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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

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Coping with the Competitivity Challenge at Enterprise Level: Innovation, New Technologies and Institutional Support*

Prepared by

the UNIDO Secretariat

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INTRODUCTION

1 There has been a considerable increase in manufactured exports from developing countries during the last decade. Such exports rose to $700 billion in 1992, amounting to 26 per cent of world manufactured exports. With liberalized trading conditions and increased access to developed-country markets, it should be possible to substantially increase the volume of exports of manufactured products from developing countries, as also the percentage of such exports. It is significant, however, that the pattern of export growth has not been directly linked to the use of more complex and sophisticated technologies, and export competitiveness has not solely depended on technological factors except for the establishment of basic production and processing facilities.[1]. Some countries, such as the Republic of Korea, Singapore, Taiwan Province. China and Thailand in Asia, and Brazil in Latin America, have concentrated more on products based on high-technology largely because of the high absorption of electronics technologies in these countries. Most other developing countries including Bangladesh, Mauritius, Pakistan, Sri Lanka and others have developed an export capability based on less sophisticated technology and a low-productivity growth path. The technological pattern in manufactured exports is, however, fairly blurred and the two alternative paths tend to merge over time, through the process of technological upgrading, following increased technological capability, both at the level of the exporting enterprise and the overall economy. The development of an indigenous technological capability is undoubtedly a vital function in this context, in which the role of government policies and institutional support is becoming increasingly pronounced tied to the promotion of technological innovation at plant and cluster levels.

2. The potential for economic and technological cooperation between developing countries (ECDC/TCDC) needs to be highlighted in this context. Countries such as Brazil, India, Mexico and more, particularly, the Republic of Korea, Singapore and Taiwan Province, China are in a position to provide most industrial technologies required by less-industrialized developing countries. In many instances, the technological adaptations made in these countries are much more suited to the conditions and inputs available in other developing countries. Nevertheless, technological upgrading cannot be mistaken for technological imitation in the globalized context. Straight single source technology transfer operations can hardly provide the international differentiation on costs, products and services required to create and sustain international competitiveness. In recent years, there has been increase in outward FDI from countries such as the Republic of Korea, Singapore and Taiwan Province, China but while such investments were initially undertaken in other developing countries, these have been largely concentrated, in recent years, in industrialized countries to gain access to these markets. While ECDC/ TCDC has received considerable emphasis and support, the mechanisms to promote such cooperation have proved to be inadequate. It would be desirable to prescribe specific mechanisms, perhaps linked to an international organization, which should concentrate on this function and create synergies with other complementary functions.

3. Fundamental and far-reaching changes have taken place, in recent years, in the global economic environment and in the impact of technological innovations on competitive industrial growth in developing countries and transition economies. While private sector

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[1] For a more detailed discussion of this theme, see Main Background Paper II(I): Charles Cooper: "Technology, Manufactured Exports and Competitiveness", UNU/INTECH, July 1995.

development and liberalized global trade and investment conditions are of major importance, it is the usage of industrial technology most suited to local factor conditions and the effects of *technological change on various value functions of the enterprise which are most critical.* This requires not only the development of technological skills and capability, but effective technological innovation management to enable a wide range of new technologies to enhance the differentiation in the enterprise value-adding functions.

4. There has been a marked acceleration in the last two decades in the pace of technological innovations and in the development of generic technologies that have extensive effects on production and management processes and on information, communications and marketing. These generic technologies, particularly informatics, biotechnology and new materials, are not only bringing about a significant transformation in products and production and management functions, but their interrelationship and combination of developments have resulted in new technological applications in fields such as remote sensing, lasers, robotics, optic fibres, space and marine technologies, solar energy applications. and bioengineering and bioelectronics. It is necessary to promote the application of new technologies for competitive capability in order to accelerate technological innovation at the enterprise level, together with the national and sectoral policies and institutional measures necessary to support it. National strategies have to be evolved in developing countries and transition economies both to enhance the positive effects of generic technologies on competitive and sustained capability for increased exports of manufactured goods, but also to solve social problems and minimize the possible negative effects on employment. The factor advantage of cheap labour is being substantially eroded by increased automation and replacement of labour-intensive production processes, not only in light industries such as textiles and clothing but also in the production of machinery and other engineering goods and products. The demand for several minerals and industrial materials and processed commodities is also being severely affected by new synthetic materials. These trends are likely to become increasingly accentuated with continuing technological innovation during the next decade and will require varying degrees of adjustment and industrial restructuring, particularly at the enterprise level.

5. The basic technological objective for industry is to ensure the enhanced use of suitable technologies to enable local enterprises to compete in global markets and increase exports of manufactured products, besides providing increased employment and income. This requires the exercise of initial technology choice from among alternatives and thereafter acceleration of the pace of indigenous technological innovation. These functions must be effectively integrated under technology management at the enterprise level, where technological innovation plays a crucial role in the processes of business rearchitecture, building and deployment of strategic assets and organizational networking and partnership, the skilful interplay of which leads the enterprise to sustainable competitiveness.

I. THE TECHNOLOGY FACTOR IN COMPETITIVENESS

6. International competitiveness is influenced by several factors, extending from the macro-economic strength of an economy, to government policies for competitiveness; participation in global trade and investment; strength of capital markets; enterprise management skills; scientific and technological capability and human resource development.[2] These factors are undoubtedly crucial for assessing the structural competitiveness of a particular economy. While macro-economic policies and incentives, the structure of the technical education system, ecological standards and various other features of the national economy inevitably have a major impact on the performance and capability of local enterprises, the crucial factor at the enterprise level will be the firm's capability to effectively perform technological innovations for the rearchitecturing and other processes mentioned. Competitiveness will increasingly depend on the strategy and management of enterprises and on the manner in which entrepreneurs and managers perceive their industry, the role of their enterprise in a competitive, global market and their ability to take initiative in specific, changing situations.

7. The crucial role of technology for the competitiveness of firms in global markets has to be viewed in terms of not only entry to such markets, but also of capability to continually remain in them. Entry into external and internal markets can initially take place with relatively low-technology manufactured products, based on indigenous or foreign technology or a judicious mix of the two. Labour intensity will tend to be higher for most products such as textiles and garments, leather products, agricultural equipment and other engineering goods, at this stage of manufacture and technological application.

8. With increasingly open markets combined with stricter application of intellectual property rights, technological imitation is likely to play a much more limited role in the future. At the same time, technological innovation at enterprise level can not be based exclusively on technology transfer. Shelf-ready solutions may lead to the production of products and services within required specifications, but do not guarantee sales. It will require enterprises to be competitive to redraw market segment boundaries, set new price-performance standards, innovate products and services and develop capabilities for global marketing. In order to achieve the above, local enterprises must compete also for the development of core competencies, or bundles of knowledge, skills and technologies which can provide valued benefits for customers.

9. The competitiveness of enterprises in the medium and long term is often a direct result of their ability to learn continuously and to build - at lower cost and more rapidly than competitors - the core capabilities that enable them to generate new products, services and value-added activities; and new relationships and other dynamic and value-adding competitive advantages that competitors cannot easily imitate or foresee. The effective management of these core capabilities and derived innovations, characterized as *technology management*, is itself a crucial core capability. Through technology management, an enterprise can effectively

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[2] World Economic Forum, Geneva and IMD Lausanne: World Competitiveness Report, 1994, Sept. 1994.

integrate and manage the *interdependence* between technological innovations and other innovations in organizational structures, systems, management methods, financial resourcing and others, required to achieve the enterprise restructuring for sustained competitiveness.

Competitiveness Ranking of 44 Selected Countries in Asia and the Pacific

Factors/ Countries	Domestic Economic Strength	Internationalization	Government	Finance	Infrastructure	Management	Science & Technology	People
Australia	20	24	9	15	5	18	16	12
Hong Kong	4	3	2	3	17	4	20	18
India	22	33	27	27	41	33	29	40
Indonesia	25	34	24	30	32	36	30	33
Japan	3	8	19	5	24	1	1	4
Korea	7	39	30	39	29	31	18	20
Malaysia	6	14	4	13	18	14	24	22
New Zealand	11	25	3	12	8	8	21	13
Philippines	28	30	29	25	39	28	34	36
Singapore	2	2	1	2	16	7	8	1
Taiwan	5	17	11	20	27	21	15	19
Thailand	9	21	8	14	33	23	31	23

Note : The World Competitiveness Report 1994 analyzes the competitiveness of 44 countries taking into account the following eight factors which have been used to describe the different aspects of world competitiveness:
Domestics Economic Strength - macroeconomic evaluation of the domestic economy overall;
Internationalization - extent to which the country participates in international trade and investment flows;
Government - extent to which government policies are conducive to competitiveness;
Finance - performance of capital markets and quality of financial services;
Infrastructure - extent to which resources and systems are adequate to serve the basic needs of business;
Management - extent to which enterprises are managed in an innovative, profitable and responsible manner;
Science and Technology - scientific and technological capacity, together with the success of basic and applied research;
People - availability and qualifications of human resources.

CASE:JAPAN[3]
- Industrial Competitiveness -

The Japanese industrial competitiveness as generally believed is not solely due to its management methods but a combination of factors such as:

* Selective concentration in generic technologies which are pervasive and usable in many sectors (computer-aided design, microelectronics etc.). Concentration on generic technologies have helped Japanese firms to accumulate technological capabilities and their development.
* Developing economies of scope (flexibility) apart from economies of scale by intensive use of flexible manufacturing systems, robots etc.
* Developing economies of aggregation through highly diversified but vertically integrated firms.
* The conflict-reducing role of the Ministry of International Trade and Industry (MITI) is helping firms to scan and monitor world technological trends and to develop programmes specific for developing future-oriented industrial technologies.
* Planning deliberately to take up risky projects and then through consensus decision making reducing the risks.
* Intense human resource development efforts at the firm level.
* Existence of a large number of laboratories operated by corporations in specialized areas but with specific product development objectives.
* Intensive use of databases and technology information systems.
* A low interest rate helping continuous upgrading of manufacturing facilities by regular large-scale investments to reduce obsolescence.
* Strong coupling between R&D, manufacturing and marketing by training staff in complementary functions even though in direct work they are not essential.
* Technology development projects among manufacturing firms for developing future-oriented production facilities.
* Another aspect of Japanese technology development is the rapid diffusion of new technologies. In the case of facsimile in 1975 the rate of application was only 4.4%, whereas in 1987 it reached 63.7%. Rapid diffusion of new technologies helps in improving industrial competitiveness by increasing productivity and reducing manufacturing costs.
* Yet another factor contributing to rapid technology development is the intense interaction among operators and engineers an.. .he operation of the quality circle system in Japanese industries. In the steel industry, the quality circle (QC) concept has contributed considerably to operational improvements and cost reduction. The "Jishu-Kanri" system (QC) is operational in most steel firms: in Kawasaki Steel there are about 3300 QC groups; in Kobe Steel 2400 groups; in Nippon Kokan there are 3842 QC groups; in Nippon Steel Corporation there are 7000 QC groups; and in Sumitomo there are about 4100 QC groups.

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[3] B. Bowonder and T. Miyake, Technology Development and Japanese Industrial Competitiveness, Futures January/February 1990

10. Most enterprises in developing countries, particularly small and medium enterprises (SMEs), need to develop the internal management capability to make adequate and continuous use of a technology for sustained competitiveness. Their lack of technological innovation capability also hampers the effectiveness of their restructuring processes for adjusting to a rapidly changing global economic context.

11. The management of strategic technological innovation at the enterprise level involves a blend of R&D and technology transfer in varying proportions, and needs to be carried-out through multifunctional efforts, often cutting across organizational boundaries of the enterprise's cluster (clients, suppliers). In view of the information gaps in learning and innovating in increasingly open markets, enterprises in developing countries and transition economies, particularly SMEs, tend to underinvest in technological innovation.

12. The ability to innovate, particularly in complex, new and demanding generic technologies, may also be limited because of inadequate government policy support to overcome market failures at:

* The enterprise level - particularly targeting learning costs and gaps in related management skills through innovation-supporting institutions, including R&D centres, metrology and standards institutions, management consulting firms, venture capital bodies and other technology organizations.

* The interfirm level, fomenting information linkages, coordination of investments, clustering and joint development of skills, knowledge, products and services, including commercialization systems.

* In factor markets, with direct interventions at source to eliminate the failure, particularly with respect to enabling factors for learning and innovation, besides control over unfair practices.

13. While the development of technological innovation capability for sustained competitiveness must essentially be the function of individual enterprises, the supportive role of Governments is also of vital importance. Governmental support functions are represented by policies and institutional support for innovations. Policies can be directed towards more diversified training programmes, particularly with respect to new generic technologies; financial incentives for the development of enterprise-level research and development of technology management skills among SMEs, and provision of advisory services on technology management to local firms in particular subsectors or in specific regions. Examples of government interventions in developed countries in this field can be found in the United States, where subsidies are provided by several federal agencies, besides in Australia, Canada, Denmark, France, Germany, Italy, Japan, Sweden and the United Kingdom, among others.

