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The UNIDO Programme on Microelectronics for Development: Suggestions for Some New Initiatives

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1. Background

Following the Third General Conference of UNIDO in 1980, a major new programme was established in the Technology Programme of UNIDO dealing with the potentials and implications of technological advances for developing countries (DCs). This new programme arose out of the realization that the interplay of new advanced technologies is likely to bring about substantive changes in the production process at all levels. These advanced technologies have potentials as well as limitations for DCs and it should be part of the industrial and technological strategy of each DC to see how it can tap the potential of the new technologies without being unduly affected by their limitations. Of these advanced technologies, three -- namely, microelectronics, biotechnology, and renewable energy sources -- would seem to offer major opportunities for exploitation by DCs.

Microelectronics technology has certain characteristics which make it appropriate for use in DCs. Microelectronics has opened the door to a vast array of needed applications which can, apart from improving productivity over a wide front, help obviate the shortage of middle-level technicians and skilled-workers. Microelectronics lends itself to applications which could improve the quality of life of the large rural population in the DCs, either through providing income generating opportunities or through direct improvement of their life-style. Other advantages of simpler microelectronics-based information and control products are that they can be made cheaply from standard off-the-shelf components which can be customized by the user; these can be very reliable, less sensitive to changes in environment and to hard use; easier to develop and expand modularly, and better able to cope with the inadequacies of other systems skills. Their use requires relatively low skills and decentralized applications are possible. The fact that microelectronics replaces many intricate shop-floor skills may be an advantage to those developing countries which have not yet built up such skills, thus saving training time and effort. This could enable them to enter into the export market wherever and whenever feasible at an earlier stage of the production process of the product to be exported.

It is against this background that UNIDO's activities to promote microelectronics technology for development should be viewed. Initiatives so far taken by UNIDO are summarized in the latest version of the document UNIDO/IS.445/ issued in July, 1987. Of these initiatives the following may be listed as items of long range importance.

1. In an attempt to coordinate the activities of organizations and professional groups active in the

area of information technology for development, the UNIDO Secretariat convened a meeting in Vienna in March, 1984, which brought together representatives of these groups, identified possible areas of cooperation, and considered a mechanism for keeping mutually informed and for formulating joint programmes. As a result of this meeting a Consultative Group on Information Technology (COGIT) has been established which would meet periodically to review ongoing activities, exchange experience, and formulate joint programmes.

2. The UNIDO Secretariat has tried to promote the concept of software as an industry and actions that DCs could take to promote that industry.

3. As a step in the direction of realizing a cooperative Latin American Programme of Action in the field of microelectronics, a Latin American Micro-electronics Network including the Caribbean (REMLAC) was established on a pilot-basis from June 1985 for a 6-year period. The overall objective of the Network is to carry out joint activities with the aim of strengthening technological capabilities in micro-electronics in the participating countries individually and collectively. A UNDP-funded regional project for strengthening microelectronics infrastructure and capabilities in REMLAC member countries was started in 1986. Among other aspects, the project would

explore the possibility of generating a capability for multichip design and of establishing Silicon foundries in the region.

4. Studies have been carried out to explore the feasibility of establishing a capability for the design and fabrication of customized ICs in the West Asia region. At a follow-up regional Workshop it was agreed that the establishment of a regional silicon foundry-cum-design centre with a network of national centres should be pursued in an evolutionary manner.

5. A quarterly bulletin, the Microelectronics Monitor, has been published since January 1982 to create awareness and provide current information to a target audience of policy-makers, scientists and technologists, particularly in DCs. The Monitor includes surveys of technological and market trends, and state-of-the-art reviews in the field of micro-electronics.

The above initiatives of UNIDO can be grouped into three categories: 1. Awareness Building; 2. Capability Building; and 3. Information Dissemination. Our immediate objective in this paper is to analyse what new initiatives UNIDO could take either in these categories or others to promote microelectronics technology for development among the DCs. To set the stage for this it is useful to survey briefly the current status of and trends in the technology itself.

2. Microelectronics Technology: Current Status and Trends

Microelectronics technology at the microchip fabrication-level has been steadily maintaining its progress. Microprocessor chips have been continuously growing in their computing power and speed. At the same time memory-chips have been steadily growing in their storage capacity. As a combined result of both these developments the performance to price ratio of hardware has been steadily improving in absolute terms.

