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TRENDS

IN

INDUSTRIAL AUTOMATION

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PREFACE

As part of its work on regional policy issues, the Regional and Country Studies Branch carries out policy-oriented studies and provides advisory services in key issues of industrial policy that affects groups of developing countries. These include issues of economic integration, issues in the relationship between technological change and industrial organization and policy issues in international cooperation for industrial development.

An important area of analysis is that of automation in industry. The spread of automation is having a profound impact on the manufacturing sector, both in terms of products and processes. It is associated with equally significant changes in the organization of industrial production. The effects of industrial automation in terms of costs and spread and flexibility, as well as in terms of reduced inputs of labour, are eroding cost advantages enjoyed by developing countries in traditionally labour intensive industries. In fact automation is associated with a general restructuring of world industry, and this finds expression in new and distributed forms of production.

UNIDO, in cooperation with the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria, has carried out a detailed examination of the impact of industrial automation and how it is changing the production process. The analysis examined policies, both at the national and the company level to make recommendations on approaches to automation for consideration by developing countries. The work covers the whole field of industrial automation, but there has been a special concentration on the textiles, clothing and footwear sectors. *Financial support for the work has been provided by the Government of Finland.*

The present document provides a wide analysis of the main trends in industrial automation. It examines types of automation and their diffusion. It summarises national policy requirements, trends in the costs of automation, the role of design, and education and training needs, together with organisational change. It also provides the basis for further work, and has been used in the preparation of guidelines for automation and of programmes of technical cooperation in this field, which are shortly to be issued.

With respect to country coverage, the research has included both developed and developing countries, with a special concentration on research in six African countries and in Brazil.

The study has been carried out by the Regional and Country Studies Branch of UNIDO in cooperation with Dr. W. Haywood, Dr. P. Vuorinen and Ms. E. Toth-Hizsnyik of the International Institute for Applied Systems Analysis (IIASA).

SUMMARY

(1) The advent of the computer, and information technology in general, has created a radical transformation of production possibilities which has provided the opportunity to integrate manufacturing processes in a way no earlier technologies have offered. The ability to link the whole process of a company's activities from design, through materials processing, manufacture, packaging and transfer, has increased dramatically.

(2) A holistic response to international competitive demands is required. Only by an evolution towards a simplified structural set-up, e.g.,reduced functional and hierarchical barriers; allied to organizational adaptation, e.g.,just-in-time production, total quality control, design for manufacture, closer supplier links; and with the use of new technologies, e.g.,CAD, Robotics, FMS, could modern industry compete internationally. The "systemic" nature of information technology based on the microchip, is permeating all aspects and functions of companies.

(3) Without creating a vigorous design function developing countries may be increasingly consigned to the role of providing low value added goods or agricultural/raw materials supplies. This is because in traditional product cycle theories it was assumed that only very minor changes in product <u>design</u> would take place in the mature phase of a product, and this was the point at which relocation to low cost countries would occur. Now there is a danger that the product will go through rapid and constant change facilitated by flexible production processes and CAD options. The relocation may thus not take place.

(4) With respect to organizational and manpower issues, some combination of technological and organizational adaptation is essential for manufacturing efficiency. This has profound implications for national education, skills, and training institutions.

Such an integrated and total concept of industrial adaptation requires:

- the development of coordinated skills,
- design and redesign for manufacture,
- a joint technological/organizational approach to change,
- closely coordinated buyer/supplier relations, and the adoption of JIT; and
- allocating to the computer what it is good at, and leaving the innovative, creative, and flexible actions to the human being.

(5) The emphasis in explicit discussion in this report focuses on mechanical engineering as well as textiles, clothing, and footwear on which there is a special concentration. However, the technologies are of much broader application, as is highlighted throughout the report.

(6) With regard to individual technologies, robotics, in the context of developed country use, is still relatively unsophisticated, expensive and lowly utilized. How much more difficult for developing countries must this then be? Since this is a technology which is largely labor replacing, it is probably the least relevant.

(7) Of all technologies covered in this report CAD is probably the most relevant option for African countries for a variety of reasons. The cost of both hardware and software had reduced significantly - and in the case of the latter it is now possible to buy packages for application in textiles, clothing and footwear that are extremely cheap. For example, complete systems are available for under $15,000.

By application in the basic development industries, textiles, clothing, footwear, etc., the learning-by-doing, demonstration effects, and diffusion impacts of CAD would spread across industrial sectors, and the engineering, construction and many other industries would also benefit.

Some of the benefits of the technology include:

- savings in material costs - up to 9 per cent;
- increased productivity - up to 20 to 1;
- replacing scarce labor skills;
- maintaining competitive position vis-à-vis developed countries;
- increased user countries design/redesign capability.

(8) As with CAD, and in close association with it, NCMT has now become a rational investment decision for even low-to-medium wage countries. In a direct comparison with traditional machine tools, NCMT has now become a logical choice.

Examples of productivity increases achieved by NCMT compared with conventional machine tools indicate that the former is on average around 3 to 4 times more productive; instances of improvements up to 15 to 1 have been suggested.

As noted for CAD, NCMT is imperative for industrial development; and in conjunction with CAD it forms the basis for a significant improvement in performance.

(9) As for FMS/FMC, the rationale for the technology is a logical extension of many of the requirements for NCMT, e.g., to improve production flexibility, reduce lead-times, etc. In addition it offers system operations during an unmanned third shift, reduces physical machining areas (4 machines in an FMS normally replace about 16 conventional machines), and can be totally integrated with pre-machining functions, e.g., materials and tools planning, etc.

In appropriate sized companies in Africa, a limited approach to the use of FMC, in particular, might prove the best approach both in terms of economic costs and benefits. Significant benefits in a learning and demonstration sense might be forthcoming.

(10) A (Swedish) technology policy approach, with the development of education and skills, the provision of consultancy services for small to medium-sized enterprises, and help with marketing and work organization changes, appears to be the most appealing approaches for African countries - and probably at somewhat lower costs than some of the other approaches, e.g., funding of basic research.

The advantages of German support schemes has been that they have generally:

- been administered simply, usually through existing professional organizations, e.g. industrial engineers;
- have a very simple application and approval system;
- concentrated on specific industries, and/or on small- to medium-sized enterprises;
- undergone constant evaluation procedures.

A further advantage has been that support has been directed to exactly those areas in which Germany has been industrially strong in the past, e.g., machine tools, precision equipment, etc., and in the specialist small/medium-sized firms. Concentration has therefore been focused upon established strengths, and on its established highly skilled workforce, working in collaboration with technical institutes and other research bodies.

The Japanese approach has concentrated on four general types of policy objective:

- to modernize industry which has failed to adopt best practice techniques;
- to correct imbalances in business practices;
- to encourage development and growth in small- to medium-sized enterprises;
- to assist companies facing financial/investment barriers.

The support provided in order to perform these tasks includes:

- Development of the manpower and skills infrastructure. In this they have developed extensive training programmes and these have been largely administered by the Japan Small Business Corporation (founded in 1980). The demand for such training is very heavy.

- The creation of special support programmes aimed at diffusing new technologies, e.g., robots, FMS.

- The establishment of collaborative networks for research in high-tech areas.

(11) Among the policy options that could be considered are:

- Support for the provision of information and advisory services regarding specific technologies.

- Support for consultancy services and feasibility studies regarding appropriate technologies.

- Support for the purchase of - at the least - demonstration sites where those technologies can be seen in action, and people can gain hands-on experience. Funds for their diffusion through the appropriate industrial sectors would be desirable. Application support was strong in almost all of the developed countries covered.

- To provide, as far as possible, a long-term programme of support in order to reduce uncertainty, though not to create dependency.

- To encourage inter-firm collaboration both in an engineering sense and in a modern buyer/supplier sense. In addition to this, to help create stronger links between educational and technology research institutes, and the bodies they are intended to serve, i.e., manufacturing industry.

- To help organizational adaptation. Ir many companies visited in the case study countries, management expertise was weak and based on traditional structures. The whole system of managerial control and organizational structures needs to be modernized by less hierarchical or functional activities; and by the adoption of JIT, TQM, etc.

- A considerably greater concentration on education, skills and training *at all levels*. There is clear evidence from the experiences of the developed countries, that this has proven to be the starting point for a "virtuous circle of success" in a development context.

(12) The basic industrial policy issues in most African countries have often been import substitution as a main target and strong confidence associated with comparative advantages based on cheap labor. In this setting, it is assumed that import substitution - in contrast to export promotion - is a less demanding target, a strategy in which a country can rely on a less sophisticated industrial base.

Export promotion strategy has been seen as the next step in this development. It is assumed that export promotion requires a more developed and productive industry to be competitive on the global market. In the African context, this next step is often something of a mirage since domestic industries lagging behind international standards in performance are safeguarded behind protective barriers. In most cases, where export promotion has been adopted as a target the strategy has usually been based on the same competitive basis as import substitution, relatively cheap labor.

(13) There is a pressing need for comprehensive industrial development policies. Experiences from countries with above average success in manufacturing in the Sub Saharan region at least point to some guidelines for policy options:

- price factors are not the only, not even the major issues behind success: management, design and engineering skills often play a more critical role in explaining differences in performance. Even more generally, the development of manufacturing depends critically upon the presence and promotion of adequate skills;

- sustained manufactured exporting does not succeed by looking only at short-run cost advantages;

- questions related to management and machinery-choice are of critical importance in creating vital industries;

- sheltered, but not too protected, regional markets can assist in creating efficient manufacturing units. Thus a very liberal regime is not a sufficient condition for efficient manufacturing production;

- the role of product quality has increased, and is to a growing extent ranked above price factors in market competition.

(14) Rigid import regulation policy is more harmful than beneficial to industry, even if import substitution should be the prevailing strategy. Thus a reduction in import tariffs and an elimination of quantitative restrictions should be considered. In this context, a policy promoting the expansion of manufactured exports and an import substitution policy should be linked with each other, but in the context of policies which give priority to raising the level of efficiency of existing manufacturing firms. Sensitivity to market signals - a basic issue in export promotion - is required, but there is also a need for more interventionist policies to strengthen the expansion of manufacturing industry and support the creation of inter-linkages with the other sub-sectors of the economy.

(15) In developing countries, technology policy has quite different objectives to those in the developed countries. The role of technology transfer is crucial, and the main policy targets are to manage the technology transfer process efficiently and to assimilate the technologies imported into the existing structures in a way that could contribute to a sustainable, dynamic technological and economic development. In this, the main policy areas are:

- management of the international technology transfer process;
- execution and management of technical change;
- acquisition and accumulation of technological and managerial capability.

Technological capability lies at the heart of successful technological development. It is through mastery of the technical basis of production that many of the increases in production efficiency arise. However, the accumulation of technological capability is not an automatic process, and it is not costless. Capabilities accumulate through experience, experimentation, conscious efforts and allocation of money and people to solve technological problems. The methods to acquire technological capabilities are many; dynamic capability development can only arise from a mixture of various methods such as institutionalized education, formalized training programmes, learning-by-doing, technological apprenticeship programmes, learning-by-researching and reverse engineering.

(16) In most African countries no clear priorities have been developed for technology policy objectives. In addition to the ad hoc manner in conceiving policy objectives, there is also an obvious lack of a clear sequence of the objectives outlined. In a country with scarce resources prioritizing objectives would be even more necessary than in more affluent countries.

Concrete action programmes are missing. Based on poor monitoring of technological problems, vague theory, and unclear and unsequenced policy objectives it is not easy to formulate clear action programmes. Technology policies in Kenya, Tanzania, Zambia and Zimbabwe have been described as badly "operationalized" and no real action programmes have been generated. Policy documents concentrate on broad statements. The lack of action programmes limits the usefulness of the policy documents and puts into question the operationability of technology policy.

(17) There is a bias towards scientific institutions rather than technological ones. The scientific bias of research is contradictory to the logic of technological development in the East African countries where most technological development takes place through minor changes and incremental innovations. This does not benefit from highly specialized talents and basic research. It needs considerably more general technical assistance, basic technical capabilities, and the overall mastery of all the technical and economic aspects of the production process.

(18) Generally, technology policy seems to be considered in a rather subordinate role in the countries under study. In spite of recognition in official documents of the importance of technology, the actual policy seems to be to ignore technology. It is more often regarded as a possible creator of unemployment, rather than a possible generator of industrial development and economic wealth.

(19) The main identified technology policy considerations are as follows:

- There is a need to reorganize a variety of public technology policy institutions. They should be dealing with tasks more relevant to the local economic and technological development and this should be done in more intense cooperation with individual firms and other economic actors. This implies more cooperation between universities, research institutes and firms.

- There is a specific need to spread information on the use and possibilities of new technologies. This could be done through, for example, establishing specific 'information technology centres' with differing targets, e.g.,CAD centres. There are many possible alternative forms to organize this kind of centre, but it is important that they are in close contact and cooperation with educational and training institutes as well as with firms. This kind of information technology centre has proved to be rather successful in developed countries.

- Companies need direct aid in getting information on production technology developments and making technology acquisition decisions. This could be arranged for example through sectoral research institutes, branch organizations or parastatal holding companies employing personnel specialized in information gathering, and creating contacts to sources of technological information abroad. The specialists should carry out contract tasks for individual firms, to help them both in creating contacts to technology suppliers and in technology contract issues.

- Quite similar aid is needed by firms in technology assimilation and adoption matters. In this case, however, the need is for highly specialized knowledge on production technologies and for long-term support, which starts before the actual implementation of new technologies and continues until the new systems have been totally incorporated into the everyday activities of the firm. This kind of aid may, in many African cases, be only available through foreign donors.

- Even more general awareness programmes on the effects and possibilities of technological development are needed. They should be associated with an open and wide social discussion on the themes of technological development.

- Companies also need more direct financial aid in technology acquisition. This means facilitating the regulation of foreign currency in production technology matters. New production technologies are, however, means to make the economy more effective and productive and thus creating new possibilities for economic growth and increased exports. The need to make customs procedures less complicated and less bureaucratic is as important.

- For capability building it is important that local firms are deeply involved in every technology transfer case, even when foreign donors are completely responsible for the process. Technologies imported should be 'appropriate' in at least three senses: they should fit the existing production processes in the recipient organization, they should raise the technological level of the organization and serve as a basis for capability building, learning and further technological development, and, third, they should support the macro level national development targets. The last topic may often include for example the target of diminishing the variety of machine types and makes in the country.

(20) The three sectors studied, textiles, clothing and footwear are all quite important in the six African case study countries. They are also industries where the microelectronics based automation has not yet caused any major changes. However, signs of changes in the global market environment, current technological developments and new enterprise strategies in the developed countries are evident.

Production processes in the textiles industry are characterized by mainly incremental but continuous technological changes. The introduction of micro-electronics into the control operations of textile machinery has significantly increased both productivity, effectiveness, reliability and flexibility in the industry.

(21) The textiles industry is, out of the three sectors studied, the most technology driven. The basic products are quite standardized and not changing dramatically. The role of manufacturing performance is highly important. There is little room for technological indifference, for the international standards of product quality and company performance are determined by the best practice equipment. Consequently, if a developing country firm intends to reach international competitiveness, it does not have many alternatives. Continuous development of production technology and further automation is a necessity, in order to reach better product quality and overall performance.

(22) The clothing industries were less important in the case study countries, both in terms of output and employment. In this respect Mauritius was an exception because it had a very large clothing industry, mainly producing knitwear from imported raw materials for developed country markets. The clothing industry is also less production technology driven than textiles. Product design and market considerations are more important. It is also a much more segmented industry with very differentiated products - in terms of materials, designs and production requirements - for a variety of markets.

The clothing industries in the case study countries, with the exception of Mauritius, seemed to be facing more problems than textiles.

(23) The footwear sector is, of the three industries studied the least automated and the most labor intensive. Paradoxically it was also the sector facing the most serious problems. Only a few firms in the case study countries were operating profitably, and they were mostly plants of multinational corporations. There were problems with supply raw materials, quality of products, uncompetitiveness in relation to imported shoes and overall productivity of manufacturing.

(24) Generally the main problams faced by companies in all of the three industrial sectors were, however, more policy and infrastructure related. The companies had problems especially with import duties and regulations, restricted finances - availability of foreign currency above all - telecommunications problems and shortages of labour skills, particularly managerial skills at all levels of supervision and administration.

From the study of the three sectors it seems that there is actually an inverse relationship between labor intensity and company performance. The more automated the firm was, the fewer performance problems it had.

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In preparing this study a wide range of individuals and institutions were contacted to secure information, ideas and views. Nearly 300 supplier company questionnaires were circulated, 20 national embassies or missions were contacted, over 100 interviews were carried out with industrialists, academics and policy makers in seven countries, and more than 50 individual experts operating in the field of technology promotion were consulted. It is not possible to list individually all the many people without whom this study could not have been completed. Their contribution is nevertheless gratefully acknowledged.

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Technical input was a specific sector provided by Joe Off and David Vasbinder of the Textile and Clothing Technology Corporation, North Carolina, United States, to whom considerable thanks are due.

List of Abbreviations

ACP	–	African, Caribbean and Pacific Convention
AED	–	African Economic Digest
AGV	–	Automated Guided Vehicle
AMS	–	Automated Manufacturing Systems
AMT	–	Automated Manufacturing Technology
BIPE	–	Bureau d'Informations et de Prévisions Économiques (France)
BMFT	–	Bundesministerium für Forschung und Technologie (Germany)
BRA	–	British Robotics Association
BS	–	Batch Size
CAD	–	Computer Aided Design
CAE	–	Computer Aided Engineering
CAM	–	Computer Aided Manufacturing
CAP	–	Computer Aided Planning
CBR	–	Centre for Business Research (UK)
CHIM	–	Computer and Human Integrated Technology
CIM	–	Computer Integrated Manufacturing
CLSMB	–	Cotton Lint and Seed Marketing Board (Kenya)
CMEA	–	Council for Mutual Economic Assistance
CNC	–	Computer Numerical Control
COMETT	–	Cooperation between Universities and Companies in the Field of Technology (EC)
DC	–	Development Certificates
DFCK	–	Development Finance Company of Kenya
DME	–	Developed Market Economy
DNC	–	Direct Numerical Control
DOD	–	Department of Defence (USA)
DTI	–	Department of Trade and Industry (UK)
EC or ECE	–	European Economic Community
EDI	–	Electronic Data Interchange
EIU	–	Economist Intelligence Unit
EPROM	–	Erasable Programmable Read Only Memory
EPZ	–	Export Processing Zone
ERP	–	Economic Recovery Programme (Tanzania)
ESPRIT	–	European Strategic Programme for Research on Information Technology (EC)
FAS	–	Flexible Assembly System
FAST	–	Forecasting and Applications of Science and Technology (ECE)
FINNIDA	–	Finnish International Development Agency (Finland)
FIRE	–	Fully Integrated Robotised Engine
FMC	–	Flexible Manufacturing Cell
FMS	–	Flexible Manufacturing System
FMU	–	Flexible Manufacturing Unit
FY	–	Financial Year
GATT	–	General Agreement on Tariffs and Trade
GDP	–	Gross Domestic Product
GNP	–	Gross National Product
GSP	–	Generalised System of Preferences
GT	–	Group Technology
IBM	–	International Business Machines

IBRD	–	International Bank of Reconstruction and Development
IC	–	Integrated Circuit
ICAM	–	Integrated Computer Aided Manufacturing
ICDC	–	Industrial and Commercial Development Corporation (Kenya)
ICSID	–	International Centre for the Settlement of Investment Disputes
IDB	–	Industrial Development Bank (Kenya)
IDC	–	Industrial Development Corporation (Zimbabwe)
IIASA	–	International Institute for Applied Systems Analysis (Austria)
ILO	–	International Labour Office
IMF	–	International Monetary Fund
INV	–	Investments
IOC	–	Indian Ocean Commission
IR	–	Industrial Robots
IT	–	Information Technology
JIRA	–	Japan Industrial Robot Association
JIT	–	Just in Time
LDC	–	Lesser Developed Countries
LSI	–	Large Scale Integration (ICs)
LT	–	Lead Time
MAP	–	Manufacturing Automation Protocol
MAPCON	–	Manufacturing Automation Protocol Consultancy
MC	–	Machining Centre
MEDIA	–	Mauritius Export Development and Investment Authority
MFA	–	Multi-Fibre Agreement
MIGA	–	Multilateral Investment Guarantee Agency (World Bank)
MIPS	–	Millions of Instructions per Second
MITI	–	Ministry of International Trade and Industry (Japan)
MNCs	–	Multi National Companies
MVA	–	Manufacturing Value Added
NASA	–	National Aeronautical and Space Agency (USA)
NBS	–	National Bureau of Standards (USA)
NC	–	Numerical Control
NCMT	–	Numerically Controlled Machine Tools
NCR	–	National Cash Registers
NIC	–	Newly Industrialised Country
NMTBA	–	National Machine Tool Builders Association (UK)
NSF	–	National Science Foundation (USA)
OECD	–	Organisation of Economic Cooperation and Development
OGL	–	Open General License Scheme (Tanzania)
OPEC	–	Oil Producing and Exporting Countries
OTA	–	Office of Technology Assessment (USA)
PA	–	Programmable Automation (NC/CNC Machines)
PBT	–	Pay Back Time
PC	–	Personal Computer
PCB	–	Printed Circuit Board
PCI	–	Per Capita Income
PER	–	Personnel
PROD	–	Productivity
PSI	–	Policy Studies Institute (UK)
PTA	–	Preferential Trade Area for Eastern & Southern African States
PV	–	Product Variants

R&D	–	Research and Development
RISC	–	Reduced Instruction Set Computer
RoI	–	Return on Investment
SAP	–	Structural Adjustment Programme (Tanzania)
SAREC	–	Swedish Agency for Research Cooperation with Developing Countries
SATRA	–	Shoe and Allied Trades Research Association (UK)
SCARA	–	Selective Compliance Assembly Robot Arm
SD	–	Standard Deviation
SERC	–	Science and Engineering Research Council (UK)
SIC	–	Standard Industrial Classification
SMEs	–	Small- to Medium-Sized Enterprises
SPRINT	–	Strategic Programme for Innovation and Technology Transfer (EC)
SSA	–	Sub-Saharan Africa
STAR	–	Special Telecommunications Action for Regional Development (EC)
STU	–	Swedish Board for Technical Development
TC	–	Technical Complexity
TC^2	–	Textile/Clothing Technology Corporation (USA)
TEXCO	–	Tanzanian Textiles Corporation
TQC	–	Total Quality Control
UCR	–	Unit Cost
UNCTAD	–	United Nations Conference on Trade and Development
UPS	–	Unit Power Systems
VCR	–	Video Camera Recorder
VDI	–	Verein Deutscher Ingenieure
VDU	–	Visual Display Unit
VLSI	–	Very Large Scale Integration (ICs)
WIP	–	Work in Progress
ZISCO	–	Zimbabwe Iron & Steel Corporation

Introduction

This report described the results of research into the adoption of automation in developing countries. The main sectoral emphasis has been on the textiles, clothing, and footwear sectors and the main developing country emphasis has been on six African countries: Ethiopia, Kenya, Mauritius, Namibia, Tanzania and Zimbabwe, with one Latin American country - Brazil - as a comparator.

The research has been to adopt a very broad view of what constitutes automation. We include office and factory computer systems, Computer Aided Design (CAD), even at its lowest levels of application, and standalone Numerically Controlled Machine Tools (NCMT), as well as highly integrated technologies such as Flexible Manufacturing Systems (FMS), Intelligent Robots, 5th Generation computers, or full Computer Integrated Manufacturing (CIM). Chapter 1 contains a description of automation, and the systemic changes brought about by microelectronics and information technology.

However, automation in developed countries is not merely a consequence of the technology itself, but is a function of the infrastructure that exists. No discussion of technological adoption and diffusion - and no research into policy options that might be adopted - would make any sense without a detailed discussion of, for example, government policies, financial constraints, logistical support systems, educational and skill availabilities, etc.

It is clear that different industries and different countries have taken on board computerisation as an international competitive weapon, at different rates and with different measures of success.

It is not the intention of this report to overemphasize the problems faced by widespread diffusion of micro-electronics in the developed countries, but it does have great significance for the prospective international division of labour and the abilities of developing countries to catch up, or even to maintain their current positions.

The report has nineteen chapters, with Chapter 1 examining some of the automation trends and some of the theoretical and empirical considerations and findings.

Chapters 2 to 5 contain an overview of four specific technologies, i.e., industrial robots, computer aided design, numerically controlled machine tools, and flexible manufacturing systems and cells. This is done in terms of the technologies themselves, their diffusion and the infrastructure for successful use.

Chapter 6 contains a supplier profile, based on questionnaires distributed to machinery, equipment and software exporters from nine countries; the United Kingdom, Germany, the United States, Japan, Italy, France, the Netherlands, Switzerland and Sweden. This was concerned with the economics of purchase, and the barriers or potential barriers concerning buyers.

Chapter 7 utilises the earlier chapters to synthesise what has been occurring related to the costs and benefits of the use of the four technologies. Chapter 8 brings together a thread which runs throughout the report regarding the importance of design and re-design.

Chapter 9 goes into more detail on the infrastructural issues which go towards making an economic success -- or failure -- of adopting automation. As noted earlier these issues are critical in the effective and efficient use of automation; and Chapter 10 is the final one relating to developed countries, containing analysis of policy options which seven OECD countries have pursued - in one form or another.

Chapter 11 opens the debate on developing country issues by examining the broad theoretical framework existing in developing countries and resulting practices. It examines development theory, industrial development, etc. Chapter 12, as was done with the developed countries, looks at industrial and technology policies, and particularly policy formulation.

Chapter 13, examines some of the infrastructural issues, this time in relation to developing countries. It examines here such factors as logistical support systems, the educational system and other manpower factors.

Chapter 14 looks in greater detail at the case study countries, examining techno-economic developments. Chapters 15 to 17 deals with the three key manufacturing branches of textiles, clothing and footwear, with particular reference to global markets, technological developments, and the case study countries.

Chapter 18 assesses developments in a number of other industries, in particular electronics, machine tools and motor vehicles.

Chapter 19 contains conclusions, and offers a number of policy options for consideration by both developing countries policy makers and the international community.

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1. Developed Countries and Technology Issues

At both national and company level, considerable attention has been focused on the need to upgrade technological capacities to successfully meet increased international competition. The responses to this have, of course, varied, not merely because of the different cultural framework in the countries adopting microelectronics based technologies, but also within each country, depending on the need in individual companies.

Organizational adaptation is also developing as an important determinant of how well firms are able to appropriate the full benefits of automated technologies. Currently there is a considerable gap between the adoption of technology and organizational adaptation in many countries.[1]

Developments towards some concept of a "factory of the future" requires a significant rethink of how production is organized, and more sophisticated managerial attitudes. In the future a blend of "best practice" production engineering will need to be combined with new management techniques and organizational forms.

These are likely to include serious reconsideration of the relationships between labour and technology, and the political and social objectives that managements operate under, and may evolve into a "new production paradigm".[2]

In many companies -- and in some countries -- much less attention has been focused on how the technology is to be introduced, and on the organizational and structural changes that are necessary to use technology to its best advantage.

Certainly the importance of such organizationally linked adaptation can be gauged from a number of reports which have remarked on the fact that 50 per cent,[3] 60 per cent,[4] and even 90 per cent[5] of the benefits of such technologies as flexible manufacturing systems (FMS), come from the radical organizational changes which accompany the introduction of such technology.

Attempts some five to ten years ago to develop totally automated factories have, in the fullness of time, come to be seen as only meeting the needs of a small minority of production situations, partly because of the types of products and the variety of parts that need to be manufactured, and partly because of the enormous risks and costs associated with such developments.

Historically, the introduction of computerization to the factory floor has been fragmented. There was little of it, it was expensive, time consuming and there were few people who knew how to run it. In addition, it was devoted to specific functions such as tool stocks or salaries. Most of these factors have changed rapidly, and in many ways the greatest effort must

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[1] Perez (1985).

[2] Dosi (1982).

[3] Haywood and Bessant (1985).

[4] Dempsey (1983).

[5] McCracken (1986).

now be made in providing adequate training of personnel, or in providing an adequate policy of how labour can be used in such technologies.

In many companies management thinking may have become too conservative to encompass effectively the integration possibilities of all aspects of manufacturing, from the sales department through design, planning, production, assembly and despatch. To complicate issues further, relationships have moved on and into tighter links with both customers and suppliers as well.

1.1 Pressures for change

There are two basic types of pressure for change in order. These are found to respond flexibly to the needs of customers particularly in the small to medium-sized batch area (an area in which approximately 70 per cent of all manufacturing companies find themselves located, i.e., with average batch sizes of less than 50 parts).

First, **internal pressures**. There is a wide range of traditional problems which are inherent in many firms, a few of which are listed below:

- high inventory levels tying up large amounts of capital;
- low machine utilization;
- poor delivery performance;
- poor production control.