II. GLOBAL TRENDS IN R&D AND TECHNOLOGY FLOWS

RESEARCH AND DEVELOPMENT

14. Governmental support for technological innovation is reflected most in the development of an institutional research and development capability. In the Republic of Korea, for example, R&D investment rose from $418 million (0.64 per cent of GNP) to $5.46 billion (over 2 per cent of GNP) in 1991, while the financing shifted primarily to the private sector (80 per cent in 1991). The number of R&D centres in the country increased from 52 private institutes in 1980 to 2,352 in 1991 and 1,445 institutes in 1993. In Singapore, R&D investment is expected to reach up to 2 per cent of GDP by 1996. In the case of the OECD countries, figures of R&D investment and the percentage of such expenditure to GDP between 1990 and 1993 is provided in the table below. There has been a significant decline in R&D growth in 1993 which has continued throughout 1994.

Selected statistics on in R&D investment OECD countries - 1990/1993[4]

Country	R&D spend $ billion	Annual growth in R&D spend		National R&D spend as % of GDP		Government spend as % of R&D		Civilian Spend as % of govt. R&D		Rate of increase in industry R&D	
	1993	1990	1993	1990	1993	1990	1993	1990	1993	1990	1993
USA	170 0	3 2%	-0 5%	2 82%	2 72%	43 8%	39 0%	37 4%	41 0%	6 6%	-0 8%
Japan	74 8	8 3%	-2 4%	3 08%	2 93%	18 0%	21 4%	94 6%	93 9%	10 0%	-6 6%
Germany*	37 2	1 5%	-1 1%	2 76%	2 48%	34 1%	37 1%	86 5%	91 5%	1 2%	-2 4%
France	26 0	6 1%	-0 8%	2 41%	2 41%	48 3%	N/A	60 0%	66 5%	5 1%	N/A
U K	13 2	1 9%	2 5%	2 23%	2 19%	34 8%	32 3%	57 5%	54 9%	-0 3%	4 6%
Italy	13 2	6 7%	-1 3%	1 30%	1 30%	51 5%	45 9%	93 9%	93 5%	0 6%	-4 4%
N America	180 2	3 3%	-0 4%	2 70%	2 44%	43 8%	39 6%	39 9%	44 6%	6 5%	-1 0%
Eu total	123 1	3 7%	-0 3%	2 00%	1 96%	40,6%	N/A	77 2%	81 1%	2 1%	N/A
OECD total	385 5	4 3%	-0 7%	2 39%	2 24%	37 7%	36 2%	60 2%	64 1%	5 8%	-2 2%

15. While much of such decline reflects reduced governmental allocations on defence-oriented research, expenditure on R&D by major corporations has also tended to level off, with lower levels of increase in recent years. At the same time, the cost of applied industrial research in industrialized countries has increased enormously. This may provide considerable potential for increased industrial research activities in developing countries and transition economies to narrow their R&D investment gap.

[4] Main Science and Technology Indicators, OECD

16. In the case of developing countries and transition economies, it is essential that governmental expenditure on industrial R&D should increase at least to the level of 1 to 1.5 per cent of GDP as Brazil and China have set out to achieve. This process may be easier in several transition economies, where R&D received considerable emphasis in the past and a large pool of research-oriented scientists and technologists continues to be available. In the case of less-developed economies, particularly LDCs, the allocation of increased resources to industrial R&D may be difficult and would require increased international support.

R&D Expenditure as a percentage of GDP in selected Asian countries[5]

	China	India	Japan	Singapore	South Korea	Taiwan
1985	-	0.8	2.6	0.7	1.4	1.0
1986	-	0.8	2.6	0.8	1.6	1.0
1987	-	0.9	2.7	0.9	1.7	1.1
1988	-	0.8	2.7	0.9	1.8	1.3
1989	-	0.8	2.9	0.9	1.8	1.4
1990	0.7	0.8	2.9	0.9	1.9	1.7

17. In addition, the effectiveness with which these investments are put into use should constitute an equally important target. Thus, a national capability-building effort for technology management, including R&D and Technology Transfer management, should urgently be implemented. It is also necessary to promote technological innovation management at the enterprise level and fiscal and financial incentives should be provided for this purpose, in addition to incentives to private investment in R&D activities.

[5] Human Resources for Science and Technology, National Science Foundation Washington, 1993

CASE: TAIWAN PROVINCE, CHINA

The Electronic Research and Service Organization (ERSO) is a government institute which develops new electronic technologies and disseminates them throughout industry. This is achieved through technical documents, meetings, licensing agreements and above all, by creating spin-off companies, including the involvement of ERSO engineers and public and private capital. ERSO has assisted in the development of integrated circuits and chips.
Similar experience has taken place in the Latin American region, as reflected by TELEBRAS R&D institute in Brazil and the Instituto de Investigaciones Electricas in Mexico.

18. Apart from R&D centres. which can directly impact innovative capability, considerable institutional support for innovations at the enterprise level can be provided through various technology institutions such as technology management centres, standardization and metrology bodies, management and engineering consultancy companies, besides financing enterprises such as venture capital organizations and many others, collectively known as the "innovation system supporting agents". Such institutions need to be promoted with governmental support, particularly in less-developed economies, and their technology management skills also need to be developed through research on specific contextual conditions and adaptation of imported management methods.

☛ TECHNOLOGY FLOWS

19. It is necessary to emphasize that revolutionary technological innovations and changes are continuing to take place particularly in the new generic technologies of informatics and information technologies, biotechnology and new materials, which are having a far-reaching impact on products, processes and value activities, and on competitiveness, in most production and service sectors. The extraordinarily rapid pace of technological innovations in these and interrelated fields has been largely concentrated in industrialized, developed economies and has been extended only to a few developing countries in South-East Asia and Latin America and in certain transition economies. Technology flows to developing countries have increased in the 1990s but are still a mSall proportion of the total of global transactions in technology. Joint ventures, non-affiliate licensing and other contractual arrangements are increasing considerably in several developing countries. Technology partnerships at enterprise level, as reflected in such arrangements also represent a growing trend as an alternative form of foreign participation.

20. With increasingly open economies with respect to global trade and investment, enterprises in developing countries and transition economies will need to become increasingly competitive in global markets. Exports of manufactured products from developing countries have increased considerably and reached a level of 26 per cent of the global exports of manufactures in 1992. Export capability in certain developing countries has been developed with relatively less sophisticated technology. Technology upgrading has been and will be necessary in such cases, based on an increased technological innovative capability.

21. Apart from revolutionary technological developments in generic technologies, certain other aspects of the global technological scene also need to be highlighted. First, other aspects non-withstanding the technological gap between industrialized and most developing countries is likely to increase significantly by the year 2000 and beyond, with the pace of technological innovations being accelerated in support of international competitiveness drives. Secondly, technology flows from industrialized to developing countries, measured in terms of fees and royalties, which tended to stagnate during the 1980s, increased considerably between 1990 and 1994 but will still be only around 15 per cent of annual global payments for technology of over $ 20 billion by 1996, mostly to corporations in the USA and other industrialized economies. Certain developing countries, such as Brazil, India, the Republic of Korea, Singapore and Taiwan Province, China are also, however, emerging as important sources of technology and know-how. The stagnation in technology flows in the 1980s was, to a large extent, caused by a slowdown in industrial growth in most developing economies. It was also, at least partially, the result of continuing regulatory controls imposed on foreign technology agreements in several developing countries, particularly in Asia and Latin American, besides some countries, such as Nigeria, in Africa. Thirdly, while the principal mechanism for foreign participation in developing countries and in several transition economies continues to be through subsidiaries and affiliates of transnational corporations (TNCs), the number of technology transfer through joint ventures, strategic business alliances (partnerships) and technology licensing arrangements, has increased significantly in a number of countries. At the same time, technology flows to developing countries with respect to

new technologies have been fairly limited and extend mainly to the production of electronic products through TNC subsidiaries.

22. An area of growing importance for technological development at the enterprise level is that of strategic alliances, which are essentially contractual arrangements between two firms for the mutual transfer of technology or conduct of research or other technological functions. Such agreements, which have become fairly common between several major corporations relate largely to new generic technologies, namely information and communications technologies, new materials and biotechnology. Most of these alliances are between TNCs and other large firms in industrialized economies, which account for 92 per cent of such transactions.

23. It will be necessary for developing-country enterprises to become increasingly involved in strategic alliances, especially in new technologies. Most such enterprises have hitherto concentrated on national markets and if they are to become more internationally competitive in their respective fields, strategic inter-firm linkages will be necessary. One area which has considerable potential is that of joint product innovation and joint research activities. Industrial research can be conducted in developing countries at much lower cost than in industrialized economies. Other areas can relate to joint external marketing and coproduction of parts and components. Such alliances can also be related to international subcontracting with technology and designs being supplied by a foreign party. The initiative for strategic alliances will, however, need to be undertaken by developing-country enterprises, who must be ready to offer production, access to market, research or services in lieu of technology and know-how. There can be little doubt that innovative capabilities at the enterprise level in developing countries and transition economies can be accelerated through strategic alliances with foreign corporations. Such strategic alliances are commonly entered into by large corporations but there have been a few encouraging cases in developing countries.

24. Industrial technology has nevertheless not only emerged as the vital element of competitiveness, but has also became a marketable commodity. Technology transactions and partnerships constitute an important alternative means of foreign participation in globalized markets. Technology licensing and contractual arrangements for the supply of know-how, franchises, marketing and buy-back of products and processed materials, and contracts for construction and management, represent important alternative mechanisms for the acquisition and absorption of technology and technical services by private-sector enterprises in developing countries and transition economies. Alternative forms of foreign participation have to be integrated with the availability of investible capital and local entrepreneurial initiative and capability in countries, that have well-developed financial institutions and expanding capital markets, together with a dynamic private sector, as in most countries of Asia and Latin America and in several of Africa. In countries, however, where a capital market is lacking and there has been inadequate development of local entrepreneurial capability, major emphasis on these factors is necessary as essential prerequisites for technology partnerships through joint ventures and non-affiliate licensing arrangements.[6] While investments through TNCs are being welcomed and promoted in most developing countries, it is necessary to provide equal

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[6]Nagesh Kumar "International Linkages, Technology and Exports of Developing Countries: Trends and Policy Implications", UNU/INTECH, July 1995.

emphasis to joint ventures and technological partnerships through licensing, particularly in countries where local enterprises are well established. In fact, with the increased growth of local industrial enterprises, it is likely that a growing shift towards technology partnerships by way of licensing and technology transfer through strategic business alliances, particularly in most Asian and Latin American countries, will take place. The immediate potential for this is limited in African economies until their local enterprises have increased and expanded. Demonstration of successful projects can accelerate this process.

25. Within the context of technological imitation avoidance, an important objective for developing countries and transition economies should be to ensure adequate inflow of foreign technology and knowhow, both for initial competitive export-oriented production and for various stages of technology upgrading as necessary. Whether at an early stage of competitive production or for technology upgrading for higher-staged manufactured products, foreign technology will be an essential element for growth of technological capability in these countries. This is all the more so as the technology gap between industrialized and most developing countries is widening rapidly. At the same time, technology inflow at various stages of upgrading should constitute an integral part of technological innovation at the enterprise level and, as mentioned, can only serve as a partial technological base for the development of a competitive innovative capability.

26. With the rapid pace of technological developments, there is a pressing need for access to technological information. First, information is necessary with respect to new technological trends in various fields. Secondly, local institutions and enterprises should have access to information regarding alternative sources of technology, experience of such technology in other developing countries, and the costs and contractual aspects of using specific technologies. Even with respect to complex techniques and processes, technology can be obtained from several alternative sources and knowledge of such sources constitutes an essential aspect of technology negotiation and acquisition. A national information system has to be set up for selected areas of priority. Information on technology costs and contractual conditions is more difficult to obtain. One valuable source is the Technology Information Exchange System (TIES), which is operated by UNIDO, and which can provide very useful information on industrial technologies to participating countries.

27. Contract negotiations on new technologies may pose greater difficulty than those relating to more mature technologies. Such technology as is essential for local enterprises should be acquired or licensed or developed indigenously and a flexible attitude needs to be adopted where new technologies and products are involved. At the same time, licensee enterprises in developing countries should be given the necessary information, guidance and training, so that they are not taken advantage of, through unfair or restrictive agreements. A proper balance needs to be achieved between the need for foreign technology inflow and flexible negotiating techniques which safeguard the basic interests of licensee enterprises.

28. The policy approach towards foreign technology has often been fairly ambivalent in several developing countries. While technology inflow has been recognized to be essential, regulatory and screening mechanisms were set up for foreign technology agreements in a number of developing countries, during the 1970s. It has only been during the 1990s, as part of policy liberalization in these countries, that restrictive regulations and controls on foreign technology inflow have been removed in most countries. At the same time, few countries

have adopted a directly promotional approach toward technology inflow. This is an issue for consideration. While indigenous technological development is of vital importance, foreign technology inflow at various stages of initial production or technology upgrading may be equally necessary. It is also essential that technology choice and conditions of transfer of foreign technology should be left solely to user enterprises in developing countries and that no restrictive controls are imposed on technology inflow in key industrial sectors. A promotional approach towards foreign technology should also be supportive of the role of the private sector, as also of state-owned and 'mixed' enterprises, with respect not only to information on alternatives but training and assistance in negotiations for technology acquisition and measures for absorption. What is true of technology and know-how agreements may be even more applicable with respect to specialized service contracts, ranging from build and operate (BO) or build, operate and transfer (BOT), or turnkey construction contracts, management agreements and other contractual and arrangements. Emphasis should be given to increased knowledge and capability, through updated information and sensitization and training for entrepreneurs and representatives of local enterprises. The changing role of Governments in this regard has to be determined in the context of specific country situations. Decisions on technology usage and technological relationships with foreign enterprises should, however, be left to local enterprises. In this process, foreign investment and technology inflow may well take place in fields which do not fall within priority areas in national economies. Such inflow, however, must be viewed as part of the process of the development of a conducive climate for increased FDI and technology inflow, which would become increasingly competitive and export-oriented, over time. The role of the governmental machinery also needs to be transformed and, in place of regulatory controls and procedures, policies and procedures should be reoriented increasingly towards promoting technology inflow; ensuring adequate competition; achieving quality standards; and meeting environmental and ecological requirements.