The advent of supermicros is beginning to erode the distinction between microcomputers and minicomputers just as earlier the advent of superminis had eroded the distinction between minicomputers and mainframes. In fact, supercomputers are now commercially available at costs which were unimaginable just a few years ago. This is due to improvements in chip fabrication and packaging technologies. If the prospects that high-temperature super-conductors are beginning to open up do, in fact, become a reality at the production level, then, we should see the gap between the present-day supermicros and the future desk-top supercomputers narrowing in price-range dramatically.

What all these rapid developments in technology at the chip-fabrication and system-packaging level add up to is that, soon, computing power and primary storage capacity will not be the limiting factors in determining how computers are put to use. Dramatic breakthroughs in artificial intelligence (AI) were forecast some years ago. At that time it seemed that inadequate computing and memory power were the main limitations. But these, as we see, are no longer likely to be the real limiting factors.

Real-life applicability of AI will be essentially determined by our understanding of what human intelligence is all about and what kinds of computational processes underpin our capabilities in vision, hearing, speech, manipulation and locomotion. The current state of research in these domains would seem to indicate that human beings are not likely to be completely replaced by computers in the foreseeable future even in fairly routine application environments. However, progress in hardware technology (as outlined earlier) is making it possible to improve productivity -- in design, on the shop-floor, in secretarial work, in decision-making for complex resource-allocation, and so on -- substantially through the use of intelligent tools and through building-in sophisticated functional capabilities in the human-machine interfaces. "Intelligence" in these contexts means circumscribed ability to cope with situational contingencies based on limited situational knowledge built into the tools or the interfaces.

Apart from routine administrative applications (like payroll, invoicing, etc.), microelectronics has been put to use in the manufacturing industry in four broad areas:

1. Production Management
   - scheduling of work-flow
   - stores issue
   - scheduling of equipment maintenance
2. Process Control
   - the measurement and control of process parameters
3. Design and Drawing
   - computer-aided design techniques in 2-D and 3-D
   - production, correction, and updating of engineering drawings
4. Control of Machinery
   - NC machines
   - programmable handling machines
     - robots
     - automatic transfer machines

Integrating all the manufacturing operations through a distributed computer environment linked by Local Area Networks (LANs) results in Computer-Integrated Manufacturing (CIM). Table 1 is a summary of the application areas covered in this context. Totally integrated manufacturing, in this sense, is still not an accomplished fact. CIM appeared to be a solution for "flexible" manufacturing, i.e., making a large variety of items in small batch sizes while maintaining simultaneously a high level of productivity and low cost. However, these theoretical possibilities of programmable automation on the shop-floor have not turned out to be practically achievable in real-life conditions. A U.S. study indicates that "excessive programming costs, frequent breakdowns of equipment and higher-than-expected material wastage have been reported with all types of computer-controlled metal-cutting machines". The study implies that rather than total automation, a manufacturing set up that provides for and supports intelligent human operator intervention at crucial junctures is likely to prove to be a more reliable, flexible and efficient production environment. For given task environments how to arrive at an optimal sharing of knowledge and control (judgment, decision-making, etc.) between humans and machines is still very much an open problem. The use of Expert Systems in real-life task environments suffers from the same kind of disadvantages.

Summing up, then, based on current trends and possibilities for the near-future, we can say that micro-electronics technology can support the following generic application categories. Their ordering indicates approximately the level of effectiveness of the support provided by the technology at present.

<u>Level I</u>

1. Complex computations
2. Operations with very large data bases - querying, retrieving, etc.

3. Large volume transaction processing.

4. Text-processing, text layout, document production, etc.

<u>Level II</u>

1. Circumscribed intelligent support for
   - designing
   - drawing
   - scheduling
   - diagnosing
   - decision-making & control

2. Computer integration of a distributed production environment.

3. Use of programmable tools in production and control.

<u>Level III</u>

1. Automation of production processes

2. Knowledge-intensive computing and control.

<u>Futuristic</u>

1. Open-ended AI.

We shall now see what our analysis, as outlined above, of microelectronics technology implies as regards development-catalyzing uses of this technology by DCs.