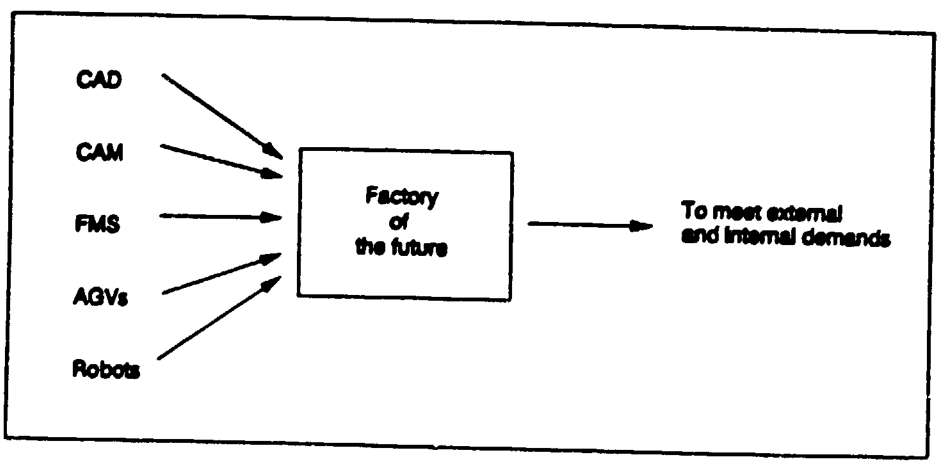
Second, *external pressures*. These mean than companies must increasingly be aware of the need to respond quickly to customer requirements, with the ability to be 'quick on their feet' or to have the capability to display 'agility' in reacting to markets that are increasingly resembling the fashion industry in changing customer consumer tastes. These require:

- shorter lead times for delivery purposes;
- high and consistent quality in the product;
- meeting increasingly customized markets.

What is called for here is the need to develop more flexibility and responsiveness – factors that might be called 'improved manufacturing agility'.

In the past, many companies have tended to respond by purely technological means, a few of which are contained in Figure 1.1.

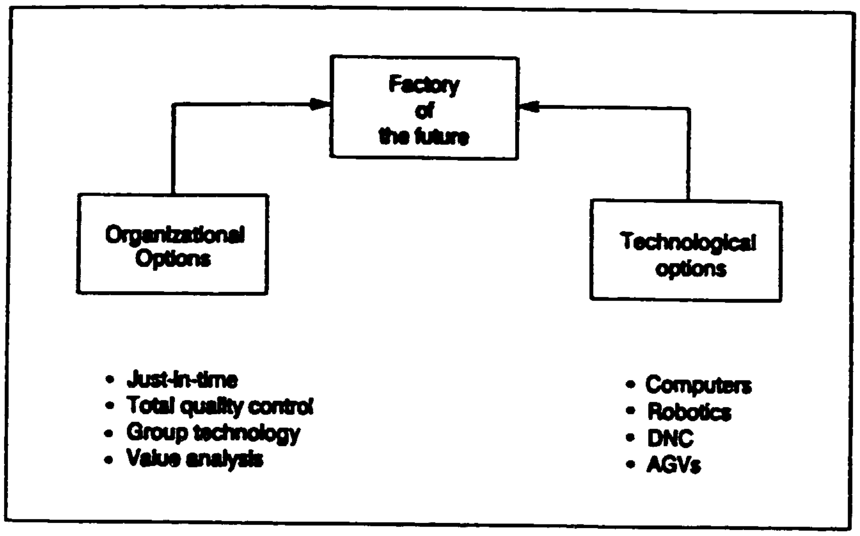
Figure 1.1 Technological options



The use of Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), FMS, Automated Guided Vehicles (AGVs) and Robotics, have been intended to upgrade production potential in order to meet the challenge from low wage countries, and to compete with other developed countries.

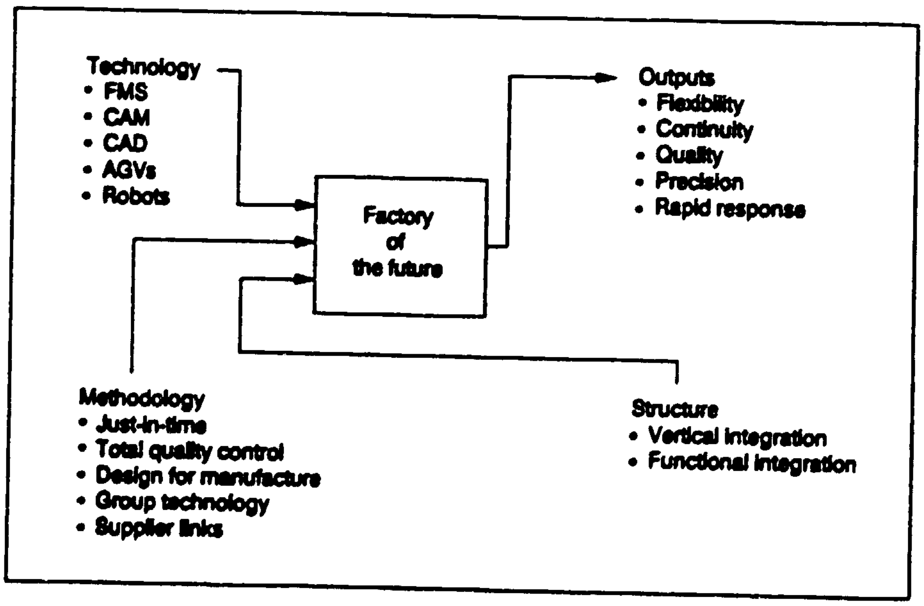
However, as observed above, this approach may fail to take note of organizational changes which can be introduced and which are included with the technological changes in Figure 1.2.

Figure 1.2 Technological and organizational options



Taking this to a third and final stage offers a more integrated approach to the organizational and technological implementation of best practice techniques in Figure 1.3.

Figure 1.3 Holistic integration of manufacturing



Within this framework it becomes possible to conceive of a much more integrated approach which takes on board the impacts of technology, the organizational changes that then become necessary, and the methodologies arising out of the changes that are created in the new international competitive environment.

1.2 Systemic Approaches to Manufacturing

It has become increasingly obvious that it is this systemic approach to manufacturing that provides the best use of resources. It is also clear that these approaches have been adopted most frequently in countries with a highly developed educational and skills base that have consensus as a goal, although there may be different forms of consensus in different countries, such as Germany, Japan, and Sweden.

The predominant mode of production in most developed countries consists of a small number of large manufacturing enterprises usually producing goods in a continuous flow or process manner. Such companies have sought to exploit the benefits of "economies of scale" as a consequence of what has been termed "Fordist" production methods. This has made production "relatively" cheap but has meant that quick response to customer needs has been difficult.

The large scale industrial companies have been accompanied by very many small to medium-sized companies producing goods in a rather less economic manner as a consequence of smaller batch sizes, but who have been able to exploit the advantages associated with producing small batches in fairly rapid response to customer needs. In fact it has been estimated that between 60 per cent and 70 per cent of all batches produced in the engineering sector consist of less than 50 parts.

However, in these smaller companies a major drawback has been the very low utilization rates of traditional machine tools due to numerous changeovers, waiting time, fixturing, etc. Figures for such production show that up to 95 per cent of the time that material or components are on the shopfloor is spent waiting or being moved. Of the other 5 per cent, three fifths is spent being positioned, loaded or gauged, leaving two fifths (or just 2 per cent of shopfloor time) in which machining takes place.

The modern goal is to achieve as many of the benefits of the large firms flow line approach as possible, but to link this to the flexibility that can be seen in smaller companies. What companies are increasingly seeking is an "economies of scope" solution to increased international pressures, with moves to a more process orientation, but one which allows a rapid response to customer demand.

1.3 Manufacturing Automation

Much of the above discussion of technology, pressures for change and systemic approaches to manufacturing have been intended to provide a background to the discussion of automation in both developed and developing countries. However, first it is necessary to try to define what is meant by automation.

> "Historically, there has been some dispute as to the meaning of the concept of automation. At issue is the specificity of the term. Thomas (1969) for example argues that:

> "automation" is a technology quite distinct from mechanization and it is concerned with replacing or aiding human *mental* effort as distinct from aiding man's physical effort.

The virtue of Thomas's perspective is that it emphasizes the *control* characteristics of automation technology (cybernetics), a field in which microelectronics devices have a particularly crucial role. However, despite its attractions, it is more common to view automation in its more general sense, defined by Einzig (1957) as

> a technological method that tends to reduce current production costs in terms of man hours per unit of output. ...Its loose use practically as a synonym for advanced mechanization may shock the technologist, but serves the purpose of economists.

Despite the logic of viewing automation technologies in the broadest sense, distinguishing control from other subsets of automation technology is important. Bell (1972) offered some clarity in a muddy debate when he suggested that there are, in fact, three different elements to automation technology in manufacture: namely control, transformation of inputs, and transfer between workpoints. In each of these areas, degrees of automation exist but a high level of automation in one area need not be associated with a high level in the other two".[6]

Kaplinsky goes on to develop these elements into a coherent and logical framework within companies, which have been significantly impacted by the arrival of the computer. These three forms of automation he defines as Design, Manufacture and Coordination automations (see Figure 1.4). Within each sphere specific applications of automation appeared, but none of these were linked (intra-activity). As the technologies evolved and their integrative nature became clear, applications within a sphere became linked (intra-sphere activity). At the third stage of development the three spheres may become linked and the enterprise becomes an organic whole (inter-sphere activity).

At this third stage of activity it becomes possible via computer applications to systematize the whole enterprise from design through sales and marketing, to purchasing, manufacturing, assembly and packing, to delivery. This means the ending of the Tayloristic, Fordist mode of production in many enterprises and the re-emergence of the unitary, undifferentiated company.

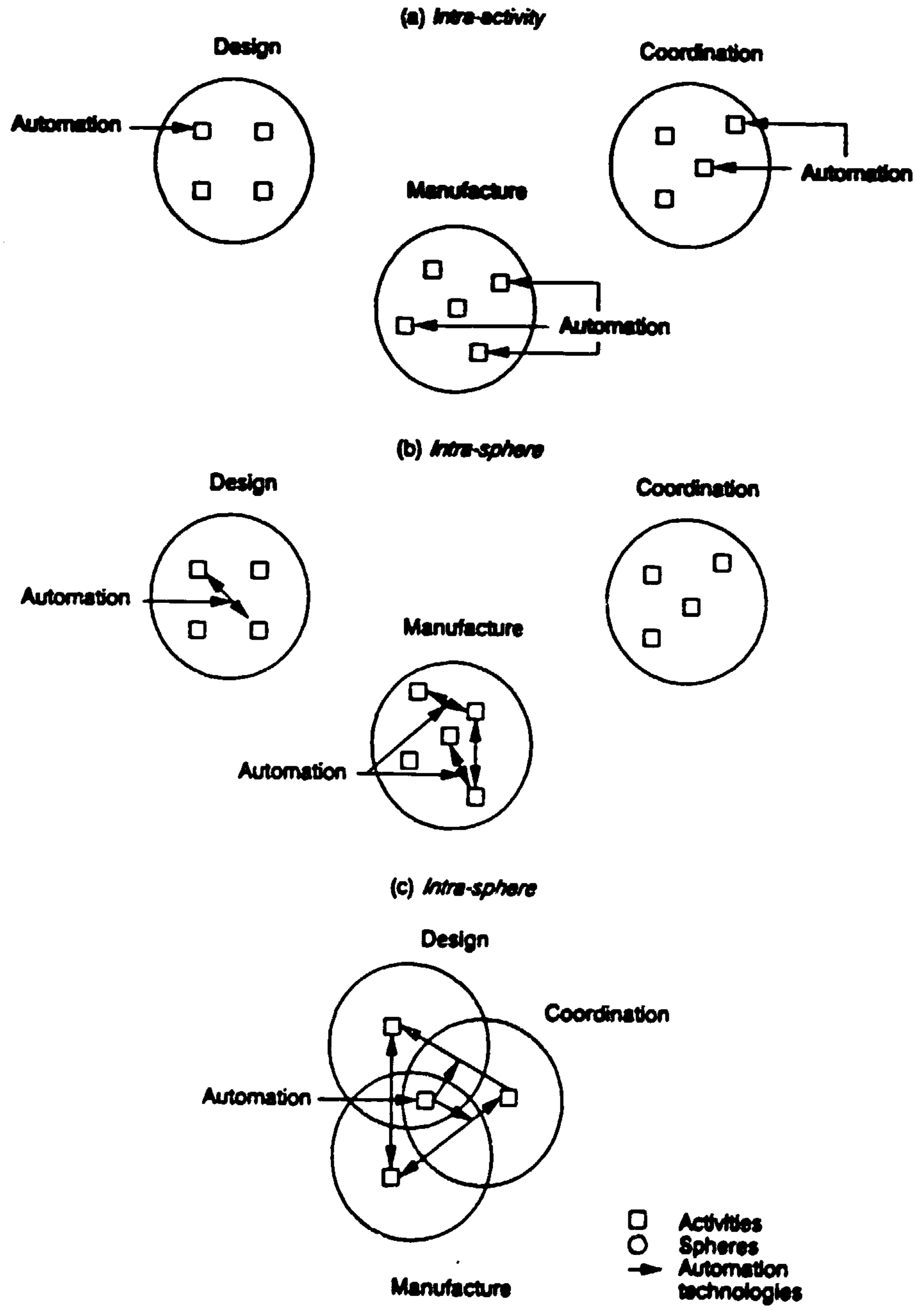
But what exactly are these three spheres and what do they contain?

"(a) *Intra-activity automation* refers to automation that occurs within a particular activity. Clearly, in line with our earlier definition of automation, this intra-activity automation may take a variety of forms ranging from the simple substitution of machine power for human power (as in the use of computer-aided drafting systems) to the more complex incorporation of machine 'intelligence' and control (as in computer-aided design systems). The determining characteristics of this type of automation, however, are that it is limited to a particular activity and that

[6] Kaplinsky (1985).

it is consequently isolated from other activities within or beyond the particular sphere of production.

Figure 1.4 The three different types of automation



(b) *Intra-sphere automation* refers to automation technologies that have links with other activities within the same sphere. Indeed, the origins of the term 'automation' in the Ford assembly plant of the 1920s illustrate this type of automation well: the new transfer line mechanized the flow of materials between different activities such as lathes, drilling and boring machines. In its more complex form -- as in the newly flexible manufacturing systems -- intra-sphere automation involves the monitoring of the progress of production with an ability to adjust components of individual activities, if this becomes necessary.

(c) *Inter-sphere automation* is the third and most complete form of automation and involves coordination between activities in different spheres of production. In view of the number of activities within each of the different spheres, there is a wide variety of potential inter-sphere combinations. These may be relatively limited and simple; for example, using design parameters to set machine settings automatically; or they may be wide-ranging and complex, such as in the linking of changes in the specification of productions to parameters generated in redesign, and thus in continual adjustments made in machine settings".[7]

The use of automation technologies in developed countries is thus leading inevitably towards an approach to manufacture in which specific "islands of automation" are being transformed into "continents of automation". The central focus of this automation is, of course, the use and control of information and communication networks brought about by the use of electronically based equipment.

> "Evidence is increasing that electronics-based automated production, built around centralized data bases, permits a greater level of control by senior management, but that this requires changes in patterns of managerial organization. In these circumstances, management is required to implement a wide, enterprise-level of organization, restructuring coordination to exploit the potential for systemic productivity gains".[8]

This analysis by Kaplinsky recognized that a major re-adjustment is also taking place in the relationship *between* firms. He did not, at that stage, develop the logic of a more systemic supplier - manufacturer - customer relationship.

The use of micro-electronics based technologies allows greater interaction between a customer and manufacturer, for example in design and redesign of products, and the use of digital data in exchanges between such firms - similarly between manufacturer and supplier, for example, quality or delivery issues can also be resolved.

One way of visualizing such links in Figure 1.5 where, for example, the use of Manufacturing Automation Protocols, or Initial Graphic Exchange Specification provides the vehicle for inter-firm exchanges of information and data flows.

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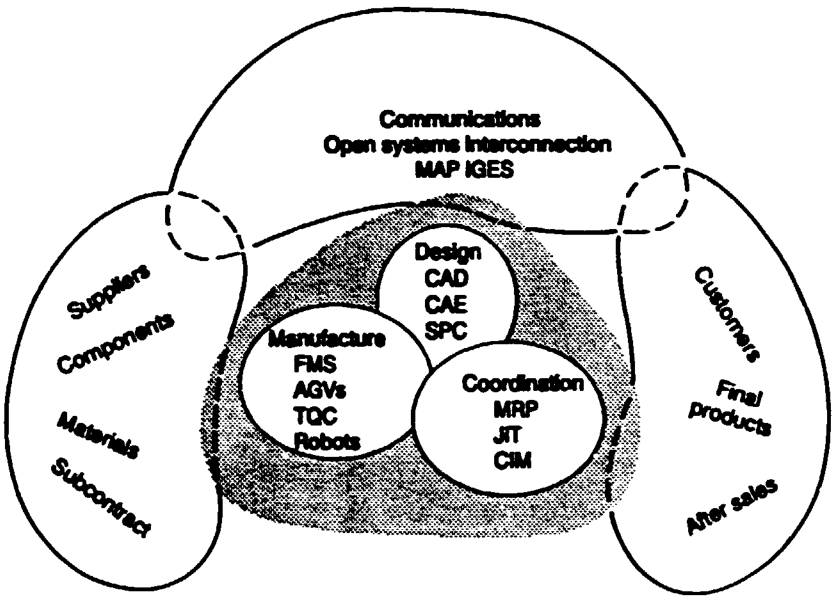
[7] Kaplinsky (1985).

[8] Kaplinsky (1985).

Figure 1.5 Supplier, manufacturer, customer links



MAP	Manufacturing Automation Protocol
IGES	Initial Graphics Exchange Speciftcion
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
SPC	Statistical Process Control
FMS	Flexible Manufacturing Systems
AGVs	Automatic Guided Vehicles
TQC	Total Quality Control
MRP	Material Requirements Planning
JIT	Just-in-Time
CIM	Computer-Integrated Manufacturing

What are the implications of automation trends in the developed countries for developing countries? Given the above discussion and the integrative nature of these trends, the costs, infrastructural requirements (education, skills, etc.) and the scale of production perhaps necessary to justify its adoption, many developing countries may face severe problems of adjustment.

> "...as the systems-based automation technologies – which depend upon the *widespread* interlinking of digital logic automation technologies throughout the enterprise -- spread in competitor countries, these partial responses to the imperatives of innovation are likely to prove inadequate. Instead, a comprehensive approach to technology acquisition is necessary, requiring the state (or its proxies) to intervene to correct the signals provided by the market. It may, therefore, not be sufficient to merely facilitate the purchase of obviously necessary electronics-based technologies such as CNC machine-tools or CAD, because for these technologies to realize their ultimate productivity gains they may necessarily have to be linked to less obviously attractive technologies such as word-processors, electronic printers and personal computers. Inevitably such policies will stimulate resistance, since it is not easy to justify high-cost automation technologies (such as word processors) when labour costs (e.g., for clerks and typists) are so low".[9]

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[9] Kaplinsky (1985).

While we agree that the problems are huge, we believe that if one takes a contingency theory attitude, the picture is not an entirely pessimistic one.

Although there are many difficulties in such an approach, especially for developing countries, companies (and countries) may be able to adopt specific technologies, e.g.,CAD or Numerically Controlled Machines Tools, and use these quite effectively to focus on particular products or markets. African countries, for instance, could not adopt a Japanese or German approach to development as it currently stands, but it should be noted that these countries too were once developing ones. The major problems associated with the current technologies is that they call for very strong infrastructural under-pinning to be successful. Few African countries possess these; and the Newly Industrialized Economies (NIEs), e.g.,Taiwan, Republic of Korea, etc., may have been very fortunate to have started their industrial development at the time they did. For follower countries the task may be much more difficult.

1.4 The Integrative Nature of New Technologies

A considerable literature has been devoted in recent years to the role of new technology in economic development.[10] Probably one of the most significant areas of interest has been the focus placed on the Schumpetarian concept of technological innovation as the driving force of economic progress.[11] This, in turn, was a further extension of the principle of long-waves of economic development put forward by Kondratieff, where a cycle of progress was suggested as peaking every 50/55 years.[12]

These theories are beyond the scope of the present report. However, in recent years the importance of a whole range of new technologies based on micro-electronics has become very clear.[13]

The bunching of new opportunities for production has dramatically altered whole industries which have existed for many years, and led to the creation of entirely new industries. One example of the former, which has been termed a "sunset" industry - printing - has been transformed into a "sunrise" industry in the developed countries, by the introduction of such new production techniques. Technologies that had barely changed in 70 years - and some parts which were similar to those of 500 years ago - had become superseded by the late 1970s / early 1980s by equipment which could hardly have been envisaged ten years earlier.

Photo-typesetting of text; graphics generation by color scanners utilizing opto-electronics; inputting of text and graphics to a central computer; computer controlled inking, and finishing functions integrated on printing presses capable of very high speeds; are all elements which are altering the international competitiveness of the industry, and with it the international division of labour. Jobs which might have gone to developing countries for production now become feasible once more in the high wage countries. The integrative or systemic nature of such recent trends has also become clear.

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[10] Freeman, (1987); Stoneman, (1987),

[11] Schumpeter (1939).

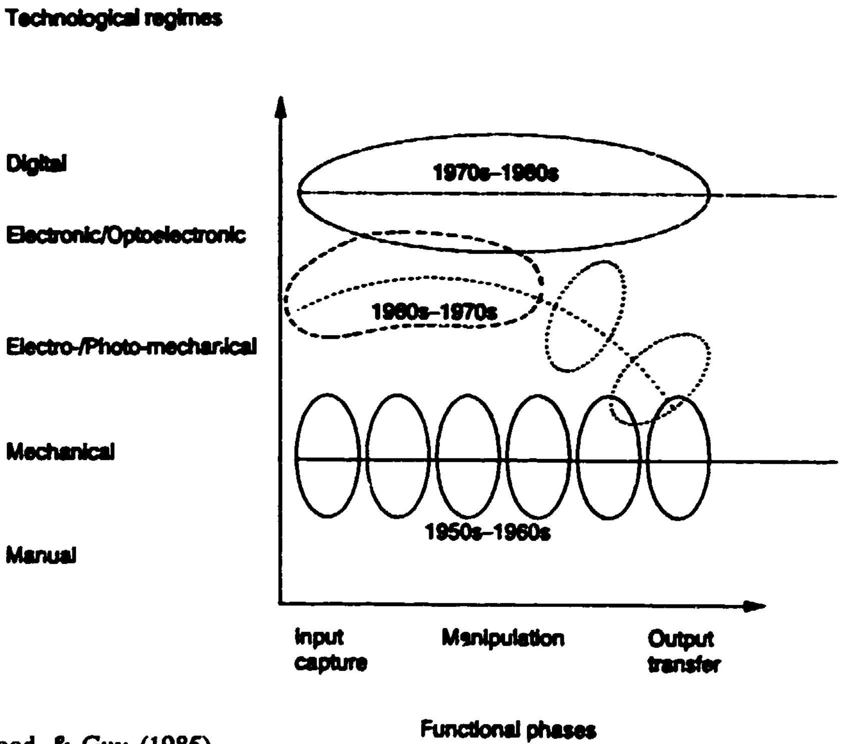
[12] Kondratieff, (1939); Mandel, (1980); Mensch (1979).

[13] See Ayres et al., 1991a,b,c,d.

One impact is that in the United Kingdom industry, which lost jobs heavily between 1970 and 1980 (-121,000) but which has now invested heavily in new technology, employment has started to grow post-1982, stabilizing by 1988 at a point 8 per cent above the 1982 level.[14]

The impact of such technologies can be seen graphically in Figure 1.6, where the integration of production in the printing industry pre-press has been facilitated by electronic means. Such integration in production is becoming diffused across other industrial sectors, and has widespread implications for both developed and developing countries.

Figure 1.6 A schematic representation of the evolution of the pre-press stage



Source: Haywood & Guy (1985).

Figure 1.6 needs some explanation. In essence it tries to convey the following points:

(a) In the 1950s and 1960s the pre-press stage could be described in terms of a large number of functionally distinct phases, all of which used combinations of technologies rooted in the manual, mechanical and electro/photo-mechanical regimes. An example of a pre-press system of this era was the hot-metal system. Text was captured by a typewriter before being passed to a compositor who re-keyboarded material on a mechanical composer. This prepared the punched tape ready for use in a hot-metal typesetter which cast letters from a molten lead alloy. In a parallel process, camera captured graphics were etched onto metal plates before hand assembled page make-up took place and a stereo plate produced as output ready for the press stage.

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[14] Haywood, (1985a, 1990).

(b) During the 1960s and 1970s a number of developments took place which had two major characteristics. In the first instance, new technological regimes had a differential impact on functional phases within the pre-press stage. Those phases nearer the output end were less affected initially than those in the central manipulation and input phases. The "bowed" picture of developments in Figure 1.1 tries to capture this. Secondly, the smaller number of discrete phases along the "bowed" axis of the 1960s and 1970s is meant to depict a tendency towards the integration of functional phases towards the front end of the pre-press stage with the development of technologies stemming from the electro-photo-mechanical and opto-electronic regimes.

(c) During the late 1970s/early 1980s, in the digital phase, it became possible to capture input, to manipulate this input and to output this to the printing press as one integrated activity.

It is also apparent that such integrative changes have not been restricted to pre-press functions, and that the whole printing function has been affected. The extent of changes in the industry are further illustrated by reference to Table 1.1, which highlights the integrative nature of the new technologies which have evolved in printing.

We use this example of printing merely to illustrate how interlinked and interrelated previously discrete functions have become as a result of the spread of new technologies.

Such new technologies have also created whole new industries, for example, in the electronics and communications areas. These industries have generally been based on high levels of research and development (R&D) - typically 10 to 12 per cent of sales revenue per annum - and highly qualified personnel - typically a 30 to 40 per cent graduate level of employees.

These examples emphasize our view that technology can no longer be viewed as a 'one-off' approach, but must be carefully planned. The more sophisticated and costly - but cost-effective - these become the greater the barriers that may emerge for developing countries with limited skilled manpower and financial resources. In fact the first of these, education and skills, may even prove the biggest hurdle to overcome. The problems in this regard may be higher in developed western economies than in Japan, according to one observer:

> "We are going to win and they (the West) are going to lose. We are beyond the Taylor model the survival of firms depends on the day-to-day mobilization of every ounce of its intelligence. For us the core of management is precisely this art of mobilizing and pulling together the intellectual resources of all employees in the service of the firm. The intelligence of a handful of technocrats is not enough to take up (the technological and economic challenges), with any real chance of success".[15]

For the present examination of developed country experiences and policy adaption, a limited number of technologies associated especially with the mechanical engineering industries will be used. Those covered are:

(1) Robotics (IR)
(2) Computer aided design (CAD)
(3) Numerically controlled machine tools (NCMT)
(4) Flexible manufacturing systems and cells (FMS/FMC)

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[15] Bessant & Chisholm, (1986).

Table 1.1 The development of printing technology

Phase	*Innovation*	*Outcome*
Manual (15th- 18th Centuries)	Wooden press (Gutenberg)	Established man:machine relations
	Iron press (Stanhope)	Increased labour productivity
Mechanical (19th Century)	Large steam-driven units (Koenig)	Increased capital intensity and labour productivity
	Mass-produced presses (Albion)	Cut capital cost
Electro-mechanical & Electro-chemical (late 19th Century and first part 20th Century)	Semi-auto casting (Linotype/Monotype)	Increased capital cost and labour productivity
	Photolithography; photogravure; process camera; better paper, inks, plates	New specialist processes; better quality work
	Small electric motors; independently powered machines; typed text (IBM)	Small flexible units
Electronic (1950s and 1960s)	Colour scanners (Printing Developments International); photosetting (Berthold/ Monotype) mainframe computer typesetting (Compugraphic/ Ferranti); visual display units (Cossar/Fairchild)	Increased labour productivity; changing capital costs; altering man:machine relations
Digital (1970s +)	Full page make-up (Optronics/Daily Mirror Group); laser electro- photography (Hell); automatic page composition (Sci-tex/ Hell/Crossfield)	Increasing integration of production phases

Source: Based on Bollard (1983) and Haywood (1985a).

The rationale for this is that this has probably been the most extensively researched area of developed countries industrial development; and that - to varying degrees - *each of these technologies is equally applicable in a range of other industries, including the cases of textiles, clothing, and footwear examined later in this study.*

1.5 Technology and Organization Issues: An Overview

The systemic nature of the current information technology and microelectronics based technologies has been noted. In the next 4 Chapters we go on to describe four of these technologies as applied in developed countries, and also try to assess their applicability in African countries.