III. IMPACT OF NEW GENERIC TECHNOLOGIES

29. Projections regarding developments in new and generic technologies beyond 2000 are difficult to anticipate, primarily because of the extraordinary pace of technological change in these fields. The rapidity of such changes highlights the drive of technological innovations for sustainable competitiveness. At the same time, investment costs for new technological applications, especially increased computerization and automation, tend to be initially much higher than for traditional production processes. Innovative capability in developing countries and transition economies must be enhanced in the form of technological innovations and also to achieve an effective mix of usage of semi-skilled labour with computerized designs and other facilities where new technologies can be blended with traditional production activities instead of total replacement of existing processes. Such blending can be developed primarily though indigenous R&D in developing countries.

30. Technological innovation is now at the core of competitive strategies of successful industrial firms. The new and rapidly evolving generic technologies, such as biotechnology, new materials and information technologies, offer many opportunities and challenges for broad competitive strategies. They engender entirely new products, services, markets and businesses. Their impact is trans-sectoral, drastically improving competitiveness of products, processes and services of firms in a large number of traditional industrial sub-sectors. New

materials improve product specifications and lower production costs in engineering and chemical industries; biotechnologies save energy and raw materials in chemicals, pharmaceutical and food processing. The pervasive applications of information technologies allow companies in all industrial sectors to re-engineer critical processes, improve overall efficiency and rearchitecture their businesses with full participation of client, suppliers and all internal functions, made possible through electronic networks. Information access, connectivity and portability are now the key to sustainable competitiveness.

31. As inflexible propietary systems - which frustrated the widespread application of information technologies in manufacturing in the recent past - are replaced by open sytems for flexible manufacturing, the confrontation between users and vendors is also replaced by cooperation, to take into account evolving business needs of the former in line with the movement towards mass customization, rapid product innovation cycles, product data management, virtual reality and related systems.

32. Moreover, the interaction among new generic technologies themselves create unsuspected business opportunities for developing countries. New bio-materials increasingly draw on new genetic resources and engineering. The recently developed combinatorial chemistry technologies are not only producing more new chemical compounds in just a few years than the pharmaceutical industry previously did in its entire history, but also allowing the development of 10,000 new materials in single experiments. Rapid prototyping gather advances in information technologies and in new materials to speed-up product development, increasing quality and reducing costs through stereolithography. Advances in the systems that process and transmit information is mainly dependent upon progress in materials science. The joining of computers and biotechnology into the new field of bioinformatics, believed to be as important as biotechnology itself, is not only changing the face of biotechnological R&D, substituting all pharmaceutical research before animal and human testing, but also inserting biotechnological products in the electronic industry, such as biochips.

33. As a result, there will inevitably be considerable impact of information technologies (starting with computer-aided design and manufacture (CAD-CAM), flexibie manufacturing systems (FMS) and industrial automation at plant level, electronic networking), biotechnology and new materials on developing countries and transition economies. It will be necessary to ensure that necessary policies and measures for technology management capacity-building are in place.

34. Developments in biotechnology and genetic engineering are likely to have a major impact on agriculture and agro-related production, besides chemicals, pharmaceuticals and several production sectors. There is considerable potential for biotechnology research and business application in developing countries and transition economies.

35. New materials are will have a major impact in several manufacturing sectors and are not only changing the structure of industry in these fields. These developments will have to be absorbed, adapted and pioneered in developing countries and transition economies.

A. Information Technologies

36. The most significant impact of new, generic technologies on the manufacturing sector is with respect to informatics and information[7] technologies impacting directly on design production and commercialization processes, particularly through FMS and increased automation. The effects of these developments, largely through networks impact and new management control software, would extend to most sectors producing capital goods, including electrical, mechanical and transport equipment (including automotive equipment), agricultural machinery and durable consumer goods and parts and components of such products.

Flexible manufacture

37. With greater precision and finishing standards for major products in the above fields, there is a growing emphasis on flexible manufacture[8] in order to adjust rapidly to changing demand and requirements providing customers with ad-hoc products and services. A marked shift is taking place from mass production to a new form of industrial organization termed as "mass customization" based on flexible manufacture, which extends both to large-scale production and to improved product quality and diversity. This might also result in the larger firms concentrating on core competence, with small and medium enterprises concentrating on the production of smaller items. The shift to flexible production obviously entails a different organizational pattern which can ensure short production runs, small batches, quick changeover of machinery, minimum inventory and a lower proportion of indirect labour.

38. The shift to the managerial and organizational requirements for flexible manufacture would require policy direction and support. It would be necessary to promote a greater awareness of the potential for flexible manufacture and to provide technical assistance to local enterprises, with respect to both a geographical and sectoral focus, particularly through industry associations. It may also be necessary to develop new incentives, including the possibility of subsidizing producer prices for limited periods and the development of a macro-economic environment for technological change in design, production and commercialization processes.

39. There has been limited growth of flexible manufacture in most developing countries, often due to market limitations and the substantial investment required for new equipment, tooling and training. Though concepts such as just-in-time (JIT) and TQM are being increasingly recognized as being of critical importance by enterprises in some developing countries, the shift to flexible manufacture has, so far, been very gradual, often due to inadequate knowledge, information and training facilities as to how such procedures can be

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[7] Edward Steinmueller and Maria Ines Bastos: "Information and Communication Technologies: Growth, Competitivenss and Policies for Developing countries, UNIDO/UNU/INTECH, July 1995.

[8] Raphael Kaplinsky "The Implications of New Organisational Techniques for Developing Countries", UNIDO/UNU/NTECH, July 1995.

introduced. Closer inter-firm relationships, particularly with supplier firms, is also necessary besides access to knowledge of application of such techniques.

40. Even in developed countries, the pushing of closed propietary systems by vendors, coupled to too high expectations on the part of clients, have substantially hampered the widespread application of FMS. With the introduction of open systems, this situation is changing and developing countries can benefit from this shift. Current systems' priorities include the integration of functions to design, manufacture and commercialize a new product. Electronic data interchange (EDI) is widely believed to be a key technology for this purpose.

Industrial automation

41. An aspect related to flexible manufacture is the extent and degree of industrial automation[9] that is necessary for various manufacturing processes. This is likely to have more impact on batch industries than those involving continuous production and may be largely related to mechanical engineering products. Recent developments of computer numerical-control (CNC) cutters and benders and automation in printing, welding and assembly through robots are being further accentuated by vision recognition and artificial intelligence (AI). Technological developments in robotics are expected to continue over the next decade. At the same time, automation in industrialized economies is expected to be largely limited to specific production processes and functions, with greater refinement.

42. It needs to be emphasized that, in several developing countries, automation has largely related to the increasing use of CNC machine tools and CAD, in the first instance, gradually moving towards the integration of several CNC machine tools into flexible production systems. Even this process is highly capital-intensive and requires considerable engineering and operating skills and, in many less-developed countries, such facilities may not be available for some time. It would also need to be considered if CNC machines could be locally produced or would need to be imported. The former course of action would only be practicable in a few developing countries where machine-tool production has already been undertaken and can be gradually upgraded for the production of CNC equipment.[10]

43. The drive for competing through mass customization and product variability places a strong pressure on the enterprises capability for effective product innovation management. The exponentially increased amount of product data which needs to be created, controled and rapidly processed cannot be effectively dealt with by conventional means. As a consequence, new software for product data management (PDM) is quickly outgrowing the past use of managing CAD files more effectively to become the fastest growth area for computing in the manufacture sector (revenues less than US$ 100 million in 1989 to US$ 600 million in 1995 and to a projected US$ 1.6 billion in 1999.

[9] Ludovico Alcorta, "The Impact of Industrial Automation on Industrial Organisation: Implications for Developing Countries' Competitiveness", UNIDO/UNU/INTECH, July 1995.

[10] Ibid.

* New PDM versions allow the management of product data across the compnay, from drawings to CAD files to assembly structures, to technical blueprints to data transfer to suppliers and clients. As a consequence, improved conditions for reducing time to access data, number and cost of changes, minimizing the length of change cycle, lead to reduced time to market, lower costs, improved quality, flexibility for future changes, early inovlvement of clients and suppliers and other competitive advantages.

* Furthermore, when integrated with other software packages for product design and simulation, including virtual reality and rapid prototyping, PDM's use may even enhance these advantages for cost effective manufacture, maintenance, disassembling and recycling, in line with DFD requirements. Through building virtual products that behave sufficiently like real products with "on-line" contributions from suppliers and clients, these programmes enable the production of just one physical model, prior to manufacture, further strengthening the competitive advantages mentioned.

* It is important to note that these programmes rely on the distribution of digital engineering data within and across organizations, including suppliers.

* If developing countries' enterprises are not able to transfer, create or assimilate these technologies, their future capability to participate in SBAs, in international manufacturing subcontracts, particularly with value-adding design and engineering services, may be seriously hampered.

Gradual shift to FMS in developing countries

44. It is clear that flexible manufacture, increased automation and associated software have emerged as essential technological features of manufacture in industrialized countries and that this process will be further extended during the next decade. To the extent that such technologies are gradually extended in developing countries, substantial changes in structures will be required for management of technology at the enterprise level, together with policy and institutional support at the initial stages. The extent to which the automation of production processes replaces labour also requires careful assessment of both the implications of labour displacement, and the stage at which such replacement is financially viable. The capital costs of robotics and automated processes are still very high and may be able to be justified in most developing countries with abundant semi-skilled labour only with respect to selected areas.

The Internet and industrial business applications

45. The Internet, connecting millions of computers, has already grown exponentially - some 30 million people are now connected to it and is expected to have as many as 100 million computers connected to it by the year 2000.[11] It is estimated that more than 21,000 businesses are already connected to the Internet. Currently, more than 75 per cent of all new users are logging on via corporate connections.[12] The table below shows the type of corporations that are currently using or planning to use the Internet and for which purpose.

Corporations using the Internet

Function	Description	Currently Doing	Planning to
Internal Communications	Keeping distant offices aware, with E-mail, of changes at headquarters	30%	14%
External Communications	Suppliers and contractors can track inventory or project schedules	49%	27%
Advertising	A Web page is an information-rich way to advertise	8%	33%
Selling Products	Cut out the middleman and sell directly to the public	5%	35%

46. Another survey conducted by Benchmark Research in the United Kingdom suggests that there are still a number of serious problems to be overcome before the Internet and related commercial on-line services become ubiquitous business tools. 91% of non-users felt that the Internet was more relevant to information technology specialists than to themselves, indicating that service providers still need to educate potential customers and to offer more information services, easier navigation, quicker access times and easier access and use.

47. Other obstacles to the global business use of the Internet have to do with the liberalization of telecommunication services, international operating standards - particularly to overcome incompatible proprietary mail systems and cross platform directory desynchronization -, guidelines for privacy and security, intellectual property rights and, particularly, a logical categorization of the knowledge stored. Furthermore, the demand for education for the self-sustained growth of the network has to be properly met.

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[11] Business Week, 3 April 1995.

[12] Ibid., 26 June 1995.

48. Some advances to make the network less insecure, unreliable and slow, are the advent of Microsoft's Windows 95 and other developments such as the introduction of a new programming language developed by Sun, called Java, that enables programs to create "Internet enabled" applications programmes that automatically adapt to different types of computers, besides initiatives of some countries to regulate related property rights and curb undue use of the net.

49. The interaction between the different information technologies is also bound to significantly impact industry. Significantly, the Internet is quickly becoming a new facility for trade in goods and services, eliminating intermediaries and becoming an integrator of information and knowledge, which may extend the process of science and technology development across borders.

50. In association with Multi-Media, it is expected the Internet will also have a considerable impact on education and training activities, by facilitating learning processes, by rendering educational material intellectually unprotected and by extending current cultural borders, educational institutions and systems.

51. It is nevertheless necessary to stress that information alone seldom produces useful insights and capability, and that the information age spurred by networks such as the Internet will increasingly give way to the *knowledge age*, where skills and insights are developed for decision-making from the mass of facts and data received and processed. New skills will be required for that.

Information management

52. The most critical aspect of management of information in the new era is the development of competence in managing, and giving meaning to the range of information technology applications and their results. This involves: building or identifying technology for transfer or acquisition; competence in building and maintaining systems and assimilating the acquired technology; in adapting or modifying information technology and information systems for local needs or requirements; in organizing for innovation, and in providing linkages between information generators, users, service providers, R&D institutions, and other concerned agencies, and enhancing competence in infrastructural measures for information technology such as testing, quality assurance and standardization.

53. For instance, increased developments in software and patent data bases are simplifying the task of monitoring data from patents, including the patent applications of competitors. Nevertheless, such information is only likely to help managers who recognize the importance of competitive patent information and who want to avoid the cost of patent-infringement litigation.