3. Applying Microelectronics Technology for Development: Some Issues

Independently of the geographical and demographic particularities of the DCs, there are certain aspects which characterize all the DCs. In a sense, they define the DCs. To begin with, the problems faced by the DCs span a very wide spectrum -- from abject rural poverty at one end to the most modern scientific and research needs at the other end. Notwithstanding the sophistication of science in the academic set-up, whatever manufacturing base there is in most of the DCs is specific product-oriented and not technology-oriented. The foundation of any technology is a set of techniques and materials that enable new products to be made or new services to be offered. "Techniques" include both design and fabrication. The design and fabrication aspects of a technology are underpinned by tools. Thus, growing a base for design & fabrication know-how in a country is equivalent to growing a base for conceptualizing and making appropriate tools. This is equally true whether the tools relate to hardware or software. Thus, a truly industrial culture is predicated on the coexistence of a tooling culture. This tooling culture is precisely what is absent in most of the DCs. "Manufacturing" in the DCs more closely relates to and, hence, reflects trading practices rather than practices relating to tool design and technological innovation. In this sense, a true industrial culture is lacking in practically all the DCs. It is important, at one level, to lay the foundations for growing such an industrial culture. At another level one must confront rural poverty and make systematic efforts to come to grips with it.

In most of the DCs the majority of the population lives away from the main urban centres. Agriculture and craft-related occupations tend to form the bases of non-urban life-style. An essential need of DCs is to underpin these non-urban occupations and non-urban life-style with modern technology. The aim must be not to destroy such a life-style or allow it to degenerate and languish, thus creating an exodus to the urban centres. The aim should be to modernize the non-urban life-style through technology so that the quality of life as also the productivity of the occupations is improved. Such a transformation would ultimately make non-urban living more attractive in terms of its intellectual and aesthetic content and physical comforts.

What this implies is that we need to select and deploy relevant technologies not only to modernize agriculture and other rural occupations, but such services as primary and secondary healthcare, primary and secondary schooling, communication, transportation, and so on. It is clear that universal access to a modern telecommunication infrastructure is an essential prerequisite to any viable attempt to modernize the non-urban life-style. Microelectronics-based information technology imaginatively deployed has a vital role to play in achieving this transformation.

Traditional crafts can be modernized and made more productive, and their outputs made more widely marketable, by equipping the craftsmen with modern tools and design capabilities. Hospitals and schools can be modernized through the incorporation of microcomputer-based techniques. Modern management techniques can be deployed through computerized task-monitoring and task-scheduling practices. Transportation systems could be improved and made more productive through the use of computerized schemes for scheduling, reservation, etc. Similarly banking and postal systems can be modernized through the deployment of appropriate information technology. The important thing is to implement technology so that the non-urban sector sees the impact of it and benefits from it. The issues involved in carrying such a programme through are not technological ones primarily. They are mostly organizational and managerial ones. Since in practically all DCs the initiatives to transform the non-urban sector have to come from the government, ultimately the problem reduces to one of changing the government culture and modernizing the thinking and practices within this sector. Because of the enormous inertia built into all government systems, changing its modes of operation is never easy.

Turning now to the more organized sectors of industry and services, Table 2 lists a set of applications of importance to the DCs which can be supported by microelectronics technology. Not all of these applications are, of course, relevant to all the DCs. But the basic issues we have emphasized and the potentials of the microelectronics technology that we have identified should provide a framework for formulating specific initiatives and action-oriented programmes of relevance to individual DCs.

4. Applying Microelectronics Technology for Development: Some New Initiatives

Keeping in mind the initiatives already taken, we can suggest now a few additional initiatives for consideration by UNIDO and the DCs. These suggestions are based on our analysis of the trends in the microelectronics technology and on our discussion of some of the principal issues faced by DCs in using modern technology to support development.

1. Wherever there is adequate preparedness to absorb and use microelectronics technology on the part of the DCs, the socio-economically relevant application sectors identified in Table 2 could serve as a guide for selecting one or more sectors of high priority for being supported by microelectronics technology. In most of these sectors, when the problems that need to be tackled through the use of microelectronics are analysed, it will be found that what are needed are managerial and engineering initiatives, and not highly complex and long-term scientific, technological and industrial efforts. System analysis, and system design and implementation of both hardware and software, are the competences that are needed, aside from organizational and management competence. South-South transfer of models for

adaptation and implementation, and South-South cooperation in system analysis and design efforts would seem to be of great value. Training Projects such as INTERACT perhaps could be cited as useful examples. UNIDO could consider structuring and supporting through UN or other funds more such highly focused design-level training projects.