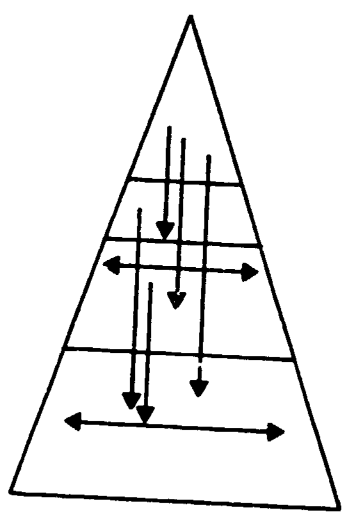
Before this it is appropriate to raise several organizational issues that are becoming increasingly important for the successful use of these new automation technologies.

Observations highlight a number of organizational factors in the effective implementation of flexible manufacturing systems -- and new technology in general. First, for example, it could be argued that in many instances, low risk, low cost changes in production methods, such as group technology or just-in-time systems, might bring significant benefits more rapidly than high risk technological investments like FMS. For small- to medium-sized firms this may represent a more viable option than full scale technology based factory renewal.

The second point concerns the strategy for change. It could be that the "island of automation" approach might be the correct one, or organizational change, or quantum leaps in technology, or simultaneous organization and technology changes. Options and consequences need to be examined very thoroughly and perhaps more attention paid to simulation exercises geared towards a post installation analysis of existing systems so that learning curve benefits might be achieved.

Third, functional structures and hierarchies need to be adapted in order to obtain effective implementation of automation. It appears that traditional Tayloristic approaches may be less than appropriate for integrated tasks and the skills that will be required in the future. In particular, in the developed countries there is considerable discussion around the options for devolving power and autonomy back to the shopfloor -- by using skilled labour as a key integrative interface. One concept that might be of some use here is the one advanced for the European Communities FAST programme, of computer and human-integrated manufacture (CHIM) -- rather than the more restrictive ideas contained in CIM.[16]

Figure 1.7 Condensing structural specialization and hierarchies



[16] Haywood and Bessant (1987).

Fourth, and linked to item three, a consequence of traditional patterns of organization has been the need for long vertical hierarchies in firms but research suggests that this is likely to be increasingly challenged by the needs of integrated technologies.

This trend towards flatter and less structurally functional occupations is being accelerated as a result of the introduction of information technology and the organizational changes that this brings with both vertical and horizontal movement occurring (see Figure 1.7).

Functional specialization and hierarchical structures which are inimical to modern information-technology systems may begin to break down, perhaps along the lines illustrated above in Figure 1.7. Instead of just being one way (downward), both top-down and bottom-up communications may develop, and horizontal expansion may also occur.

Fifth, there is a need for companies to achieve closer links with perhaps a more limited number of suppliers, i.e., the so-called "preferential supplier". Many benefits result from this organizational readjustment which involve improved product quality, reduced units costs, and improved delivery performances. While traditional linkages between suppliers and users have focused on price negotiation, evidence suggests that a radical change in this pattern is required. And as noted above, the use of electronics based technologies for interactions between suppliers, manufacturers and customers is increasing.

Finally, although there is growing evidence regarding the problems posed by integrated technologies and the need for organizational adaptation, there has been relatively little work done in this field. Factors such as education and training, job design, and organizational development interventions need to attract considerable extra attention, since these will prove to be increasingly important factors if developing countries wish to improve their adoption of new technologies, and with it their competitive position. A decision not to adopt more effective means of production means a decision to remain reliant on the sale of primary products or low value added manufactures.

2. Industrial Robots (IR)

There is no readily accepted international definition of exactly what a robot is. For many years even simple pick and place equipment was considered to be a part of the robot "family", especially so in Japan. However, a gradual consensus is emerging and the definition adopted by the British Robotics Association (BRA) is probably becoming accepted as the standard.

> "An industrial robot is a reprogrammable device designed to both manipulate and transport parts, tools, or specialized manufacturing implements through variable programmed motions for the performance of specific manufacturing tasks".[17]

Moreover, after some 25 years of development there are now succeeding generations of robots:

> "During this first decade (to the late 1970s) the industrial robot evolved from a hard-wired controlled hydraulic device suitable only for highly repetitive, relatively simple handling tasks, to a fully programmable electric-drive machine capable of complex assembly work. Nevertheless, apart from more general trends such as the application of microprocessor control, or electric-drive motors, the development of the industrial robot has not followed any single predetermined technological trajectory; rather the evolution of the technology has been intimately related to particular areas of application. Thus the original concept of "universal automation" had been abandoned, and robots had become increasingly task-specific. The main drawback of first generation machines is that they cannot obtain information concerning their work environment and therefore require well-structured environments involving expensive and inflexible fixtures and parts-orientation devices; in addition they must also be programmed on line, i.e., taught a particular sequence of movements on the shop floor".[18]

As a result, product-specific fixtures, grippers, and parts-feeders may account for between a half and two-thirds of the total cost of a first-generation system. Second-generation robots are more expensive, but in principle at least, the cost of such fixtures should be significantly reduced, and they promise the ability to be programmed off-line, allowing better computer integration. However, serious technical obstacles still exist:

(a) Sensors are still relatively expensive and require considerable computational power to translate signals into appropriate action;

(b) Information from sensors cannot readily be fed into robot or process control systems;

(c) There is still no single interface standard. Compliance with Manufacturing Automation Protocol (MAP) is still the exception rather than the rule, and in any case MAP does not deal with software compatibility;

(d) On-line programming languages are still used extensively, but are unsuitable for CIM;

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[17] BRA, 1989.

[18] Tidd, 1991.

(e) Current off-line languages cannot exploit CAD databases in real-time, and are unable to incorporate sensor input or the effect of tool compliance;

(f) The absolute positional accuracy of existing robots still results in deviations between the geometric model used off-line and actual conditions on the shop floor.

Consequently, existing sensor-based, second-generation robotic applications are expensive and application-specific, rather than cheaper and more flexible than their first-generation counterparts. For example, the use of machine vision usually requires the use of special light sources, high optical-contrast between parts and environment, accurate positioning of cameras and parts, and dedicated programming. Flexibility is sacrificed to ensure system robustness and reliability.[19]

2.1 Types of Robots

There is now a broad range of robot types and many suppliers. (See Table 2.1)

Table 2.1 Robot suppliers

Country	No. of Suppliers
Japan	24
USA	16
FRG (Pre-unification)	10
UK	9
Sweden	4
France	4
Italy	3
Austria	1
Norway	1
TOTAL	72

Source: Derived from Mortimer and Rooks (1987).

From data for specifications and characteristics of the equipment supplied by these robot manufacturers it is possible to identify the types of equipment most commonly available across nine types of industrial robot. (Table 2.2).

[19] Tidd, 1991.

Table 2.2 Robot configurations

Type	No. of Variants*	% of Total
Jointed Arm	163	40
Scara	96	24
Cartesian	59	14
Cylindrical	46	11
Gantry	26	7
Spherical	13	3
Pendular	2	}
Pivot Arm	2	} 1
Portal	1	}

* By number of variants we mean, for example, that of the detailed information contained in the volume, 163 different Jointed Arm IRs are available from the 72 suppliers manufacturing this type of robot.

Source: Derived from Mortimer & Rooks (1987).

Clearly the Jointed Arm and Scara robots are the dominant forms of IR, representing almost two thirds of robots available. Some typical specifications of assembly robots, for example, are given in Table 2.3.

Table 2.3 Specifications of typical assembly robots

Manufacturer and nationality	Model	Type	Year intro.	Repeat-ability (mm)	Maximum payload (kg)
Olivetti (Italy)	SIGMA	Gantry	1975	0.10	10
Unimation (US)	PUMA 550	Articulated	1978	0.10	2
DEA (Italy)	PRAGMA	Gantry	1980	0.025	6
Fanuc (Japan)	"A" series	Articulated	1981	0.05	10
Toshiba (Japan)	Tosman	SCARA	1981	0.05	8
Hitachi (Japan)	A3020	SCARA	1983	0.05	2
Adept (US)	Adept 1	SCARA	1985	0.05	6
ABB (Sweden)	IRB 1000	Articulated	1985	0.10	3
IBM (US/Japan)	7575	SCARA	1985	0.025	5
	7576	SCARA	1985	0.05	10

* Articulated robots include, of course, the Jointed Arm variety.

Source: Mortimer & Rooks (1987): *Automation*, January 1990.

With regard to the development of Scara robots the concept was:

"Conceived by Professor Makino and developed by a consortium of companies in Japan, the SCARA was launched in 1981. Five potential users and suppliers originally funded the project, but by the time of its launch thirteen companies had been involved in its development. The aim was to produce a robot that was more versatile than Cartesian robots such as the SIGMA and PRAGMA, but cheaper and less sophisticated than other articulated configurations like the PUMA. This was achieved through a simple but ingenious horizontal jointed-arm configuration using just two servo-motors. Thus the SCARA is significantly cheaper than conventional jointed-arms robots, but has a large work envelope and is more versatile than Cartesian designs. The unique configuration has natural mechanical compliance in the horizontal plane to correct for lateral errors, but is very rigid in the vertical direction. As a result the SCARA is claimed to be suitable for around 80 per cent of all assembly work.[20]

In Japan relatively simple SCARA-type assembly robots are the most commonplace, and are used extensively by all manufacturers of consumer electronics: Sony, Pioneer, Toshiba, Matsushita (National Panasonic, Technics), Hitachi, and Mitsubishi Electric.[21] But in areas demanding the use of more sophisticated robotics application is limited. Nissan currently uses robots at its showcase Zama plant to install batteries, window glass, seats, rear doors, lamps, and spare tires into its current range of cars, but plans to be able to automate around 50 per cent of all final assembly operations as soon as new models which have been designed for robotic assembly are introduced.[22] Honda aims to go further still, and plan to integrate its existing 150 assembly processes into just fifty, using hybrid electric-hydraulic robots to automate 80 per cent of these operations.[23] In contrast to the trend in Europe and the United States where a few, highly automated show plants exist alongside many plants having very little assembly automation, manufacturers in Japan have consistently automated simpler tasks."[24]

For the potential investor in robotics, a reading of these two source books - Tidd, and Mortimer and Rooks - might prove a beneficial exercise, particularly since the latter contains a considerable amount of detailed information on suppliers products and their configurations. A rather more dated source[25] provides information on robot costs. These costs may have changed considerably in the ensuing years (Table 2.4) though the supplier survey (in Chapter 6 in the present study) does not indicate this.

Utilizing data provided by the Japan Industrial Robot Association (JIRA), Mori did an analysis of potential automation applications of robots and Computer Integrated Manufacturing (CIM) in Japan. It was concluded that the automation of current manual operations may impact by industry as illustrated in Table 2.5.

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[20] Makino & Furuya, 1985.

[21] Makino & Yamafuji, 1985.

[22] Bairstow, 1986, p.28.

[23] Japan Economic Journal, December 1986.

[24] Krafcik, 1989 and Tidd, 1991.

[25] Flora, 1984.

Table 2.4 Typical robot models used to operate metalcutting machine tools

Robot model	Robot cost[a] (in 1982 dollar values) Minimum	Typical	Maximum
LOW-COST RANGE			
Copperweld, CR5	15,000	17,000	20,000
ASEA, MHU junior	-	20,000	-
General Numeric, MHO	-	25,000	-
MEDIUM-COST RANGE			
Prab 4200	30,000	35,000	50,000
Unimate 2000	46,000	-	64,000
Prab, E	51,000	62,000	72,000
Unimate 4000	64,000	-	74,500
Prab FA	65,000	80,000	90,000
HIGH-COST RANGE			
ASEA, Irb-60	60,000	75,000	120,000
CM T^3 586	75,000	85,000	-
Bendix, ML series CNC	-	100,000	-
Prab, FC	120,000	130,000	150,000

[a] Base price of robots from Flora (1982).
Source: Flora (1984).

Utilizing data provided by the Japan Industrial Robot Association (JIRA), Mori did an analysis of potential automation application of robots and Computer Integrated Manufacturing (CIM) in Japan. He concluded that the automation of current manual operations may impact by industry as illustrated in Table 2.5.

For example, in Textiles an average of almost 43 per cent of current manual operations may become automated.

2.2 Current Robot Diffusion

With regards to the diffusion of robots, although introduced commercially in 1959, initial acceptance was slow. Robotics began to diffuse widely in the mid 1970s in parallel with the diffusion of Computer Numerically Controlled Machine Tools (CNC) and preceding Flexible Manufacturing Systems (FMS). Some of these robots were for use in FMS but most were in the automobile industry for welding and painting. Although diffusion continues at a fast rate (over 20 per cent per annum in many countries), there has been some slackening of growth. Part of this can be attributed to saturation effects for certain applications of robotics - such as in the car industry. For example, in the early 1980s the US auto industry accounted for as much as 40 per cent of all robot investment. Many experts still consider that present levels of application are very low, being held back by lack of suitably sophisticated and intelligent technology. This is particularly true for the assembly area, where lack of suitable sensors - for vision, touch, etc. - mean that robots have so far only found limited application. Japan tends to be the exception here with nearly 40 per cent of IR applications being in the assembly area, as Table 2.6 reveals.

Table 2.5 Potential automation rate: by job type and industry sector (percentage)

Industry sector	casting	die-casting	plastic forming	heat treatment	forging	press & shearing	arc welding	spot welding	gas welding	painting	plating & surfacing	grinding	assembly, light-1	assembly, light-2	assembly, mid&hvy	loading	inspection	others	average
food										30	40	10	30	30	38	34	43	38	36
textile																27	47	46	43
wood & w.product			30							15		20			20	55	10	30	28
pulp & paper			30											30		15		38	31
chemical products			44			60				30	40	80	80	43	45	44	51	46	48
oil & coal products			55									20		80		45	55	49	50
rubber products			20			50				15		10	50	30	50	50	40	39	34
cement & clay			30			27	40	40	30	60	70	35		60	70	28	37	41	40
iron & steel	25			45	33	60	10			20	30	45		60	50	43	41	50	40
non-ferrous metals	29	40	45		40	35	15	20	10	50	40	36	45	40	40	35	27	33	35
metal products	24	30	10	32	35	34	41	41	5	51	40	46	55	36	33	43	40	57	40
general machinery	34	52	40	17	40	24	29	37	47	46	17	37	24	40	29	26	23	35	34
electric machinery	25	45	43	58	50	41	32	44	28	45	35	37	48	39	33	39	43	49	41
automobile	29	38	34	37	55	48	48	47	10	44	20	45	46	36	28	13	26	30	40
other transportation	23	20	50	33	30	44	35	45		46		43	10	37	23	40	40	33	38
precision machinery	40		45	50		20	40	20	100	39		39	38	35	30	29	44	40	38
plastic products			38							40	10	45	20	40		42	30	40	38
others	50		30	20	75	25	45	35		49	30	35	46	50	55	36	43	34	40
total	30	40	39	33	44	37	37	43	31	45	33	40	45	39	34	37	39	41	39

Source: Mori (1991).

Table 2.6 Application distribution of IR (per cent)

Application	Japan (1982-1985)	UK (1985)	FRG (1985)	Italy (1984)	Belgium (1984)	Spain (1985)
Welding (Spot)	9.2	16.9	29.0	28.0	60.0	50.2
Welding (Arc)	13.9	13.6	20.2	10.8	7.3	13.3
Assembly	39.9	9.7	8.6	11.8	0.5	6.4
Loading/Unloading	6.3	9.5	9.2	26.5	8.4	15.4
Painting	2.2	6.4	8.8	8.9		6.8
Injection molding	13.9	18.3				
Inspection/Test	1.2	1.9		1.2		2.1
Others	13.9	23.7	24.2	12.8	23.8	5.8
(Educational, etc.)		(5.5)	(2.4)		(11.4)	

Source: Tani (1991).

Tani notes:

"Japan has a much higher share of assembly robots compared with other countries. In Japan this share was about 40 per cent from 1982 to 1985, while it was only about 10 per cent in other countries. The Japanese lead in introducing assembly robots largely explains the Japanese lead in IR penetration overall. Most assembly robots are used in the electrical machinery industry (including the electronics industry) in Japan. However, this is slightly misleading, because robot assembly is most advanced in the camera, watch, and consumer electronics manufacturing subsectors. Japan's absolute level is more than 20 times higher than any other country".[26]

Although assembly robots are relatively rare in other OECD countries there are growing numbers of applications. For example[27] of a total population of 17,700 IRs in Germany (FRG pre-unification) in 1988, 3,370 (19 per cent) were for assembly purposes. This trend is very important since in many manufacturing processes, assembly represents between 40 and 60 per cent of manufacturing costs.

It has been found that in many sectors assembly has become an automation "bottleneck", with up to 60 per cent of inventory costs in the assembly area.[28]

It has also been noted that at Hitachi's VCR plant in 1981, that:

"The product consisted of 460 discrete mechanical, electrical, and electronic parts. Electronics assembly was fully automated, but the remaining mechanical and electrical parts were assembled by hand. The 1983 design had 370 parts which were assembled by a combination of 11 SCARA robots, 52 special-purpose (pick-and-place) machines, and 9 workers. The 1985 model had just 250 parts, and was assembled by 24 robots and 71 special-purpose machines. As a result the number of operations automated has increased from 86 per cent to 98 per cent".

Table 2.7 Proportion of robots used for assembly

	1980	1983	1987
FRG	4	5	16
Italy	n.a.	12	15
France	n.a.	7	12
UK	1	6	10
US	1	4	14
Japan	7	15	26

Source: Tidd (1991).

[26] Tani, 1991.

[27] Fink and Warnecke, 1991.

[28] Tidd, 1991.

In general there is a trend away from volume of applications to variety, with much of the new growth coming in new application areas, including some in non-manufacturing areas such as construction.

There has also been a discernible trend towards use by smaller firms, especially for complex applications which exploit the flexibility rather than the labour-saving potential of robotics. Table 2.8 lists the latest available data on IR installations.

Recently, much more information about the former USSR and Eastern European experience with mechatronics has become available. Measured by diffusion statistics alone things appear to be moving, with significant levels of application of these key technologies (Table 2.8). But closer inspection reveals a serious problem of under-utilization.[29] This has been attributed to a system which has been inflexible, engineering-driven and dominated by a "command economy" in which there is little customer orientation or feedback. This creates an environment in which the dominant manufacturing strategy increasingly emphasizes price rather

Table 2.8 Robot population in selected countries

Country or area	Robot* numbers	
	1981	1988
Japan	21000	176000
USA	6000	32600
EC	4600	43000
of which		
GFR	2300	17700
UK	713	5034
Italy	450	8300
France	790	8026
Netherlands	NA	845
Denmark	51	349
Belgium	242	1231
Spain	NA	1382
Sweden	1125	3042
Finland	35	545
USSR	NA	59218
Hungary	NA	89
Czechoslovakia	NA	5961
Total	32,760	363,322

NA = Not available.
* Reprogrammable robots only.
Source: ECE Annual Review of Engineering Industries and Automation, Geneva (1990).

[29] Baranson, 1987.

than non-price competition. The relevance of this to the strategies in the case study African countries, and discuss these issues further later in the report.[30]

In the former USSR, it was reported that "no less than a third of the 50,000 industrial robots produced between 1981 and 1985 had not performed even one hour's work. A sample inspection made by the People's Control Committee of the USSR in 1985 showed that the annual return on introducing 600 robots, at a cost of more than 10 million roubles, was a mere 18,000 roubles".[31]

Similar problems may face the developing countries should they fail to recognize the fact that the introduction of new technologies - while being a prerequisite of advancing their productive capacities - is not a guarantee of successful use. There are many instances of the installation of modern technologies and factories being underutilized because of problems associated with logistical deficiencies, educational and skills problems, and spare parts unavailability.

Trends in the use of robotics technology are towards increasing diffusion across sectors, firm sizes and applications, with, as noted earlier, assembly automation set to become a much larger user in the medium-term future. Indeed, since the development of the SCARA (Selective Compliance Assembly Robot Arm) robots in Japan for general purpose assembly tasks this area has experienced the most rapid growth, both in Japan and in other countries. Future diffusion to other sectors and to smaller firms will depend critically on improvement in the flexibility of robots - since this will increasingly enable them to be cost-justified on the basis of factors other than labour cost. This progress is primarily limited by technological factors; robots remain, at present, relatively unintelligent and insensitive tools which are not yet capable of the necessary judgement and adaptation for carrying out most tasks in manufacturing; and this is particularly a problem in clothing where the characteristics of the materials present major problems for robotics.

- Amongst key technological developments currently being explored are:
- direct drive robots, in which motors are directly connected to arm joints rather than via gears and transmissions
- advanced sensors, especially in image processing for vision systems
- improved, more sensitive grippers
- artificial intelligence based programming so that robots can "learn" from their own mistakes.

R&D is going on in all of these areas and several expensive and dedicated applications already exist. The real challenge is to create a "second-generation" of general purpose robots with these characteristics; if and when this emerges, the diffusion of robotics is likely to broaden considerably.

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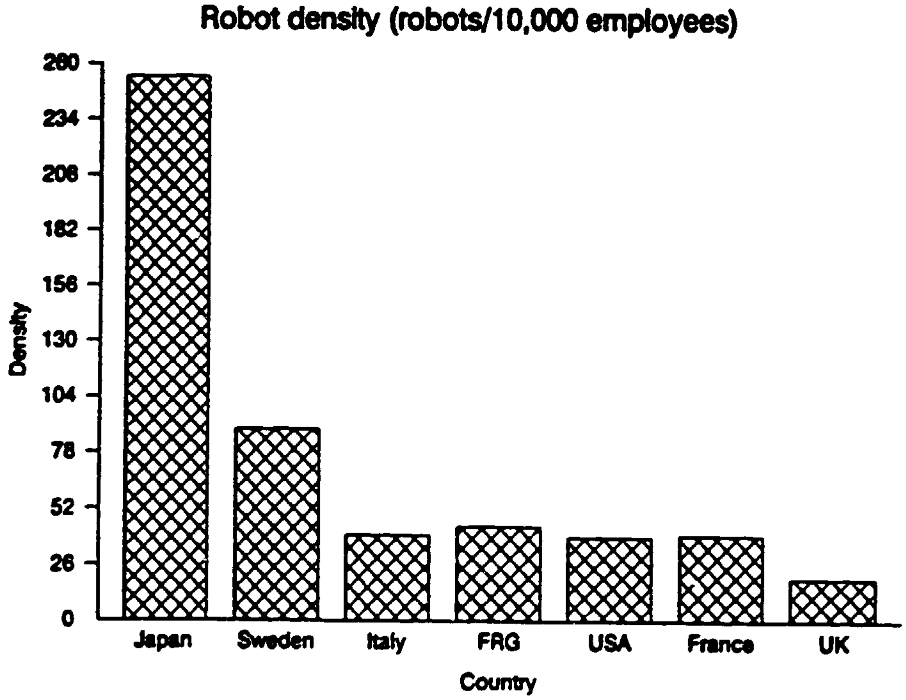
[30] Tidd, 1991.

[31] Glaziev, 1990.

As Figure 2.1 below indicates robot density per employee in a selected number of OECD countries is now quite high, with almost 260 IRs per 10,000 employees in Japan, and almost 90 in Sweden.

Some EC countries are clearly in a strong position to exploit flexible automation technologies, for example, Germany now has a relatively high rate of use of FMS, robotics, etc, and can build upon its position of strength as a specialist machine builder. Its ability to develop alternative working practices and obtain higher levels of responsiveness and flexibility will depend less on the question of skills availability - with around 70 per cent of the workforce possessing some vocational qualification Germany is well-endowed and the reunification with East Germany will swell still further the labour supply in skilled personnel - than on managerial attitudes towards changing working practices.

Figure 2.1 Intensity of robot use 1987.



Source: Tidd (1991).

2.3 Forecasts of Diffusion

A variety of attempts to forecast the diffusion of robots, using different criteria, have been carried out since the late 1970s. Miller summarizes these in Table 2.9.

By reference to Table 2.8 above, a total of 32,600 robots had been installed in the US by 1988. Assuming a growth rate of 20 per cent per annum for 1989 and 1990, one would assume a population of approximately 47,000 robots by the beginning of 1991. At this level the medium estimates of the earliest forecast, the Eikonix (1979) one, is the most accurate. The high forecasts of almost all the forecasters has been far higher than the actually achieved levels with even the nearest, the UM/SME Delphi forecast of 1985, being nearly 30 per cent too high.

However, this latter forecast covered a much smaller range of estimates - from a low of 30,000 to a high of 60,000, and might be considered the most realistic.

Table 2.9 ***Comparison of the Hunt and Hunt forecast with other forecasts of the 1990 robot population in the US***

	Low	Medium	High
Eikonix (1979)[a]	24500	48000	209000
Robot Institute of America (1981)[b]	75000		100000
UM/SME Delphi (1982)[c]			150000
Hunt and Hunt (1983)[b]	50000		100000
Tech Tran (1983)[c]			69000
Leontief and Duchin (1984)[d]	22000	69000	127000
UM/SME Delphi (1985)[e]	30000	40000	60000

[a] Eikonix, 1979:236-238.

[b] As reported in Hunt and Hunt, 1983:34.

[c] Tech Tran Corporation, 183:21; only a point estimate is given.

[d] Leontief and Duchin, 1984:1.23.

[e] Smith and Heytler, 1985:167. The medium value is the median response. The low and high values are the interquartile ranges (the middle 50 percent of the response distribution).

Source: Miller (1990).

Given the Hunt & Hunt reservations about the barriers to robots noted below (Section 2.4), even they have probably overestimated installations somewhat, though they are very close to the actual installations with their lower estimate.

A recent estimate of the potential diffusion of IRs[32] has suggested that on a basis of one robot for every two workers in the semiskilled operative categories, there may be a market of three to four million robots in the USA alone, and up to fifteen million worldwide. However, this is presented as a maximum penetration level and unlikely to be realized.

Another estimate[33] suggests a saturation level of only 400,000 robots for the USA (excluding manual manipulators and fixed sequence robots), 500,000 for Japan, 190,000 for Germany, and 90,000 for the UK (see Table 2.10) by the year 2010.

[32] Ayres, 1991.

[33] Tchijov, 1991b.

Table 2.10 Forecasts of IR diffusion - 2010 (in thousands)

Industries	Japan	USA	Germany	UK
Final Metal Products (SIC 34)	15.0	20.0	15.2	5.4
Non-Electrical Machinery (SIC 35)	50.0	48.0	32.3	9.9
Electrical Machinery (SIC 36)	185.0	136.0	38.0	15.3
Transport Equipment (SIC 37)	100.0	88.0	57.0	29.7
Other Manufacturing	110.0	108.0	47.5	29.7
Total	500.0*	400.0	190.0	90.0

* Japanese figures of 40,000 applications for the instruments sector (SIC 38) needs to be added to reach 500,000 units.
Source: Derived from Tchijov (1991).

Since these countries collectively account for a considerable number of IR installations it is unlikely that the penetration levels will reach even half of the Ayres figure of fifteen million. As Table 2.8 indicated, even including Japan, the US, most of the EEC countries and several East European countries, a figure of only 363,322 robots existed in 1988.

Taking a sample of five countries, it is also clear that considerable disparity exists with regard to the industries within which IRs are used. Table 2.11 indicates the importance of the automobile industry for robotics in Spain, Belgium and Italy. This is also true for the UK - to a lesser extent - though the dispersion across industries is considerably wider.

The importance of the electrical electronic sector in Japan is a reflection of the high degree of assembly robotics in that country.

Table 2.11 Industrial distribution of IR (%)

Sector	Japan (1985)	UK (1985)	Spain (1985)	Belgium (1984)	Italy (1984)
Automotive	24.4	34.3	72.3	66.9	48.9
Electric/electronics	33.9	11.5	1.9	1.7	9.4
Mechanical engineering	18.2	16.3	11.4	11.9	24.1
Plastics	16.7	17.3	0.0	2.1	1.9
Others	6.8	20.6	14.4	17.4	15.7

Source: Tchijov (1991).

2.4 Problems and Potential of Robots

A number of factors have been identified[34] that might impede the rapid assimilation of robots, in the US in particular, and world-wide in general.

[34] Hunt and Hunt, 1983.

(1) the lack of trained personnel both to implement robotic technology and to maintzin and support that technology once installed;
(2) the large financial commitment necessary to implement robotics;
(3) the extensive management commitment needed to adopt robots successfully;
(4) general economic conditions, which will result in incremental and gradual investment;
(5) the unlikelihood of a much more rapid diffusion of robot technology than in earlier process technologies;
(6) the limited diffusion of robotic technology to large firms, perhaps just Fortune 500 firms, for the foreseeable future.

Since this assessment is largely concerned with the USA, it might be expected that the obstacles in developing countries would be even greater.