Information technologies and re-engineering

54. Re-engineering is the framework for the structural transformation of enterprises, currently adopted for various applications of information technologies to foster sustained competitiveness. Industrial enterprise re-engineering is an approach characterized by a focus

on the design of processes valued by customers to seize new business opportunities and to achieve strategic competitiveness. In search of radical changes, it uses information technologies as enablers, not as drivers of the change process. Opportunities for supporting the process innovations sought with information technologies fall into at least the categories shown in the table below, in line with the needs of businesses to reduce costs and time, access updated information, etc.

The impact of Information Technology on Process Innovation

Impact	Explanation
- Automational	Eliminating human labor from a process
- Informational	Capturing process information for purposes of understanding
- Sequential	Changing process sequence, or enabling parallelism
- Tracking	Closely monitoring process status and objects
- Analytical	Improving analysis of information and decision making
- Geographical	Coordinating processes access distances
- Integrative	Coordination between tasks and processes
- Intellectual	Capturing and distributing intellectual assets
- Disintermediating	Eliminating intermediaries from a process

55. Several additional tables are provided in Annex I at the end of this working paper on information technology, indicating the range of technologies (table 1); projections for informatics-related products (table 2) and estimates of business advantages in using new information technologies (table 3).

B. Biotechnology and Genetic Engineering

56. The impact of biotechnology will be increasingly felt in several key production sectors, ranging from agriculture and food production to pharmaceuticals, chemicals and several other industrial subsectors. Biotechnology research in agriculture, plant technology and livestock improvement has enormous potential and can be initiated in most developing countries, for a wide range of agriculture-related activities. In pharmaceuticals and chemicals also, there is considerable potential for research and introduction of new products.

Range and coverage

57. Biotechnology developments have opened up enormous possibilities for the large-scale manufacture of genetically engineered products and materials. There has also been rapid increase in the commercialization of biotechnology and genetics applications. A large number

of research-intensive companies have entered the field, not only in medicines and pharmaceuticals but in various plant and agricultural applications. Applications and production have extended to enzymes, chemicals, metal beneficiation, pharmaceuticals (diagnostic and therapeutic applications), agriculture, food processing, livestock development, and several service sectors. The enormous potential of biotechnology, particularly through gene splicing, has also raised considerable controversy with respect to the dangers of ecological damage, as well as ethical issues regarding the creation of new life forms and bringing about changes in human and animal embryos. The extension of patentable rights with respect to biotechnology innovations has also led to the greater commercialization of innovations which were formerly in the public domain, as in the case of high-yielding crop varieties, which are now becoming increasingly privatized. While basic patent rights have been recognized in this field, there continues to be considerable uncertainty regarding intellectual property rights and considerable litigation is continuing to take place, particularly in industrialized countries.

Patents in biotechnology

58. The patenting of innovative biotechnical developments in industrialized countries, particularly of agricultural techniques that were formerly in the public domain could have a considerable adverse impact on developing countries as the costs of agricultural operations may increase significantly. At the same time, major improvements in plants and crops and increased bio-diversity can be achieved through research in developing countries in genetic engineering, including implantation of nitrogen-fixation genes. Tissue culture and related techniques can bring about considerable improvements in plant breeding and production capability. New and modified species of plants can be developed which could survive in desert regions. Livestock breeding could be significantly improved through genetic applications. The production of proteins, the conversion of biomass of food products and major increases in food production could be achieved through biotech applications. The right to patents and ownership of technological innovations in this field may, however, result in constraints in extending such technologies to poorer countries. With the extension of patent rights on the new varieties of plants, crops and other agricultural developments achieved through biotechnology, the cost of such new biotechniques including improved seeds, has tended to increase considerably. This may necessitate much greater research efforts in developing countries, as well as the development of joint research and linkages with leading companies, to the extent possible. It will also be necessary to develop appropriate bio-safety regulations, particularly on aspects of special interest to developing countries.

International Centre for Genetic Engineering and Biotechnology

59. Recognizing the major impact of genetic engineering and modern biotechnology on industry, UNIDO catalyzed the establishment of the International Centre for Genetic Engineering and Biotechnology (ICGEB), in 1982, to provide training and research and development in genetic engineering and biotechnology, in areas of special concern to developing countries, such as human health, food and nutrition. ICGEB became operational in 1987 and its twin Centres in Trieste, Italy and New Delhi, India are engaged in research on diseases such as hepatitis, AIDS and malaria, as well as on pest-resistant crops, peptide antigens, and lignin biodegradation. ICGEB became autonomous in 1994, with 35 member States, and currently operates with a network of affiliated institutions in developing countries.

A number of courses and meetings focused on specialized research topics or techniques have been organized by ICGEB during the period between 1988 and 1994.

Agenda 21

60. The Agenda 21 Programme on Biotechnology is a comprehensive range of activities, focusing on the need for the increasing availability of foods, feed and renewable raw materials, improving human health, enhancing environmental protection, ensuring biosafety and international cooperation and facilitating transfer and applications of biotechnology.

Business applications of biotechnology

61. Developed countries have largely been the leaders in the development and application of biotechnology. Innovative institutional, legal and financial arrangements that relate to private sector collaboration, university-industry linkages, strategic business alliances and venture capital have been extensively developed to address the emerging issues relating to the starting up and successful operation of new biotechnology businesses.

62. As commercial biotechnology applications gradually increase in scope, and boundaries are erased between agriculture and industry - from pharmaceutical and health care to agriculture and environment - their economic impact will undoubtedly increase globally. Pressure to decrease dependency on chemical pesticides, for instance, is expected to drive the growth of biopesticides and the sales of genetically-engineered products worldwide.

63. Several reports on the United States commercial biotechnology industry have predicted that the coming decade will see an enhancement of biotechnology activities, especially in the private sector, on the basis of an increasing number of products entering the market and the global pressure for more flexible government regulation of biotechnology products. A similar trend has also been reported in Europe, Japan and Canada. On the basis of current data, a 1994 report[13] estimates a global market value of biotechnology of US$ 50 billion. Revenues are expected to double by the year 2000. The number of jobs directly related to biotechnology is currently estimated to be only 184,000. Investment in biotechnology, is estimated to be US$ 1.2 billion annually.

Biotechnology in developing countries

64. In contrast to industrialized countries, most developing economies have achieved only limited development of modern industrial biotechnology. Most of these countries lack proper promotional, regulatory, risk assessment policies and mechanisms; do not have access to timely information on technologies, markets and opportunities; lack support for the creation of new biotechnology businesses, particularly concerning genetic resources, and face a considerable shortage of specialized skills for the management of bioindustrial innovation.

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[13] Commissioned by the Senior Advisory Group on Biotechnology.

Some recent initiatives, such as the Argentinean/Brazilian Centre for Biotechnology CABBIO, established within the context of MERCOSUR aim to mitigate those deficiencies. Considerable initiative has also been undertaken for biotechnology research at the national level, including in India, Malaysia, Pakistan and Thailand among Asian countries, in Argentina, Brazil, Chile, Costa Rica, Cuba and Mexico in Latin American and in Nigeria in Africa.

65. In most of these countries, incipient policies have been attempted to stimulate biotechnology business, while regulating environmental risks and the potential loss of proprietary resources. In several cases, FDI has been encouraged, besides joint-ventures and strategic business alliances of local companies with foreign enterprises, but there has been considerable delay in the proper utilization of genetic resources, which constitute one of the vital tradeable products for gene-rich developing countries in the future.

66. Policies to promote the international trade of products based on indigenous genetic resources should be gradually promoted. The global market for genetic resources is currently estimated of US$250 billion/year[14] and a substantial share of this growing market could accrue to developing countries.

67. As R&D on indigenous genetic resources receives greater impetus, the efforts should go beyond prospecting into synthesis, product development, business creation and trade, in spite of the daunting odds of discovering new marketable products.

CASE: NIGERIA

The Bio-resources Development and Conservation Programme, started in Nigeria, has now spread to five Central African countries. The prospecting for genetic resources through "safari science" carried out with the involvement of poor communities in association with international pharmaceutical companies is another interesting model. Its financial support to community-level activities is a good example of how high-tech can assist poverty alleviation.

68. While biobusinesses are flourishing globally, the risk of losses of national proprietary genetic resources is very real and the regulation of underground leaks and other "asset depletion" is necessary. Examples like the loss of the alkaloid from Cameroon's Ancistrocladus Korupensis, which inhibits the growth of the *AIDS* virus, and of the Astaxanthin molecule and the genus Phaffia are illustrative. Astaxanthin gives the pinkish cast to shrimp, lobster, salmon and is possibly the most powerful antioxidant in nature, which may become an effective anticancer agent in the future. Prevalent in algae, plankton, krill and other foods at the base of the oceanic food chain, the molecule is now made synthetically and sold to aquaculturist farms raising salmon at more than US$ 1,200 per pound.

[14] World Bank Paper No. 133/1991.

69. Genetic resources should also be considered for adding value to related plants. Recent advances in enzyme chemistry are making it scientifically feasible to genetically reengineer plants in order to manufacture particular chemicals. Given the genes to generate the ones that together catalyze the right reactions, plants might prove able to produce their own protective pesticide. Plants might be made to create novel synthetic pathways leading to new products altogether. These developments may open new opportunities for developing countries to add value to their genetic resources in the future and further erase the boundaries between industry and agriculture.

70. Developments in biotechnology during the next decade are likely to be very far-reaching in their scope and application. It is difficult to anticipate the enormous range of new use and applications that can be developed in sectors such as agriculture, pharmaceuticals and chemicals. It is necessary for developing countries to expand biotechnology research, both through research institutions, universities and enterprises, as also to develop close technological linkages with foreign biotechnology institutions and enterprises. In this relatively new field, there is considerable potential for achieving a closer level of technological parity, particularly in agriculture-related research and development, between developing countries and industrialized economies. UNIDO is in a position to assist policy-makers in developing countries to design policies to foster indigenous biotechnological development, and to assist in development of norms against the unauthorized use of genetic resources, while enabling Governments to maintain controlled access to their bio-diversity for sustainable business development.

C. New Materials

71. Developments in materials science have been very rapid and are having a considerable impact on competitive capability in various fields, ranging from energy engineering to information and communications (optic fibres), transport and automotive design and production and microelectronic systems. New and advanced materials range from composites with very high strengths to silicon wafers. The development of new composites, ceramics, special alloys and functional materials, including electronics, magnetic and super-conductive materials, besides photonics and sensor devices will inevitably have a major effect on material usage in various fields.

72. Materials research is expensive and requires inter-disciplinary capability and costly facilities. Nevertheless, effective research has been, and is being, undertaken in several developing countries with respect to building materials and polymers and composites based on local materials. Such research needs to be promoted through institutional support, while technological linkages and partnerships should be sought for access to new materials for use in construction and the manufacture of various products, ranging from water pipes to automotive equipment.

73. The technological impact of new materials on several industrial subsectors will be very significant. Because of their central importance for the development of new products in many industrial subsectors, materials and related processing technologies are viewed internationally as being at the core of product and process innovation efforts to provide an international

competitive edge to enterprises in these sub-sectors. There will be significant spillover effects on virtually all industrial sectors from the application of new materials technologies.

74. For the period beyond 2000, new materials engineering will provide the greatest degree of interlinkage with other engineering fields and with major positive external effects in energy, transportation, housing, health, etc. The paradigm for materials competitiveness is that the synthesis of new materials must be integrally linked with the design and processing of the corresponding final products, since the materials are only basic components of complex systems and, as such, critical to their performance. Thus, improvements in materials quality and price can have dramatic effect on international competitiveness across sub-sectors.

75. Priority applications are expected to focus energy engineering; transportation system; information and communication systems; micro-electronic systems; optoelectronic systems; and medical engineering. Table I (New Materials) in Annex I illustrates the enormous range of uses of new materials technology.

76. Innovations in engineering materials have created major technological advances in recent years and the trends are set to continue into the next century. Worldwide demand for advanced materials has been increasing rapidly within the last decade and it is forecasted to rise by 2000 and beyond. Between only 1985 and 1988, the number of worldwide companies involved with advanced materials grew from 302 to more than 1,800. The most important impetus for new materials comes from large TNCs in industrialized countries. Analysis of industrial materials research in Germany, Japan, and the USA demonstrates that the companies with the greatest turnover attach high importance to materials research, and that 33 of the 50 companies with the highest turnover around the world invest in materials research. The specific R&D plans and projects of the firms are focused on strategic corporate goals. On the whole, however, materials research activities indicate considerable potential for cooperative research activities. Projections for the new materials market are shown in Table II in Annex I. The annual growth rate projected in the coming 10 years in the field of advanced materials is shown in Table III (New Materials) in Annex I.

77. The design and structural control of advanced high performance materials for use in hazardous and extreme environments such as intermetallic compounds and advanced composites are also important R&D fields, together with electric batteries for the automobile industry. As discussed earlier, information technology is a rapidly evolving set of technologies, both hard and soft, encompassing, inter alia, communications (mobile, satellite, rural, and others), photonics, computers, information networking, software, information storage and support systems. The changes are propelled by a series of chain reactions due to the fusion of many technologies as well as their applications, fuelled by the speed requirements of data-accessed processing for decision-making in globalizing markets.

Conclusion:

78. There can be little doubt that technological innovations in the generic technologies of informatics, biotechnology and new materials and in related fields are likely to continue at their present rapid pace, during the next decade and thereafter. Their impact on competitiveness of various products and processes will be substantial, though this will vary

significantly in different fields. For developing countries, awareness and knowledge of new technological development in various fields is an essential pre-requisite for development of increased technological capability through indigenous R&D or external technology inputs.

