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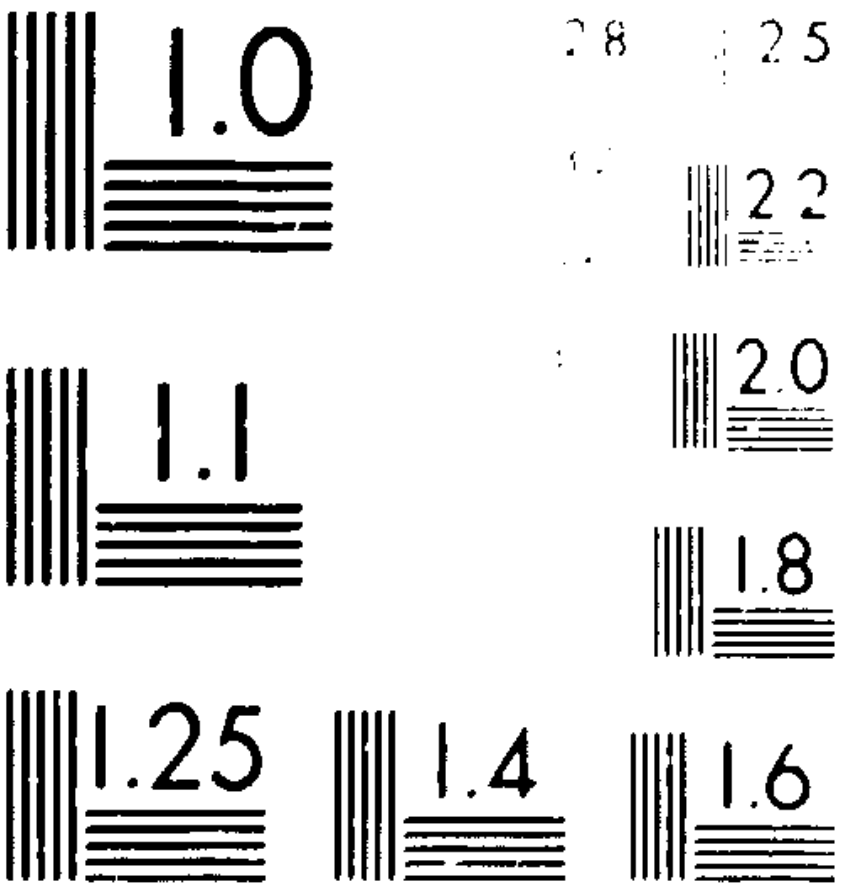
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MICROELECTRONICS AND DEVELOPING COUNTRIES *

Towards an Action-oriented Approach

Note by

UNIDO Secretariat

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Contents

INTRODUCTION

1. The implications of microelectronics for developing countries and the issues arising therefrom have been considered for some time past, particularly at the international level. This paper attempts a resumé of the issues with a particular orientation to national-level actions and the concerns of policy-makers in developing countries. 1/

2. The basic question before policy-makers in a developing country is whether or not their country should enter the microelectronics field by way of applications or by manufacture. The other options before them are not to enter at all or pursue a policy of disengagement for a given period. Hesitations could arise either on account of an impression that the technology is too sophisticated or on account of possible socio-economic implications for the country, particularly in regard to employment.

3. It is therefore necessary to assess the socio-economic implications of microelectronics for developing countries in general, based on which the policy-makers could make their own judgement with reference to the conditions obtaining in their country. A review of the impact of microelectronics, based on the limited empirical evidence available and more on the perceptions of developing countries will be made in section I, followed by discussion of a policy framework for national action in section II, and concluding with possible international actions in section III.