In analysis of future problems associated with robot penetration by industrial sector (Table 2.12) price has been identified as an important or very important factor - except for the textiles industry.[35] The most important barrier to the use of robots in textiles was associated with vision systems for pattern recognition. This latter failing in robotics was the second most important barrier to use overall.

Table 2.12 Future problems of industrial robot penetration by industry sector.

Industry sector	speed	precision	degree of freedom	sophisticated control	weight of robot	heavy load handling	pattern recognition	size	reliability	cleanness	price
food	○			○			○				●
textile				○			●			○	
wood & wood products											●
pulp & paper	○		○			○	○		○		○
chemical products				●			●				●
oil & coal products	●			○			○		○		○
rubber products							○		●		○
cement & clay		○		○			○		○		○
iron & steel	○	○		○		○	○				●
non-ferrous metals				●			○				●
metal products		○		○			○		○		●
general machinery		○		○		○	●				●
electric machinery				○			●				●
automobile	○	○		○							●
other transportation				○			○				●
precision machinery	○			○			○				●
plastic products							○				●
others	○						●		○		●

● very important
○ important

Source: JIRA (1988)

[35] Mori, 1991.

Another barrier, as a consequence of the cost problem, is the sheer volume of purchases necessary in order to reduce the unit costs of robots. Using a $60,000 priced robot as an example, the installation of one robot is roughly double that of the unit cost obtained from the purchase of 30, as Table 2.13 illustrates.[36]

The consequences of this are, of course, that the adoption of robots will be a function of the size and scale of the user, i.e., that companies with large volumes of investment capital and employing considerable numbers of people are the ones likely to invest in IRs. Developing countries, in general, do not have many companies operating on this scale. Even in the developed countries e.g. between Europe and the USA, and Japan, and one classification of the difference is reproduced in Table 2.14. While it might not be universally accepted it is useful in indicating the possible range of emphasis in automation strategies.

Table 2.13 ***Total and average cost of $60,000-base-price robot, assuming development cost decreases with multiple applications (in thousands of dollars)***

	a = 5%		a = 10%	
Number of robots	**Total cost**[a]	**Average cost per robot**	**Total cost**[a]	**Average cost per robot**
1	240	240	240	240
15	2,832	189	2,329	155
30	4,627	154	3,523	117

[a] Total cost of installing *n* robots is approximated by

$$I_n = nR + D\sum_{i=0}^{n-1}(1-a)^i = nR + D\left(\frac{1-(1-a)^n}{a}\right)$$

where

I_n	=	total cost of installing robots
R	=	robot base price
D	=	development cost for first installation
a	=	constant percentage of decrease in development portion of total cost for each successive installation

Key assumption: The development cost for each successive application of a *similar* installation decreases by a constant percent (given by the parameter a).

Source: Miller (1989).

[36] Miller, 1989.

Table 2.14 Factors influencing the development and adoption of flexible manufacturing technologies in Japan and the West

	Europe and US	Japan
Organizational context	Poorly trained, low-skilled operators; little communication between design, manufacturing, and sales functions; distant relationship with suppliers and customers; 'robust' production systems	Highly trained, multi-skilled operators; good communication between design, manufacturing, and sales functions; close relationship between suppliers and customers; 'lean' production systems
Source of most significant developments	Specialist suppliers, essentially 'technology push'	Major users, essentially 'demand pull'
Primary motives for development and adoption	To increase productivity and improve quality through the elimination of direct labour	To improve flexibility of production but continue to reduce costs through the elimination of waste
Technological trajectory pursued	Complex, sophisticated technology consistent with long-term goal of CIM; essentially a 'computer systems' approach	Relatively simple, proven technology with continued reliance on operators; essentially a 'production engineering' approach
Manufacturing strategy	Reduction in diversity of production to facilitate further automation and computer integration	Flexible, but low-cost production

Source: Tidd (1991).

2.5 The Benefits of Robotics

Some estimates of increases in available production time resulting from factory changes - though this is *not* a consequence of robots alone, and includes other technological and organizational factors[37] are given in Table 2.15.

Table 2.15 Potential percentage increases in available production time

	Increase in utilization of days plant is closed	Increase in utilization of unscheduled production time	Total percentage increase in output
High volume	28	3	31
Low volume (two-shift operation)	74	43	117
Medium volume	83	115	198
Low volume (one-shift operation)	148	187	335

Source: Miller (1989).

[37] Miller, 1989.

Another estimate of savings from the point of view of different factors is given in Table 2.16.

Table 2.16 Breakdown of estimated percentage of total savings from robot use represented by direct labour cost, product quality, and other factors for 1985 and 1995

	Estimates for 1985			Estimates for 1995		
Application	Direct labour productivity	Product quality	Others factors*	Direct labour productivity	Product quality	Others factors*
Machine tending	93	6	1	74	15	11
Material transfer	56	6	38	55	12	33
Spot welding	50	32	18	60	18	22
Arc welding	62	15	23	54	27	19
Spray painting	40	34	26	34	28	38
Processing	50	18	32	50	21	29
Electronics assembly	38	38	24	41	32	27
Other assembly	41	26	33	47	13	40
Inspection	55	36	9	56	38	16

* Includes savings as a result of improvement in indirect labour productivity, reductions in energy and floor space requirements, material waste, inventory, and worker safety-related costs, a simplification of management, and improvement of other factors not specified.

Source: Smith and Heytler (1985), given in Miller (1989).

In terms of individual company improvements resulting from IR applications, in Italy, the Fiat plant at Termoli introduced a Fully Integrated Robotized Engine (Fire) assembly system which is alleged to have automated 90 per cent of production and employs 56 robots together with 92 programmable handlers. Taking the experiment further, Fiat now has about 25 per cent of final assembly at Cassino automated using over 400 robots, together with a labour force of around 7,000.

In Germany, Volkswagen have automated approximately 30 per cent of final assembly at Wolfsburg; while at Emden a labour force of 10,000 people uses over 500 robots to assemble a wide variety of versions of the Golf and Passat cars.

In the UK, the benefits claimed for robots have largely centered on increased productivity and improved quality. (Table 2.17)

It is notable that one of the early claims for robots, i.e., increased flexibility of production, has not been experienced in practice in the UK.

In Japan, the diversity of products, and improvement in the working environment were considered to be very important across a wide range of industrial sectors. Similarly, improved capacity utilization rates and financial circumstances were considered important results of the use of robotics. (Table 2.18).

Table 2.17 Benefits claimed by users of robotic assembly in the UK

	%Plants with benefit		
	None	Some	Great
Increased productivity	12	44	44
Better quality	16	37	47
Improved Process control	50	34	16
Better use of materials/less scrap	41	47	12
Greater flexibility for volume change	56	28	16
Less work in progress/inventory	66	12	22
Greater flexibility for product change	66	22	12
Reduced lead time	66	25	9

Source: Tidd (1988).

Table 2.18 Incentive for robot implementation; by industry sector in Japan

Industry sector	diversification of products	flexibility of process line	capacity utilization rate up	quality & yield rate up	better finance circumstance	working env. improvement	less available workers	more safety in factory	young workers less available	skilled workers less available	energy and resource saving	others
food	A				B	C						
textile	A		B			C			C			
wood & wood products					B	B				A		
pulp & paper	A		C		B							
chemical products	B				C	A						
oil & coal products					B	A		C				
rubber products	A		A	A		A						
cement & clay	A				B	B						
iron & steel			B			A		C				
non-ferrous metals	A		A			A						
metal products			B		B	A						
general machinery			A		B	C						
electric machinery	A	B	C									
automobile	A	B	C									
other transportation	C		A			B				C		
precision machinery	B		A		C							
plastic products			A	C	A							
others	A		C		B							

A: very important
B: important
C: rather important

Source: JIRA (1988)

"The key feature is that the use of robots, in conjunction with other types of automation (e.g., CAM systems), makes it possible to increase the capacity of the factory substantially without proportionately increasing labour and capital inputs. As a result, the average cost per unit decreases as the quantity of output increases. The primary reason for the increase in capacity is that the reorganized factory is more fully utilized than a conventional facility. It is designed to stay in operation around the clock for the whole year. In contrast, many conventionally organized batch production factories do not operate on weekends or holidays, and they may also close down during parts of the days they are scheduled for operation. The secondary reason for the increase in capacity is that the throughput rates are higher in the reorganized factory than in the conventional one as a result of robots operating more continuously and stricter control over operating conditions".[38]

Other analysis of the international diffusion of IRs has been summarized in six conclusions as follows.

- Differences amounting to a factor of more than five in IR penetration are not only observed at present, but also existed ten years ago between the leading country (Japan) and other major countries.

- The penetration trend curves show a very similar pattern among the countries studied, including Japan.

- The differences of IR penetration can be expressed by introducing a time lag for each country. The time lags behind Japan for the USA and the major European countries range between 4.4 and 7.8 years.

- The application distribution of IR is different between Japan and the other countries. Assembly robots prevail in Japan, while welding robots are still dominant in other countries.

- The industrial distribution of IR, as well as their application, is also different between these countries: they are mainly applied in the electrical/electronics industry in Japan, and in the automotive industry in the other countries.

- Industrial robots have so far been used mainly for welding in the automotive industry and for assembly in the electrical/electronics industry. These applications and sectoral distributions are strongly correlated."

2.6 Industrial Robots: A Brief Summary

Robots have developed quite considerably over the years but are still relatively inefficient and expensive for the modes and scales of production carried out in many developing countries, including most African countries. There is also a need for considerable computational power to drive the technology at present.

Of the types of robot available, the Jointed Arm and SCARA are the most popular with the latter being more versatile than the Cartesian robots but cheaper and less sophisticated than articulated configurations like the PUMA. One consequence is that the SCARA robot can be used in around 80 per cent of all assembly work.

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[38] Miller, 1989.

Assembly robots, of course, are likely to prove invaluable to developed countries in the longer term since assembly can usually result in 40/60 per cent of final product costs. Assembly robots are very widely diffused in Japan – particularly in electronics – and are also increasingly important in Germany. We should also note that of the many developed countries using robots it is the structure of their industrial sectors which has been the driving force, e.g., automobiles, electrical/ electronic, mechanical engineering, plastics, etc. These are not in general strong in developing countries at present.

There are several areas which have proven to be inhibitors of the diffusion of robotics even in developed countries. These include:

- shortages of trained personnel to maintain or support the technology;
- the general economic conditions;
- only large firms can afford multi-purchases thus justifying robots economically.[39]

Successful applications have usually been in such industries or large companies, e.g., Ford, Volkswagen and Fiat. What is perhaps more important is that these have been utilized in the context of broader changes in production, for example, in conjunction with CAD and FMS.

Given the forms of production most African countries possess, and their surplus of low cost labour, robots are not amongst the most useful forms of automation which could be applicable, and this is unlikely to change in the short-term.

However, robots can be fairly extensively utilized even in the NICs, and as industrial development grows, and the technology reaches a more mature state, robotics use may increase providing the industrial structure (i.e. the size of companies and the sectors they operate within) allows for this.

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[39] Hunt and Hunt, 1983.

3. Computer Aided Design (CAD)

CAD systems can be based on various computer configurations, from large, expensive and sophisticated mainframe computers costing US$ 1 million or more, through minicomputers costing approximately US$ 100,000 to simple personal computers (PCs) costing as little as US$ 5,000, Edquist & Jacobsson (1988). The capability of such systems does, of course, vary tremendously but as the technology evolves and costs reduce per unit of computing power, the PCs gain in application and popularity.

The growth in efficiency has been outstanding.

> "Today we find PCs priced in the $5,000 range performing 5 to 10 millions of instructions per second (MIPS) at the low end of the spectrum. These are PCs with 80386 or 80486 microprocessors that can run most two-dimensional CAD applications. They can, for example, perform limited schematic capture, circuit layout, routing, simulation, and analysis, with a response time much better than that of the time-sharing environment of minicomputers. Programs for these functions are selling from $100 to $5,000 each.
>
> Dramatically improved performances have recently been experienced in 32-bit microprocessor-based RISC-architecture work stations, first introduced in 1987 by, for example, Sun Microsystems, Hewlett-Packard, and Intergraph.[40]
>
> These work stations perform from 5 to 50 MIPS. The price of these work stations ranged between $40,000 and $100,000 at their time of introduction and now between $5,000 and $50,000. In comparison a $100,000 VAX 11/780 minicomputer had a peak performance of 1 MIPS in 1977. An important feature of these work stations is the dedicated graphics processor with burnt-in graphics algorithms, so-called 3-D CAD accelerators".[41]

The shift to PC based systems is clear.

> "Users are finding that "personal computer-based systems often give them 70 per cent of the benefits for 20 per cent of the cost ...". This is reason enough for an explosive acceptance by the market. As a matter of fact, a whole new market segment has emerged. With an estimated 42,000 units installed globally at the end of March 1985, it is believed that already more than one-third of all CAD seats are based on PCs. The move to personal computers is expected to accelerate quickly now that more powerful machines with better displays are in the process of introduction. By 1990 "personal computer power will have increased so much that more than nine of every 10 CAD/CAM, CAE seats will use a personal or desktop computer".[42]

CAD systems in the garment industry share certain common characteristics.

> "Although available CAD systems differ in their hardware configuration, all computer graders and marker makers include a *digitizer* for converting the basic pattern configuration into computer language, a *minicomputer* for storing information and controlling equipment, a *graphic display unit* for visual monitoring and pattern checks, and a *high speed plotter* for

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[40] Mokhoff, 1987a, 1987b.

[41] Astebro, 1991b.

[42] Design Graphics World, 1985.

drawing accurate full-size production markers. The basic applications software is sold as part of the system with no breakdown between hardware and software costs".[43]

3.1 CADs Integrative Bias

Computer aided design itself is a relatively new technology, it being the late 1960s before integrated systems were evolved. However, at this stage the systems were expensive and not extensively distributed, and it was not until some fifteen years later that growth in installations really took off. In part this was as a consequence of the growing computing power and diffusion of the personal computer - as noted above - and expansion of the mainframe computer sector.

> "Original CAD approaches allowed computer-based entry, manipulation and storage of symbols. They were primarily useful for graphic or topological representation.
>
> The new CAD technology captures and keeps track of the substantive information the symbols represent. It makes possible significant analysis of engineering designs which was not previously possible, and it creates an engineering database. In other words, the technology of the 1970s helped draw diagrams; that of the 1980s designs and analyses systems".[44]

The spread of CAD involves a movement towards the integration of processes or a "systemofacture" rather than the traditional "machinofacture" of previous eras. This point has already been emphasized in Chapter 1. The integrative nature is summarized in the following comment:

> "The integration concept will see to it that formerly discrete approaches now converge under one system - and this convergence goes well beyond classical design references. It includes bills of materials, quality control aspects, integration with manufacturing (particularly robotics) and the ability to follow up product reliability at the end-user site.
>
> The greater the competitive pressure to design new products rapidly, and the quicker the old ones become obsolete, the greater the need for computer-based approaches. This leads to more rapid adoption of CAD in consumer electronics, architectural design and service oriented companies than in older businesses less subject to product and process evolution. Yet these, too, can be revitalized through newer, more competitive CAD-assisted products".[45]

3.2 The Diffusion of CAD

It is clear that CAD has now become a widely diffused technology - especially in the developed economies - and the range of capabilities has broadened considerably.[46] It has been calculated that by 1986 over 300,000 CAD seats were in operation in 21 countries (see Table 3.1) though clearly the 12 Western developed countries listed accounted for about 98 per cent of these installations. The three East European countries accounted for about a third of

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[43] Hoffman and Rush, 1988.

[44] Chorafas, 1987.

[45] Chorafas, 1987.

[46] Astebro, 1990.

one per cent; Latin American countries for about one tenth of one per cent; and Korea, India, Singapore and Taiwan collectively, for only a fraction over one per cent.

Table 3.1 The diffusion of CAD in 21 countries and the world

Year	USA	UK	FRG	France	Italy	Japan	Yugosl.	Sweden	Republic of Korea	India
1976						160				
1977					120	150				
1978					170	320				
1979	7,150				260	730		240		
1980	9,900		400		410	1,120		360	20	
1981	14,000	1,660	1,230		580	1,530		550	40	
1982	35,800	4,000	1,500	2,250	800	2,900		820	80	
1983	44,100	10,000	11,000	10,000	890	5,300	100	1,340	130	100
1984	54,400	13,000	16,000	12,000	1,000	9,100	130	2,200	250	200
1985	132,200	17,000	21,000	14,000	1,500	10,400	250	3,620	430	390
1986	210,000	23,000	26,000	16,000				5,880	740	770
1987		31,000								
1988		56,000								

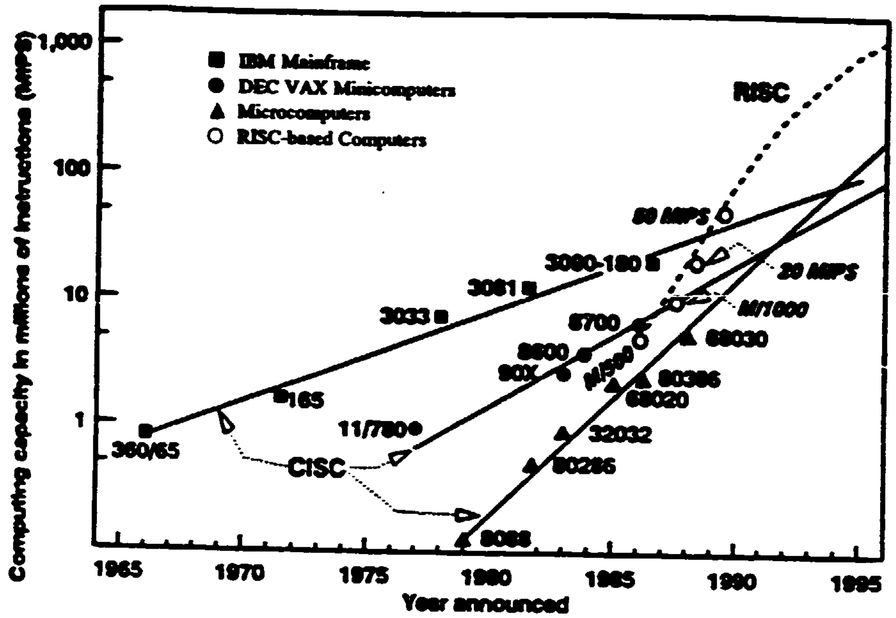
Year	Arg.	Brazil	Norw.	Singa.	Finl.	Denm.	Icel.	Bulg.	USSR	Taiw	Canad	World
1976												4,000
1977												5,200
1978												6,900
1979												9,000
1980												17,600
1981										190		28,800
1982	40	60	280							350		47,000
1983	70	110	360					0		650	2,000	60,000
1984	90	190	450	200				60				76,000
1985	190	340	900	290	630	750	20	120	770	1,300	5,000	211,100
1986					1,260	1,260	30	170	1,000			303,000
1987								230	2,300			
1988								290			10,000	

Source: Astebro (1991a).

If Astebro's data is correct (Astebro, 1991), and there is no reason to suspect it is not, explosive growth in the number of CAD seats in place has occurred in the mid 1980s with spectacular annual growth, leading to a US capacity of some 500,000 seats and a worldwide

61 per cent in 1985. The increased computing power since the mid-1960s is clearly illustrated by reference to Figure 3.1.

Figure 3.1 The performance of different computers, 1965-1995



Source: Electronic Design, Jan 7, 1988.

In a personal communication with Joe Off (Managing Director of Textile/ Clothing Technology Corporation [T.C]^2 of North Carolina) he notes that textiles and clothing application software packages on their own now cost as little as $6,000, and he understands that there is another package on the market for as little as $3,800. He comments that there are now many small companies who can use CAD systems who could not do so in the past.

He further states that:

> "As far as foreign use of CAD systems in Africa, Asia, and Latin America, the latest I have heard is that the Mattel toy company is installing many automated cutting systems in Indonesia in very remote locations. These will be fed CAD data by electronic data interchange (EDI) sent from the United States directly to the cutting room in these remote locations".

Another [T.C]^2 expert was able to write, in 1988, that CAD systems in the garment industry could now be obtained for $40,000 which embodied all hardware and software costs, such as, computer equipment, monitors, digitizer and plotter; with the software containing programmes for pattern design, pattern digitizing, marker making and full scale marker plotting. He further noted that:

> "Introduced for the first time was an Apple-MacIntosh based marker making system. Fully utilizing the 32-bit architecture of the Mac, this system demonstrated icon-driven user interfaces to pattern design, garment design, specification sheets, cost sheets, marker making, automatic marker making utilizing artificial intelligence, output to almost any plotter, and textile design and data management. Optical disk mass storage capabilities

allow for a vast number of markers and designs to be stored and accessed via the relational database.

Another first for the marker making arena was the introduction this year of a new system running on the PC micro-computer technology operating under Microsoft Windows. Windows is a multi-tasking environment for the IBM PC and clones. This allows for more than one program to be running at the same time, generally allowing for increased speed. Anyone accustomed to the Microsoft environment won't have any trouble using these systems. Probably the most striking difference in this system is its software price tag of $3,375. That is, manufacturers may purchase the software only if they already have hardware or wish to purchase the hardware from their local vendor. In addition, a Developer's Tool Kit is available to enable customization of the program to meet specific needs.

These low-price systems are obviously targeted to bring the smaller companies into the computer marking age. With a bit of ingenuity at work, any company can have complete marking, grading and plotting including hardware for under $15,000. In some cases, only a 36" width plotter is available at such a low system price. However, this may be perfectly applicable to some companies since 72" makers can be plotted by plotting the left side first and then the right. Wider plotters are also available".[47]

3.3 Problems to Solve

Such incremental improvements in the effectiveness of the technology are apparent and will clearly be continued in the future. In a Delphi type study carried out by Ranta and Ebel, and utilizing data from the Office of Technology Assessment in Washington, they found that many of the key problems currently associated with CAD usage would be resolved in the next ten years - as Figure 3.2 indicates.

3.4 CAD's Economic Viability

The question then becomes one of whether CAD technology is economically viable, and whether improvements in productivity match expectations. Clearly in the early stages of diffusion of technology there may be some element of experimentation and learning about the opportunities afforded by any technology. However, CAD has now gone through a period of approximately 25 years of development and its potential is now quite well understood in the developed countries. A few examples of the use of the technology give us some idea of how effective it is.

One Swedish company (ASEA) adopted CAD for transformer design in the mid 1970s. Design times for some of these transformer variations was said to have declined from 3000 hours using traditional design methods, to 40 hours utilizing CAD.[48] Other researchers,[49] have remarked on productivity increases ranging from 2.74 to 1, to 20 to 1, depending on the

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[47] Adams, 1988.

[48] Kjellborg, 1986.

[49] Arnold (1984), Senker (1982) and Kaplinsky (1983).

Figure 3.2 Key problems of CAD

	Before 1987	1987-1990	1991-2000	2001 and beyond
Hardware				
1. High resolution, color display of designs, with rapid generations of images	◇ ○	■	□	
Both hardware and software				
2. Low-cost, powerful microcomputer-based work stations for:				
a) electronics design	◆ ● ◇	○ ■ □		
b) mechanical design	◆ ◇	● ○	□ ■	
3. Independent CAD work stations linked by network, with access to super-computer for powerful analysis and simulation	◆ ◇	■ ○	□	
Software				
4. Three-dimensional solid modeling systems, resulting in:				
a) more realistic images	◆ ● ◇	■ ○	□	
b) enhanced ability to connect with manufacturing equipment	◆ ◇	● ○	■ ○	
5. Comprehensive, powerful computer aided engineering systems for mechanical design		◆	●	■
6. Extensive design/manufacturing integration	◆ ◇	●	○ ■ □	

◆ ◇ Solution in laboratories.

● ○ First commercial applications.

■ □ Solution widely and easily available (requiring minimal custom engineering for each application).
Solid symbols (◆ ● ■): OTA, 1984. Open symbols (◇ ○ □): IIASA, 1988.

Source: Ranta & Ebel. Vol. II.

Table 3.2 ***Developed country imports of manufactures from developing countries in relation to design and draughting intensity***

	Value $ million				Rankings (N = 15)		
	1970	1978	Growth 1978/1970	Value (1978)	Growth	Drafting intensity	Design intensity
Major traditional manufactures							
Semi-finished textiles	1,815	9,615	5.3	1	13	11	11
Clothing	1,181	9,502	8.1	2	10	12	14
Shoes	151	2,033	13.5	7	6	14	13
Major higher-technology manufactures							
Chemicals	588	2,282	3.9	5	15	9	6
Metals and metal products	319	2,223	7.0	6	12	10	9
Machinery except electrical and business	81	1,136	14.0	8	5	4	3
Electrical machinery	372	4,4[illegible]3	12.0	3	7	1	1
Business machines	81	600	7.4	12	11	2	5
Scientific instruments	24	359	15.0	13	3	3	4
Motor vehicles	23	603	26.2	11	2	8	10
Aircraft	18	737	40.9	10	1	6	2
Shipbuilding	40	355	8.9	14	9	5	8
Consumer electronics	214	2,391	11.2	4	8	*	*
Total other manufactures	401	2,922	7.3				
Total major traditional manufactures	3,330	22,095	6.6				
Total major higher technology manufactures	1,762	15,178	8.6				
Total manufactures	5,493	40,195	7.3				

Source: Kaplinsky (1982).

environment and type of products; while improvements of up to 100 to 1 in labour saving associated with modifications to existing designs have also been cited.[50]

Furthermore, they indicate that savings in fabric usage resulting from the use of CAD averaged 4-6 per cent in companies interviewed by them - with one company achieving a 9 per cent saving. All the companies were satisfied that the material savings alone were sufficient to justify the CAD investment. This is not too surprising a result since fabric costs averaged between 40 and 60 per cent of total costs for these companies, and almost all of them had annual fabric costs of between $10 million and $200 million.[51]

What are the implications of CAD for developing countries? Given the rapid diffusion of CAD post-1982 in the developed world, it appears that although developing countries have started to adopt CAD - and as seen in Table 3.1 Brazil, Argentina and Taiwan have higher growth rates than many developed countries - the volume of installed systems in the developed countries is dramatically higher.

This may have profound impacts when relating CAD technology in the OECD countries, with the manufactured products of the less developed. Using 1970s US data which now clearly understates the adoption of CAD in the OECD countries, it has been shown that CAD was diffusing in exactly those product areas where exports were high in the 1970s, and in which the less developed countries were likely to specialize in the 1980s.[52]

It has also been noted that:

> "Given the very significant gains in labour productivity and lead time which the use of CAD confers, unequal diffusion between developed and developing countries could erode the international competitive advantage of Third World firms operating in markets where their competitors are using the systems".[53]

3.5 The Infrastructure

> "The developed countries face an extremely broad policy agenda as a result of the pervasive character of the technology and the complex economic and social changes that will accompany its diffusion. These changes are occurring so rapidly that it is imperative that policy makers in those countries formulate a comprehensive set of policies that deal with both the short and the long-term problems.
>
> From the perspective of the developing countries one could argue that the technology's effects will be equally pervasive and that these countries too must develop comprehensive policies. Indeed, a number of analysts and institutions such as UNIDO have been propounding such a view and urging the formulation of national "informatics" policies as a main priority for the Third World (IBI, 1980; Nolan, 1983). There can be little doubt that the technical, economic and social changes associated with this technology will profoundly alter the global context within which the Third World pursues development in the future.

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[50] Hoffman & Rush, 1988.

[51] Hoffman and Rush, 1988.

[52] Kaplinsky, 1982.

[53] Hoffman and Rush, 1988.

Policy-makers must become well informed about the nature of these changes so that they can respond in a reasoned manner: and this should ideally be done on the basis of a comprehensive policy framework".[54]

This becomes increasingly obvious when we see that the infrastructure within which such a technology as CAD is implemented, and the relationships between this and its successful use. In the work of Astebro reported earlier, a strong positive relationship was found between the level of research and development (R&D) activity in a country (r = 0.78), labour costs (r = 0.77), a good educational framework (r = 0.71) and the availability of a strong CAD supplier presence in the country (r = 0.70), related to successful adoption of CAD. The labour/capital ratio was a lesser though important factor too (r = 0.54) (see Table 3.3).

Table 3.3 *Correlation matrix and number of observations in parentheses*

	LAB/ CAP	LAB	CAP	SUPPL	SIZE	R&D	INT	EDU	CAD
LAB/ CAP	1.00								
	(16)								
LAB	.88[b]	1.00							
	(16)	(18)							
CAP	-.40	-.36	1.00						
	(16)	(16)	(20)						
SUPPL	.23	.33	-.08	1.00					
	(16)	(18)	(20)	(21)					
SIZE	.03	-.11	-.18	.19	1.00				
	(16)	(16)	(20)	(20)	(20)				
R&D	.25	.34	-.19	.54[a]	.61[a]	1.00			
	(13)	(13)	(15)	(15)	(15)	(15)			
INT	.38	.49	-.30	-.36	-.10	-.28	1.00		
	(16)	(16)	(19)	(19)	(19)	(15)	(19)		
EDU	.61[a]	.72[b]	-.19	.56[a]	.10	.25	.15	1.00	
	(13)	(14)	(16)	(17)	(16)	(11)	(15)	(17)	
CAD	.54[a]	.77[b]	-.31	.70[b]	.27	.78[b]	.09	.71[b]	1.00
	(16)	(18)	(18)	(21)	(18)	(14)	(17)	(15)	(21)

[a]Significant at 0.05 level.
[b]Significant at 0.01 level.