79. The pattern of technological development has varied considerably. The impact of such development is generally assessed in terms of increased production. It is equally important, however, that such production is competitive in internal and external markets and in terms of manufactured exports. In most developing countries, technology issues have revolved largely around the development of technological infrastructure, the acquisition and use of foreign technology or development of indigenous technological capability. With increasingly open markets, the principal emphasis must now shift to the development of technological innovative capability at plant and cluster levels for the achievement of sustained competitiveness.

IV. MAIN EMERGING ISSUES FOR CONSIDERATION IN INDUSTRIAL TECHNOLOGY POLICIES

80. With the increasing costs of research and development and the shortage of technical research personnel in industrialized countries, an area of considerable potential for developing countries is outsourcing of research in these countries. Several TNCs have set up research facilities in developing countries, including Nestlé, Astra, Texas Instruments, IBM, Hewlett Packard and AIWA. Such research facilities benefit from the much cheaper costs of R&D personnel in these countries. At the same time, the results of research accrue only to the parent company, which provides the necessary investment for the research facilities. This pattern is expected to grow during the next decade, with research activities being increasingly undertaken in developing countries and in transition economies, which have a large pool of scientific and technical personnel available at a much lower cost. It should be possible, however, for developing countries to also undertake specific research activities under contractual arrangements with foreign companies as in the case of software research and development in India. This will constitute a new form of international subcontracting with considerable potential.

81. In the light of the key role of technology for competitiveness and global trends and developments in this regard, the principal issues and policy options that need to be considered are the following:

(a) In order to strengthen the technological base in less-developed countries, increased foreign technology will be necessary, including through increased economic and technological cooperation between developing countries (ECDC/TCDC). While initiative in this regard must be taken primarily by national enterprises, it should be considered what policy and institutional measures are necessary, both to promote technological partnerships and linkages with foreign enterprises and for rapid technological absorption and adaptation. It should also be considered as to how indigenous technological development can be promoted through applied research activities in enterprises, universities, R&D institutions and other technology-innovation bodies.

(b) It should be considered how closer linkages can be established between privatization policies and increased use of innovative technologies. This should include infrastructure activities, particularly the operations of privatized utility companies, which must be increasingly competitive. Measures should also be considered for increasing technological competitiveness of state-owned enterprises during any process of restructuring.

(c) It should be considered how technological innovations and use of new generic technologies can be promoted in resource-based industries and the industrial commodities sector, as also in various manufacturing subsectors, both through upstream (improvement of raw materials, productivity etc.) or downstream (re-engineering customer services) activities, or through strategic business alliances for technology on R&D.

(d) It should be considered how technological research activities of TNCs can be promoted in developing countries and transition economies and how new TNC investments can be channelled in more dynamic and complex subsectors, including those involving new generic technologies.

(e) It should be considered how national and regional R&D institutions in developing countries and transition economies can develop a strategic framework and monitoring mechanisms for dealing with new generic technologies, including through subcontracting with foreign firms.

(f) It needs to be considered how developing countries and transition economies can derive the full benefits of the Uruguay Round Agreements through technological innovation in various subsectors and product ranges, taking into account the opportunities offered by the TRIMs and TRIPs dispositions.

(g) It should be considered how a "fair competition" environment can be established for national companies in high-tech sectors, particularly informatics and biotechnology, and how their activities can be promoted and strengthened.

(h) It may be considered how the competitiveness of national enterprises engaged in international services subcontracting through electronic networks can be strengthened through the increase of their technological innovation capability.

(i) It would be necessary to consider measures and regulations for biosafety, for safe and efficient use of advanced new materials, for technologies required to design new products with a view to dissassembly, reprocessing for reuse oR safe disposal of components (DFD), besides other environmentally-suitable technologies.

(j) The growing relevance of technological innovation in manufactured-related services for sustainable competitiveness, needs to be highlighted. It should be considered how related capacity-building processes can be accelerated in developing countries and economies in transition.

(k) The design and implementation of new creative financial and fiscal incentives is also called for some examples in different countries, are:

* One-off capital infusions of 2 billion kroner (drawing on resources from privatizations) to speed up development o new products too risky to be carried-out without some form of external support. Interest payments are used to co-finance up to 50% of the cost of industrial projects (Denmark).

* Indefinite extension of the 125% tax subsidy to R&D after June 1993 (Australia).

* Tax concessions of 125% for firms with international R&D projects (Denmark).

* Strategy to entice the development, production and diffusion of advanced manufacturing technologies. Extension of the bounty scheme for the machine tools and robots industries. Updating of the information industry strategy (Australia).

* Multiplication of regional manufacturing cetners and of funds devoted to civilian R&D. Permanent R&D tax credit. Expansion of the National Co-operative Research Act to permit joint production ventures and reduction of the tax rate on capital gains (USA).

* R&D subsidies of 100% granted by MITI through the New Energy and Industrial Technology Development Organization (NEDO), particularly to consortia, with results and intellectual property jointly owned by NEDO and the beneficiaries (Japan).

* Direct support to: project development; technical and human resources; co-ordiantion of R&D efforts; infrastructure for servicing innovation firms; internationalization of domestic technology; and technological development with emphasis on electronics and informatics, advanced automation, pharmaceuticals, biotechnology, chemicals and materials (Spain).

CASE: JAPAN[15]
- Strategic Alliances -

To cope with the problems of rapid technological obsolescence, the need to have new competencies built in a dynamic manner and the intense competition resulting in the rapid introduction of new products, various firms in Japan have used strategic alliances. For example, Hitachi Ltd. has initiated many alliances for the quick generation, utilization and diffusion of product, process, application and systems innovations. The strategic alliances have been used in many areas and with diverse firms, leading to competence fusion and technology fusion. Some illustrative examples of alliances are: Hitachi Ltd and Nippon Steel Corp. have developed jointly the world's first artificial intelligence system for operational control of blast furnaces; Hitachi Metals Ltd, Hitachi Ferrite Ltd, Hitachi Ltd and the Hitachi Electronic Co. have developed a microwave oscillator using a plane magnetostatic wave generator which features video frequency and low noise capabilities;Hitachi Ltd and Takeda Yakuhin Co. Ltd have jointly developed high precision liquid crystal displays. Strategic alliances facilitate the fusion of competencies, through the pooling of resources, quick product development, quick commercialization of ideas, joint technology development and concurrent engineering. They also tend to lower transaction costs through the use of complimentary assets and competencies. Furthermore, strategic alliances help in pooling resources, reduce the concept-to-market cycle time and provide for a wider window of opportunities.

82. As a result, the management of technological innovation or technology management, should be contemplated as the core of industrial policies in developing countries. Accordingly, *crash capacity-building programmes for proper technology management (MOT)* in public and private enterprises besides innovation system agents like R&D institutes, small and medium consulting enterprises, incubators, etc., should be contemplated.

83. Through this programme, the learning process in existing enterprises would be accelerated to overcome the lack of "Innovation Tradition" culture recognized by institutions like the World Bank as the differentiator between the highly innovative companies of industrialized countries and their counterparts in the developing world.

84. This capacity-building process should not only contemplate the development of ad-hoc MOT methodologies and human resources development programmes, but also field studies and *demonstration effect projects* - and consequent ample dissemination successful

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[15] B. Bowonder and T. Miyake, Innovations and Strategic Management : A Case Study of Hitachi Ltd., Technology Analysis and Strategic Management, Vol.6, No.1, 1994.

experiences -the clustering of innovative large medium and small enterprises around joint innovation programmes to facilitate the on-the-job exchange of MOT experiences, fora for the advancement of MOT techniques, MOT performance benchmarking and other initiatives to promote the culture of innovation.

85. The MOT capability thus developed catalyses the complementary business rearchitecture and network abilities for sustained competitiveness and include the managerial technologies - leadership styles, teamwork, communication and negotiation skills, human resources empowerment, etc. - required for seizing tacit knowledge and to sustain the high quality services required by customers.

86. Radical innovations in services seem particularly needed to gain competitiveness in internal and external commercialization activities, in sub-contracting of international services, high-tech businesses, DFD, and to enhance the competitiveness and survival of national companies catering only for domestic markets.

87. All indicates the following fields of technology management deserve special emphasis by developing countries and economies in tmsition in the short-term:

- Diagnostics of the technological competitive position of companies and ensuing definition of technological strategies for sustainable competitiveness, highlighting "ad-hoc" blends of R&D and technology transfer activities.

- Management of R&D for devising new selected applications of existing and emerging technologies - different functions from the ones for which they were originally intended;

- Management of R&D for manufactured-related services;

- Management of technology transfer negotiations and agreements, including technology absorption and adaptation;

- Product innovation, particularly, but not exclusively, industrial design for DFD;

- Technology information - particularly on clean technologies - technological forecasting and monitoring;

- Performance benchmarking, total quality management and process reengineering.

88. Therefore, policies for strengthening and regionally integrating innovation system supporting agents - such as R&D centres, small and medium consulting enterprises, standardization boards, incubators, etc. - should contemplate the multiple channeling of those MOT capacity-building services for the required level of MOT effectiveness in private sector enterprises. Strengthening small and medium management consulting enterprises, for instance, with MOT methodologies and ready access to up-dated information on clean technologies,

may turn them into new channels to promote technological innovations in the private sector which are both competitive and environment friendly.

89. Sophisticated equipment and human resource development programmes in R&D centres and standardization boards contribute to provide the specialized services required to overcome technological non-tariff barriers. Incentives for the establishment of both MOT capabilities and R&D centres in large enterprises might be balanced with R&D consortia for SMEs <u>plus</u> internal MOT capabilities in each company, Furthermore, MOT capabilities at the policy level, either national or regional, should provide for the continuous MOT proficiency of the different agents of the innovation system, benchmark their respective performances and possibly integrate them through electronic networks.

90. One of the most important aspect of technology policy in developing countries relates to human resource development unrelated to MOT. This has to be considered at two levels. First, a strong entrepreneurial culture has to be developed and a strong entrepreneurial class has to be developed which recognizes the key role of technology at the local enterprise level. Second, with the growth of demand for new products and new technological applications, new categories of technical personnel need to be created. While emphasis has been given in most countries to higher science education, equal emphasis is necessary on education and training facilities for specialized technical personnel - such as computer programmers and systems designers and specialists, besides microbiologists and specialized researchers in biotechnology, and energy specialists - the demand for which will multiply with the growth of new technological applications.

CASE: MEXICO
Technology policy orientation

Prevailing Policy Orientation

In the last decade there was an important shift from a supply side policy to one that attempts to reinforce the demand side of the equation. Thus, technology policy in the current administration, as implemented by CONACYT, has some new lines of action, such as: i) placing the firm and the entrepreneur at the center of the process of innovation and modernization; ii) creating, together with other public entities, support centers for competitiveness; iii) impelling firms to develop their "learning capacities" so that they can participate in both the process of innovation and in the continuous improvement of productivity and quality. These main threads are guiding the redesign of programs and instruments, which are now being directed to: i) promote investment by firms in learning capacities through financial stimulate and non-economic support for the creation of centers for competitiveness, where firms should be the source and users of the innovative process; ii) promote the elimination of bottlenecks in information flows, and the connection of scientists and technicians with firms; iii) promote the use of international standards and norms and support the diffusion and utilization of quality control methods; iv) support programs for the development of suppliers in public entities; v) promote technological centers which can offer normalization and metrology services, as well as technological services for industry in general; vi) support linkages between firms and research institutions. As seen from these measures, the emphasis is clearly placed on strengthening the demand side of the innovation process.

Specific recommendations:

A stronger and more extensive technology management practice in firms, as well as the availability of appropriate mechanisms to promote it, are at the core of almost any recommended strategy for improving Mexican firms' technological capabilities. As long as firms strengthen their managerial resources and skill in technology management, other aspects of their technological capabilities will also improve. Self-awareness, monitoring and assessment of technological opportunities from improved technology management lead to better strategy definition. Quality and productivity are better aligned to longer term R&D strategies if companies possess well trained technology management personnel. Incorporation of R&D results and new technologies into the firms' operations is another key issue to technology management. Thus, it is important to: promote stronger and more diverse training programs in MOT; low interest rates for the first stage of development of technology management skills and capabilities in micro and small firms; promote more diverse and strong consulting and advisory services on technology management to tend to industrial firms and public R&D centers.

91. Given the assurance of MOT, developing countries and economies in transition should feel safer to consider the massive investments in technological innovation required for sustainable competitiveness, beyond the relatively timid or spasmodic levels of the past, which provided coverage mostly limited to R&D activities.

92. As proposed, the required financial and fiscal incentives should cover the whole gamut of technological innovation and associated activities, including strategic technological planning at the enterprise level, technology transfer negotiations, monitoring and forecasting, benchmarking, management changes in leadership style, teamwork, human resources empowerment, total quality management, reengineering, networking through international strategic business alliances, etc.

93. Finally, the strengthening of the capacity of central institutions in charge of policy design and implementation, including the coordination of the work of innovation system agents, merits special attention. The diversity of areas and agents involved, their different capacities, political power and willingness to cooperate with each other have frustrated the implementation of many policies in the past. The above can only be achieved if macro-economic policies are congruent with and supportive of technological policies, what cannot

be verified to have happened in developing countries' experiences in the past. Exceptions like the case of Korea should illustrate the above.

