international competitiveness in that market niche.

(b) Shortage of skilled personnel. The machine-tool industry requires engineers, technicians and skilled machine operators specialized and having acquired several years experience in the metalworking and engineering industries. Such highly qualified personnel are not easily found in developing countries. A human resource development programme, coupled with an integrated strategy to develop the metalworking and engineering industries, could alleviate this constraint. In this respect, it may be useful to define clearly the role of the State vis-a-vis the private sector.

(c) Lack of supporting industries. As already established, the machine-tool industry functions most efficiently where it is served by a well-developed network of subcontractors. These subcontractors provide parts and components as well as some technical services to the machine-tool producers. Due to the underdevelopment of engineering industries in several developing countries, subcontracting firms are not easily found and this has led to the tendency to establish highly vertically integrated machine-tool plants. This situation has led to inefficient plant utilization and high prices of products in some of these countries.

(d) Difficulties in technology acquisition. Historically, the main channel for technology transfer in the machine-tool industry has been "reverse engineering", while formal technology transfer agreements have played a far smaller role. This non-formal channel of technology transfer has been widely used in the U.S.A., Japan, and more recently in some East Asian countries. Reverse engineering involves learning by using imported machine tools and developing replicas or adapted models. The lack of access to blueprints makes reverse engineering very difficult, a problem which puts many developing countries at a disadvantage due to their shortage of skilled personnel in the engineering sector. Thus for these developing countries, technology acquisition will be based mainly on the formal channel involving licensing and/or joint ventures. Successful transfer of technology under these arrangements requires a long step-by-step process of backward progression from sales, servicing, licensing for assembly of completely knocked-down kits and then to licensing for full production. Since the design aspect is crucial in this industry, licensing arrangements should reflect this priority as well as the production know-how so as to ensure effective technology transfer.

(e) Product mix restriction and need to diversify. The product mix is determined by the nature of the domestic market. In most developing countries conventional machine tools will remain the most widely used machine tools in the foreseeable future. Also, since producers in the industrialized countries are shifting towards NC machine

tools, this opens up new export opportunities for developing countries. Thus the product mix for new entrants will be of the conventional type. As a guideline, Table 4 categorizes some examples of different types of machine tools in relation to the level of manufacturing capabilities in a given country. Usually newcomers start with simple standard equipment like bench drills, bench grinders and sheet metal forming machines and gradually progress with the introduction of the more sophisticated equipment. It is not advisable, neither is it desirable, to attempt to be self-sufficient in this industry. However, product diversification to include other products of engineering industries (such as agricultural machinery), is often sound business practice due to the cyclic nature of the machine-tool market. For the more advanced developing countries, entry into NC machine-tools production may be viable depending on the strength of their precision mechanics and electronics industries. While NC controls may be imported, it is necessary to develop skills in software production and system integration as well for effective production and use of NC machine tools.

(f) Inadequate industrial policies. Industrial policies have played a significant role in the development of the machine-tool industry in the industrialized countries through fiscal incentives, local protection from imports, State procurement policies, and financial support for research and development. Such comprehensive industrial policies are often lacking in the developing countries. This situation is aggravated by the increasing trend towards imports liberalization which could jeopardize newly established machine-tool plants. Fiscal incentives to encourage local production could help to sustain machine-tool plants operating under an imports liberalized economy. Where protection is offered, this should take into account the need to encourage competitiveness so that the local engineering industries do not suffer undue disadvantages arising from inefficiencies of the machine-tool industry. Governments could also play the important role of mediating between the sometimes conflicting interests of users looking for the best equipment available at the lowest price, and those of machine-tool producers endeavouring to upgrade local production. Close collaboration in product development is essential between users and producers so as to ensure that the machine-tool industry adequately meets the technological requirements of the user industries. The establishment of government-funded engineering design and development institutes to assist producers and users, has been an important motivation for the development of machine-tool industries in several countries.