2. In the long-term, as we discussed, it is extremely important to grow in the DCs a design culture which is technology-oriented. The initiatives that UNIDO has already taken to promote REMLAC and design centres structured around silicon foundries are precisely the kind of efforts that are needed in this context; such efforts should be multiplied. The capability to system-engineer microelectronics technology-based supports calls for expertise in hardware and software system design and implementation, as we saw just now. Regional-level software training centres and microelectronics application centres have been outlined and discussed in various earlier meetings sponsored by UNIDO. The desirability of setting up such regional centres has also been emphasized at other DC regional group meetings. Perhaps, an initiative on the part of UNIDO, like the one that catalyzed REMLAC, is now needed to bring together regional groups of DCs and help them to establish regional centres for software development and training and, possibly, also for design of systems for well-identified applications.

3. It was argued earlier that it is of extreme importance to the DCs to deploy high technology to improve the quality of life in the rural regions. It was suggested that microelectronics technology could be effectively used to upgrade and make more marketable craft-based activities. Upgrading and modernizing these activities requires essentially three kinds of inputs: 1. design competence and design facilities; 2. modern and more productive tools; 3. an organizational framework which would link together, coordinate and provide management-support to activities carried out by individual craftsmen or small family groups. In the recent past there have been a few highly successful projects seeking to blend traditional skills and occupations with modern technology along these lines. Some examples are the following:

(i) The Prato textile project in Tuscany, Italy, has sought to tie together through telematics 10,000 micro-concerns. Later, the project might promote the use of computerized-looms, etc. An analogous project in wood-craft covering the whole cycle from wood production -- tree growing -- to the use of machines and robots in furniture factories, has been talked about.

(ii) The Anand Cooperative Dairy in Gujarat, India, has a centralized computer facility with a comprehensive data-bank containing information on all the animals and participating dairy farmers. Using the updated status reports, all the necessary inputs are provided to the clients at appropriate times on the basis of systematically worked out schedules. Microelectronics-based instruments are used to analyze the fat-content of milk, etc.

(iii) The Rubber Industry Smallholders Development Authority (RISDA) in Malaysia has created a data base (Smallholders Information System) and has been working on a system for computer-aided agricultural planning and action which aims to improve local management and logistic support for the smallholders relating to credit, input supplies and marketing.

Figure 1 is a schematic of the interconnecting network in the Prato project. With appropriate modifications of the actors and the agencies identified by the nodes of the network, such a schematic would be equally applicable to the two other examples above and most other similar projects. Clearly, communication plays an essential role here. In addition, computerized databanks, terminals, design facilities, computer-supported tools, document preparation and information dissemination services, and so on, could all be put to effective use to transform a traditional, low-productivity set-up into a modern, market-oriented and high-productivity enterprise.

If production and market-orientation are replaced by service and client-orientation, the same schema could equally well apply to activities like primary healthcare delivery to rural populations, etc. Because of their very wide applicability and their basic relevance to DCs, UNIDO might want to consider seriously promoting the implementation of schemes like these jointly with the DCs.