CASE: THE REPUBLIC OF KOREA

INDUSTRIAL TECHNOLOGY POLICY

Korea has built up a deep and diverse industrial structure through deliberate governmental interventions in the trade and industrial regimes, guiding the allocation of industrial investments in particular directions, relying less on direct foreign investments, and pressing local firms to be export-oriented in the short term.

The resulting technological challenge was met by promoting the involvement of national private firms in licensing technology from abroad, technology absorption and imports of equipment. Simultaneously, the government stimulated firm-level training, allocating massive resources to high-level technical education (1991 - 17.6 researchers/10,000 people, goal for 2000 - 30/10,000), to R&D projects approved by the "chabeols" and to building-up the S&T infrastructure:

KOREA - EVOLUTION OF R&D INVESTMENT

YEAR	AMOUNT US$ MILLIONS	% GNP	SOURCE: RATIO PUBLIC/PRIVATE R&D
1981	418	0.64	50/50
1991	5.46	2.02	20/80
1998		4.00 (goal)	
2001		>5.00 (goal)	

Criteria for strategic national R&D projects: technological intensiveness, broad international competitive advantage, conservation energy and resources, growth potential, spill-over effect, contribution to social development.

94. The above elements will obviously vary in their significance from country to country. What is, however, important is to view the technology policy framework as a dynamic and continuing process, which is related directly to the technological needs of the existing principal production sectors in each economy and emerging new areas.

95. It is of growing importance, at the national level, to assess and forecast the impact of new technological developments on national economies. This is a field of growing complexity with the fast pace of technological change. The monitoring of technological change is of particular importance in developing countries and must be viewed as an integral element of technology policy in these countries. The appropriate mechanism for such assessment may differ from country to country but the basic objective of regularly monitoring, assessing and forecasting new technological developments and their impact on the respective national economy is of vital importance.

96. Through its human resources development and technology services, UNIDO is in a position to support developing countries and economies in transition to effectively face the new technological and competitive challenges brought about by current and future i. 'ustrialization contexts. Annex I & II detail some of these services.

Annex I

UNIDO's Technology Services

The industrialization process ideally follows an integrated strategy covering interrelated functions, services and programmes. Too often, functions such as investment promotion, development of small and medium industries or entrepreneurial development are pursued separately. They should, however, be seen as part of a broader process of integrated and sustainable industrial growth. While important prerequisites for such growth include political and macroeconomic stability, these have to be combined with adequate physical infrastructure - facilities such as power generation, transportation and communications - and a broad range of basic policy and institutional elements. These include: creation of a conducive climate for mobilizing private sector investment and technology transfer arrangements; restructuring and/or privatization of sate-owned industrial enterprises; institutional support for entrepreneurship development; technological assistance and promotion of small, medium, and micro-industries; promotion of rural industrial development; and ensuring that industrial growth at various levels and in different sub-sectors is environmentally sustainable.

It is also vital that these functions, and the programmes relating to their activities, are effectively integrated. For example, promoting foreign direct investment and technology inflow has to be linked with development of local entrepreneurship and small and medium enterprises (SMEs). SME development itself includes several services: promotional policies and incentives, financial, technological and marketing support in various industrial sub-sectors, strengthening of national institutions, integration of environmental requirements, and the development of enterprise-to-enterprise relationships. It is the provision of such an integrated industrial growth strategy that constitutes UNIDO's main goal. Broad goals such as accelerated industrial growth and greater competitiveness also call on nearly all of UNIDO's specialized services including use and development of technology management, specific technologies, and quality and standardization.

Given the potential for complementarily and synergy between specialized support services, UNIDO offers them as integrated packages, geared to the problem solution and capacity-building in the context of the country or region involved. For example, enterprise restructuring and rehabilitation requires interlining the use of competitive, environmentally suitable technologies improving quality standards, HRD and technology management. Sectoral support for sustainable development will often involve environmental considerations, as well as use of cleaner technologies and the management of the technological processes as an essential element of sustainable industrial growth.

The ability to effect combination of several innovative industrial services in order to tackle the wide-ranging problems of industrial growth is a major asset in a large multidisciplinary organization like UNIDO. Its integrated approach to industrial development enables the functions and services it carries out to interact in order to provide solutions to problems posed by the needs of changing industrialization, paradigms with particular concern on equitable and sustainable social development.

Some principles behind the technological services provided by UNIDO are::

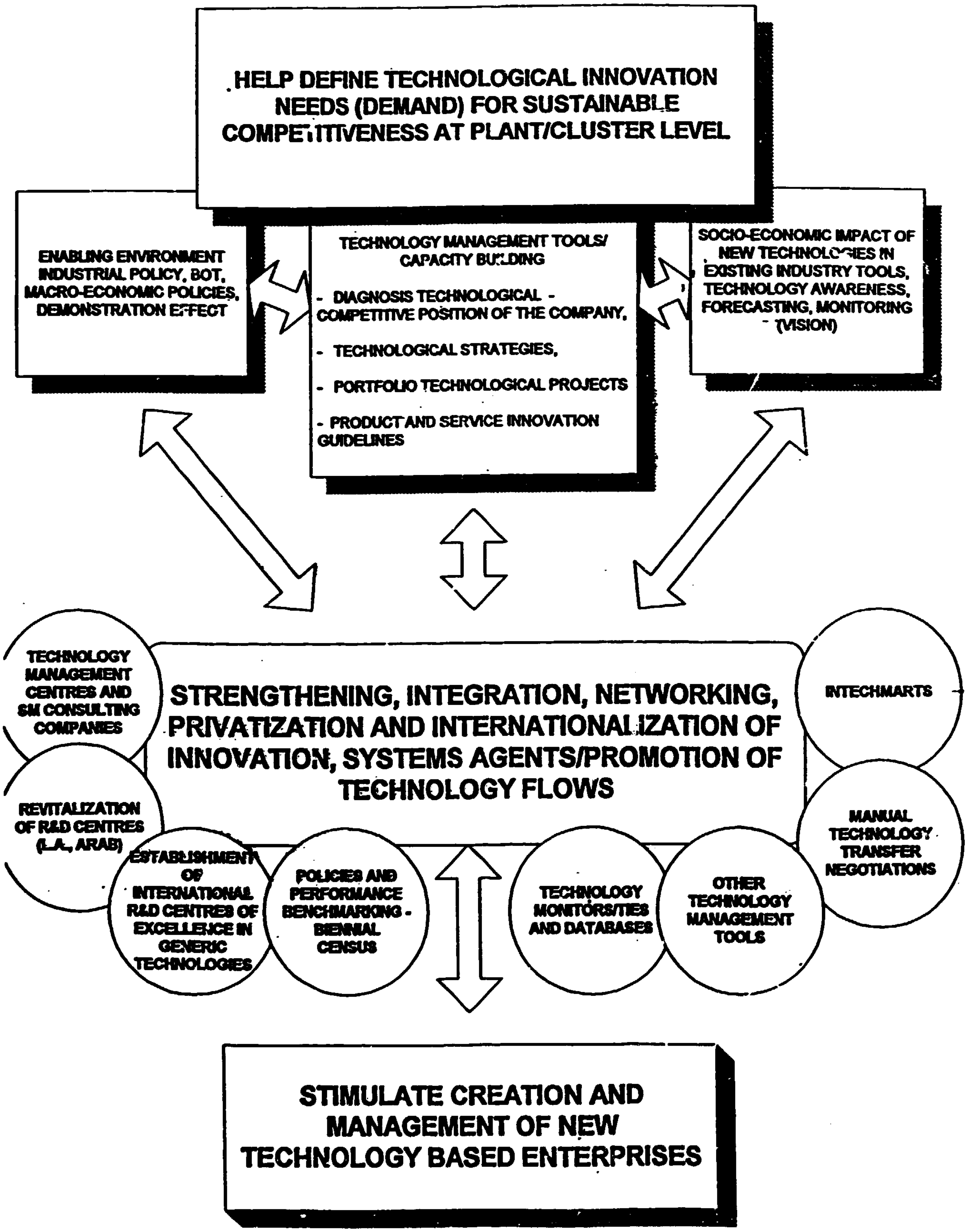
- Democratization of knowledge, particularly for technological innovation management (avoiding denominator management);
- Assist developed countries' organizations in "expeditionary" marketing (globalization/potential future growth);
- Multilevel assistance (policy, institutional infrastructure, sub-sector, plant/cluster);
- Normative character;
- Demand oriented;
- Large programmes/high quality;
- Search for synergies;
- Maximize impact;
- Integratioin with other UNIDO services.

Strategy Focus for Technology Services

In response to the new challenges facing technological in developing countries and countries in transition, UNIDO's technology services focus on designing and implementing integrated strategies that: (a) make demands for technology at plant and cluster levels more focused and explicit; (b) strengthen, integrate and promote innovation system agents and technology flows; and (c) support the processes that create and develop new technology-based enterprises. **(Figure 1)**

Figure 1:

STRATEGY FOCUS



Creation of new technology-based enterprises

This set of services is applied to generic technologies, such as Biotechnology, Information Technology, New Materials Technology, Renewable Energy and Marine Resources. Mechanisms promoting the latter include science parks, university-industry linkages, entrepreneurship development, incubators, venture capital, joint ventures, strategic business alliances, technology transfer, and innovative credit and fiscal schemes, among others.

UNIDO services help developing countries focus on technology as the basis of competitive strategies, policies, institutional and plant/cluster levels.

Technology Management at plant/cluster levels

Making technology demand explicit, i.e., defining technological innovation needs (in terms of sustainable competitiveness), requires accelerated development of strategic and technology management capabilities. For plants or clusters, this includes technological diagnosis of their competitive position, evolution of their technological strategy, development of a portfolio of technological projects, and using effective technological innovation product and service guidelines. The above is supported by specific MOT methodologies, enabling technological policies and the "vision" of future development provided by activities such as technological monitoring and forecasting.

Assessment and support of National Innovation System agents

Accordingly, UNIDO assists in creating and strengthening R&D institutions and their linkages to other innovation system agents and enterprises. Measures to promote innovation and technology flows include support for technology management centers, technology management in small and medium consulting enterprises, revitalization and establishment of new R&D centers, UNIDO's own technology publications and Intechmarts. It also promotes collaborative activities such as joint research projects. UNIDO can also assist in the commercialization of R&D results. UNIDO's INTIB (Industrial and Technological Information Bank) programme offers information and documentation on alternative technology sources in 20 industrial sectors. It also provides advisory on information policy and design, training needs and opportunities in the information field.

Technology Forecasting and Monitoring

UNIDO also keeps advanced technologies under review and directs special attention to a group of generic ones having an increasing impact on the nature of industrialization and the competitive situation of developing countries. These are: genetic engineering and biotechnology, microelectronics, informatics and telecommunications, new materials, new energy technologies, and marine industrial technologies. Trends and advances are monitored and evaluated in relation to the needs and opportunities of developing countries. UNIDO also helps develop national and regional capabilities for the monitoring and evaluation of new technologies; it promotes cooperation between developing countries in monitoring; and prepares corresponding policy recommendations.

Technology Acquisition and Transfer

UNIDO assists institutions and enterprises in building up and/or strengthening capacities to handle technology transfer operations and the establishment of SBAs and joint ventures. Its tools include advisory services, training programmes, technical documentation and studies and guidelines. The Organization's experience and know-how in this field are consolidated in a Manual on Technology Transfer Negotiations, which is a comprehensive assessment of the range of issues faced by technology buyers in the various phases of the technology transfer process. UNIDO also promotes build-operate-transfer arrangements and strategic alliances and can assist in the development and implementation of such schemes.

Technology for Environment and Traditional Industrial Sub-sectors

In 1994, UNIDO concentrated its environmental programme on five areas, including the transfer of technology for environmentally sustainable industrial development; capacity-building in support of national plans or programmed for environmentally sustainable industrial development; energy and industry.

Most enterprises, particularly small and medium scale, have not shown internal capability to make adequate use of clean technology, on a continued basis. Their lack of technology management abilities, including technology transfer management, the lack of technology information and availability of financial resources are considered major factors hampering the effective transfer of clean technologies.

UNIDO technology transfer support at the level of industrial sub-sectors in which environmental aspects are incorporated concentrated on offering, tailor-made solutions to enterprises. During the past several years, a large number of UNDO projects have addressed the specific needs of various sectors: some 50 projects were under implementation in the leather sector, 12 in wood, 13 in textiles, more than 30 in the pharmaceutical sector, over 30 in the sectors of rubber, plastics and petrochemicals, 12 in pulp and paper, 35 in non-metallic minerals, building materials and cement, around 100 targeting small and medium enterprises in the engineering sector, 65 in machine tools, of which 12 were at the high-tech level, 18 addressing environmental issues of the metallurgical industries sector, 30 in rural food-processing industries, 17 in non-wood forest products, 20 in agro-chemicals, 20 in agro-related metalworking, 4 in small-scale mining and 7 in the development of new and renewable energy sources. Some principles behind the UNIDO's strategy on the new and renewable energy are:

- Development and application of efficient, cost effective and environmentally sound energy systems in developing countries;

- Strengthening and networking institutions R&D new and renewable sources and commercializing results;.

With this strategy focus, UNIDO can join forces with governments, national infrastructure institutes, financial agents, industrial associations and international partners to implement integrated regional, sub-regional or national programmes.

New Generic Technologies

UNIDO sensitizes policy makers, entrepreneurs, scientists and technologists concerning the formulation of policies and the building up of technological strengths that will enable them to take advantage of the new and advanced technologies including advanced manufacturing systems.