IV. UTILIZATION OF ADVANCED MACHINE-TOOL TECHNOLOGIES

A. Numerical Control Machine Tools

27. All countries utilize machine tools either for repair and maintenance or engineering production. Hence technological developments affecting machine tools are of concern to all countries. The most fundamental innovation which has occurred in the machine-tool industry, has been the application of microelectronics technologies in the development of numerical control systems. This innovation has led to the realization and rapidly increasing utilization of flexible automation equipment such as CNC machine tools, flexible manufacturing cells and flexible manufacturing systems. The underlying feature of these technologies is the greater degree of flexibility in production than was the case for classical electro-mechanical automation based on exploitation of economies of scale.

28. Flexible automation allows a new compromise between flexibility and economies of scale. While economies of scale were gained because the cost of producing a single unit declined as volume of production increased, economies of scope are gained in the volume production of a set of differentiated goods 7/ and they are created by standardizing processes to manufacture a variety of products. Economies of scope are said to exist when a firm which produces two products simultaneously is able to produce them at a lower cost than two separate firms producing each one of these products separately.

29. Compared to mass production systems, flexible automation equipment offers greater flexibility in terms of:

(a) accepted variance of throughputs (defined as the number of cost-effectively produced homogeneous items per unit of time);

(b) acceptable variances in output varieties; and

(c) minimum scale of production.

30. The trend towards more flexible production systems has also to be considered in the context of changes affecting market demand. In the period of relative scarcities following the Second World War, price was the most important criterion for consumer products and enterprises mass-produced goods looking for the cheapest labour costs. In the 1970s, quality became a criterion as important as price, and in the 1980s consumers demanded quality products which were simultaneously more tailored to their individual tastes and needs. With these changes in the market place, the era for mass production systems appears to be giving way to that for flexible production systems.

7/ J.D. Goldhar, M. Jelineks "Plan for economies of scope", Harvard Business Review 61, Nov-Dec, 1983, page 141.

31. This demand pressure which was first felt in the consumer electronics market and subsequently in the automotive industry, has accelerated the pace of development of flexible automation equipment. Corporations which produced customized goods aimed at market niches, had to be flexible enough to increase production in those market segments in which demand proved high. These corporations needed equipment which could produce economically in small batches in order to reduce work in progress, minimize inventories and allow consumer demand to be met in the shortest possible period. In some markets, there is a growing "time-based competition" among manufacturers since consumers are willing to pay more for the privilege of speed.

32. The consequences of these changes go beyond a retooling of manufacturing facilities since a significant level of flexibility can often be achieved through organizational innovations. In order to face up to these new challenges, manufacturing companies, especially in Japan and increasingly in the other industrialized countries, are reorganizing their production processes under just-in-time (JIT) principles. JIT has evolved into an overall system for eliminating waste and maintaining high levels of reliability and quality in the total production process.

B. Social impact of flexible automation

33. The social impact of flexible automation technologies relates to employment, work intensification, work organization and job contents.

34. With regard to employment, flexible automation technologies generally save on labour. As an example, it has been estimated that a CNC machining centre with a robot and tool management system required only one or two operators. A comparable arrangement using conventional machine tools would require 10 or more operators.

35. Despite the labour saving characteristic of flexible automation technologies, it is necessary to consider both direct and indirect effects so as to assess the overall impact on employment. Direct effects include employment lost or generated inside or outside the enterprise. Indirect effects refer to the gains obtained due to the competitiveness acquired or the employment which could have been lost on account of lack of competitiveness caused by failure to adopt new technologies.

36. At the macroeconomic level, studies in industrialized countries have revealed no significant correlation between unemployment rates and the use of flexible automation techniques. Investments in flexible automation equipment have not led to significant job displacements since against this reduction, there is the additional demand for indirect support in areas such as maintenance, production planning and computer programming.

37. Introduction of flexible automation equipment leads to work intensification. When conventional machine tools are used the effective time for machine utilization is, on average, only about 5-6 per cent of the total time spent on a work piece. The rest of the time the machine is idle because

of placement, measurement, unloading, tool change, etc. With numerical control machine tools, the effective time for machine utilization is typically 15 to 25 per cent.