Key: LAB/CAP = Labour / Capital Ratio
LAB = Labour Cost
CAP = Capital Cost
SUPPL = Local Presence of US Suppliers
SIZE = Natural Potential User Industry
R&D = Level of R&D Intensity
INT = Subject to International Competition
EDU = Higher Levels of Education
CAD = CAD as a Function of the Above Factors

Source: Astebro (1991a)

[54] Hoffman, 1986.

From this analysis the greater use of CAD is related to a high labour/capital ratio since CAD is a positive function of the cost of labour, and a negative function of capital. Other positive factors include strong local presence suppliers, the level of R&D activity in a country, and substantial higher levels of education.[55]

Astebro (1991) concludes that:

"For developing countries the situation is difficult. Not only is information and knowledge about the technology scarce, but also there is limited availability of the technology. Edquist and Jacobsson (1988) mention that for a long time the US Government applied an export embargo to India. In [the Republic of] Korea there was a general lack of information about CAD, and a lack of trained personnel to use CAD; the presence of a supplier industry was low. In 1985 there were only five sales offices from the supplier industry in Korea and six in India. This problem stems from the fact that there has been primarily one supplier country (the USA) and many recipient countries.

The technology tends to be undersupplied.[56] The recipient countries can form a coalition to pay a lump sum to the supplier for the provision of adequate amounts of goods, but free-rider problems among recipient countries induce each to try to avoid payment. Another possibility would be for each country to subsidize the supplier industry to set up sales or production offices in the recipient country. These offices should disseminate information and facilitate the installation and maintenance of equipment.

Another measure would be to promote the growth of domestic CAD industries. However, in developing countries labor is cheap and the firms mostly compete in national markets. These factors reduce the demand for CAD. A further complication is that developing countries to a large extent depend on the licensing of foreign technology.[57] The market for CAD in the engineering sector thus becomes substantially reduced since little design work is carried out. Because the domestic market may be too small, the domestic CAD industry would most certainly need to compete in the international market; this may require large subsidies.

The study indicates that major barriers to adopting CAD are related to access of information and knowledge and to the ability of the potential adopters to gather, assimilate, and apply this knowledge. This was also identified by the Ministry of Industry in Sweden".[58]

3.6 Computer Aided Design: A Brief Summary

In this chapter evidence has been provided of substantially reduced costs associated with CAD. Hardware and software is now found suitable for applications in even very small companies, and evidence exists of widespread diffusion in the developed countries, in those industries most prevalent in developing countries, e.g.,clothing, footwear, food processing, metal manufactures, etc.

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[55] Astebro, 1991.

[56] Tirole, 1988.

[57] Edquist and Jacobsson, 1988.

[58] Carlsson and Selg, 1983; SOU, 1981.

These simple PC or desk top based CAD systems are available for less than $15,000.[59] This provides potential users in developing countries with a cost effective production aid which is capable of giving them considerable savings in the materials used, up to 9 per cent in the clothing industry, for example.[60]

CAD also provides a greatly enhanced productivity capability which, because of skills shortages, may well be one of the most considerable benefits of its use.

Competitiveness is increased through the use of CAD, and failure to adopt it would perhaps be increased dependence on companies in developed countries transmitting data electronically to remotely located production sites in the developing world, e.g., Mattel to Indonesia.

The importance of developing a design and redesign capability in developing countries is thus highlighted. A failure to do so may well lead to the failure of whole markets, and loss of value added in many others.

Finally, the infrastructure for the successful introduction of CAD is highly important. The existence of a reasonably high level of R&D nationally; a good educational framework; and the presence of a strong supplier of CAD equipment within the host country, have all proven to be vital to success. These are all factors that policy makers in developing countries must consider in what is an inevitable and essential move into CAD.

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[59] Adams, 1988.

[60] Hoffman and Rush, 1988.

4. Numerically Controlled Machine Tools (NCMT)

The introduction of computer controllers to machine tools began in the 1940s, largely as a consequence of the interest of the American Air Force in achieving improved accuracy and repeatability in the machining of aircraft parts. At this stage of development the focus was on metal-cutting machine tools and not on metal-forming. However looms, weaving, cutting and sewing machines, etc, can also be NCMTs.

> "There are two kinds of machine tool used in metalworking. The first shapes the metal by *cutting* it to the correct shape and correct size. Machine tools of this type remove the metal in the form of chips. These tools are power-driven, usually by electric motors, and are too large and too heavy to be hand carried. The second kind of machine tool shapes the metal in one of two ways, either by shearing, or by hammering or squeezing the metal into shape. Such machine tools are known as metal-*forming* tools".[61]

The earliest NC applications were to a Swiss jig-borer and a Parsons Corporation milling machine, both in 1948.[62] At an early stage the Massachusetts Institute of Technology became involved, largely as a result of contracts issued by the Air Force; which subsequently employed a strategy of heavy investment in the technology in order to improve diffusion in its supplier companies.

> "The point of this story is that the same thing that made NC possible, massive Air Force support, also quite possibly determined the shape the technology would take. Criteria for design of machinery normally include cost to the user. Here cost was hardly a major consideration; machine tool builders were simply competing to meet performance specifications for government funded users in the aircraft industry. They had little concern with cost effectiveness and absolutely no incentive to produce less expensive machinery for the commercial market".[63]

In the UK too, concentration became centered upon sophisticated applications and control of the technology, rather than on simple micro-processor control of basic machine tools.[64]

4.1 Early Developments and NCMT Rationale

The first really new machine tool to emerge as a result of numerical controllers (for almost ten years the NC function was an add-on to existing models) arrived in 1958 with the Kearney and Tracker machining centre - which could perform milling, drilling, boring and tapping operations. This was thus the first real instance of a numerically controlled, multi-functional machine tool. Previously these four operations would be carried out on several different machine tools.

The impact of the evolution of machine tools from conventional manually operated ones through to full CIM can be seen by reference to Table 4.1 with regard to the seven steps of the

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[61] Sciberras and Payne, 1985.

[62] Sciberras and Payne, 1985.

[63] Noble, 1979.

[64] Bhattacharay, 1976.

machining process. With the evolution of the technology the degree of control possible by the computer becomes greater.

Table 4.1 ***Production methods***

	Conventional	NC	MC	CIM
1. Move workpiece to machine	manual	manual	manual	computer controlled
2. Load and fix workpiece	manual	manual	manual	computer controlled
3. Select and insert cutting tool	manual	manual	computer controlled	computer controlled
4. Establish and insert speeds	manual	computer controlled	computer controlled	computer controlled
5. Control cutting	manual	computer controlled	computer controlled	computer controlled
6. Sequence tools and motions	manual	manual	computer controlled	computer controlled
7. Unload part from machine	manual	manual	manual	computer controlled

Key: Conventional M/C Tool = Pre Numerical Control
NC = Numerically Controlled Machine Tool
MC = Machining Centre
CIM = Computer Integrated Manufacturing.

As noted above, early development centered on metal cutting rather than metal forming and this area is still by far the heaviest user of NCMTs, with about 80 per cent being of this type.[65]

"Metal cutting is one of the most fundamental processes of modern society. In the past decade it has undergone important changes as regards the technology used. Manually operated machine tools are being substituted by computer numerically controlled machine tools. This process started in the 1950s but only took off after 1975 when the microcomputer began to be used as the basis for the computer numerical control unit.

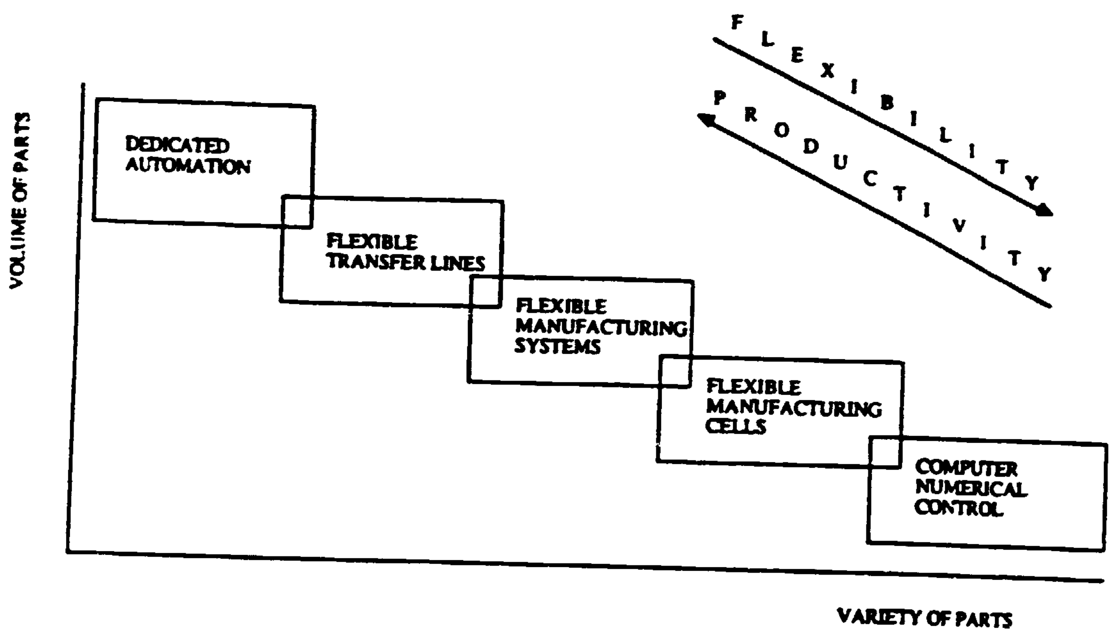
As a response to the technical and economic changes in the 1970s, the choice of technique in turning has altered and this change is reflected in a decline in the market for the simpler types of lathes that the NICs have specialized in producing. This change is in itself sufficiently alarming for the lathe producers in the NICs to contemplate adjusting and starting to produce CNC lathes too. The CNC lathe technology is, however, a technology whose operation involves the use of such a combination of factors of production that one may well argue that this technology is of as great a benefit to investors in the NICs as in

[65] American Machinist, 1983a.

the developed countries. Furthermore, the break-even wage for skilled workers, when the choice of CNC lathes becomes profitable, is fairly low, indicating that even if there is not an absolute scarcity of skilled labour the use of CNC lathes can be advantageous to investors".[66]

The rationale for the introduction of NCMT is based on the opportunities it affords to change what is essentially a one off or small batch production (< 50 parts) into a more flow line process. The nature of production can be captured by the trade-off between large-scale "economies of scale" and small-scale "economies of scope". (see Figure 4.1).

Figure 4.1 Volume/variety trade off



It is now accepted as conventional wisdom, and as a result of empirical observation, that by far the highest proportion of production produced across the manufacturing sector, is in batch sizes of less then 50.[67]

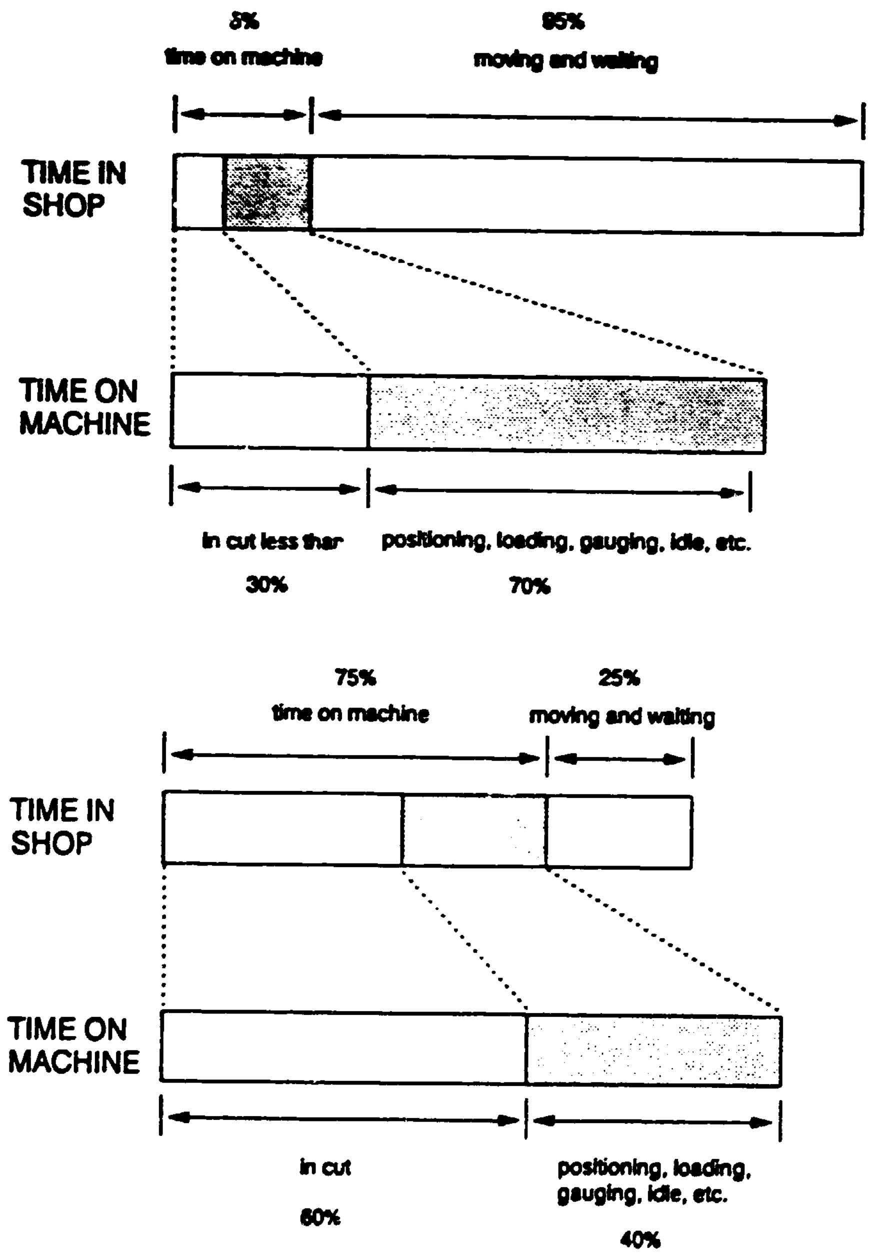
One consequence of this has been very low utilization of machine tools. Taking an average component (in the upper half of Figure 4.2) it can be seen that it will actually be having cutting operations performed on it for only about 1 per cent or 2 per cent of the time in the workshop. The lower half of Figure 4.2 indicates the future potential that might be achieved by

[66] Jacobsson, 1986.

[67] Nakao (1983), Peregudov and Solomentsev (1991).

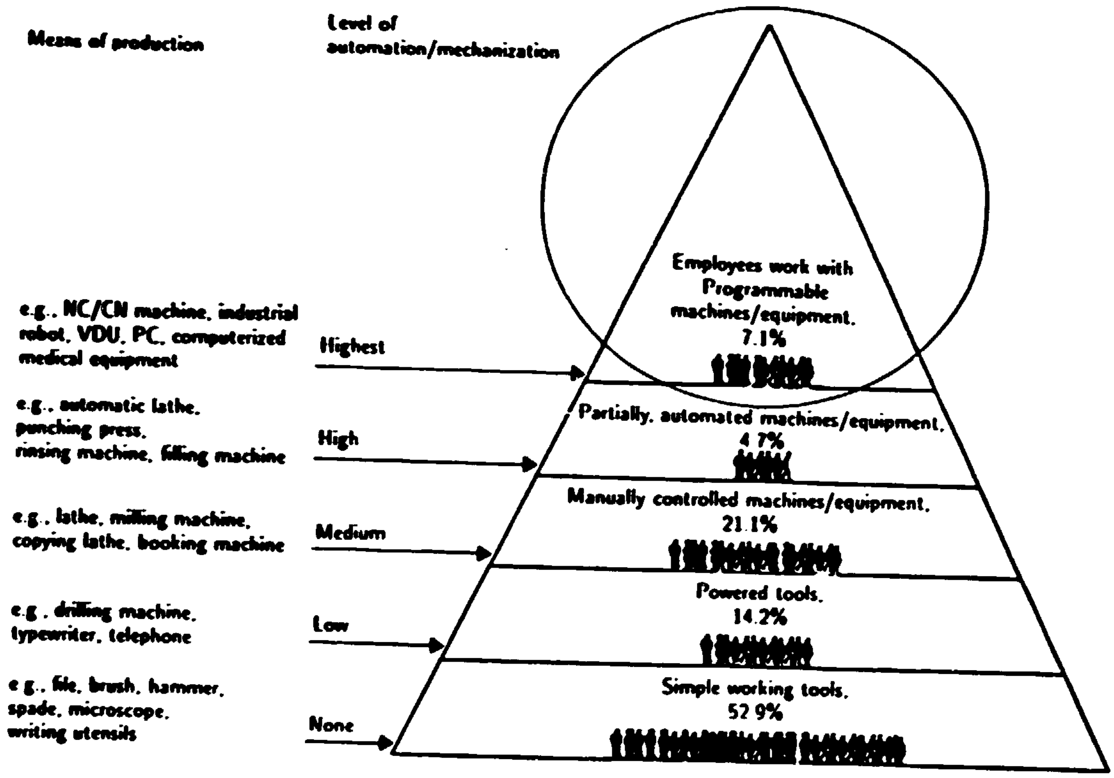
a combination of computerized machining and planning functions, allied to effective organizational control, e.g. Just-in-Time (JIT) parts control.

Figure 4.2 Machining times conventional and future



In closing this section we should note that despite the benefits of NCMT and its growing diffusion in the developed countries, it was estimated that in 1985/86, only 7.1 per cent of employees were working with programmable equipment/machines in the Federal Republic of Germany - a country where we might anticipate NC adoption to be high compared to many other countries (Figure 4.3).

Figure 4.3 Use of means of production by employees in the Federal Republic of Germany in 1985-1986, by level of automation and mechanization



Source: Ebel (1991).

4.2 NCMT Types and Applications

There are six major types of operation involved in metal-cutting, though these no longer need discrete items of equipment to perform all these operations.

1. Turning and boring
2. Milling
3. Drilling
4. Grinding
5. Shaping, planing and slotting
6. Miscellaneous, e.g., Electrical discharge machining (EDM), laser cutting, etc.

These may be performed by conventional standalone machine tools or a variety of increasingly sophisticated NCMT equipment.

N.C.	Numerically controlled and standalone
C.N.C.	Computerized numerical control, and linked equipment
D.N.C.	Direct numerical control and linked equipment, under central computer control.

Examples of modern capabilities are provided in Table 4.2.

Table 4.2 Examples of products of the modern machine tool industry

	GENERAL PURPOSE		SPECIAL PURPOSE	
	Standard	Custom	Standard	Custom
CONVENTIONAL				
Standalone	Turret lathes, milling machines	Longer bed lathes	Jig-grinders	
Systems				Transfer lines
CNC				
Standalone	CNC lathes, machining centres	Larger bed and taller head machining centres	CNC jig-borers	High precision, extended tool magazine machining centres
Systems	Flexible manufacturing cells (FMC)	Flexible manufacturing systems (FMS)	CNC gear-cutting machines with robot feed	Versatile transfer lines

Source: Sciberras & Payne (1985).

Data on the growth in sales of NCMT among OECD countries shows that the percentage value of installed equipment has risen from 36 per cent in 1976 to 76 per cent in 1984. (Table 4.3).[68]

Table 4.3 Share of NCMTs in total production of milling, drilling and boring machines, lathes and machining centres in six OECD countries, 1976, 1982 and 1984

	1976		1982		1984	
	(US$m)	(%)	(US$m)	(%)	(US$m)	(%)
NCMT	1,145	36	3,658	66	3,750	76
Conventional	2,005	64	1,846	34	1,157	24
Total	3,150	100	5,504	100	4,907	100

"NCMTs for turning, boring, drilling and milling functions can be said to be mature technologies in terms of the S-curve concept. They had already moved to the stage in their product cycle where standardization and mass production was essential by the latter half

[68] Edquist and Jacobsson.

of the 1970s. Today, the main innovative efforts lie in system building. The mature character of the technologies is reflected in the diffusion of these NCMTs to smaller firms too. In Japan, firms with less than 300 employees have accounted for the majority of sales for some time. In terms of stock, data from the USA in 1983 revealed that 40 per cent of the number of NCMTs installed are in firms with less than 100 employees. In the period 1978-83, these firms accounted for 47 per cent of the market for NCMTs in the USA. If we add to this market share approximately 15 per cent from the group of firms with 100-300 employees, the share of "medium and small firms" in the market for NCMTs would be about the same as that in Japan in 1980-1. Hence, in the USA also the smaller and medium-sized firms have accounted for the bulk of the market for some time".[69]

A little caution is required in interpreting these figures, since "share of total production" is measured by value and not by units installed. For example, in 1987 in the UK some 37 per cent of all machine tools manufactured had numerical controls fitted, and this was considered as catching up with the world trend.[70]

However, a productivity increase factor of 2 or 3 to 1 was found in the transition from conventional machines to NCMT; and by 2.5 to 6.5 to 1 from using conventional machines to the adoption of Flexible Manufacturing Systems.[71]

In terms of the production of one specific type of NCMT, lathes, Jacobsson has recorded the extent to which Japan has emerged as world leader as a consequence of a concentration on an "overall cost leadership strategy", i.e. producing a product of low/medium performance aimed at the medium to small sized firm. (Table 4.4)

Table 4.4 The production of CNC lathes in Japan, Europe[a] and the USA (units)

Year	Japan		Europe		USA		Total
	No.	per cent	No.	per cent	No.	per cent	
1975	1,359	30.0	1,535	33.8	1,640	36.2	4,534
1976	2,073	41.0	1,656	32.8	1,321	26.1	5,050
1977	3,900	52.6	2,332	31.5	1,178	15.9	7,410
1978	4,986	49.8	3,551	35.5	1,464	14.6	10,001
1979	8,065	57.9	3,505	25.2	2,354	16.9	13,924
1980	12,036	60.4	5,137[b]	25.8	2,751	13.8	19,924
1981	12,133	63.6	4,904	25.7	2,021	10.6	19,058
1982	10,344	64.4	4,225	26.3	1,489	9.2	16,058
1983	10,020	65.3	4.106	26.8	1,203	7.8	15,329
1984	16,555	72.3	4,818	21.0	1,524	6.7	22,897

[a] FRG, France, Italy, the UK and Sweden.
[b] Assuming production of 300 units in Sweden.

Source: Jacobsson (1986).

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[69] Edquist and Jacobbson, 1988.

[70] Garnett, F.T., 4.10.1988.

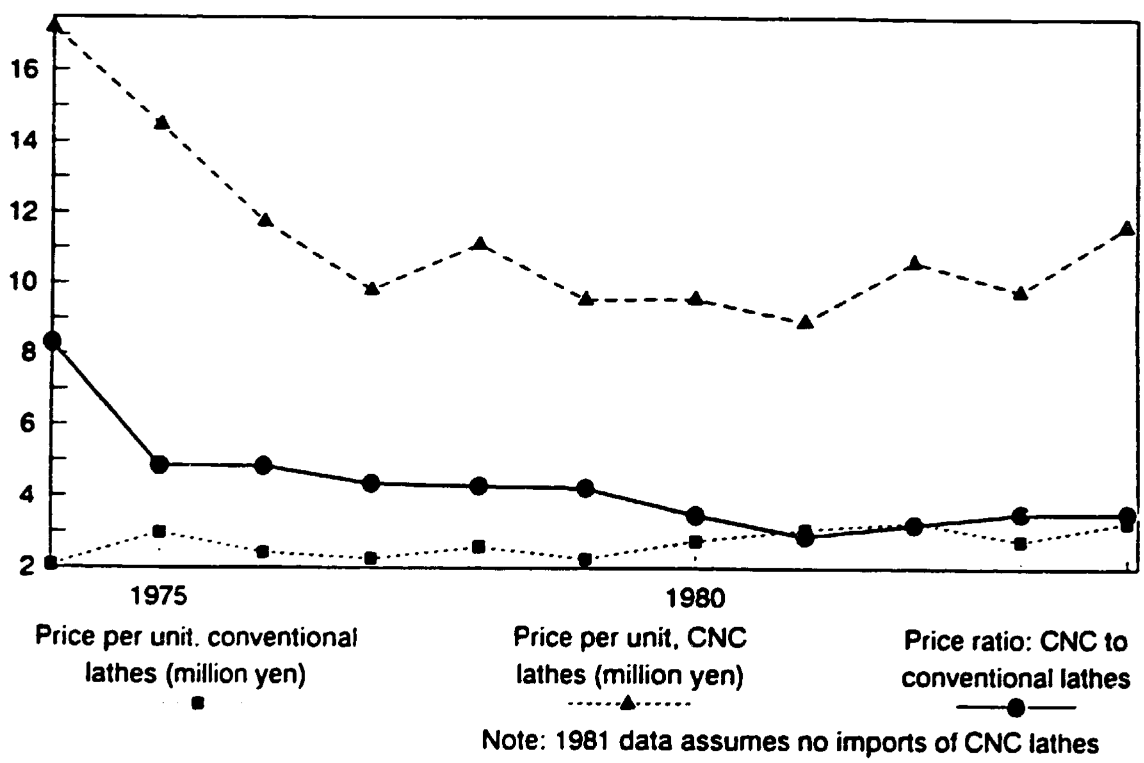
[71] Rempp, 1982.

The trends in development have been summarized as follows:

"R&D aims at simplification and easy use. Emphasis is also given to designing a product that can easily be manufactured at a low cost, i.e. through a reduction in the number of components in the machine. A large volume of output is required. A few firms produce their own CNC units. The main barriers to entry are economies of scale, access to a large marketing network, and design skills".[72]

Clearly, as a result of this concentration on lower performance/price, the price ratio between conventional and NC lathes has reduced dramatically from the mid-1970s to the mid-1980s (see Figure 4.4). The ratio has dropped from roughly 4-1 to almost parity by 1984 and remains fairly stable post 1981.

Figure 4.4 CNC & conventional lathes in Japan. Unites purchased and price ratio



Source: Jacobsson (1986).

Two of the most important developed countries with regard to NCMT are Japan and the USA. While by the early 1980s the latter country had a stock of NCMT four times greater than the former country (103,308 to 26,725) the percentage distribution by sector was roughly comparable. (Table 4.5)

[72] Jacobsson, 1986.

Table 4.5 Distribution of the stock of NCMTs by sector in Japan (1981) and the USA (1983)

	Japan[a]		USA[a]	
	No.	%	No.	%
General machinery	11,394	43	52,541	51
Electrical machinery	4,262	16	10,772	10
Transport equipment	6,276	23	15,284	15
Precision machinery	1,775	7	4,874	5
Metal products	1,460	5	14,463	14
Casting/forging products	580	2	2,662	3
Miscellaneous	978	4	2,712	2
Total	26,725	100	103,308	100

[a] The Japanese inventory covers plants with 100 employees and more. The USA inventory covers all size classes
[b] Fabricated metal products
[c] Primary metals

The five largest user branches are:

1. Miscellaneous machinery, except electrical, which means mainly what are called "jobshops".
2. Metalworking machinery.
3. Aircraft and parts.
4. Construction, mining and material handling machinery.
5. General industrial machinery, e.g. pumps, compressors etc.[73]

4.3 NCMT Diffusion

By the mid to late 1980s the number of NCMT installed had risen rapidly - more than doubling in the USA (222,356) and rising by approximately 160 per cent in Japan (70,255). By this time the FRG had 50,000 units installed and France 35,000. (Table 4.6)

Table 4.6 The population of NC machine tools in the USA, Japan, the Federal Republic of Germany (excluding the former German Democratic Republic), and France

Country	Year	NC machine tools	Source
USA	1989	222,356	American Machinist, 1989
Japan[a]	1987	70,255	MITI, 1988
FRG	1985	50,000	Fix-Sterz and Lay, 1986
France	1985	35,000	Margirier, 1987

[a] The survey was carried out for all establishments with more than 50 employees in the machine industry.
Source: Tani (1991).

[73] Jacobsson, 1986.