4. In addition to consideration of selected aspects of the impact of microelectronics, the policy-maker has to bear in mind the overall perspective. In an interdependent world economy with a technology-dependent third world, the diffusion of microelectronics, first through consumer goods and more gradually through capital goods will be

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1/ This paper draws mainly on the following: Implications of microelectronics for developing countries: a preliminary overview of issues (UNIDO/IS.246 and Corr.1); Report on Exchange of Views with Experts on the Implications of Technological Advances in Microelectronics for Developing Countries (UNIDO/IS.242/Rev.1 and Corr.1); Report of UNIDO/ECLA Expert Group Meeting on Implications of Microelectronics for the ECLA Region (ID/WG.372/17).

difficult to stop. Microelectronics in combination with other technologies, particularly telecommunications, leads to a convergence of effects and will lead to a widening of the already wide technology gap between developed and developing countries, not only in the field of electronics but in the whole range of industrial and service activities. In this sense microelectronics can hardly be ignored because of its wide-ranging impact and contribution to productivity. In this connection, a historical parallel can be drawn with the advent of the internal combustion engine which profoundly affected economies and societies. A proper response to its advent would not have been found in limited evaluations based on short or medium-range economic considerations alone.

5. The potential of microelectronics and its growing dominance can be attributed, inter alia, to the following:

(a) it improves and substitutes a wide range of intellectual and intuitive skills;

(b) it can replace a wide range of electrical, mechanical, pneumatic and hydraulic control devices;

(c) consequently, it can replace a variety of existing products and services or extend their capabilities and create altogether new products and services;

(d) it is reliable, cost-effective and energy saving.

The products are easier to develop and to expand modularly and they are better able to withstand inadequacies in other systems, skills and materials. Their use requires relatively low skills and small-scale decentralized operations are possible.

6. More importantly, microelectronics lends itself to applications which could improve the quality of life of the large masses of population in the rural areas of developing countries, either through providing income-generating opportunities or through direct improvement in welfare. This is, however, the potential; it is still to be tapped, which enterprises in developed countries may not attempt in the absence of a market pull. On the other hand, the products developed for the markets of the developed world are already there. It is in the context of these dual aspects that the implications of microelectronics have to be considered.

I. IMPLICATIONS OF MICROELECTRONICS

7. Several studies already exist on the impact of microelectronics on the industrial and service sectors and on the economy and society in general. What would be of immediate interest to a national-level policy-maker might be the potential impact of microelectronics on employment, capital, foreign trade and society. Empirical studies relating to developing countries in these respects is limited and assessments have to be made, based on observed and projected trends in developed countries and the perceptions of developing-country experts to the extent available.

8. In regard to employment, the trends in developed countries could be noted at the outset. Generally speaking, it is anticipated that in regard to products, there is likely to be a substantial decrease in employment in specific instances but offset by growth in others; in regard to processes, the decrease is likely to be slower and lesser whereas in the services sector, particularly offices, substantial decrease in employment is expected. An important effect in the short run is the change taking place in the skills profiles. Certain industrial skills are becoming redundant, necessitating retraining of workers. A polarization of skills is also expected, around unskilled labour and professional skills, with a marked decrease of rural-level skills. New management skills are required as production processes tend to integrate several activities which were earlier objects of control by separate managers.

9. The trends in developed countries cannot be applied mechanically to the developing countries. Though there are some developing countries where shortage of labour is noticed, it will be assumed for the present discussion that employment is a serious socio-economic constraint in developing countries. By and large, there would be two streams of impact on employment. One is that due to the adoption of microelectronics in the developed countries international competitivity and the terms of trade of the developing countries could be eroded, with a consequential loss of employment. The other impact is the compensatory effect that internal utilization of microelectronics in the developing countries could have through the creation of new activities and skills. Employment could be expected to be generated in the microelectronics industry

as such as well as in production of software and in the services sector.