38. New work organisations are required when flexible automation equipment replaces conventional machine tools. With the latter, work organization is characterized with relative separation between production planning activities and those of the workshop. Use of NC machine tools necessitates greater interaction between the production planning function and workshop activities. Thus, the traditional work separation between production planning and workshop activities tends to disappear when flexible automation equipment is used.

39. The impact of flexible automation technologies on workers' skills is still a subject of debate. It has been argued that these technologies are fundamentally de-skilling since they substitute for intellectual activity, judgement and experience. On the other hand, opponents to the de-skilling thesis stress the positive impact of automation on workers skills. It is, however, generally agreed that these new technologies do not generate employment for low-skilled workers.

40. Flexible automation technologies change the nature of the workers skills in two ways. Firstly, the know-how of the skilled worker is partially "memorized" upstream from production. Secondly, the functions of execution and command tend to be transferred to the machine itself.

41. Transformation of workers' skills as a result of the introduction of CNC machine tools appears outside the workshop as well. This is particularly so for maintenance technicians for whom knowledge of microelectronics technologies becomes an absolute necessity.

C. Sectoral diffusion of NC machine tools

42. The trend towards use of flexible automation technologies in engineering industries can be deduced by analysing the sub-sectoral diffusion of NC machine tools (including CNC). This analysis would indicate which sub-sectors have had the highest diffusions and hence the biggest changes on rules of international competitiveness.

43. The diffusion of NC technologies can be determined from inventory statistics of leading machine-tool users. Analysis of these inventories reveals that:

(a) there is an accelerated pace of acquisition of NC machine tools by small and medium scale enterprises. The advent of highly "user friendly" manual data input NC machine tools and off-line programming systems have made this technology much more attractive to smaller engineering firms;

(b) the greatest number of NC machine tools is found in the non-electrical machinery sub-sector (ISIC 382). However the rate of

diffusion has been highest in the transport equipment sub-sector. The diffusion rate has also been increasing in the electrical machinery sub-sector;

(c) projections on the population of NC machine tools in engineering industries show that the rates of diffusion will continue to increase for most of the 1990s.

D. Flexible Manufacturing Systems and Computer Integrated Manufacturing

44. NC machine tools are essentially substitution innovations which offer more efficient ways of doing what can be done by conventional machine tools. Flexible Manufacturing Systems (FMS) represent revolutionary innovations with potential gains that are considerably greater than those attainable with stand-alone NC machine tools.

45. Due to the variety of definitions and inadequate data, estimates of installed FMS vary widely. Diffusion of FMS has, however, been restricted to selected industries: mainly transport equipment, non-electrical machinery and electrical machinery, in that order.

46. When successfully implemented FMS can dramatically reduce production costs as a result of increased machine utilization, reduction in set-up and lead times and savings in stocks, work in progress, capital employed and labour costs. Investments in FMS have, however, not always yielded the anticipated results due to:

(a) technical problems in terms of interface software and network organization;

(b) organizational problems; and

(c) problem diagnosis difficulties due to the integrated nature of the system.

47. As a consequence of the above difficulties, many firms have opted for a step-by-step approach whereby small islands of automation are progressively linked with workpiece transport and tool management systems.

48. Whilst NC machine tools and flexible manufacturing systems are confined to the manufacturing sphere, computer integrated manufacturing (CIM) concerns the integration between design, production and management. The CIM concept will be further exploited in the 1990s to yield integrated business systems.

49. One major constraints on the diffusion of CIM is the lack of industry-wide standards in software. The International Standards Organization is promoting the Open Systems Interconnection (OSI).

V. FINANCING MECHANISMS FOR CAPITAL GOODS INDUSTRY DEVELOPMENT

50. Financing is one of the major constraints hindering capital goods (including machine tools) development in developing countries. Many of these countries are experiencing acute shortages of financing for new production facilities, modernization projects and trade development. This situation arose from the consequences of the excessive debt burdens and economic crises faced by several developing countries. Financing problems are especially severe for small- and medium-sized enterprises that often cannot satisfy loan conditions imposed by financial institutions.