Advice on Industrial Technology Policies and Strategies

Advice on design and formulation of integrated sets of technological policies and strategies covers the key elements in the use of technology for competitiveness. The issues covered include: building up domestic technological capabilities including investment in human capital; strengthening national and regional innovation systems; managing technological change effectively, including technology monitoring and forecasting, acquiring foreign technology efficiently, improving, upgrading and developing technology, the role of new and advanced technologies, regulations and many other aspects.

Specific Services in New Generic Technologies

- **UNIDO Services in Biotechnology**

Recognized in its level of technical expertise as the leading United Nations specialized agency in the field of biotechnology, UNIDO can help coordinate UN support programmes across agencies.

The organization's technological services in biotechnology focus currently on:

- assessment of specific national threshold factor for R&D/production/marketing of biotechnology products - with specific focus on food industry production, security, bioremediation;

- the management of prospecting, valuation, conservation and rational exploitation of indigenous genetic resources;

- design of regulatory framework on biosafety and genetic resources, security, of voluntary code conduct guidelines for the release of modified organisms into the environment;

- management of technology transfer through both licensing and strategic business alliances;

- promotion of networks in genetic resources prospecting and small scale bioindustries;

- biotechnology monitoring and information/joint R&D/HRD support particularly in management of biotech innovation process.

- design, assessment and networking of infrastructure agents such as national and regional R&D centers.

Future UNIDO activities will include also:

- international technology risk assessment, advisory services on biosafety;
- international harmonization of biosafety regulations to facilitate technology transfer and foreign investments in biobusiness;
- clearing house for oversight procedures on biological diversity products and processes deployment;
- creation of new biotechnology business enterprises - management of critical supporting mechanisms;
- development of new bio-based small- and medium-scale industry;
- formalized consultative international policy mechanisms with bio-industry;
- complete tools for biotechnology innovation management with particular emphasis on genetic resources prospecting and rational exploitation.

☛ UNIDO Biotechnology Programmes

<u>Biotechnology Monitoring</u>

Monitoring, forecasting and assessment of technology are the essence of a management approach to technological change and to technology management in general.

The quarterly Genetic Engineering and Biotechnology Monitor was brought out in response to a recommendation by a group of experts in February 1981. Over the ensuing years, the Monitor has continuously reported on various aspects of genetic engineering and biotechnology, ranging from new developments to applications, regulations, patenting and legislation, bio-informatics and news of institutional activities.

Biosafety Information Network and Advisory Service (BINAS)

In addition to the above, UNIDO has recently put its electronic Biosafety Information Network and Advisory Service (BINAS) on-line, making information and advice on biosafety issues more accessible to both developed and developing countries.

Stemming from the joint Informal UNIDO/FAO/WHO/UNEP Working Group's Voluntary Code of Conduct for the Release of Genetically Modified Organisms (GMOs), BINAS contains a number of databases that include biotechnology guidelines, regulations and standards for release of transgenic organisms into the environment. BINAS contains global information on national regulatory authorities as well as a roster of experts involved in field release of transgenic organisms. At the same time, BINAS provides an electronic gateway to other biosafety-related data banks. Access is currently through Internet; however BINAS will soon be also accessible through X.25 Public Data Networks.

UNIDO works closely with the Organization for Economic Co-operation and Development (OECD) in information and data sharing, thus providing a comprehensive coverage of developing and developed countries. OECD's "Biotrack" database on the impact of GMOs already introduced will shortly be added to BINAS.

In addition to its databases and information services, BINAS assists national biosafety authorities to formulate and implement biotechnology guidelines. To reinforce the capacity-building aspect of its services and stimulate developing countries to make wider use of them, BINAS promotes also the establishment of national and regional biosafety focal points that will provide immediate decision support to government authorities and industry through ready access to data and provision of expertise. A number of countries have already designated national focal points, so as to avoid exclusive use of BINAS databases by solely developed countries which, as Table 3 shows, are substantial.

Table: Examples of US Loggings into BINAS during the period of 1 March to 12 May 1995 (130 days)

US Companies	1,775
US educational organizations	4,166
US government institutions	346
US military	16
TOTAL	**6,303**

Examples of biosafety regulations available in some of the Latin American countries are:

Table: Biosafety Regulations in Some of the Latin American Countries

Country	**Status**
Argentina	Guidelines for Testing Genetically Modified Plants
Brazil	Law on the Use of Genetically Modified Organisms
Chile	Guidelines for Testing Genetically Modified Plants
Mexico	Guidelines for Testing Genetically Modified Plants

The International Center for Genetic Engineering and Biotechnology **(ICGEB)**

Recognizing that the major impact of genetic engineering and modern biotechnology in industry, in 1982, UNIDO catalyzed the establishment of the International Center for Genetic Engineering and Biotechnology (ICGEB), to provide training and research and development in genetic engineering and biotechnology, in areas of concern to developing countries, such as human health, food and nutrition and others.

ICGEB became autonomous in 1994, with 35 Member States and currently count with a network of affiliated institutions in developing countries. A number of courses and meetings focussed on specialized research topics or techniques have been organized by the Center during the period between 1988 and 1993 and more than 200 participants attended the events from Latin America and the Caribbean.

Technology Infrastructure and Human Resource Development - Regional programme of biotechnology for Latin America and the Caribbean

Since 1987, UNDP, UNIDO and UNESCO jointly executed a programme providing a framework for the gestation of integrated policies for development in biotechnology and for the elaboration and implementation of collaborative actions aiming towards the solution of regional priority problems. It involved 17 countries in the region and 70 organizations and enterprises participated in the programme. Activities included R&D and human resource development in basic science and projects on identification and evaluation of technologies for industrial applications in the region. The first phase was successfully concluded in 1993. The second phase aims towards the practical commercial application of biotechnology for ecologically sustainable industrial development, the strengthening of electronic communications regional networks and human resource development in specific areas.

☛ **UNIDO services in new materials**

Current UNIDO services in this area include:

- Policy advise to national authorities;
- promotion of international networking of on-going related institutions and programmes in developing countries, for training, exchange of experiences and information, joint R&D standardization of testing certification and accreditation purposes; this is carried out through the establishment and operation of UNIDO's international associated centers;
- revitalization of existing R&D centers;
- capacity-building in negotiation of technology transfer agreements ;
- dissemination of market and technical information, trends monitoring;
- design and implementation of mechanisms for the creation and development of spin-offs,
- human resource development.

CASE: INDIA

Ceramic Technological Institute

The Ceramic Technological Institute (CTI) in India was established by UNIDO (ISED) in the company, Bharat Heavy Electrical Limited (BHEL), in 1989, to support the Indian ceramic industries in building capacity to carry out research on advanced ceramic materials. The national market for advanced materials was estimated in 1993 as US$ 35 million with an annual growth rate 10%.

CTI concentrated on fabrication of ceramics, structural and technical ceramics, mineralogy of advance ceramics and electronic ceramics and serves local industries by bringing solutions to operational problems related to raw materials, product composition, kiln operations and refractory applications. Besides testing of raw materials and ceramic bodies, reports on beneficiation of raw materials, cordierite ceramics, ceramic coating systems and energy saving.

The Centre developed several products commercialized with considerable success. Among them special glaze for railway wheel castings and expansive mortar for the Indian railways, explosion proof ceramic vent plugs for battery manufacturers, high temperature alumina crucibles for local laboratories and cordierite kiln furniture for ceramic whiteware industry. Chiefly successful is the ceramic honeycomb substrate for application in the Indian automotive industry in catalytic converters.

Future UNIDO services will also include, inter-alia:

* the harmonization of new materials certification and accreditation processes in developing countries;

* the certification of the above procedures;

* the cross fertilization with other new generic technologies for the creation of new technology-based enterprises.

UNIDO PROGRAMMES

International Centers for new materials' technologies

UNIDO's International Center for Science and High Technology (ICS) located in Trieste, Italy, has a large component of research and training programmes in new materials and is dedicated to establishing a network of laboratories in the developing world.

The variety of advanced materials requires more sophisticated and systemized techniques for testing and evaluation. However, activities associated with the development and establishment of widely recognized evaluation methods are slow and dispersed in developing countries. An International Center for Materials Evaluation Technology (ICMET), which is planned to be established in Taejon, the Republic of Korea, will provide a framework for international cooperation and facilitate the problems faced by developing countries in this important field of materials science and engineering. The preparatory and pilot activity phase of the ICMET project starts operating this autumn.

At present, there is no institution at the international level which addresses the techno-economic issues relating to the development and use of diverse materials in a trans-sectoral and integrated fashion. The feasibility study on the establishment of an International Materials Assessment and Application Center (IMAAC) carried-out by UNIDO, clearly indicated that such an institution would provide a global forum and function as a protagonist for international cooperation based on an integrated approach for the development and use of raw materials. The establishment of IMAAC is being promoted now by UNIDO and preliminary negotiations with Brazil and Colombia are being maintained.

Technology Monitoring

New achievements in materials science and engineering are based on the knowledge-intensive information. Therefore, UNIDO provides information analysis and the monitoring of technology trends in selected materials areas through a series of studies and a quarterly publication entitled: "Advances in Materials Technology: Monitor".

A new periodical "Advanced Materials Technology Series" is issued in response to recent technical change across virtually all high technology fields today. It is focused on the interest of policy makers in government departments, senior managers in industry and scientists who deal with materials issues and assists them to identify the functions new and advanced materials have in stimulating and sustaining industrial competitiveness.

UNIDO SERVICES IN INFORMATICS

Recognizing the importance of information technologies for developing countries, UNIDO is undertaking the following activities:

- Capacity-building for awareness/introduction/evaluation of information technologies at plant level for enhanced competitiveness through reengineering
- Strengthening and networking innovation systems agents - R&D centers, engineering and consultancy firms, associations of software producers (Peru, Brazil, Argentina and Chile)
- Awareness service on trends, assessed software packages, suppliers and other critical information for policy-making, including regulatory measures and social applications of information technologies;

- Development/diffusions of "ad-hoc"customized software packages for developing countries' SMEs, particularly on technology management issues.

UNIDO PROGRAMMES

Latin American project on cooperation in informatics and micro-electronics

Designed to strengthen the capabilities of Latin American and Caribbean countries in the use and diffusion of informatics technologies, its focus has been placed on the development of institutional capabilities, particularly with respect to software production, negotiations for hardware and software purchase, as well as to legislation and design of related R&D policies.

Changes that have taken place in the regional scenario, in terms of economic liberalization and reduction or elimination of state intervention in the informatics sector, provided a framework for further work in the second phase of the project, notably for software production and exports, and diffusion of informatics in small and medium enterprises.

The small and medium firms were addressed as producers (of software) and as users of computer technologies. The social and economic importance of those enterprises in Latin American economies is well recognized, as well as the limitations they face in competing in a new economic scenario and, particularly, in improving their productivity and access to international markets.

The execution of the second phase has attracted the interest of national associations of software firms, and enjoys the support of the European Commission, IDRC, ECLA, and various national entities. Software production and exports create jobs for specialized (mostly young) professionals and opportunities for the development of indigenous entrepreneurship.

During the execution of the REMLAC project the following countries participated in the selected activities of the projects: Argentina, Brazil, Colombia, Costa Rica, Cuba, Ecuador, Mexico, Nicaragua, Panama, Peru, Uruguay and Venezuela.

The time now seems to be appropriate to look at a relatively neglected facet of informatics: its application to satisfy basic social and economic needs.

The potential of these applications in Latin America and the Caribbean is largely unexplored. A survey on existing applications in the region, their possible networking and transfer to other countries/areas, the identification and implementation of new applications by intermediate organizations and local governments, are some of the issues that still need to be addressed in a systematic way and with a regional perspective.

Information technology monitoring

As information technology is now the largest single sector in the world economy, the advances in technology as well as the state-of-the-art are monitored by UNIDO on a continuous basis. The selected topics are published and disseminated in the form of studies, whereas current developments are presented in the form of a document issued on a quarterly basis, 'Microelectronics Monitor'. The 'Microelectronics Monitor' provides analyses and information covering a broad span of subjects on advances in information technology. The important issues of interest to developing countries is software development for domestic applications and export as well as services information technology which, with the growth of networks, may in future constitute their first priority.

In one hand, with these networks, developing countries will have access to information needed for their growth and development. On the other, it is possible through these networks to export services globally. The 'Microelectronics Monitor' offers updated information of these and other issues of importance to developing countries.

Information technology for SMEs

The introduction of information technology to small and medium-sized enterprises (SMEs), to increase their competitiveness, is a specific UNIDO priority..

As SMEs are capable of changing their production capabilities faster and switching to new products and process technologies swifter than large enterprises, the role of information technology in SMEs is essential. SMEs can also make decisions regarding new markets faster, and for that easy access to information is needed. To be able to react rapidly, adequately and in the right direction, SMEs must be tuned to what is happening on the software market, the products that are selling, why they are selling, the alternative products, the technology available and its processes.

The limited marketing capabilities of SMEs could also be widened through information technology in general, and specifically through the global networks, such as INTERNET.

Future additional activities

With respect to information technology, UNIDO will, in future, undertake the following additional activities:

- Awareness service on trends, assessed software packages, suppliers and other critical information for policy-making, including regulatory measures and social applications of information technologies;

- Development/diffusions of "ad-hoc" customized software packages for developing countries' SMEs, particularly on technology management issues.