Table 4.7 Share of NCMTs in total production of metal-cutting machine tools in a number of OECD[a] countries, 1976, 1982 and 1984, by type of machine tool

	1976		1982		1984[b]		Growth of production 1976-84
	US$m	%	US$m	%	US$m	%	%
Boring machines							
NCMT	92	35	297	57	174	57	89
conventional	171	65	226	43	131	43	-23
total	263	100	523	100	305	100	169
Milling machines							
NCMT	145[c]	23	633	53	597	64	311
conventional	493	77	557	47	332	36	-33
total	638	100	1,190	100	929	100	46
Milling machines							
NCMT	34	13	93	34	54	29	59
conventional	229	87	178	66	135	71	-41
total	263	100	271	100	189	100	-28
Gear cutting machines							
NCMT	0	0	15	6	29	17	—
conventional	193	100	250	94	146	83	-24
total	193	100	265	100	175	100	-2
Grinding and polishing machines							
NCMT	10[d]	1	115	8	126	11	1,160
conventional	480	99	1,330	92	998	89	108
total	490	100	1,445	100	1,124	100	129
Lathes							
NCMT	479	30	1,403	61	1,492	73	211
conventional	1,112	70	885	39	559	27	-50
total	1,591	100	2,288	100	2,051	100	29
Other complete metal-cutting machine tools							
NCMT	441	30	1,617	38	2,084	62	372
conventional	1,016	70	2,639	62	1,236	38	22
total	1,457	100	4,256	100	3,320	100	128
of which machining centres	395	27	1,232	29	1,433	43	263
All metal-cutting tools							
NCMT	1,201	25	4173	41	4,511	56	275
conventional	3,694	75	6065	59	3,575	44	-3
total	4,895	100	238	100	8,086	100	65

[a] USA, Japan, Federal Republic of Germany, France, Italy and the UK.

[b] For boring machines and lathes; excluding the UK.
For drilling machines; excluding the UK and Italy; US data are from 1983.
For grinding and polishing; excluding the UK and Italy.
For others; excluding Italy.

[c] For machining centres excluding UK. In the USA in 1976, in the case of NC[illegible] [illegible]al-cutting and metal-forming machine tools', mainly NC milling, NC grinding and NC polishing [illegible] [illegible]duced at the value of US$67.9 million. As very few grinding and polishing machines were being eq[illegible], we have assumed a US production of $60 million worth of NC milling machines (National Machine Tool Builders' Association, 1981/2, p. 101). As is shown above, grinding and polishing machines were still, in 1982, 92 per cent conventional.

[d] USA data are excluded as they do not show NC grinding machines separately.

Source: Elaboration on data supplied by CECIMO.

Tani notes that the share of NCMT in the total machine tool population of Japan had reached 9.2 per cent by October 1987; apparently the USA achieved roughly this proportion (9.5 per cent) in 1989. Japan has clearly been utilizing the technology a little faster then the US, though still lagging in the total numbers installed.

Table 4.7 shows the position in the mid 1980s, with growth being seen in each type of NCMT and a consequent small decline in the use of conventional machine tools in six OECD countries.[74]

Although the decline in use of conventional machine tools is relatively modest - from 3,694 to 3,575 (-3 per cent) the growth in the use of NCMT was very strong - up from 1,201 to 4,511 (+275 per cent).

Similar calculations for Japan and the US, though compiled slightly differently in each case show that in Japan the percentage of all turning machines (lathes) installed which were NCMTs, rose from less than 1 per cent in 1970 to almost 63 per cent in 1986; similarly machining centres rose from 0.27 per cent in 1970 to almost 31 per cent in 1986. The comparable figures for US lathe installations in 1968 of 1.6 per cent to 18.3 per cent in 1989 - a much lower rate of adoption. (Table 4.8 and Table 4.9).[75]

Table 4.8 ***NC share in production for each type of machine tool in Japan (per cent)***

Year	Turning	Drilling	Boring	Milling	Grinding	MC/CBM[a]	Total[b]
1970	0.93	0.12	2.63	1.22	0.16	0.27	0.57
1971	1.42	0.15	2.24	1.79	0.14	0.37	0.75
1972	1.57	0.25	2.88	1.71	0.15	0.48	0.82
1973	2.94	0.36	3.65	2.31	0.29	0.64	1.30
1974	3.92	0.46	2.35	3.29	0.29	0.80	1.80
1975	7.07	0.40	2.25	4.62	0.19	1.26	2.48
1976	9.66	0.33	1.69	5.35	0.33	1.12	2.78
1977	16.19	0.65	2.29	5.52	0.67	1.88	4.14
1978	21.80	0.66	2.78	7.16	0.26	3.12	5.37
1979	28.85	0.35	2.45	10.61	1.00	5.55	8.72
1980	34.72	0.62	4.14	14.00	1.39	9.81	12.33
1981	36.74	0.87	4.88	20.24	1.99	15.09	15.63
1982	41.74	0.61	6.05	21.93	2.62	15.12	16.47
1983	45.93	1.70	6.67	25.41	3.51	18.85	18.85
1984	52.63	1.60	12.31	25.88	4.99	19.74	22.00
1985	56.92	1.82	8.19	23.37	7.34	27.68	25.66
1986	62.84	5.07	13.32	27.24	9.97	30.82	28.27

[a] Share = machining centers/drilling + milling + boring.
[b] Including other machine tools.
Source: Tani (1991).

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[74] Edquist and Jacobsson, 1988.

[75] Tani, 1991.

Since the NC share amongst recent installations was a little over 33 per cent in Japan - compared to a rate of only 11 per cent in 1987, which covers the period in Table 4.8 above, a greatly expanded population of NCMT by the year 2000 may be assumed. The predicted NC share of installations is 40 per cent which implies a population of 240,000 by 2000, more than three times the late 1980s level; bringing significant economic and social impacts.

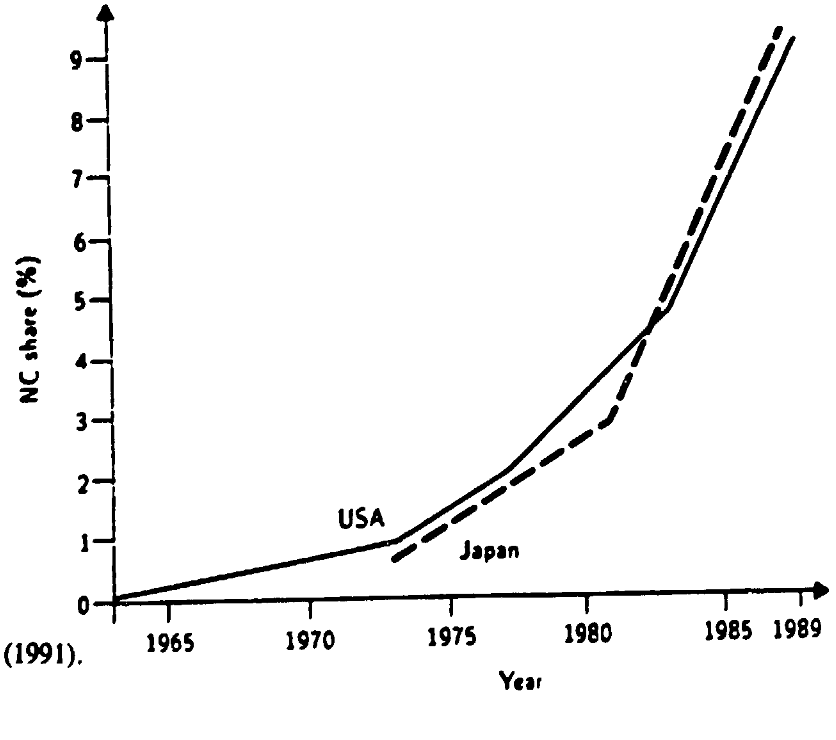
Table 4.9 NC shares of machine tools in the US metalworking industry (per cent)

Machine	Consumption 1968	Year of installation[b] 1969-1978	1974-1983	1984-1988	Installation 1989
Turning machines	1.6	11.0	33.2	52.0	18.3
Boring machines	8.8	17.4	35.1	52.0	22.2
Drilling machines	1.4	3.3	4.5	8.6	3.6
Milling machines	1.8	6.5	17.5	26.9	11.3
Grinding machines	0.9	2.1	3.1	8.4	2.9
Machining centers[a]	0.9	4.2	14.2	30.9	9.2
Total metal cutting	1.8	6.3	15.3	27.1	10.5
Total metal forming	0.7	2.0	6.3	14.6	3.9
Total machine tools	7.6	5.4	13.7	25.2	9.6

[a] Share = machining center/drilling + milling + boring.
[b] Year of installation corresponds to the following generation of machine tools: 0-4 years, 1984-1988; 5-9 years 1974-1983; 10-19 years, 1969-1978; more than 20 years, before 1968.
Source: Tani (1991).

Since past trends in Japan and the US have been similar (see Figure 4.5) similar increases in the US to those in Japan can be expected.

Figure 4.5 Past trends of NC share installation, metal cutting and metal forming, in the USA and in Japan



Source: Tani (1991).

The same analysis used a logistic curve fitting formula to calculate the growth in NC machine tool installations. Comparing this with the actual data for these years, a very close fit was found for most years, and this was (see Table 4.10) then extrapolated up to the year 2000 using a 12, 15, and 18 year basis of diffusion to saturation point levels, these ranged from a high of 33.32 per cent to a low of 30.87 per cent.

Table 4.10 Logistic-curve fitting to NC share in production of machine tools in Japan

Year	Estimated (%)	Observed (%)
1970	.418999	.57
1971	.600309	.75
1972	.85807	.82
1973	1.22246	1.30
1974	1.7335	1.80
1975	2.44227	2.48
1976	3.41021	2.78
1977	4.70461	4.14
1978	6.38776	5.37
1979	8.49847	8.72
1980	11.0282	12.33
1981	13.9007	15.63
1982	16.9689	16.47
1983	20.0396	18.85
1984	22.9188	22.00
1985	25.4579	25.66
1986	27.579	28.27

$f = 1/[a + b * EXP(-c * t)]$
PARAMETERS(IT =8)

$a = 0.0294022$
$b = 2.35723$
$c = 0.364993$

SD of a = (2.04186E03)
SD of b = (.592942)
SD of c = (.0277865)

$*R^2$ = 0.992445
R S S = 9.57137
D.W. = 1.10768

Source: Tani (1991).

The diffusion of any technology depends on a variety of factors. These include:

(1) the cost of the technology;
(2) the stage of the life cycle the technology now represents;
(3) the presence of a pool of skilled workers to run and maintain the system;
(4) linkages into customers, suppliers, etc.

Table 4.11 *Forecasts of NC share in Japan*

Year	NC share (%) in production $f(t)$	NC share (%) in installation $m = 12$ $g(t)$	$m = 15$ $g(t)$	$m = 18$ $g(t)$
1987	29.27	15.85	13.04	10.97 (11.3)[a]
1988	30.57	18.11	14.99	12.64
1989	31.55	20.35	16.98	14.36
1990	32.26	22.50	18.97	16.11
1991	32.77	24.53	20.93	17.86
1992	33.14	26.37	22.82	19.60
1993	33.40	27.99	24.62	21.32
1994	33.58	29.38	26.30	23.00
1995	33.71	30.52	27.81	24.61
1996	33.80	31.42	29.13	26.14
1997	33.86	32.12	30.26	27.54
1998	33.91	32.65	31.19	28.82
1999	33.94	33.04	31.92	29.93
2000	33.96	33.32	32.49	30.87

[a] Observed data for the establishment of more than 50 employees in the mechanical industry at the end of September.
Source: Tani (1991).

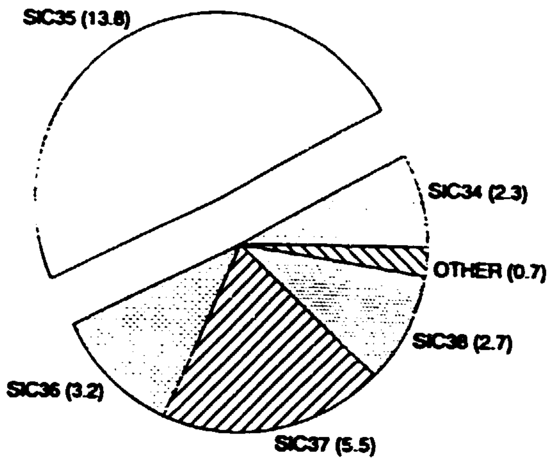
NCMTs are now relatively low cost compared with ten years ago; extensive numbers exist and they are in the mature stage of diffusion; in the developed countries there are skilled personnel to use them; and information links between manufacturers and their customers and suppliers are improving, in general. Price trades have an important role in explaining diffusion:

> "All the projections suggest a very rapid NCMT diffusion during the period 1990-2000. This can be explained by the significant reduction of NCMT relative prices in the 1980s, corresponding to the expansion phase of the technological life cycle. Leontief and Duchin (1983) considered the NC/non-NC price ratio to be equal to 11 to 1. But this price ratio is true only in average (for a mixed bag of non-NC machine tools). If we compare the prices of NC and non-NC machines by type [for example, NC lathes versus non-NC lathes (NMTBA, 1989)], the price ratio drops to three or four to one for lathes and to about three to one for boring machines in the mid-1980s. If we also take into account the higher productivity of NC machine tools (four times greater), we are able to conclude that since the mid-1980s NCMT implementation has become economically beneficial enough to be justified even by conservative "cost minimizers". This corresponds with an expansionary phase of the technology's 'life cycle'".[76]

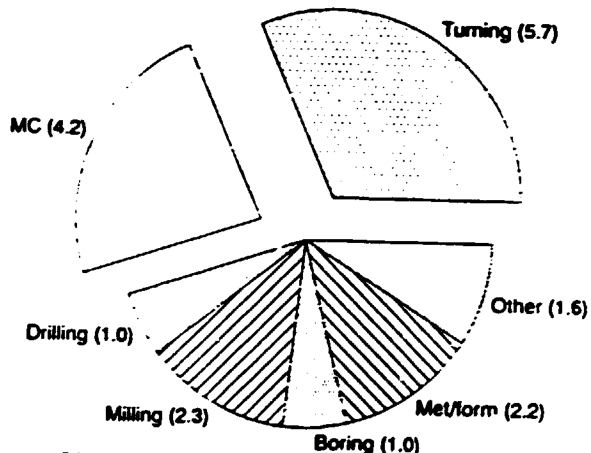
The forecast expansion of NCMT in the USA, UK and FRG is graphically presented in Figure 4.6.

[76] Tchijov, 1991.

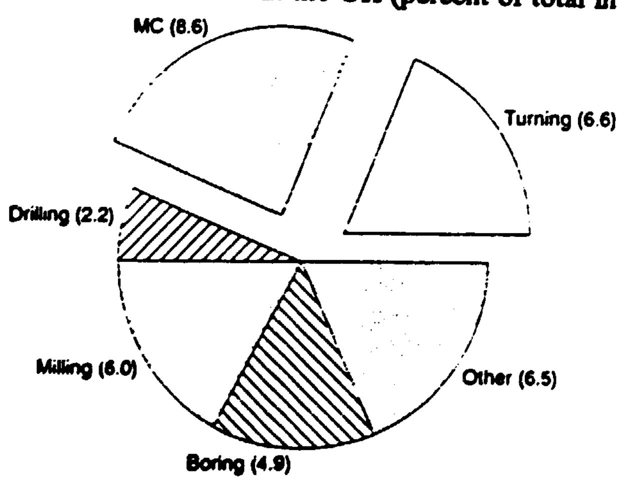
Figure 4.6 Structure of NCMT 2000 in the USA, UK, FRG (per cent of total in parentheses) (a) in the year 2000 and (b) in the year 2010.



Structure of NCMT 2000 in the USA (percent of total in parentheses)



Structure of NCMT 2000 in the UK (percent of total in parentheses)



Structure of NCMT 2000 in the FRG (percent of total in parentheses)

Source: Tchijov (1991).

"Comparing the forecasts for the US and UK metalworking industries one can observe similar tendencies:

1. The NCMT diffusion process accelerates in the 1990s and is followed by saturation effects.
2. There are two main "engines" of the process: conventional turning machines are replaced by NC lathes and single function drilling/milling/boring machines are replaced by NC machining centers.
3. NC machines of new types (laser cutters, electronic beam machines, etc.) will play an important role in NCMT diffusion in the forecast period.
4. The non-electrical machinery sector will remain the main NCMT user, though the shares of NC machine tools used by the electronics and instruments industries will increase significantly.

The main difference between the two forecasts is the lower saturation level predicted for the UK in comparison with the USA. In other words, the share of NCMT in the total number of machine tools in the USA is projected by approximately 50 per cent higher than in the UK. We can suggest no explanation for this difference, except perhaps the greater importance of the NCMT-intensive aerospace industry in the USA.

A comparison of the future structures of the NC machine population in the three countries (Figure 4.6) (for the USA, the UK, and the FRG) suggests that the share of NC lathes and machining centers will be more than 50 per cent in the first two countries, while in the FRG it will be lower. This is because of significantly higher shares of NC milling and boring machines in the FRG.

The overall NCMT share is higher for the FRG, reaching 35 per cent of the total number of machine tools in 2000 and 44 per cent in 2010. There are also some differences in the industrial distribution of the NCMT population. The share of the main user (non-electrical machinery) is higher in the FRG than in the USA and the UK".[77]

The OECD countries are not alone in the pattern of their development and the diffusion of NCMT. Analysis of data in the former Soviet Union, shows that the share of NC machines in relation to the total population of metal-cutting machines is still relatively small, though this was stated to have risen to 15.1 per cent in 1988 (from 0.8 per cent in 1970). This is a healthy proportion given the data on the USA (9.5 per cent in 1989) and Japan (9.2 per cent in 1987). However, reservations are expressed about the quality of these machines (see below).[78] For metal forming the percentage was 4.8 per cent in 1988. Figure 4.7 shows the curve of NCMT diffusion by physical and value indicators in the Soviet Union. Figure 4.8, shows an extrapolated trend of diffusion which is similar to those forecast by Tani (1991) and Tchijov (1991) for Japan, the USA and a number of other countries. They note that the Soviet saturation level of diffusion is similar to that of Japan - over 30 per cent - but that a major time-lag exists of about 10 years.

"For the USSR the saturation level of the process seems to be close to that of Japan -at least 30 per cent. However, there is a major difference in the time period that is required for the diffusion process to approach this level in the two countries. For example, it is estimated that the saturation level will be reached in 1990 in Japan (using Tani's simplest model estimate) and in 2000 in the USSR. Hence, the time lag between the two countries is 10 years.

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77 Tchijov, 1991.

78 Perminov and Botvinova, 1991.

Figure 4.7 Curve of NCM diffusion measured by physical (1) indicators and value (2) indicators

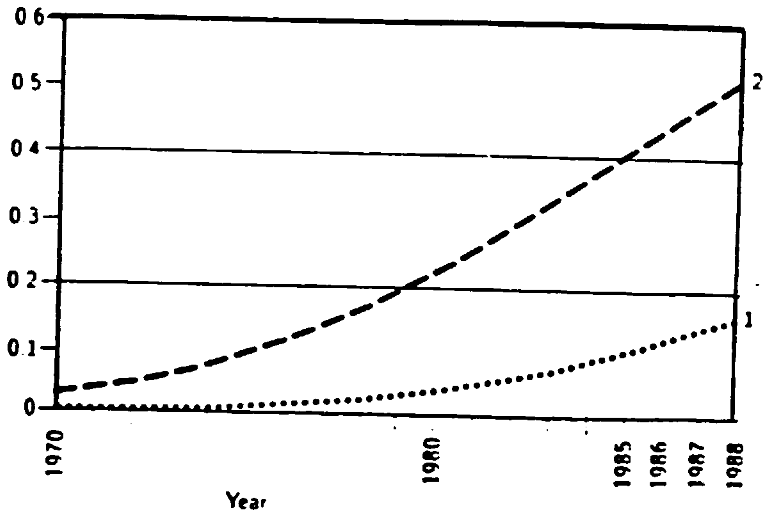
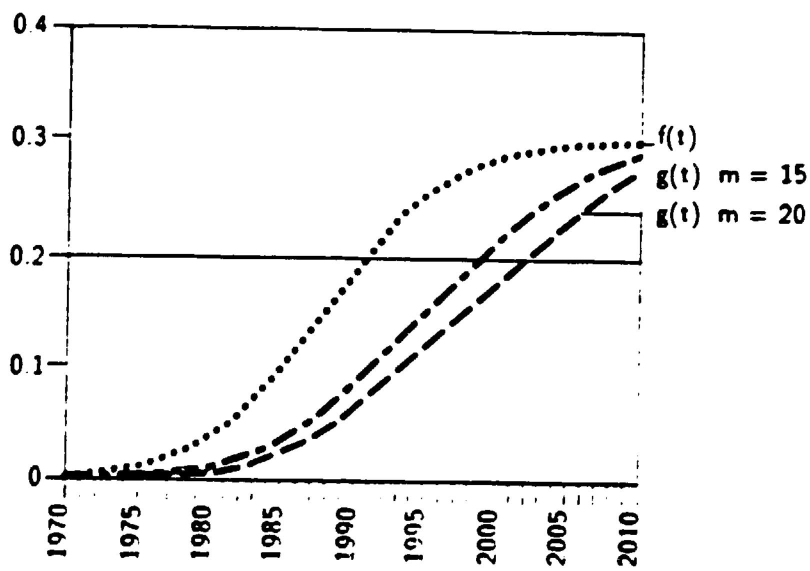


Figure 4.8 Forecasts of NC machine diffusion in the former USSR



f(t) = the NC machines share in the total number of metal-cutting machines produced;
g(t) = the NC machines share in the total number of metal-cutting machines installed;
m = lag (Tani refers to this a s"replacement time").
In Figure 4.10, estimated curves f(t) and g(t) for the USSR are shown. According to our estimation, the curve g(t) seems the most realistic when m =- 15 for the metalworking industry and when m = 20 for the economy as a whole.
Source: Perminov & Botvinova (1991).

"However, the lag may be even greater taking into account that, as it has already been pointed out, the amount of modern equipment among the NC machines produced in the USSR is still rather small. If the diffusion rate of more modern equipment as a proportion of the NC machine tool population in the USSR maintains past tendencies, NC machines in the USSR in the late 1990s will, *a priori*, be somewhat less advanced than equipment installed in Japan 10 years earlier".[79]

The conclusion is that:

1. Trends in the USSR have certain similarities with those observed in countries with market economies. Similarly, the predicted diffusion process saturation levels appear to be comparable (based on the S-curve describing the NC machine diffusion in total metal-cutting equipment produced). For the USSR the saturation level is estimated to be 30 per cent. Tani's model, which investigated the NC machine diffusion in Japan, turns out to fit the process in the USSR quite well.

2. A rather lengthy time lag exists between NC machine tool diffusion in the USSR and the same process in Japan. This time lag is estimated to be at least 10 years. This value may even be underestimated because NC machines currently being installed in the USSR belong to a different generation from those now being installed in Japan.

3. In the USSR, groups of technologies or products that are considered to be "highly developed" often appear to consist mainly of technologies that are obsolete or utilize obsolescent categories of equipment. In fact, the dynamics of the group life cycle is rather slow for advanced technologies. This is illustrated, in the case of diffusion of NC metal-cutting machines, by the limited number of really progressive kinds of equipment within the NC machines group".

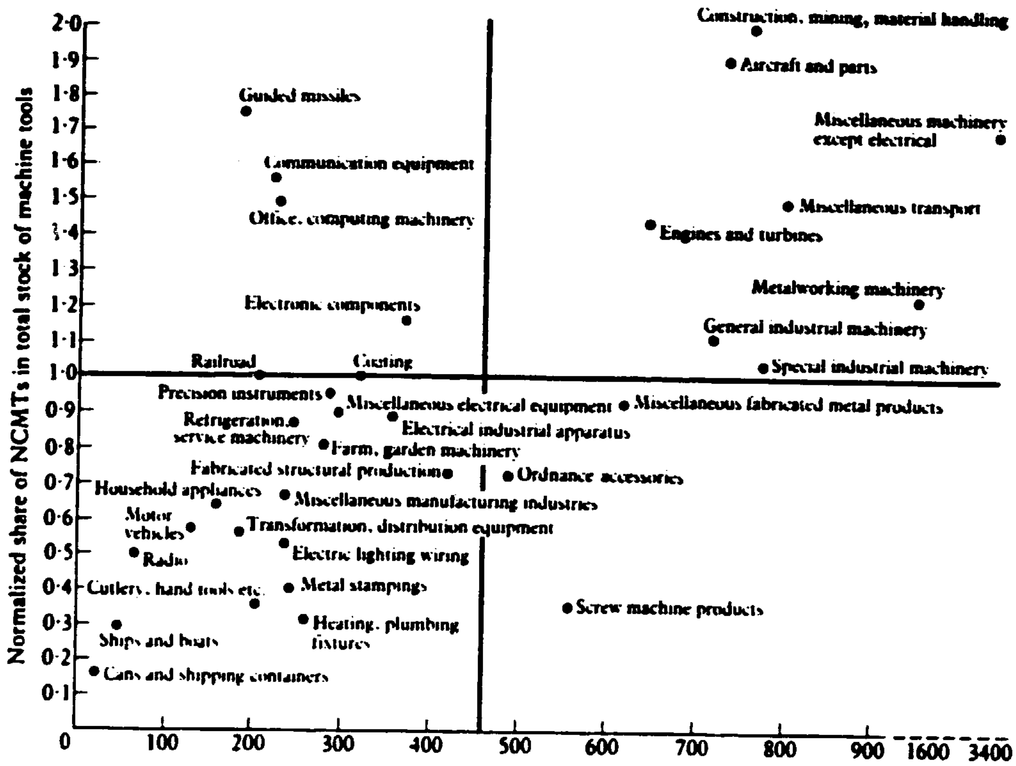
4.4 Main Users of NCMT and Firm Size

Taken that the above diffusion rate is likely to occur - installation rates of over 30 per cent by the year 2000 in Japan and the US - which sectors of manufacturing are likely to be impacted most heavily? Edquist and Jacobsson (1988) conducted an analysis of sectors adopting a four quadrant approach, with the number of NCMTs installed divided by their value added (on the horizontal axis), and the normalized scheme of NCMT in the total stock of machine tools. (Figure 4.9). The results in the USA in 1983 were an impressive indicator, which provides developing countries with a useful tool of analysis, since from the figure various industrial sectors, e.g., metalworking machinery, miscellaneous and general machinery can be identified that are heavy users, but that do not have the high barriers to entry found in the aerospace, engine, or special machinery sectors.

In the north-east quadrant lie the heaviest intensity and users of NCMTs. In the north-west quadrant, heavy intensity of NCMTs, though less utilized. In the south-east quadrant only four branches exist, with low use of NCMTs; for example, screw machine products are manufactured in large batches and made on relatively inflexible specific machine tools such as heading, slotting or rolling machines. In the south-west quadrant are the branches least impacted by NCMT.

[79] Perminov and Botvinova, 1991.

Figure 4.9 The intensity in use of NCMTs by branch in the USA in 1983 as measured by normalized share of NCMTs in total stock of machine tools and number of NCMTs installed divided by value added



<u>Source:</u> Edquist & Jacobsson (1988).

What would have been of considerable interest here is the location of the textiles, clothing and footwear industries. One assumes a south-western location, but moving in a north-easterly direction under the influence of automated design and cutting, NC sewing-machines, NC looms, etc.

Given the preponderance of small to medium sized firms in all national manufacturing structures the likelihood of adoption of NCMT (or other new technologies) assumes great importance relative to size factors.

An examination of new technology adoption in the US found clear evidence that the likelihood of a firm installing NC or CNC (what they refer to as PA) is related to firm size (see Figure 4.10).[80]

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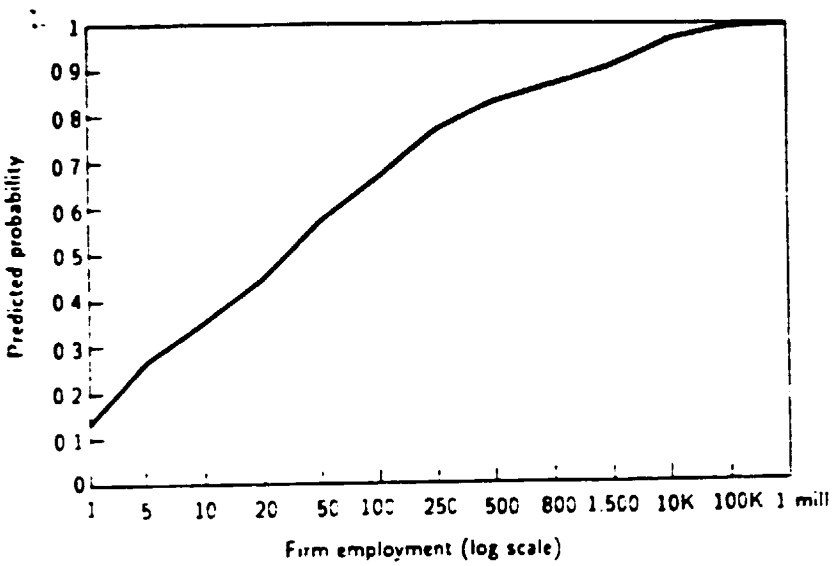
[80] Kelley and Brooks, 1991.