10. In process industries involving the use of local raw materials or natural resources (for example, sugar, cement and metallurgical industries), employment losses may be essentially in the instrumentation and quality control fields but against these there will be productivity gains. In engineering industries, employment losses may be more direct, particularly where exports or unprotected internal markets are involved. Some of these may be direct reductions and others may be more in the nature of future employment opportunities foregone. Employment in industry in developing countries has so far been limited and how critical will these employment losses be to the overall employment and will they be sufficiently critical to forego the benefits of microelectronics applications? The services sector, whose share in employment is low in the developing countries, but whose growth is important for them, may be improved qualitatively and quantitatively. The fact that microelectronics replaces many intricate shop-floor skills, could be an advantage to developing countries, which have not yet built up such skills, thus saving training time and effort and enabling them to enter the export market where they can in an earlier phase of the product life-cycle.

11. All this would seem to indicate that reduction in industrial employment may be only one of the considerations that have to be taken into account in decisions on microelectronics applications and the consideration should go beyond effects and individual sectors to the totality of costs and benefits of the applications. It has been suggested that technological change has been and always will be taking place and developing countries have to face the issue of employment not only in regard to microelectronics but also in other sectors such as agricultural mechanization.

12. As regards capital requirements, the investment requirements for manufacture of chips are high. This may not necessarily be a discouraging factor since developing countries have still to go in for several capital-intensive projects in other fields, requiring even higher investments. It has been pointed out that companies in developed countries leading in this technology are not necessarily big in size. Investment requirements for application are not necessarily high. Capital costs of products and equipment incorporating microelectronics may be less. As regards social investments, investments in skill-building may be reduced to the extent that operations involving microlectronics applications require lesser skills; fresh investments in microelectronics skills in hardware and software will, however, be required.

13. In the field of foreign trade, the patterns of comparative advantage are being affected. Though comparative advantage is not a static concept and is a function of several factors, the developments in this regard have to be noted carefully by developing countries. In regard to products incorporating microelectronics, there are trends in specific sectors which point to the erosion of comparative advantage to the detriment of developing countries. Ready-made garments and custom-made shoes are cases in point. 2/ The impact on engineering industries involving assembly operation will be substantive since introduction of microelectronics through such methods as numerically-controlled machine tools, computer-aided design, computer-aided manufacture and robotics will not only considerably improve productivity but replace manpower. For example, the application of microelectronics in a sewing machine has reduced some 370 parts. Electric motors are now produced in Japan through robots. Such examples go to show that the beginnings made in export of engineering and capital goods by some developing countries will be substantially affected. 3/

2/ Textiles, garment-making, shoes and leather goods account for more than 40 per cent of the exports of manufactured goods from Hong Kong, Singapore, South Korea and Taiwan. Alexander King, "Microelectronics and world interdependence" in Microelectronics and Society, A report to the Club of Rome (Editors Gunter Friedrichs and Adam Schaff, Pergamon Press, 1982),p.325.

3/ In 1975, capital goods and consumer durables were 20 per cent or more of total exports in Argentina, Brazil, Hong Kong, Malaysia, the Republic of Korea and Singapore. See Table V.12, UNIDO, "World Industry since 1960: Progress and Prospects" (United Nations publication, Sales no. E.79.II.B.3),pp. 170-171.

14. In regard to the electronics field itself, there is a reversal of the trend in the 1970s of offshore production of components. Comparative advantage in unskilled labour is no longer a decisive factor in this field. However, there could be an advantage in regard to skilled professionals and software, provided they are trained in sufficient numbers and are encouraged to remain in the country. Capabilities in software could substantially save imports in addition to contributing to exports. It has been argued that import substitution should be given greater consideration since exports based on low wages alone have neither been durable nor contributed to endogenous technological development.

15. The social implications of microelectronics would arise not only from the impact on employment and skills but also from changing concepts and practices of work, work environment and leisure. The rapid changes in information technology [4/] promoted by microelectronics will be particularly relevant in regard to the social impact. In the case of developing countries, such a social impact will be an important additional factor to the social impacts of urbanization and industrialization. This type of impact will vary considerably depending on country conditions.