- Establishment of a centre of excellence in software technology in order to disseminate modern production methods and globally acceptable standards;

- Development of a programme that will inform SMEs what is on the market. This will be used for industrial automation, office automation, product and process innovations, and some other related areas using PC hardware basis. To this end, a software handbook will be prepared;

Annex II

Information Technology

There are some current advances in information technology that will find different applications but will have an impact on industry in the year 2000 and beyond. Those are summarized in Table I below.

Tables 2 and 3 show the estimated evolution of selected information technologies, estimates of the primary business competitive advantage of applying a sample of new information technologies and their relevance to developing countries.

Table 1: New Information Technologies

Multimedia and Imaging	• Multimedia includes information in all its forms (text, voice, image, graphics, video and animation) with primary applications including marketing, sales, education and decision support. • Imaging is the premier multimedia application and provides the basis for re-engineering.
E-mail, Groupware and Video-conferencing	• E-mail and groupware are technologies which lower communication cost and allow team work even over long distance permitting remote employees to work simultaneously on the same project on the basis of shared information communicated cheaply and instantaneously. • The Electronic Mail Association expects E-mail messages to rise from under 3 billion per year in 1991 to 15 billion by the end of the current year, while the number of E-mail users triples from 8.9 million to 27 million. • The groupware market is also expected to grow tremendously, driven by the current competitive imperative to work in multi-disciplinary and multi-organizational teams. Workflow-management software that automates the movement of documents and forms between users within a work group (collocated and distributed) is expected to grow in number of users by 1,000 percent. • Video-conferencing gives managers the option of doing less travelling. By permitting video, spreadsheet software screens, and whiteboard sketch pads to appear on-screen simultaneously in separate windows, computer video conferencing is probably the most useful new multi-media business application supporting strategy-making.

challenges for broad competitive strategies They engender entirely new products, services, markets and businesses. Their impact is trans-sectoral, drastically improving competitiveness of products, processes and services of firms in a large number of traditional industrial sub-sectors. New materials improve product specifications and lower production costs in engineering and chemical industries; biotechnologies save energy and raw materials in chemicals, pharmaceutical and food processing. The pervasive applications of information technologies allow companies in all industrial sectors to re-engineer critical processes, improve overall efficiency and rearchitecture their businesses. Access to information is now basic to competitiveness.

Moreover, the interaction among new generic technologies themselves create unsuspected business opportunities for developing countries. New bio-materials increasingly draw on new genetic resources and engineering. Rapid prototyping gather advances in information technologies and in new materials to speed-up product development. Advances in the systems that process and transmit information is mainly dependent upon progress in materials science[12]. The joining of computers and biotechnology into the new field of bioinformatics, believed to be as important as biotechnology itself, is not only changing the face of biotechnological R&D, substituting all pharmaceutical research before animal and human testing, but also inserting biotechnological products in the electronic industry, such as biochips.

In order to support policies, institutions and the international competitiveness of developing countries' enterprises based on technological innovations, UNIDO keeps advanced technologies under review, and gives direct special attention to five generic technologies that have far-reaching effects on industrial development:. microelectronics and information technology, new materials, advanced manufacturing technology, renewable energies and marine industrial technology and genetic engineering and biotechnology.

12 Lakis Kaounides, The Advanced Materials Revolution. Its Crucial Role in Industrial Competitiveness in the 21st Century. Business News December 1994.

Mobile Computing, Pen-based Computing and Wireless Communications	• Mobile computing incorporates all forms of portable personal computers. Typical examples of this are palm-top computers and notebooks. By 1996, 85 percent of all portable computers will include fax modem facilities. Portable computing expands the reach of information technology. Improved wireless communications, extension of battery lifespan between recharging, colour, and an increasingly mobile workforce contrive to stimulate the market. Worldwide notebook PC sales are expected to grow at a compound annual rate of 8 per cent, from 6.65 million to 9.9 million, between 1994 and 1998. • Pen-based computing is the evolution of the pen and paper metaphor to computing with the electronic stylus serving as the pen and the terminal serving as intelligent electronic paper. Since pen and paper are the main current means of written communication, it is reasonable to believe that pen-based computing will become the chief form of computing interface as the most comfortable and natural form of input evolution in the short-term. • Wireless technologies include both wide-area and local-area technologies. Industry analysts predict that the wide-area wireless market will be growing at 30-40 percent annually.
Voice Processing and Speech Recognition	• Voice processing and speech recognition systems (VP/SRS) refer to a wide range of voice technologies such as voice message, voice response, interactive voice response, transactional voice processing, text to speech and speech translation. Voice mail is growing at 16 per cent and interactive voice response increasing at 25 per cent/year. VP/SRS is the definite computing interface of the future.
Electronic Commerce	• Electronic commerce is the networked-based coordination of materials, process and people to facilitate commercial exchange. Electronic commerce include electronic data interchange, electronic funds transfer, interactive voice response, electronic bulletin boards, data base purchasing services, electronic trading and reservation systems. Electronic commerce binds a business with a supplier and/or customer and provides benefits in speed, quality and process improvement at well as establishing competitive barriers to entry.

Artificial Intelligence - Expert Systems	• Artificial intelligence is the automation of business knowledge. Main applications include expert systems, scheduling, monitoring, configuration, diagnosis, design and compliance.
Robotics	• The official forecast for the industrial robot market was 24 per cent growth in global robot sales last year, followed by further rises of about 17 per cent for this year and 15 per cent for 1996 and 1997. The number of total units in the market in 1997 is expected to be 831,000.
Virtual Reality(*)	• The use of virtual reality technology, which enables users to "see" and "walk through" complete computer-generated and environments, will allow speed-up product innovation and could grow by as much as eight times over the next five years.
Rapid Prototyping	• Rapid prototyping is a process which drastically cuts the time to produce a prototype from a computer-aided design (CAD). Rapid prototyping can be applied to a wide range of industries such as the automotive, mechanical and electronics industries, significantly reducing product development cycles.
Satellite	• Satellite communication and computer technologies are expected to transform aircraft navigation. • Remote sensing for agricultural policy, oil exploration, urban planning, cartography and pollution end environmental monitoring are some of the commercial applications of satellite technologies.

(*) Adverse effects (headaches, nausea and eye strain) from the use of virtual reality system have been reported.

TABLE 2

Projections for informatics-related products market

DATA FOR STRATEGIC PLANNING FOR INFORMATION TECHNOLOGY

TECHNOLOGY	FROM		TO		ESTIMATED GROWTH FACTOR	DEGREE OF INVESTMENT	DEGREE OF DIFFICULTY OF DEVELOPING COUNTRY ACCESS
	YEAR	REVENUE US$	YEAR	REVENUE US$			
Multimedia	1991	600 million	1996	12 billion	20 times	High	Medium
Imaging	1991	3 billion	1996	9 billion	3 times	Medium	Medium
Optical storage	1991	800 million	1994	1,5 billion	1.5 times	Medium	High
E-mail messaging	1991	3 billion	1995	15 billion	5 times	Low	Low
E-mail services	1991	3 billion	1996	11 billion	3.66 times	Low	Low
Groupware	1991	10 million	1995	600 million	60 times	Low	Low
Video conferencing	1991	50 million	2000	600 million	12 times	Medium	Low
Pen-based computing	1991	0.5 million	1998	16 million	32 times	High	Medium
Wireless LANS	1991	20 million	1996	700 million	35 times	High	Medium
Voice mail equipment and services	1991	1.5 billion	1996	7 billion	4.33 times	High	High
Speech recognition hardware and software	1991	150 million	1995	600 million	4 times	Low	Medium
AI	1989	200 million	1996	850 million	4.25 times	Low	Low
Object-oriented software products (Languages, Tools, Case, and DBMS)	1990	200 million	1996	3.5 billion	17.5 times	Low	Low

TECHNOLOGY	FROM		TO		ESTIMATED GROWTH FACTOR	DEGREE OF INVESTMENT	DEGREE OF DIFFICULTY OF DEVELOPING COUNTRY ACCESS
	YEAR	REVENUE US$	YEAR	REVENUE US$			
Object-oriented DBMS	1990	13.5 million	1996	445 million	33 times	Low	Low
Object-oriented analysis and design tools	1991	20 million	1996	250 million	12.5 times	Low	Medium
Massively parallel computers	1990	150 million	1994	600 million	4 times	High	High
Electronic commerce	1989	USA only 100 million	1995	USA only 750 million	7.5 times	Medium	Medium

TABLE 3

INFORMATION TECHNOLOGY ADVANCES

TECHNOLOGY	PRIMARY COMPETITIVE BUSINESS ADVANTAGE			RELEVANCE TO DEVELOPING COUNTRIES
	MANEUVEAABILITY	PRICE/PERFORMANCE	IMPROVEMENT OF FUNCTIONS	
Multimedia			X	High
Imaging			X	High
Optical Disk		X		Medium
E-Mail	X			High
Groupware		X		High
Workflow Software		X		High
Videoconferencing		X		Medium
Pen-based Computing			X	High
Wireless Communications	X			High
Voice Technologies		X		Medium
Electronic Commerce		X		High
AI			X	High
Object-oriented Technologies	X			High
Massive Parallelism		X		Medium

Biotechnology

Table I: Projections for the Market of Biotechnology Products

unit : US$

	1980	1994	1997	2000
World Market	0	50 billion		100 billion
Market in the USA	0	10 billion		50 billion
Biopesticide market in the USA	0		150 million	

Table II: Sample of Forthcoming New Biotechnology Products and Processes

Oral Vaccine for Stomach Ulcers	• It is now believed that stomach ulcers are the result of a common bacterial infection and it is hoped that the vaccine will completely eradicate the disease.
Bioluminescence	• Bioluminescence is already being used to detect microbial contamination in industries ranging from cosmetics to pharmaceuticals.
Bioremediation	• Bioremediation processes to overcome environmental problems.

TABLE 1 - IMPACT OF NEW MATERIALS

Advanced Materials Technology	Energy	Environment	Health and Safety	Information/ Communication	Infrastructure	Transportation
Biomaterials	Catalysts Low temperature materials processing	Biodegradable plastics Bioextraction and processing	Artificial organs and tissues	Bioelectronic sensors	Rubber Greases Lubricants	Tires; Deicers Fuels Lubricants
Ceramics	High temperature chemical processing; Fuel cells; Coal conversion	Nuclear waste storage/Catalitic convertors; Wear resistant coatings	Bone/joint implants Artificial teeth	Electronic packaging	High performance concrete High temperature insulation	Low-emission, fuel efficient engines
Composites	Wind turbines Lightweight structures	Waste storage and processing	Dental restoration Implants	Printed wiring	Insulating building materials	Lightweight aircraft and automobiles
Electronic Materials	Photovoltaic conversion	Hazardous materials sensors	Hear pacemakers/Hearing aids/Safety alarms	Computer chips Integrated circuits	"Smart" buildings	"Intelligent" highway systems Advanced electronic cockpits
Magnetic Materials	High strength magnets	Waste separation	Magnetic resonance imaging	Hard disk magnetic storage Visual/audio displays	Machinery magnets	Electric vehicles/magnetic levitation trains
Metals	Energy transmission devices	Corrosion resistant products	Hip implants	Wiring circuits Transmission lines	Corrosion sensors	Long-life, corrosion resistant, high-temperature aircraft structures

TABLE I (Continued)

Advanced Materials Technology	Energy	Environment	Health and Safety	Information/ Communication	Infrastructure	Transportation
Optical/ Photonic Materials	Energy conversion sensors/ controls	Pollution detection	Biosensors; Safety control sensors X-ray detectors	Laser systems Fiber optics Computer interconnects	Traffic sensors	Intercity rail guides; Fly-by-light aircraft systems
Polymers	Solid state batteries; Gas/fluids pipelines	Hazardous waste piping Chemical separation membrane	Disposal hospital products Safety protection devices	Liquid crystal light displays	Building products Adhesives Pavements	Lightweight auto bodies Flame resistant aircraft interiors High temperature adhesives and sealants
Superconducting Materials	Energy storage and transmission	Ore deposits mapping	Diagnostic imaging of human body	Supercomputers	Marine population	Magnetic levitation devices

Table II: Projections for the New Materials Market

unit : US$

	1990	2000
Global Market of New Materials		about 100 billion
Advanced Ceramics	15 billion	35 billion
Polymers	15 billion	35 billion
Metallic Materials and Alloys	8 billion	20 billion
Semi-finished Products	4-5 billion	7 billion

Table III: New Materials

Category	Component	Estimating Annual Growth Rate (%)	Relative Importance/ Category	Major Demanding Sub-sectors
Metal and Alloys	Aluminum-lithium Alloys	11		Aircraft and Space Automotive
	Titanium & Titanium Alloys	3		Aircraft and Space Automotive
Ceramics	Functional Ceramics	9(*)	80	Electronics, Electrical Communication Computer Medical Engineering
	Structural Ceramics		13	Aerospace Automotive, Chemical Industry, Energy, Cutting Tools, Medical Implants
	Ceramic Coatings		7	Medical Application, Cutting Tools, Engines
Polymers	In General	9		Electronics, Electrical Engineering, Automotive Industry
	Plastic Electronics			Electronics
	Hydrogels			Biomedical Applications
Composite Materials	Carbon fibers	5		Aerospace Automotive Construction Industry
				Medical Treatment

(*) Average of functional ceramics, structural ceramics and ceramic coating