Figure 4.10 Probability of PA adoption by size of parent company in the USA



Source: Kelley and Brooks (1991).

Where less than 50 people are employed the likelihood of adoption of NCMT ranges from around a one in ten chance, to around a four in ten chance. However, by the time we reach a level of employment of around 250 the likelihood is almost 80 per cent and by 10,000 almost 100 per cent.

> "There appears to be considerable qualitative similarity among industrialized countries in the pattern of adoption with respect to firm size or plant size or both. For the United Kingdom, for example, the results of a 1987 survey of manufacturing establishments from a wide variety of industries show that large plants (with 1,000 or more employees) are nearly four times as likely as small plants (with between 20 and 49 employees) to have adopted CNC (Northcott, 1990). In their 1988 survey, Ewers *et al.* (1990) find that large plants with 1,000 or more employees are nearly three times as likely as small plants (20 - 49 workers) to have adopted computer-controlled machines in two regions of Germany. Our 1986-1987 survey of US manufacturing plants in 21 metalworking and machinery manufacturing industries yields a similar pattern: large plants (with 1,000 or more employees) are more than two times as likely as small plants (with less than 50 employees) to have adopted PA machines.
>
> Comprehensive statistics on adoption rates for a random sample of plants across industries or regions or both are not available for Japan. However, statistics from a 1988 survey of firms that are subcontractors to major machinery equipment enterprises show that large firms (with more than 300 employees) are more than two times as likely as small firms (with 20 or fewer employees) to have adopted any NC/CNC machines".[81]

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[81] Kelley and Brooks, 1991.

The role of large firms is then very important. In the study it was discovered that only two variables were dominant in the company learning about new technology.

(1) Contacts with sales representatives from equipment manufacturers or their distributors, and

(2) Meetings at trade or professional contacts or associations.

"For all plants but those attached to the largest firms (500 or more employees), we find that when management has active/social linkages to external resources for learning about new technological developments the chances of PA adoption are substantially higher than those plants with passive/asocial types of linkages. Active/social linkages raise the chances of PA adoption the greatest among plants belonging to the smallest-size firms. For the very smallest firms with fewer than 20 employees that have only passive/asocial linkages to various external resources, the chances of PA adoption are quite low, less than one in five (prob. = .18). With active/social linkages through which the exchange of technical expertise and learning among firms is facilitated, the conditional probability of PA adoption increases by more than 250 per cent (prob. = .65). For small firms with 20 to 99 employees, active/social linkages to external resources outside the firm increase the chances of PA adoption over firms with passive/asocial linkages from less than three in ten (prob. = .29) to more than three in four (prob. = .77). Even for medium-sized firms with 100 to 499 employees, we find that such active social linkages to resources external to the firm augment the chances of PA adoption by a substantial margin.

When the very smallest firms (with fewer than 20 employees) are well connected to all four of the active/social linkages we have identified as having a positive impact on PA adoption, these external economic advantages compensate for much of the diseconomies of small size and scale. Indeed, the chances of PA adoption for such well-connected small firms actually exceed those estimated for the typical plant of medium-sized firms that are nearly 10 times at large (with between 100 and 499 employees) but have only passive/asocial linkages to external sources of expertise".[82]

These findings are summarized in Table 4.12.

However in Japan, while sales of NCMT to large firms have increased by a factor of approximately 6 between 1970 and 1981; sales to small firms (<300 employees) have risen by a factor of almost 21, clearly a reflection of the Japanese suppliers technology policy noted above; and the long established network of formal contacts which have been established between large and small firms, and buyers/suppliers. (Table 4.13)[83]

It should be noted that because the sheer number of small to medium-sized firms is so much greater than those in the large firms range - as observed earlier in the chapter - the widespread diffusion of NCMT, CAD, etc., depends to a large extent on small firms entering the new technology field.

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[82] Kelley and Brooks, 1991.

[83] Edquist and Jacobsson, 1988.

Table 4.12 Estimates of the importance of external learning opportunities to the probability of PA adoption in plants of different size firms. For both scenarios, the plants of these firms are assumed to sell output from the machining process to some other firm

Size of parent company	Estimated probability of PA adoption[a] Passive/asocial[b] linkages	Active/social[c] linkages	Percentage increase
20 employees	.18	.65	+256.5
20-99 employees	.29	.77	+167.7
100-499 employees	.42	.83	+105.4
500 employees	.94	.99	+5.6

[a] Probabilities are estimated for each scenario by setting all other variables in the model to the means for the sample of establishments in that size category.

[b] Passive/asocial linkages refer to plants in which management depends only on written media (newsletter, brochures) as an outside source of information about technological developments, is not an active participant in industry or professional association meetings, does not rely on know-how trading with managers or engineers outside the plants, does not depend on contacts with sales representatives from equipment vendors or their distributors to learn about new technology, and does not have business customers who share any technical information or expertise.

[c] Active/social linkages refer to plants in which management is an active participant in industry or professional association meetings, relies on know-how trading with managers or engineers outside the plant, depends on sales representatives from equipment vendors or distributors to learn about new technology, and has special-order customers who provide technical information and expertise.

Source: Kelley and Brooks (1991).

Table 4.13 Sales of NCMTs to large and small enterprises in Japan, 1970-81 (in billion yen)

Year	Large firms	Medium and small firms[a]
1970	15,510	7,404
1971	17,278	8,639
1972	13,951	10.600
1973	23,075	25,122
1974	25,310	25,547
1975	12,921	17,756
1976	17,069	22,178
1977	23,820	24,856
1978	19,957	38,445
1979	49,013	79,017
1980	68,847	126,960
1981	92,068	153,292

[a] Firms with less than 300 employees.

Source: Edquist & Jacobsson (1988).

4.5 The Cost Effectiveness of NCMT

The use of NCMT offers a number of advantages to potential users.

1. It is a technology which is skill saving. In the UK the technology has been adopted because of shortages of skilled labour which is consequently high priced.[84] For developing countries too, there are advantages to such a technology where skilled labour is just unavailable.

2. It is not necessarily a labour replacing technology. While in instances, for example the UK, it has been used as a substitute for skilled labour, in developing countries it may act to enlarge demand as a result of improvements in quality and productivity.

3. It is now a relatively rational capital investment choice, as noted above by Tchijov, in regard to its unit trade-off with several conventional machine tools.

Thus NCMT represents a technical change which is a function of both skilled labour and capital.

> "The economic efficiency of (stand-alone) NCMTs is well established. The degree of saving on the cost of production of a part varies, however, as would be expected, from case to case. In one study of the Federal Republic of Germany (Rempp et al, 1981), the range of total cost saving varied from 3 per cent to 40 per cent. In a Swedish study of six firms (Elsässer and Lindvall, 1984), five firms decreased their cost of production of parts by using NCMTs (though for the sixth firm the use of NCMTs resulted in an increased total cost of production). The maximum cost reduction amounted to around 50 per cent".[85]

On both CAD systems and NCMTs the payback is usually quick and easy to see. For example,

> "Newman Industries, a British maker of electric motors, is achieving the same output of spindles from two CNC lathes that it was getting from 30 standard lathes two years ago".[86]

This implies a ratio of improvement in productivity by a factor of 15 to 1 by using NCMT rather than conventional ones.

The impact is, of course, not purely a technological one. As with other technologies, particularly FMS - the subject of the next chapter - their are less quantifiable benefits that accrue. Bud Whitney of Allen Bradley commented:

> "When discussing our own company's major investment in a new CIM assembly line, I argued that it would keep us on top for the long-term. Based on traditional ROI (return on investment) criteria, it would never have made it".[87]

---

[84] Senker, 1983.

[85] Edquist and Jacobsson, 1988 .

[86] Rodger, FT 7.1.1986.

[87] Bud Whitney of Allen Bradley commented.

It has been found that in a high technology environment there was quite a difference between the true measure of costs and that achieved by measuring by standard costing systems. (Table 4.14).[88]

Table 4.14 Relative costs

	By costing systems	True costs
Materials	10%	55%
Overheads	15%	35%
Direct labour	25%	10%

Clearly using traditional costing systems is an almost inverse relation to reality. For example, should the adoption of NCMT save say 5 skilled jobs, traditional accounting would measure this without reference to such benefits as the reduction of lead-times, or increases in flexibility or quality.

> "As the level of investment in factory automation increases, the amount of direct labour as a percentage of total product cost decreases. Correspondingly, technology cost as a percentage of total product cost increases. As this happens, it becomes important to assign the cost of the technology to the products that are using it. The process of making this assignment is referred to as Technology Accounting.
>
> Technology costs should be allocated to products based on production usage and depreciated based on the expected useful life and output of the technology. This is in contrast to current financial accounting principles which use fixed depreciation periods.
>
> Focusing on simple payback, return on investment or net present value causes inaccurate assessment of alternatives in today's manufacturing environment. The decision process must include *qualitative* and *quantitative* non-financial measures that are crucial to long-term viability".[89]

Also, it has been found that in the majority of US manufacturing industries, very few now have a cost structure in which direct labour cost represents more than 10 per cent of sales.[90]

With specific reference to improvements in the cost relationships between, for example, conventional and NC lathes, it was found in one Swedish company that while the unit capital costs were higher for the latter, the real benefits lay with NC machines.[91] (Table 4.15)

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[88] Hopwood (referred to by Lawrence in Industrial Computing, April 1988).

[89] Fralix, 1989. Fralix is manager of manufacturing operations at [TC]^2 which is the US National Apparel Centre.

[90] Skinner, 1986.

[91] Jacobsson, 1986.

Table 4.15 Investment calculation comparing CNC and conventional lathes, assuming one shift operation (Sw.kr. per unit of output)[a]

Cost item	CNC lathes	Conventional lathes
Machine investment p.a.	875,000	560,000
Building		126,000[b]
Labour	793,968	2,101,680
Total costs	1,668,968	2,787,680

[a] Other assumptions are: (1) One CNC lathe operator's annual wage (including social security and other costs incurred by the employer) is 96,744Sw.kr.(2) A setter's wage is 116,760Sw.kr.One setter is used for seven CNC lathes. (3) One conventional lathe operator's wage is 100,080Sw.kr.(4) The p-factor is 3, i.e. three conventional lathes are assumed to produce as much as one CNC lathe. (5) Ten year depreciation and 15 per cent interest rate.
[b] Only the extra cost of buildings (i.e., for more space) associated with the choice of conventional lathes is known.

Source: Jacobsson (1986).

Using CNC lathes increased investment by 27 per cent and reduced labour costs by 62 per cent. Even on a single shift basis the NCMT option was best. However, with a double shift operating on the high cost NC equipment, the advantage increases further. (Table 4.16)

Per unit of output costs reduced by 52 per cent over conventional lathes, though the labour saving costs dropped to 58 per cent.

Table 4.16 Investment calculation assuming two shifts for CNC lathes and one shift for conventional lathes (Sw.kr. per unit of output)[a]

Cost item	CNC lathes	Conventional lathes
Investment p.a.	1,041,000	1,235,000[b]
Labour	1,587,936	3,783,024
Total cost	2,628,936	5,018,124

[a] A depreciation time of 7.5 years is assumed for CNC lathes. It is also assumed that the output of the second shift for CNC lathes is only 80 per cent of that of the first shift. The other assumptions are the same as in Table 4.15.
[b] The extra costs for the building are included in investment costs p.a.

Source: Jacobsson (1986).

The operation of CNC and traditional lathes in Argentina has also been calculated: Where the CNC lathe was a substitute for 3 or 4 traditional lathes, both with one shift and two shift working, it was more economical to use CNC. (Table 4.17a,b).[92]

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[92] Jacobsson, 1986.

Table 4.17a Choice between CNC lathes and conventional lathes in Argentina assuming one-shift operation[a] (US$)

	CNC lathe	Conventional lathe		
		p = 4	p = 3	p = 2
	130,000	72,000	54,000	36,000
Initial investment costs				
P.A. depreciation	13,000	7,200	5,400	3,600
Interest	6,500	3,600	2,700	1,800
Subtotal	19,500	10,800	8,100	5,400
Repair and maintenance costs	10,400	3,600	2,700	1,800
Labour costs				
(a) operators	12,000	48,000	36,000	24,000
(b) programming, etc.	2,400	--	--	--
Total costs	44,300	62,400	46,800	31,200

[a] Assumptions: (1) 10 per cent interest rate; (2) 10-year depreciation; (3) 8 per cent repair and maintenance costs on the initial investment for CNC lathes; 5 per cent for engine lathes.

Table 4.17b Choice between CNC lathes and conventional lathes in Argentina assuming two-shift operation[a] (US$)

	CNC lathe	Conventional lathe		
		p = 4	p = 3	p = 2
	130,000	72,000	54,000	36,000
Initial investment costs				
P.A. depreciation	17,333	7,200	5,400	3,600
Interest	6,500	3,600	2,700	1,800
Sub-total	23,833	10,800	8,100	5,400
Repair and maintenance costs	10,400	3,600	2,700	1,800
Labour costs				
(a) operators	24,000	96,000	72,000	48,000
(b) programming, etc.	4,800	--	--	--
Total costs	63,033	110,400	82,800	55,200

[a] Assumptions: as in Table 4.17a, except for the depreciation time which is 7½ years for CNC lathes.

Making the same calculation for both Taiwan Province and the Republic of Korea, he discovered there were even better returns than for Argentina because of these countries higher priced labour.

4.6 NCMT: A Brief Summary

As with CAD, the conclusion must be that utilization of NCMTs is imperative for industrial development. This is for reasons of improved quality in the product, improved delivery performance, savings in materials, and their ability to compensate for scarce skills. Their increased productivity has brought them to a point where they can also be considered a rational economic proposal.

NCMTs are now acknowledged as having progressed to their mature stage of development, and have diffused widely through the OECD countries with, for example, Japanese and American firms employing less than 300 people accounting for around 50 per cent of their national markets since the early 1980s.[93]

By the late 1980s this diffusion had lead to over 220,000 installations in the US, and over 70,000 in Japan. This represented about 10 per cent of the capital stock of all machine tools in those countries. However, this figure alone is not a good indicator of the increased interest in the technology since by the late 1980s, around 30 per cent of annual sales of machine tools in most developed countries was of NCMT.[94]

Reference to Figure 4.9 shows that while the aerospace, special industrial machinery, and engine and turbine industries are heavy users of NCMT (not areas where developing countries are strong) metalworking machinery, miscellaneous machinery, and general industrial machinery are also heavy users, and these are areas where developing countries might increase their activity.

Since most indicators of future diffusion[95] suggest that the OECD countries will have a stock of NCMT which represents around a third of their equipment by about the year 2000, developing countries would be well advised to note the competitive threat this represents -- should they fail to utilize the technology.

Analysis of the use of NCMT lathes in a number of developed and developing countries suggests that in the Republic of Korea, Taiwan Province and Argentina, investment in NCMT is indeed a rational decision -- even in these relatively low labour cost countries.[96]

Some combination of CAD and NCMT tools would prove a valuable, indeed indispensable, form of manufacturing. Not only metal cutting or forming equipment is NCMT; but that automated looms, printing presses, wood working machines, etc, are NCMT too.

Production based on these two technologies would help developing countries to produce higher quality goods, more rapidly, at lower cost, and using indigenous design capabilities; and could lead to broader industrial development, in an expanding range of industries.

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93 Edquist and Jacobsson, 1988.

94 Tani, 1991.

95 Tchijov (1991), Tani (1991) and Mori (1991).

96 Jacobsson, 1986.

5. Flexible Manufacturing Systems and Cells (FMS/FMC)

As with so much advanced manufacturing technology there is a major problem with definitions. Suppliers, users and others resemble Humpty Dumpty in "Alice in Wonderland" - to whom words meant whatever he wanted them to mean! In the case of FMS/FMC the problem begins with the user, for whom there are a number of different dimensions of flexibility which may be sought and which may be more or less important in competitive terms, depending on the individual company context.

What is evident is that FMS/FMC represents the clearest stage yet of what is evolving into computer integrated manufacturing and which is a "philosophy" applicable in a very wide range of industries, both metal based and others, e.g., clothing, plastics, woodworking, etc.

5.1 User Requirements, Benefits and Applications

Typically users are looking for flexibility:[97]

- in product life - to permit frequent model changes;
- in product range - to permit high levels of product differentiation and produce to individual customer specifications;
- in volume flexibility - to cope with fluctuating demand levels and match capacity better;
- in routing - to make efficient use of plant, to avoid bottlenecks and consequent delays and to reduce response time;
- in machining operations - to extend the range of tasks and products which can be made on a single piece of equipment and hence improve the utilization of capital;
- in plant life - to permit the same elements of capital investment to be used for a different range of products.

In order to meet these needs they require answers to one or more of the following problems:

- Machine flexibility: the ease of making the changes required to produce a given set of part/product types;
- Process flexibility: the ability to produce a given set of part/product types in different ways, each possibly using different materials;
- Product flexibility: the ability to change over to produce a new (set of) part(s) product(s) economically and quickly;
- Routing flexibility: the ability to cope with breakdowns and continue producing a given set of part/product types, e.g. by processing via alternative routes, or every operation can be performed on more than one machine;
- Volume flexibility: the ability to operate a system profitably at different production volumes;
- Expansion flexibility: the capability to expand the system modularly;
- Operation flexibility: the ability to interchange the order of several different operations for each part/product type;

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[97] Bessant and Haywood, 1988.

- Production flexibility: the universe of part/product types that the system can produce.[98]

Thus, the reasoning behind the adoption of FMS/FMC seems to be wide ranging and "contingent" on the particular circumstance facing the firm. Decisions are largely the result of "strategic choice" and are influenced by management skills and style.[99]

All manufacturing firms share the desire for some measure of flexibility, even at the high volume, process industry end of the spectrum, where there is a marked shift towards shorter production runs and greater product differentiation to match fragmenting specialised customer demand, e.g., the car industry. But the problem is perhaps most acute for the small/medium-sized batch manufacturers. Evidence suggests that most parts are made in batches of less than fifty and recent studies of flexible manufacturing bear this out. For example, a study of French FMS firms found that 54 per cent had batch sizes of less than one hundred parts,[100] and a study of Scandinavian FMS indicates that around two-thirds (62 per cent) averaged less than fifty parts per batch.[101]

The UN/ECE 1986 report on flexible manufacturing offers some general observations on possibie benefits. As a rule of thumb, it can be estimated that the potential of FMS are of the following order of magnitude as compared with conventional systems[102] summarized in the UN/ECE 1986 report:

- Labour costs: savings of 30 per cent or more;
- Material costs: savings of 13-15 per cent;
- Inventory and work in progress: reductions of 50 per cent or more;
- Lead time: very substantial reductions, on average of 40 per cent. Examples of reductions in lead time from 15 to 2 days or even from 16 days to 16 hours;
- Machine utilization: average increase of 30 per cent;
- Number of machines: examples include reductions from 31 to 6 machines and from 80 to 12 machines. However, requirements for ancillary equipment - e.g. AGVs, robots etc. - are increased;
- Floor space: reductions of more than 50 per cent;
- Total production costs: reductions of 14-27 per cent; and
- Operating profits: increases of 112-310 per cent.

As noted earlier just one of these items, material cost savings, can in itself justify the use of FMS/FMC in particular circumstances.

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[98] Browne et al., 1984.

[99] Child, 1977.

[100] Margirier, 1986.

[101] Haywood and Bessant's, (1978a).

[102] FMS Magazine, (July 1985); US Dept. of Commerce, (July, 1985).

"FMS has the potential of reducing direct material costs - that is, per unit of output - as well as indirect overhead costs related to input materials. The savings in material costs are obtained through:

- Higher yield from input material. In sheet-metal processing, for instance, FMS linked to CAD and CAP systems often lead to a higher yield for a given sheet of metal. By applying stock entry and pre-machining inspection, preferably computer-aided, defective input material can be detected and its costs debited to the suppliers;

- Higher product quality following a reduction in the number of defective parts and products being manufactured. A defective part gives rise not to revenues but to losses corresponding to the value added. The later in the manufacturing process the defect arises, the greater the loss - a loss whose value must be added to over-all production costs and, hence, to the prices of the output of non-defective goods; and

- A reduction of material overheads and other indirect costs relating to materials. If a part or a product becomes defective in the course of the manufacturing process, it has to be replaced. Besides leading to additional costs for the administrative work involved, this also causes disruption in the production process.

Defective parts can also give rise to late deliveries to customers and thereby to delays in cash inflow, as well as to a loss in good-will - losses which are even higher in cases where the defective products are not detected before being shipped to customers".[103]

(UN/ECE, 1986).

The study by Hoffman and Rush (1988), of automation and the clothing industry remarked that these are exactly the criteria justifying investment in that industry.

Two examples from the UK and Swedish experience have shown significant improvements in lead-times, work-in-progress, and machine utilization (Table 5.1) of FMS contributions to improving competitiveness.[104]

Table 5.1 Benefits of FMS use by company size

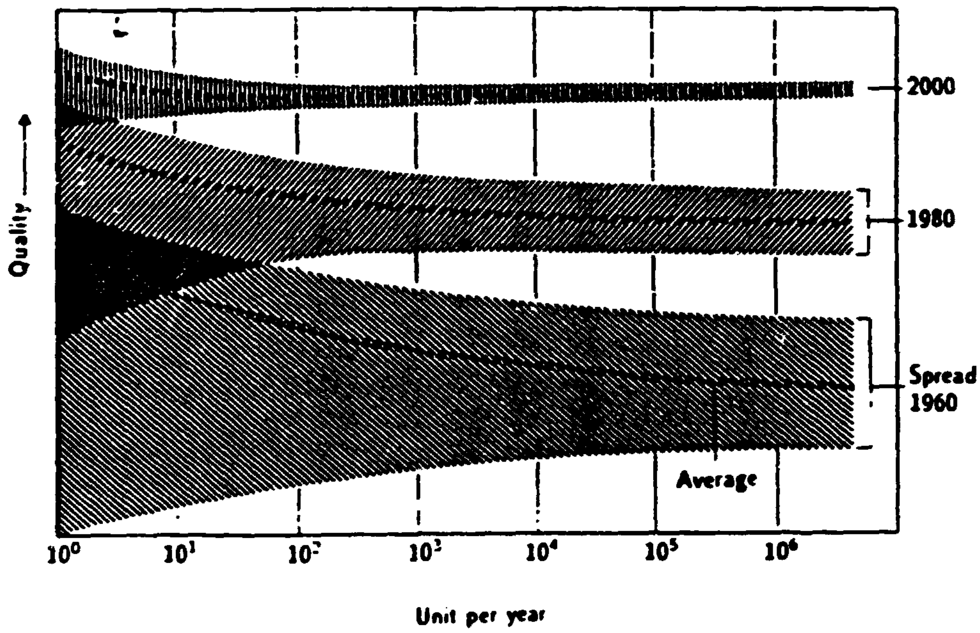
Size of firm (no. of employees)	Lead time (per cent)	WIP percent (per cent)	Machine utilization (per cent)
1-500	-66	-66	+45
501-1000	-76	-63	+50
1000+	-86	-70	+55
UK average (50 firms)	-74	-68	+52
Swedish average (20 firms)	-69	-60	+74

103 (UN/ECE, 1986).

104 (1987a).

In both countries the implementation of FMS also appears to have improved competitiveness with overall productivity increases (although these could clearly not all be attributed to technological change). In the UK the average increase over 50 firms was about 380 per cent and in Sweden 350 per cent when comparison is made directly between those areas where FMS had replaced more traditional production processes.

Figure 5.1 Increase in quality and reduction of quality spread made possible by flexible manufacturing.



Source: Wyss (1985).

Also much of the above evidence supports the view that one of the most important competition criteria is quality of products, and that flexible manufacturing is capable of providing a significant weapon in the international competition battle (Figure 5.1).[105]

Five examples of the impact of FMS on individual companies now follow. The first is the Vought Corporation in the US.

Next we briefly highlight several applications of FMS which have impacted on five companies.

"The Vought contract was given to Cincinnati Milacron, who produced the workshop for 10 million dollars; this seems high compared with the average European development for workshops of the same class, which would cost about half this amount. The figures required for a precise breakdown of costs are not available, but it is possible to estimate the investment made by Vought directly with reasonable accuracy. Taking account of the Cincinnati contribution, the total cost of the installation must have amounted to some 15 million dollars.

[105] Wyss, 1985.

The estimated savings by the company over the entire B1 (Bomber) programme must be compared with these figures. The saving envisaged was of 25 million dollars on parts produced up until 1988. Allowing for the imprecision of such rapid calculation, the return on the investment would be realized in about 3 years which, for such a large sum and for an installation with such a short life expectancy (between 10 and 15 years), is remarkable, and all the more so because the workshop occupies a relatively small area of 2,800 square metres".[106]

The second example is of the Yamasaki installation in Japan.

"The results of operations in the workshop allowed Yamasaki to quantify the savings. While it is difficult to use such data at their absolute value or with perfect precision, the tendency is nevertheless clear.

The palletization machine makes a distinct improvement in the rate of operation since loading is carried out in advance of operation. This represents an improvement of 33 per cent in machine use as compared with the traditional workshop.

Indirect operation times for the workers are reduced by 5 per cent (a reference in this comparison is a modern workshop comprising NC machines). The distribution of parts in the assembly workshop in a strictly controlled and precise way, together with the constant manufacture time, allowed a reduction in assembly time of 3.5 per cent. The floor space required was reduced by two-thirds. This result is particularly spectacular, even though its financial consequence is indirect.

These figures are only partial, but the main effects achieved are increased flexibility and adaptability to demand, a capacity for 24 hours' work per day, improved productivity, the possibility to produce the exact quantity of each part required, and a reduction in the manufacturing cycle and in indirectly associated work. This set of objectives justified the overall investment in the workshop, which amounted to 450 thousand francs in 1983".[107]

Three other examples from the UK are as follows:[108]

In another article attention is drawn to several UK companies perceived benefits from FMS.

"For example, in the limited CIM facility installed for the development of the replacement for the Metro saloon, the Rover company report major improvements such as reductions in lead time for machining components such as cylinder heads from 648 hours to 72, for camshafts from 200 to 48 hours and for die blocks from 65 to 23 hours.

In another widely-publicized facility - the Rolls-Royce Advanced Integrated Manufacturing System - the high capital costs (some £ 4 million) of the system were offset by major savings in inventory (around £ 4.5 million) in the first year of operation. To this must be added the long-term benefits of reduced lead times, improved quality and greater flexibility. Another plant, JCB Transmissions at Wexford, reports a 30 per cent increase in turnover and a 50 per cent increase in productivity as a result of its AMT (advanced manufacturing technology) programme.

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[106] Bonetto, 1988.

[107] Bonetti, 1988.

[108] Bessant and Haywood, 1988.

In one FMS case which we examined, for example, redesign of the product led to a reduction in the number of operations (handling and machining) from 47 to 15 - with significant implications for cost and lead time savings. As one manager put it, 'FMS is going to drive the shop - but it's also going to drive the people who design the product and the production engineering ...those parts have got to be made on this investment if we are to justify it".

The IIASA database on FMS/FMC is an extensive collection of information on the experience of these systems ion a large number of installations in many countries. The perceived benefits can be summarized as follows:[109] (The parenthesis contains predictions of future trends)

- Average batch size: 50 to 100 (20 to 50).
- Lead-time reduction: two to three (three to five).
- Work-in-progress reduction: two to three (four to five).
- Inventories reduction: two (four to five).
- Personnel reduction: two to three (three to four).
- Number of machines reduction: two to four (the same).
- Floor-space reduction: two (the same).
- Capacity utilization increase: 1.4 (2).
- Unit cost-reduction: 1.25 to 1.5 (2).

The rationale for adoption is also clearly expressed in the UN/ECE (1986) report.

"FMS is widely recognized as being a key technology both in short- and long-term respects. In the short run, enterprises can increase their competitiveness by realizing the economic benefits of FMS as well as by having a production system streamlined to accommodate to variable market demands. In the long run, FMS constitutes the groundwork for the future implementation of CIM".

This study has illustrated both the importance of FMS and the potential benefits that companies can realize from the technology. At the same time, it has been pointed out that the success of FMS depends primarily not on technical perfection but rather on the care devoted to the planning and preparation of its implementation".

5.2 FMS Definitions, Configuration and Downscaling

An FMS may be defined as follows:

"A flexible manufacturing system (FMS) is an integrated computer-controlled complex of numerically controlled machine tools, automated material and tool-handling devices and automated measuring and testing equipment that, with a minimum of manual intervention and short change-over time, can process any product belonging to certain specified families of products within its stated capability and to a predetermined schedule".[110]

When comparing systems labelled FMS which are in operation in industry, it is obvious that they vary considerably with respect to, for instance, machine configuration, number of

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[109] Tchijov, 1991.