16. The subject of information technology also brings to the fore the close relationship between microelectronics and telecommunications which encompasses technical, economic, social and cultural considerations. A developed telecommunications infrastructure is necessary for widespread microelectronics applications, particularly information processing. At the same time telecommunications provide a major source of demand for microelectronics and would therefore serve as an engine of growth for that industry. This would mean that telecommunications policies should be carefully designed and closely aligned with microelectronics policies.

4/ See also in this connection Juan R. Rada, A Third World Perspective in Microelectronics and Society. A report to the Club of Rome, (eds. Gunter Friedrichs and Adam Schaff, Pergamon Press, 1982), pp. 213-242.

17. There is obviously a need for a good deal more of empirical evidence on the socio-economic impacts, particularly on developing countries. Overall studies cannot, however, be a substitute for country-level assessments. However, as in many other fields policy-makers have to formulate policies in the context of a measure of uncertainty if the policy responses ought to be timely and effective. The question therefore arises whether developing countries should lose any more time in formulating policy responses to the impact of microelectronics, which could have in-built mechanisms for monitoring the impacts and for making changes, as appropriate. This perception is particularly evident in several developing countries. For example, the Expert Group Meeting on Implications of Microelectronics for the ECLA Region held in June 1982 was decisively in favour of taking a positive and dynamic approach to the introduction of microelectronics technology in the region within a long-term perspective, and based on an integrated strategy which would maximize the potential of microelectronics for unique developing country requirements. The opportunity costs of not introducing the technology are, in the view of that meeting, too high.[5/] A policy framework for microelectronics has therefore to be evolved as several developed countries have already done.

II. POLICY FRAMEWORK FOR NATIONAL ACTION

18. A microelectronics policy framework in a developing country may involve the following components, the sequence depending on the situation of each country [6/] and fitting into its specific socio-cultural context:

Monitoring and awareness

(a) Monitoring on a continuous basis, through a multidisciplinary national team, the developments in microelectronics technology

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5/ ID/WG.372/17, op. cit., p. 18.

6/ King makes a classification of developing countries: India, Brazil, Mexico; oil-producing countries; newly industrialized countries of South East Asia; and others. Alexander King, op. cit. pp. 324-329.

and its impact on priority areas in industry and other sectors, in particular in terms of skill and infrastructure requirements and comparative advantage in international trade;

(b) An awareness campaign directed to a target audience of decision-makers and end-users.

Endogenous capacities and applications

(c) Promotion and establishment of a microelectronics industry, ranging from assembly to design and manufacture of chips and instrumentation, the actual feasibility being dependent on local requirements and applications, comparative advantage, technological capabilities and other relevant factors;

(d) Promoting applications, based on identified national tasks, in priority areas in industry and other sectors, including the accessing, handling, processing and use of information;

(e) Short-term and long-term programmes of education and training in hardware and software, to meet local requirements and, where possible, for exports; existing programmes and institutions should be kept under review and reoriented as appropriate;

(f) Setting up or encouraging applied R and D, particularly in the fields of special applications of importance, including the training and sensitization of R and D personnel in those fields; special attention should be paid to the possible applications of microelectronics for the development of rural areas, the satisfaction of basic needs and for finding solutions to other particular concerns of developing countries;

(g) Setting up and/or linking national institutions to develop endogenous capacities and applications mentioned above;

(h) Reviewing or formulating appropriate policies for transfer of technology and investment and the encouragement of endogenous capacities and applications.

Review

(i) Keeping under review the implementation of the several elements of the strategy and ensuring coherence and consistency of the strategy with overall development aims and other sectoral strategies, in particular a telecommunications strategy.

19. The above framework should be characterized by a systems approach and long-term planning and should,to be effective, incorporate appropriate co-ordination mechanisms.