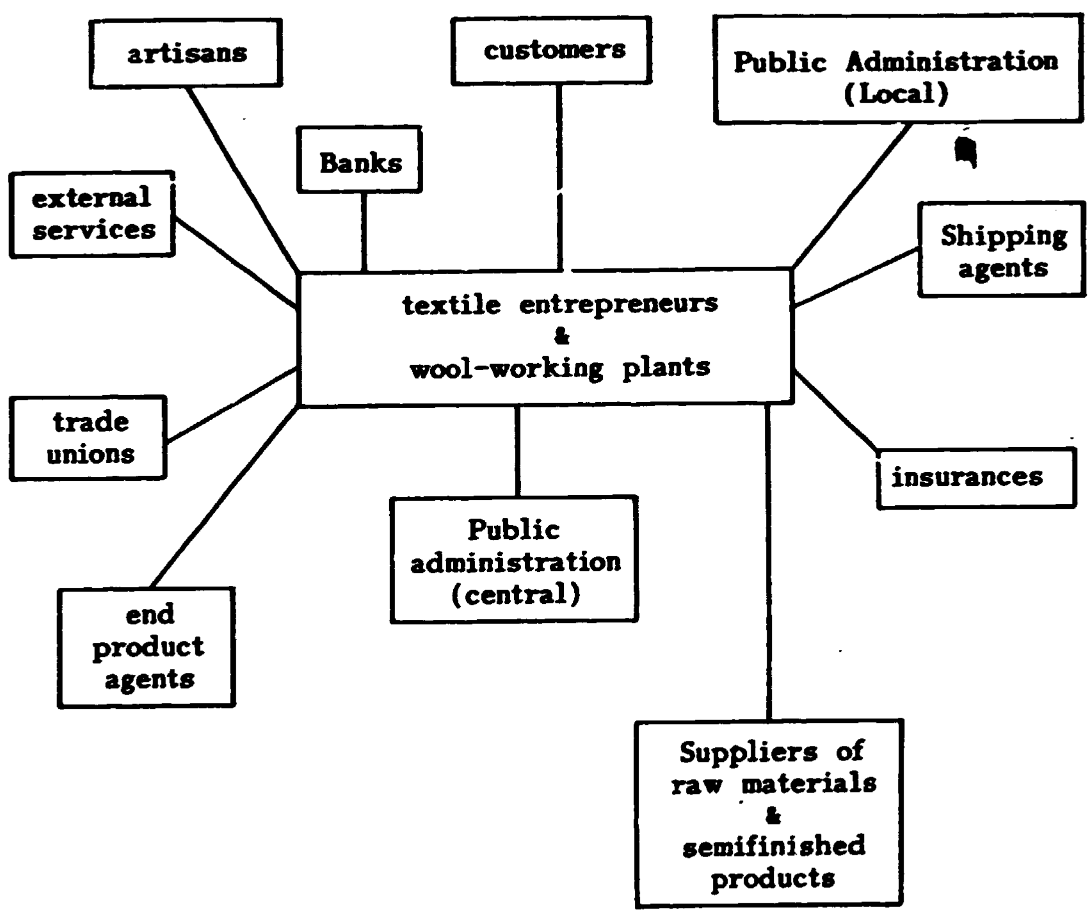

Fig.1 Communication Network of the Prato Project (Schematic)

In conclusion it may be worth emphasizing that deploying technologies to bring about changes in the socio-economic profiles of DCs is not easy. There are no ready-made solutions, Nor can solutions be borrowed from elsewhere: least of all from highly industrialized countries. The reason for this is that most of the problems of development faced by the DCs now, have been solved by most industrialized countries over a historical period of time through evolutionary methods. Apart from cultural constraints, the technologies that highly industrialized countries are accustomed to cannot be transferred and put to use immediately to tackle the development problems facing the DCs. The technologies must be unpacked and repacked to suit the particular contextual constraints within which specific problems faced by each DC have to be attacked. This customized effort needs much indigenous initiative and involvement.

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1.	Customer order handling	Record-keeping, tracking and reporting on the status of individual customer orders, particularly when part of an integrated on-line system.
2.	Production, material and inventory control	Scheduling and information handling related to material requirements planning, inventory control, facilities planning and order scheduling, particularly when incorporated as part of an on-line system.
3.	Automated production	Numerical & Computer control of machine tools, lathes, milling and boring machines, pattern and fabric cutting, welding, brazing, plating, flow soldering, casting, flame cutting, spray painting etc.
4.	Automated material handling	Integrated materials handling using computer operated conveyors, robots, etc.
5.	Automated Testing	Automated inspection of machine parts; testing of electronic components, circuits, and products; automated material inspection & grading using sensor-based computer systems; pattern-recognition
6.	Automated packaging	Computer-implemented coordination of material and information in packaging, bottling, labelling and weighing systems.
7.	Automated warehousing	Computer-implemented order picking and material handling for both work-in-progress inventory and finished goods inventory; automatic lable reading; routing of packages, parcels, baggage in shipping, sorting and distribution.

Table 1 : Aspects covered in Computer-aided Manufacture

1.	Agriculture & Water resources management
2.	Weather : monitoring & prediction
3.	Space technology & applications
4.	Energy : utilization and management
5.	Oil : exploration, refining & distribution
6.	Railways : reservation, wagon management, etc.
7.	Airlines : reservation, scheduling, maintenance, etc.
8.	Tourism : hotels & travel agents
9.	Heavy industries : steel, cements, etc.
10.	Construction : buildings, roads, railways, etc.
11.	Engineering industries : production management, design, etc.
12.	Commercial & business offices : office support
13.	Legal sector : judiciary, police, etc.
14.	Banks, insurance & stock exchange
15.	Printing & publishing
16.	Government informatics
17.	Education & research

Table 2 : Application Sectors of importance