51. Leasing agreements in the capital goods sector in developing countries could play a far greater role than hitherto and hence help to alleviate part of the problem. This is particularly so because guarantees are not normally required under a leasing contract as would be the case for commercial loans.

52. In the industrialized countries leasing is a multibillion dollar industry. As an example, at the end of 1989, nearly 30 per cent of the gross capital formation in the United States of America was financed through leasing. This translated to the sum of $120,000 million.

53. Leasing firms are often affiliated with financial institutions, machinery suppliers or marketing concerns. The firms enter into leasing contracts with user enterprises which give the latter the right to use the machinery in their production activities for a specified period without undertaking to purchase. The user enterprise (the lessee) pays a periodic fee to the leasing firm (the lessor) during the contract period. At the end of the contract period, the lessee usually has three options, namely:

(i) to purchase the machinery at a residual value specified in the contract; or

(ii) to extend or renew the leasing contract; or

(iii) to let the contract expire with no further obligations.

54. Although there is a wide variety of leasing contracts, it is possible to classify them into three basic types. These are operational leasing, financial leasing and sale lease-back.

55. Operational leasing contracts are designed to cover a period which is less than the average useful life of the machinery. The average useful life of machinery has been defined in some countries as that for which the present values of all periodic payments would equal to 75 per cent of the cost of the machinery, i.e. the current residual value represents 25 per cent of the original cost. This type of contract is common when the lessee has only a temporary need for the machinery or when it is not possible to specify exactly for how long the machinery will be required. Operational leasing is usually accompanied with a complete service contract.

56. Under a financial leasing contract, the lessee may use the machinery for the entire average useful life. The machinery is frequently tailored for the specific requirements of the lessee. The lessee often specifies the supplier although it is the lessor who acquires the machinery. Financial leasing contracts may also be accompanied by service contracts although the coverage of this contract will be more limited to reflect the degree of specialization of the machinery. Financial leasing contracts bear many similarities to loan agreements and this fact has sometimes given rise to legal problems and resulted in substantial differences with regard to tax deductions.

57. Sale lease-back contracts involve two elements:

(a) the leasing firm acquires used machinery from a manufacturing enterprise;

(b) the leasing firm leases the machinery back to the same manufacturing enterprise.

The interesting feature of sale lease-back contracts is that the machinery never physically leaves the lessee's factory, but is only reflected in the balance sheet. This arrangement is particularly attractive to enterprises that need to increase their working capital and/or reduce their level of indebtedness. The arrangement may also be used to finance modernization projects while continuing to use the old machinery for a temporary period.

58. Leasing arrangements can only function when an appropriate legal framework has been determined. Among the legal issues to be specified are:

(a) laws governing the establishment and operation of local and foreign leasing firms;

(b) laws defining the rights of the lessee in case of bankruptcy of the lessor;

(c) laws defining the rights of the lessor in cases of bankruptcy or non-payment of fees by the lessee; and

(d) tax laws and customs regulations relating to leasing arrangements.

VI. ENVIRONMENTAL IMPACT

59. The machine-tool and supporting engineering industries involve industrial processes that could have adverse impacts on the environment if adequate precautions are not taken. These processes are of 4 types, namely:

(a) mechanical: e.g. sandblasting, grinding, finishing and polishing;

(b) chemical: e.g. through solvent cleaning, acid pickling, salt bath hot cleaning and quenching, conversion coating and electroless plating technology;

(c) physical: e.g. powder coating and dipping; and

(d) electrolytic: e.g. electro cleaning, electro polishing, anodising and eletroplating.

60. The potential health hazards and other negative effects on the environment that may arise from pollutants released by the above industrial processes are well documented. Exposure pathways for these pollutants include direct contact inside and outside the plant as well as through effluent discharges. The latter may lead to disastrous effects if discharged directly into water. Even discharges into sewage systems may affect the operation of monitoring equipment and pumps for these systems. Thus waste control and management is an important consideration in all engineering industries, including the machine-tool industry.