20. Each of the elements of the framework have to be elaborated into a series of measures depending on each country's conditions. To illustrate, hardware development may require government financing of the development; bank loans for software industry; tax concessions; compilation of a programme register to avoid duplication and promote distribution of available programmes; protection of software. Promotion of applications may require identification of priority applications; applications in small enterprises; and applications in central and local government offices. Improving human resource environment may include training informatics specialists; computer-aided learning; awareness programmes for the general public.

21. The actual operation of the policy framework would depend for its success on continuous monitoring and review. Within the framework certain key issues will have to be decided upon. These are referred to below.

22. One major issue would be whether to enter into manufacture in addition to applications. Arguments have been advanced that manufacture will be skill- and capital-intensive and not possible for developing countries. While the point of entry should be decided by each country keeping in mind the feasibilities in terms of investment, skills and infrastructure requirements, there are countries whose manufacturing efforts would extend to the production of chips, instruments and related equipment and yet others whose efforts might have to be limited to assembly-type activities and/or manufacture of peripherals.[1/] Attempts to develop applications,

1/ Silicon foundries and chip fabrication facilities started on a relatively small scale but have been rapidly superseded by large-scale facilities. It may be useful to retain the"memories"of the former for potential use by developing countries, should any of them find it appropriate to do so.

it is pointed out, should not be at the expense of efforts to develop, design and manufacture components; without these efforts mastery of the technology is not possible. This has become all the more necessary due to technological trends which increasingly incorporate added value in the components and erase the traditional distinction between hardware and software.

23. Efforts to develop applications would create a demand base for manufacture and also obviate imports of applications from abroad. Though application areas are known to some extent, setting up of criteria for applications by each country may be necessary to focus efforts. Broadly, these criteria would relate to (a) areas that would enable the country to maintain, improve or create competitiveness in the international markets; and (b) critical areas of internal demand including those which will improve the quality of life in areas such as transportation, health, education, etc. In this sense, the criteria for applications should be derived from a diagnosis of the needs and ultimately from the development strategy of each country. The public sector and public services are areas which hold out potentials for applications. The optimization of critical activities in public services (for example, wagon turn-round in railways, berthing of ships in ports) could be considerably improved through microelectronics applications.

24. Any programme on applications has to be based at the country level on a detailed survey of the potentialities in several sectors of the economy. Such surveys should take into account the socio-economic aspects and problems of acceptance by producers and users. A close interaction between electronics professionals and users will be necessary to ensure successful application.

25. Building up of technological capabilities should occupy a central place in any policy framework. The concept of technological capability may have to be looked at de novo in the context of microelectronics. The developing countries will, among others, require capabilities in the

field of electronics manufacture and assembly; while such capabilities are not totally different from manufacturing skills in general, the capabilities required for applications of microelectronics are non-existent in most developing countries and are lagging behind hardware development even in the developed countries. Software capabilities will be critical. The manpower required will include programme designers, systems analysts, data-base designers, programmers, controllers and managers, in addition to the more basic specialists in operations research, mathematical logic and scientific management. The objective in the development and use of software should not be only to meet routine requirements but to promote the design of applications for local problems and also to serve an export market where possible. In the final analysis, the actual impact of microelectronics on developing countries will be largely determined by their capacity to develop and apply software.

26. Software should be looked at in the broader sense of the requisite technological capabilities and should not be confined to select groups of programmers, systems engineers and operators. These specialized skills are crucial, of course, but it is equally important for developing countries to try to develop a software/microelectronics consciousness among as many people as possible. Persons working in all fields must be trained and encouraged to think about the potentialities of micro-electronics for their own activities and to recognize that pre-packaged technology could be unpackaged to serve local needs as perceived by themselves. Much of the software ought to be developed in the culture in which it is to be applied. Innovative training programmes starting from familiarization with computers at the school-level would be needed in addition to learning kits, micro-informatics clubs, etc. Several developed countries and some developing countries, like Singapore, have initiated such programmes. Investment in human resources will be the most important key to realizing the benefits of microelectronics. If the infrastructure for application of microelectronics is created the benefits could be expected to come sooner. 8/

8/ The term 'infrastructure' should be looked at in a broad sense, including repairs, maintenance and service facilities and above all an industrial milieu which permits and provides microelectronics applications.

27. Education and training are therefore the key areas to which policy action should address itself. This would require not only an inter-ministerial effort but also interactions with the academic community. Given the socio-economic nature of education, innovative but carefully formulated policy directives from the highest levels in government will be needed to initiate the necessary changes and allocate the requisite resources.

28. While human resource development would belong to one of the longer term measures, certain short-term measures would also need attention. One key area in this respect is the policy for public purchases. The purchase policies for computers, telecommunications and microelectronic equipment in several developing countries would at present appear to be uncoordinated. Apart from avoiding possible distortions, the purchasing power of the government could be considered as an important tool and utilized for the development of national industries and technological capabilities.

29. A corollary would be strengthening the capabilities for selection and acquisition of technology, hardware and software. Government policies in this respect have to include an element of socio-economic assessment. To build up capabilities for public purchases as well as selection and acquisition of technology, equipment and software; unbiased expert assistance will be required and here UNIDO's Technological Advisory Service may have an important role to play. Technology transfer registries, where they exist in developing countries, will have to be strengthened in regard to their capabilities for screening the acquisition of microelectronics technologies.

30. To conclude, the policy framework at the national level has to be informed by a consciousness of the nature and significance of microelectronics technology; be equipped with assessment and monitoring mechanisms in regard to the socio-economic impact; include short and long-term measures; and identify and initiate action in key result areas.

III. INTERNATIONAL ACTION

31. Considerable potentialities for co-operation among developing countries exist in regard to every aspect of the problems discussed above. [9/] A full-scale programme of co-operation among developing countries in this field may need to be elaborated together with a detailed and specific list of services and consultants available in developing countries. Collective strategies in regard to purchases and acquisition of technology may also be considered.

32. Regional co-operation would also be beneficial in several areas. For example, the Joint UNIDO/ECLA Expert Group Meeting on Implications of Microelectronics for the ECLA Region recommended [10/] a co-operative Latin American programme in the field of microelectronics which is being elaborated by the UNIDO and ECLA secretariats.

33. At the international level support to national action may be required in regard to sensitization; monitoring; research and studies; methodologies for national-level investigations; technical assistance; technological advisory services, particularly for acquisition of technology; software development; microelectronics applications including methodologies; pilot projects; software development; microprocessor application and design centres; manufacture, and mobilization and linkages of institutional effort. The Meeting of Experts on the Implications of Microelectronics for Developing Countries, held at Vienna, in June 1981, and the Expert Meeting held for the ECLA Region in June 1982, have both identified and recommended a series of activities to be undertaken by UNIDO. Several activities have already been initiated by UNIDO.

34. Amidst a variety of international actions possible, it is important to develop a programme that will (a) address the key result areas and (b) have a critical mass necessary to make an impact commensurate with the importance of microelectronics. An important key result area is software and chip design capability which will not only provide the real insight into the technology but also pave the way to unique applications for developing countries on which very little progress has been recorded.

9/ For example, a computer technology development and training programme in India is intended to promote co-operation among developing countries. See Microelectronics Monitor, Issue 2, April 1982, pp. 16-18.

10/ ID/WG.372/17, op. cit., pp. 6-7.

The setting up of microprocessor design and application centres could be an important activity in this regard. 11/

35. In the final analysis, however, it is the integrated policy response of each developing country that can enable it not only to have technological self-reliance in the acquisition, development and application of the technology, but also realize the potential benefits of microelectronics for the economy and society. The quickness and perception with which developing countries respond to the situation may well be a major factor in determining their industrial, economic and social development in the coming decades.

11/ See in this connection "Microprocessor applications in developing countries" by James M. Oliphant (UNIDO/IS.351).