61. A basic requirement for industrial waste control and management is to understand what is happening. This involves use of monitoring equipment to measure concentrations of solvents, acids and effluents as well as carrying out waste audits. Depending on the results of this analysis, action programmes to minimise adverse environmental impacts may involve some or all of the following elements.

(a) more efficient housekeeping: a major consideration here is waste water which is one of the main sources of pollution in this industry. Water conservation may be achieved through flow rate adjustments to minimum requirements and recycling of rinse water;

(b) process modifications to reduce environmental impact: e.g. through solvent substitution and detoxification of effluents before discharging;

(c) resource recovery and recycling; and

(d) use of cleaner production technologies.

62. A regulatory mechanism is essential for environmental management. While laws and regulations for environmental protection are necessary, these are not sufficient on their own. Additional factors to promote cleaner industrial production include public awareness and training, and government funding of R&D in cleaner technologies and demonstration projects. Transnational corporations may also play a major role by ensuring that the same environmental standards are maintained in all their facilities world-wide including those in developing countries.

VII. FINAL CONSIDERATIONS

63. Newcomers into the machine-tool industry have to confront the pertinent conditions of entry into the sector. Having embarked on production activities it is necessary to adopt certain measures to sustain competitiveness and ensure internal dynamism. Effectively utilized, machine tools can make a major contribution to the development of engineering industries including

provision of repair and maintenance services, production of spare parts for industrial machinery, and inculcating an industrial tradition through imparting requisite skills and attitudes towards manufacturing. Flexible automation technologies offer new opportunities for the more advanced developing countries. The main points to be considered in such a programme include:

(a) Industrial policies: what incentives should be provided to local machine-tool and other capital goods producers to enable them to sustain production while countries simultaneously pursue import liberalization policies? What policies should be adopted vis-a-vis importation of second-hand capital goods including machine tools?

(b) Financing: what are the prospects for enhancing leasing practices in the capital goods sector in developing countries? If leasing is to be promoted, what general parameters for legal frameworks should be adopted for foreign and local leasing firms? How should these leasing firms relate to other financial institutions including commercial banks? What tax provisions and customs regulations are required to sustain leasing arrangements at the national, regional and international levels? What role should regional and international trade and development banks play in promoting leasing practices? How can small- and medium-sized engineering firms be assisted to secure financing more readily from financial institutions? What are the prospects of using debt conversion schemes in alleviating the financing problems of the industry in developing countries?

(c) Entrepreneurial policies and marketing strategies: how can the private sector be encouraged to play a larger role in the engineering industries that are crucial for providing essential subcontracting services to the machine-tool industry? What specific entrepreneurial policies should be promoted to encourage private sector investments in engineering industries? What kind of inter-company relationships should be encouraged between the machine-tool builders and subcontractors? Since the main markets for machine tools are the engineering industries, what measures should be taken to ensure stable development of these industries? Also, considering that market specialisation is an absolute necessity in this industry, what specific proposals could be made to enhance South-South and North-South trade in machine tools?

(d) Human resources development: what additional impetus should be given to formal education and on-the-job training in mechanical and electronics engineering? This should cover the complete spectrum of skilled technical personnel encompassing design engineers, production planners, machine setters, machine operators, maintenance technicians and software specialists. How can licensing agreements be strengthened to ensure that local personnel are adequately trained? What incentives should be provided to attract and retain skilled workers who may be tempted to leave the industry due to fear

of periodic layoffs necessitated by widely fluctuating business cycles? What specific programmes should be promoted to enhance capacities in precision mechanics?

(e) Acquisition and promotion of technology: what are the prospects for reverse engineering in developing countries? What action should countries take to strengthen their innovative capacities? What are the implications on patent restrictions, bearing in mind many leading producers extensively utilized the reverse engineering route in building up their own national capacities? How can a greater flow of conventional machine-tool technologies and flexible automation technologies be effected on a North-South and South-South basis?

(f) Production complementarities and regional co-operation: what are the major impediments in promoting production complimentarities at the regional level and how could these be overcome? What should be the main elements of a co-operation agreement among countries participating in a programme for production complimentarities in capital goods including machine tools?

(g) Industrial re-organization: how can developing countries prepare themselves for the imminent era of flexible production systems? What industrial reorganization could be implemented even prior to the introduction of flexible automation technologies? Are Just-in-Time principles appropriate for developing countries?

(h) User-producer relations: what should be done to ensure greater interaction between users and producers of machine tools? What institutional mechanisms are required? What role should engineering design and manufacturing technology institutes play in enhancing user-producer relations? What role should the government play?

(i) Environmental considerations: what specific assistance should be given to developing countries to enable them to control the environmental impact of the engineering industries more effectively?

Table 1: Geographical Distribution of Machine-Tool Production according to Regions (in millions $)

Region	1980	1985	1989
North America	5043 (18.7%)	2878 (13.1%)	3659 (8.7%)
Western Europe	10869 (40.3%)	7228 (32.9%)	16276 (38.7%)
Eastern Europe and the USSR	5475 (20.3%)	4811 (21.9%)	8201 (19.5%)
Latin America	378 (1.4%)	286 (1.3%)	505 (1.2%)
Asia	4828 (17.9%)	6327 (28.8%)	12743 (30.3%)
Others	378 (1.4%)	439 (2.0%)	673 (1.6%)
World	26971 (100%)	21969 (100%)	42057 (100%)

Source: American Machinist (different issues).

Table 2: Main machine-tool producers in 1990 (in $ millions)

	Country	1990 Production	Share (%)
1.	Japan	10,832.1	23.25
2.	Germany (former FRG)	8,826.5	18.95
3.	USSR	4,580.0	9.83
4.	Italy	3,966.0	8.51
5.	Switzerland	3,183.6	6.83
6.	U.S.A.	3,140.0	6.74
7.	United Kingdom	1,719.7	3.69
8.	France	1,364.8	2.93
9.	Former GDR	1,085.0	2.33
10.	Taiwan, Province of China	1,034.9	2.22
11.	Spain	1,034.9	2.22
12.	People's Republic of China	989.7	2.12
13.	Republic of Korea	733.3	1.58
14.	Yugoslavia	629.0	1.35
15.	Romania	530.7	1.14
16.	Brazil	450.0	0.97
17.	Canada	368.9	0.79
18.	Austria	280.5	0.60
19.	Belgium	271.9	0.58
20.	Sweden	251.7	0.54
21.	India	243.5	0.52
22.	Poland	200.0	0.43
23.	Czechoslovakia	191.9	0.41
24.	Bulgaria	160.0	0.35
25.	Hungary	97.8	0.21
26.	Netherlands	97.8	0.21
27.	Denmark	80.3	0.17
28.	Singapore	65.7	0.14
29.	Finland	57.8	0.13
30.	Argentina	38.2	0.08
31.	Others	76.3	0.16
	TOTAL	46,582.5	100.00

Source: American Machinist, February 1991.

Table 3: Engineering industries value-added production (and subsectoral structure) and machine-tool production (in $ millions)

	Value added	Sub-sectoral structure					Machine-Tool Production
	1987	381	382	383	384	385	1989
People's Republic of China	22000	N/A	N/A	N/A	N/A	N/A	832
Brazil	20932	17%	30%	25%	26%	2%	449
Taiwan, Province of China	10989	16%	14%	51%	15%	3%	695
Yugoslavia	8378	28%	23%	26%	21%	2%	671
Republic of Korea	8219	18%	20%	53%	39%	4%	597
Argentina	5897	30%	17%	15%	37%	2%	38
India	5882	9%	30%	29%	29%	3%	272
Mexico	5630	23%	18%	20%	33%	5%	18
Iran	3696	21%	22%	29%	44%	2%	p*
Singapore	3062	11%	14%	56%	16%	3%	37
Hong Kong	2557	20%	12%	46%	6%	16%	1.50
Nigeria	1825	24%	5%	8%	63%	0%	
Venezuela	1735	32%	16%	20%	31%	2%	
Thailand	1681	13%	16%	19%	50%	2%	
Algeria	1561	34%	21%	15%	29%	1%	18
Iraq	1366	30%	26%	42%	2%	0%	p
Egypt	1328	18%	21%	33%	27%	1%	p
Malaysia	1192	12%	10%	57%	19%	2%	p
Philippines	729	20%	9%	61%	9%	2%	
Syrian Arab Republic	715	45%	19%	30%	5%	0%	
Colombia	705	33%	11%	27%	24%	5%	
Peru	610	32%	21%	26%	19%	3%	1
Indonesia	526	34%	12%	20%	33%	0%	1
Chile	317	45%	18%	20%	16%	1%	
Pakistan	281	12%	22%	38%	27%	2%	5
Zimbabwe	220	43%	18%	28%	11%	0%	p
Ecuador	101	43%	5%	34%	13%	5%	
Tunisia	160	58%	1%	23%	18%	1%	p
Morocco	146	45%	10%	27%	16%	1%	p
Uruguay	143	29%	10%	27%	34%	1%	
Nicaragua	134	81%	3%	8%	5%	2%	
Kenya	115	23%	13%	39%	25%	0%	
Malta	79	19%	8%	48%	9%	16%	
Zambia	65	40%	14%	23%	23%	0%	

*p: Recorded production of parts and components or conventional machine tools. No detailed data available for Cuba and Democratic Republic of Korea. Sub-sectors refer to ISIC.

N/A: Not available.

Table 3 (Cont.)

Engineering industries value-added production
(and subsectoral structure) and machine-tool production
(in $ millions)

	Value added 1987	Sub-sectoral structure 381	382	383	384	385	Machine-Tool Production 1989
Bangladesh	61	20%	36%	18%	20%	7%	p
Dominican Republic	58	72%	10%	16%	0%	2%	
Cyprus	55	53%	27%	13%	7%	0%	
Bolivia	47	57%	23%	13%	4%	2%	
Senegal	46	52%	17%	4%	26%	0%	
Guatemala	39	41%	8%	36%	13%	3%	
Panama	39	59%	3%	18%	13%	8%	
El Salvador	37	30%	24%	41%	0%	5%	
Honduras	37	65%	3%	24%	8%	0%	
Sri Lanka	33	33%	24%	30%	12%	0%	
Cameroon	31	3%	68%	16%	13%	0%	
United Republic of Tanzania	31	42%	6%	10%	42%	0%	p
Jamaica	17	35%	6%	18%	41%	0%	
Ethiopia	11	91%	0%	9%	0%	0%	p

*p: Recorded production of parts and components or conventional machine tools. No detailed data available for Cuba and Democratic Republic of Korea. Sub-sectors refer to ISIC.

Source: World Machine-Tool Industry (UNIDO ID/WG.514/), 1991.

Table 4: Machine-tool manufacturers' capabilities and scope of production

LIMITED	MODERATE	SUBSTANTIAL	HIGH
Bench drills	Lathes	Turret lathes	Gear grinding machines
Bench grinders	Simple Milling	Automatic lathes	Special purpose machines
Sheet metal	Bench and Pillar	Bar and Chuck type	Transfer machines
Forming machines	Drilling machines	Tracer lathes	NC drilling machines
	Surface grinding	Precision grinding	NC boring machines
	Tool and cutter	Horizontal boring	Electro chemical machines
	Drilling machines	Jig boring	Milling machines
	Shaping machines	Gear Hobbing	
	Small Mechanical	Broaching machines	
	Presses and brakes	Radial drilling	
		Screwing machines	
		Hydraulic and mechanical presses	

Source: United Nations, The Machine-Tool Industry, 1974, page 21.