[110] UN/ECE (1986).

machines controlled by the system and investment costs. For these reasons it is useful to distinguish between the following size categories of flexible manufacturing:

- Flexible manufacturing unit (FMU), which is a one-machine system, usually a machining centre or a turning centre, equipped with a multi-pallet magazine, an automatic pallet changer or robot, and an automatic tool-changing device. The unit is able to operate partly unattended;

- Flexible manufacturing cell (FMC), which comprises two or more machines, usually at least one machining centre or turning centre, multi-pallet magazines and automatic pallet, and tool changers for each machine. All machines, as well as the operations carried out by the cell, are controlled by a DNC-computer;

- Flexible manufacturing system (FMS), which is made up of two or more FMU connected by an automatic transportation system (automated guided vehicles, computer-controlled cranes etc.) which moves pallets, workpieces and tools between machines and to and from workpiece and tool storage. The whole system is under the control of a DNC-computer which is usually connected to a factory host computer.

> This study has illustrated both the importance of FMS and the potential benefits that companies can realize from the technology. At the same time, it has been pointed out that the success of FMS depends primarily not on technical perfection but rather on the care devoted to the planning and preparation of its implementation".[111]

The organizational aspects are particularly important in the context of developing countries:

> "It must be recognized that flexible systems represent a marvelous tool for progress, but whatever the levels of advancement, both human and technological, of the organizations that use them, they cannot be introduced in the absence of suitable methods.
>
> Flexible manufacturing systems represent one of the few means available to countries with high standards of living to compete with countries having low salary levels in the field of industrial manufacture. *Indeed, the technology involved requires a human environment that developing countries cannot yet provide*".[112]

To a large extent the choice of FMS/FMC configuration depends on the type, range and batch size of parts being handled by the FMS. One of the major splits so far has been into "prismatic" - that is parts based around cuboid shapes such as gearboxes - and "rotational" parts such as axles and shafts. The former are suitable for machining on advanced CNC machining centres whilst the latter depend on lathes and cylindrical grinding equipment; the majority of FMS-installations are for prismatic types, reflecting the difficulties in handling rotational parts and their relatively lower value.

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[111] UN/ECE, 1986.

[112] Bonetto, 1988.

Most prismatic parts systems make use of pallet-based handling. Conveyors are used to move pallets containing light weight components and those with short machining cycle times, whilst AGV's are used to transport heavier components. Since AGVs are slower than conveyors, efforts have been made to develop suitable fixtures to enable one pallet to carry several different components which will mean a longer cycle time at the machines and compensate for the speed disadvantage. One answer to this problem is the adoption of cube fixturing which allows several components with short machining times to be attached to a cube. When this is then palletized and presented to the machine tool, machine utilization is rapidly increased.

Most prismatic systems employ automatic pallet changers and other transfer machinery; many use pallet systems for tool management as well, often employing a tool-changing robot at the machine tool. All FMS in use have some form of automatic tool change and many have head changing ability on machine tools as well. Experience with rotational FMS is less developed but here the handling is usually based on conveyors and robot transfer to and from machine tools.

A major problem emerges in the heavy costs associated with multiple fixturing devices and jigs. An enormous amount of effort is required to ensure conformity of such equipment. For example, if floor to machine tables on individual machines vary there are no major problems. However, in an automatic feed associated with FMS, it is essential that each piece of equipment is able to deliver components in a precise manner to the various items of equipment in the system. Furthermore, if the number of parts of a similar nature being put through the FMS is reasonably large - by this we mean 5 to 10 - it may require the purchase/manufacture by the user of a multiple number of relatively high cost jigs/fixtures.

The Ingersoll Engineers (1983) following influences on configuration have been identified:[113]

- variety of parts to be handled - the greater the number, the more flexibility required of the machine tools and may require special purpose machinery.
- volume of parts to be handled - this will influence the number of machine tools required.
- size of parts to be handled - and weight of parts to be handled - this will influence the choice of machine tools and also the design of the relevant worktables, shuttles and materials handling devices such as conveyors and robots.
- workpiece material used - this will influence the choice of tools, the horsepower requirements of the machines, the provisions for chip and swarf removal, the cooling systems and the decision to go for a multi-material FMS or a standard one material type as the Japanese seem to be mostly doing.[114]
- dimensional tolerance required for the final parts - this will influence choice of machine tools, type of inspection equipment, tooling, fixturing and parts location technology.

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[113] Ingersoll Engineers, (1983).

[114] Driscoll, 1984.

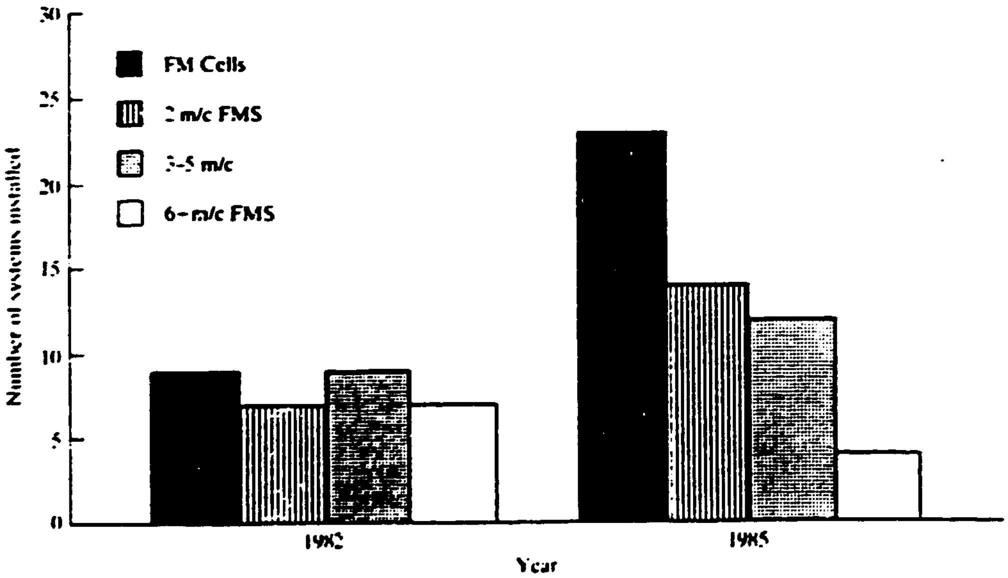
- product life of parts to be handled - short product life will require high levels of flexibility in machine tools and a minimum of dedicated tooling.

As a consequence of the problems associated with some of the early FMS installations, a growing trend towards smaller, less sophisticated and less costly FMC has emerged.

> "From our data analysis it is possible to conclude that in the 1980s the tendency toward higher technical complexity (TC) encountered a number of obstacles. First, the experience in FMS usage indicated that from the economic viewpoint some expensive subsystems were not viable and increased the pay-back time. Second, certain limits to the growth of the number of machines are connected with hyperbolically increasing software costs when the number of pieces under computerized control increases. The third reason for TC stabilization, or even decrease, is the growth of the FMS world market. Highly sophisticated FMS could be invested in and managed by large companies sufficiently experienced in high-tech use. But in the 1980s several FMS adopters came on the market, and some were relatively small companies, often subsidized from government funding. Having no experience in FMS use, they demanded relatively simple and inexpensive systems".[115]

These trends can be seen in a number of OECD countries. With regard to the FRG:

Figure 5.2 Growth of flexible manufacturing cells in overall FMS diffusion



<u>Source:</u> Bessant & Haywood (1988a).

Even by the mid-1980s the FMC/FMS ratio was quite high across a range of countries.[116]

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[115] Tchijov, 1991.

[116] Tchijov, 1991.

Table 5.2 Selected values of FMC/FMS ratio in 1985

NL	UK	France	FRG	Sweden	CSFR	Hungary	11 countries on average
3.0/1	4.0/1	2.4/1	2.4/1	6.4/1	12.7/1	2.4/1	4.6/1

Sources: ECE (1986); Berenschot (1988).

> "According to Berenschot (1988), the FMC/FMS ratio was 4.6/1 on average for 11 countries (see Table 5.2), and the projected increase of the FMC population at the end of the 1980s exceeds the analogous increase of the FMS population in Dutch industry by a factor of 3.3.
>
> On the other hand, indirect evidence, based on national surveys, gives a much larger FMC/FMS ratio. For example, in the USA it reached between six and eight to one at the end of the 1980s. Even more startling, among approximately 200 metal-forming flexible systems, lines, and cells surveyed by JIRA (1986) for the Japanese industry, only 13 were defined as FMS about 15/1 in fact". (Tchijov 1991).

It appears that the main FMS vendors are simplifying and standardizing them to make them more marketable to potential adopters.[117] These tendencies are evident in both the USA and Japan too: remarks "The former country passed a technical complexity peak in 1986, and the latter in 1983."[118] There is evidence of changes in cost distribution, and a trend towards lower average investment costs.

> "The analysis of the fourth version of the data bank shows that FMS distribution over investment cost is similar to the FMS distribution over technical complexity. More than half of all FMSs, where investments were reported, cost less than US$3 million (44 per cent in ECE, 1986). Approximately one-quarter cost from $3 to 7 million, and one-quarter cost more than $7 million (20 per cent and 36 per cent, respectively, in ECE, 1986)".[119]

There is also a trend towards standardization:

> "Current trends favour simpler systems, the setting-up of which do not present so many problems. We are leaving the age of prototypes and entering a period of industrial applications, but it will take another few years before the full cycle of this new generation of workshops, mainly based on standard modules, can be evaluated".[120]

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[117] Akamatsu, (1988), FMS Magazine (1987-9).

[118] Tchijov.

[119] Tchijov, 1991.

[120] Bonetto, 1987.

5.3 Feasibility and Introduction Aspects

With regard to the introduction of FMS/FMC, detailed pre-installation work is required. This may take up to a two year period of feasibility studies if the wrong choice of configuration and operation is to be avoided. All the interfaces in an integrated approach to production need to be assessed, and a high level of management and workshop personnel have to be involved. This should include:

- a high level project leader - preferably one of the 3 or 4 most senior persons in the company, and with knowledge of the industrial process;
- a top level methods expert;
- a planner with production/management expertise;
- a senior representative of the buying department with strong links to the equipment supply industry;
- a production planning and inventory control expert;
- a senior representative of the personnel department;
- last, but not least, a top level manufacturing engineer.

Clearly, if such a grouping of personnel is required for implementing FMS/FMC in the most developed countries, considerable barriers - though not insurmountable ones - are raised for developing countries.

What all countries are faced with is the task of bringing about a workshop that integrates production control, planning and automatic manufacturing systems. The workshop is organized around the following functions:[121]

- dynamic scheduling;
- launching of operations;
- production control;
- handling control;
- DNC;
- tool management;
- management of work in progress;
- planned maintenance and statistics;
- quality control;
- system control;
- information management.

The possible changes that follow from the impact of FMS/FMC, and the integration required for efficient use may be summarized as follows:[122]

- integration of direct and indirect jobs on the shop floor;
- increased knowledge, skills and responsibility on the shop floor;
- increased decision-making autonomy on the shop floor, possible via autonomous working groups rather than traditional line management;
- shallow management hierarchies, with few levels between strategic and operational management;

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[121] Bonetto, 1988.

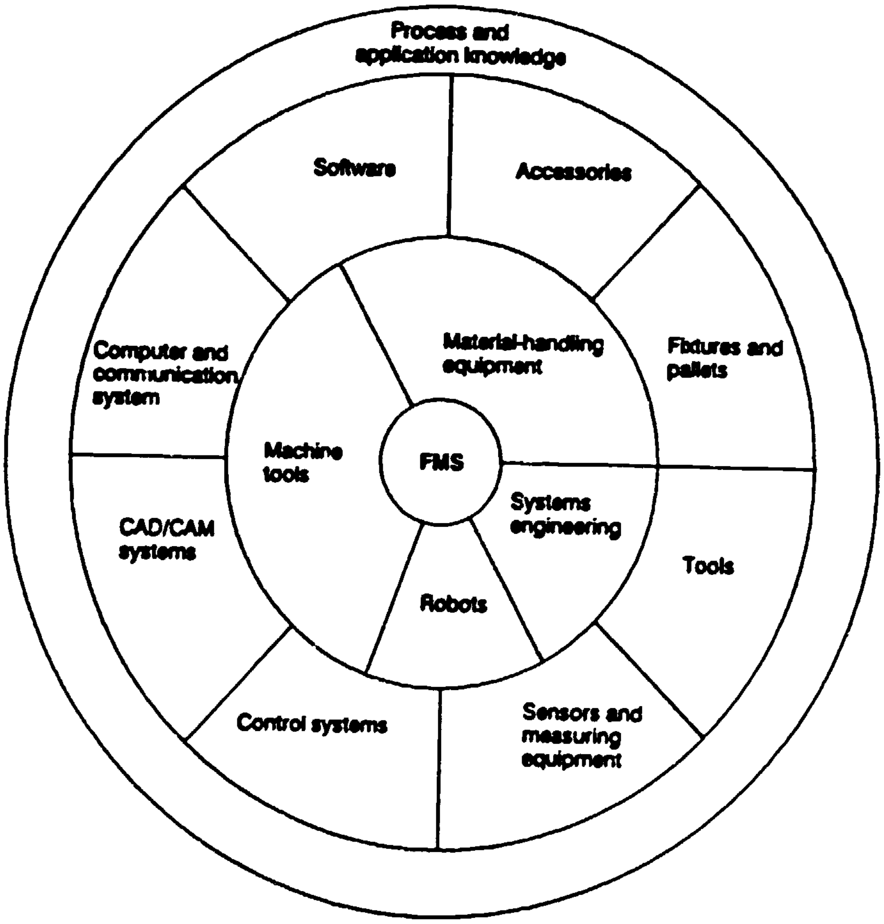
[122] Haywood and Bessant, 1985.

- stronger horizontal integration, mirroring technological capabilities (CAD/CAM, blurring of marketing/design/production interfaces etc);
- increasing role of operational management in short/medium-term planning and increasing longer-term planning activity amongst high level management;
- communication and coordination patterns based more on network structures than organizational hierarchies - again mirroring the technological capability;
- closer links with suppliers and customers.

As indicated above there are a wide range of criteria that need to be applied in the move to FMS/FMC. This involves major technological components (see Figure 5.3) - and later in the report we comment further on the organizational and structural implications.

The FMS then becomes the heart of a group of inter-linked support technologies. Many of these technologies are, as yet, imperfectly developed, e.g., vision robotics, computer systems unable to "converse" with other elements of the existing installed equipment, etc. However, these links improve year by year and many of the building blocks are expected to be in place during the 1990s.

Figure 5.3 Major technology components included in flexible manufacturing systems



Source: UN/ECE (1986).

However, given such diffusion of the basic technology - and the infrastructure needed for successful implementation, a detailed analysis of each individual FMS/FMC is required.

Here the sheer complexity of the problem faced by potential users is revealed. In many instances users in the early stages of the development of full FMS failed to appreciate the problems faced, and many systems were incorrectly configured and used. Many applications up to the mid-1980s failed to achieve the economic targets set for them.[123] Looking at the USA and the UK, they estimate that up to 75 per cent of such systems were uneconomic. However, more recent developments suggest that a combination of greater knowledge of FMS, and the use of rather lower level applications such as FMC are having a positive impact in developed countries.

Utilization rates in FMS are much higher than in a conventional workshop:

"The process generally takes about one-fifth of the time of that taken for a traditional solution. The reduction in the manufacturing time of a part, and thus the delivery time of the finished product, is important in itself; the main characteristics offered by a flexible system are found in the real-time control over the time taken for each process, and thus the facility for immediate action in case of failure.

The rate of utilization of production machines compared with traditional machines is in the order of three or four times more in small or medium batch production. The comparison must be made for equivalent quantities of work and not for identical numbers of machines. It is clear that an FMS with the same number of manufacturing units is more expensive than a standard system. What counts is the number of hours' work executed and not the means required for use".[124]

More recent data in the IIASA database confirms higher utilization rates:

"The most typical operational mode of FMS is as follows: three shifts a day, including one unmanned night shift. Of 276 machining FMSs (for whom information was available in the IIASA database), 66 per cent are used during three shifts a day, 30 per cent between one and three shifts, and only nine are used for one shift a day. Of 131 FMSs 72 per cent are autonomous enough to be used during one shift in an unmanned mode, 21 per cent are used automatically for less than one shift, and 5 per cent are used for longer than two shifts".[125]

5.4 IIASA Database Findings

Using the IIASA database of 880 FMS systems worldwide he found that two groups dominated in their use,

(1) transport equipment, non-electrical machinery and large electrical machinery,
(2) electronics and instruments,

though the first group accounted for around 90 per cent of the sample. He calculated that:

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[123] Jaikumar (1986) and Voss (1986).

[124] Bonetto, 1988.

[125] Tchijov, 1991.

"In group one the breakdown by sector was 76 per cent in machining (metal-cutting) processes (APP2 in Table 5.3); 8 per cent in manufacturing nonmachining processes, like plating, combination of different processes like machining and assembly (APP1); 8 per cent in metal forming (APP3); and 8 per cent in welding and assembly (APP4+5). For the systems installed in group two the shares differ: 24 per cent in machining, 29 per cent in metal forming, and 32 per cent in welding and assembly. Chronologically, assembly FMS and machining-and-assembly processes appeared much later than pure machining FMS, but the growth rate of the assembly FMS was higher than the average during later years than it was for the growth rate of FMS as a whole. It means that the future growth of FMS technologies will be based not only on the spreading of their implementation in traditional niches (metal cutting and metal forming) but on a rapid growth of new niches (assembly and manufacturing), especially in electronics and instruments".[126]

By 1988 data on almost 900 systems had been collected in the IIASA database (see Figure 5.4) -though it is believed that there were about 1,000 FMS at that time. The most dominant individual countries were Japan, the US, the UK, the FRG, and France (Table 5.4). The then USSR was also a prominent user, but information on these systems was less in the public domain at that time.

Table 5.3 The average FMS characteristics by areas of application

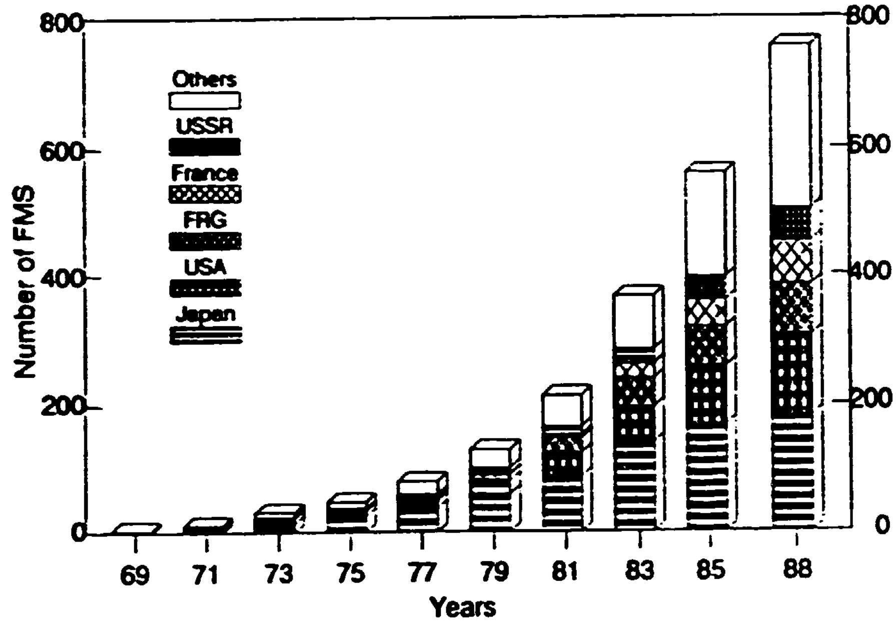
Indicators	APP2	APP3	APP4+5
Number of NC machines (NCMT)	6.9	3.9	18.0
Number of robots (ROB)	3.1	1.7	29.0
Technical complexity (TC)	4.4	1.9	9.4
Operation rate (OPR)	2.7	2.3	2.4
Number of unmanned shifts (UNM)	1.0	0.8	1.6
Number of product variants (PV)	163.0	1138.0	88.0
Batch size (BS)	207.0	71.0	324.0
Investments (INV)	5.7	3.1	5.9
Pay-back time (PBT)	3.8	3.1	3.6
Lead-time reduction (LTR)	5.1	9.5	10.1
In-process-time reduction (IPT)	7.3	4.0	4.1
Inventories reduction (INR)	3.9	NA	NA
Work-in-progress reduction (WIP)	3.7	NA	NA
Personnel reduction (PER)	4.2	1.8	4.1
Number of machines reduction (NOM)	4.0	NA	NA
Floor-space reduction (FLS)	3.1	1.7	1.7
Capacity utilization increase (CAP)	1.8	NA	NA
Unit-cost reduction (UCR)	1.7	2.4	2.4

NA = Number of observations is not enough for averaging.

Source: Tchijov (1991).

[126] Tchijov, 1991.

Figure 5.4 FMS population in the world



Source: Tchijov (1991).

Just seven of the typical trends of results coming from FMS/FMC applications are given in Figures 5.5 through 5.7. In the first figure, work-in-progress (WIP) has reduced by a factor of five as a result of FMS and associated organizational changes. Similarly, lead-times (LT) have also reduced by almost the same ratio.

In Figure 5.6 the number of machines (NOM) installed has reduced by about a half; while capacity utilization (CP) has nearly doubled.

Figure 5.7 shows work-in-progress (WIP), personnel reduction (PER) and unit cost reductions (UCR), for four countries.

Figure 5.5 Trends in lead-time (LTR) and work-in-progress (WIP) reductions

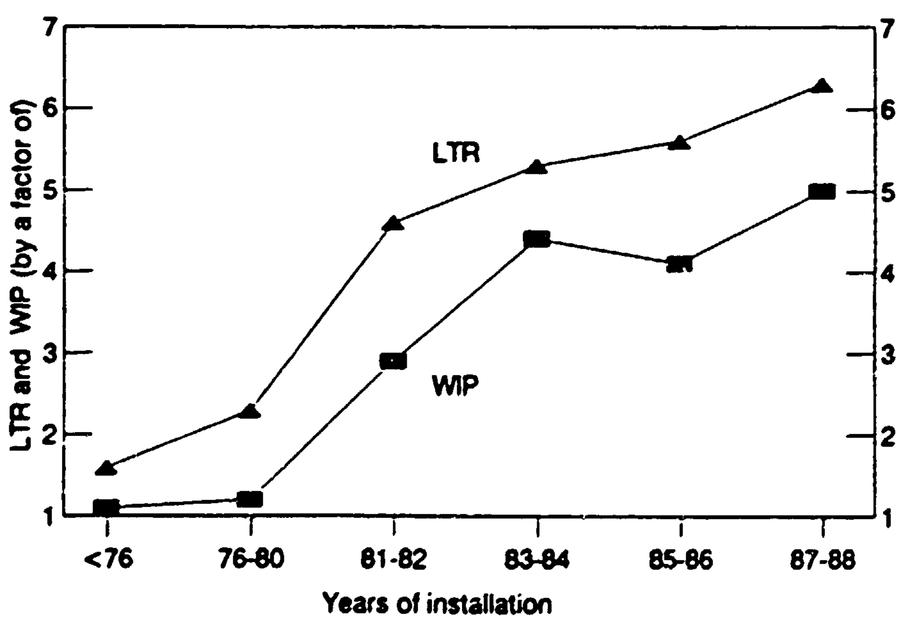


Figure 5.6 Trends in number of machines reduction (NOM) and capacity utilization increase (CAP)

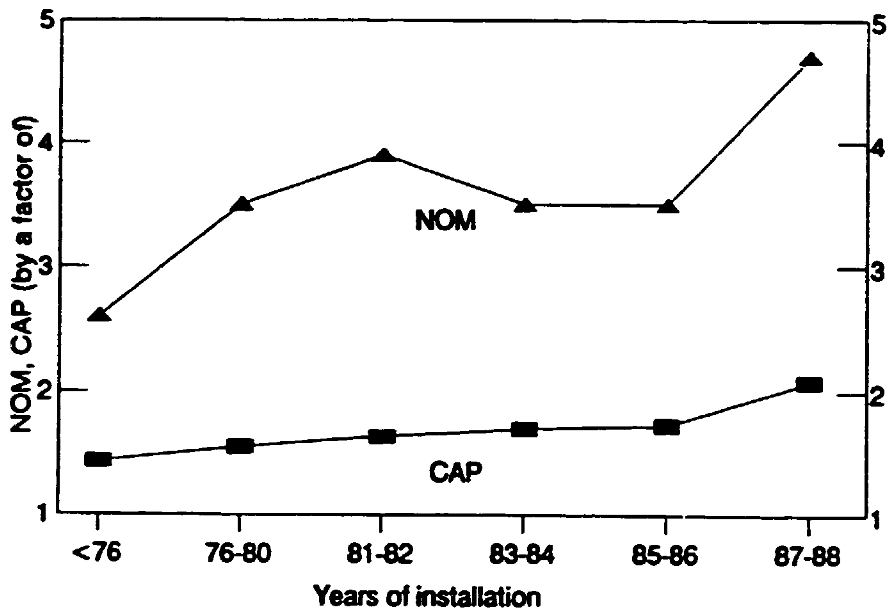
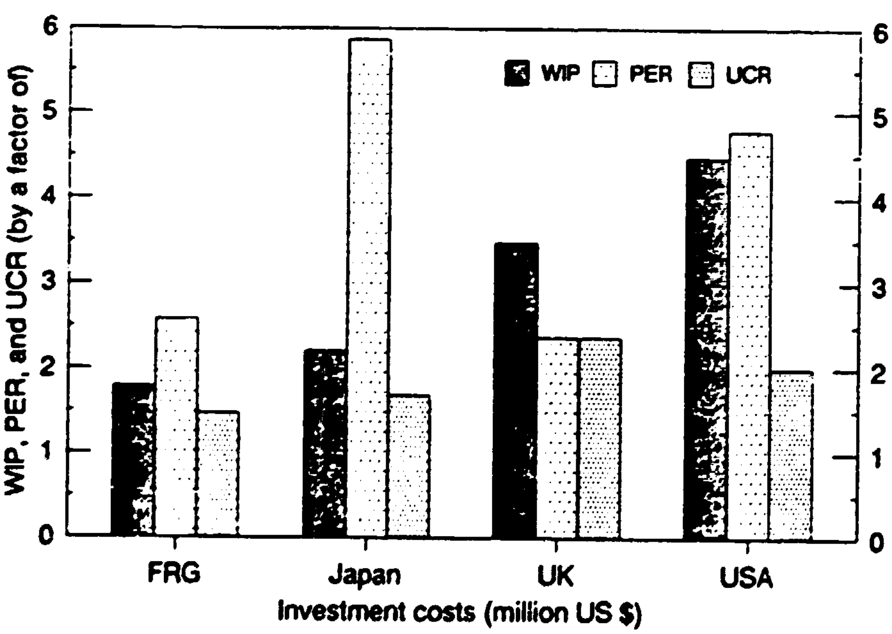


Figure 5.7 Average WIP, PER, and UCR by countries



<u>Source:</u> Tchijov & Sheinin (1991).

A full breakdown of application by country is given in Table 5.4 including several East European countries, e.g., Hungary and Poland and a number of newly industrializing countries, e.g., India, Singapore, South Korea, and Taiwan.

Table 5.4 Geographical distribution of FMS installations

Country	Number of FMS installed	Share, per cent
1. Austria	6	0.7
2. Belgium	6	0.7
3. Bulgaria	15	1.7
4. Canada	4	0.5
5. CSFR	23	2.6
6. Finland	12	1.4
7. France	72	8.2
8. FRG	85	9.7
9. GDR	30	3.4
10. Hungary	7	0.8
11. India	1	0.1
12. Ireland	1	0.1
13. Israel	2	0.2
14. Italy	40	4.5
15. Japan	213	24.2
16. Netherlands	8	0.9
17. Norway	1	0.1
18. Poland	5	0.6
19. Romania	1	0.1
20. Singapore	1	0.1
21. South Korea	4	0.5
22. Spain	2	0.2
23. Sweden	37	4.2
24. Switzerland	6	0.7
25. Taiwan	5	0.6
26. UK	97	11.0
27. USA	139	15.8
28. USSR	56	6.4
29. Yugoslavia	1	0.1
Total East	138	15.7
Total West	742	84.3
Total	880	100.0

Source: IIASA Database.

Dividing the information on FMS installations into three geographical groups, East Europe, Developed Market Economies and the USSR, gives results in Table 5.5, which shows a variety of economic and production factors.

The USSR has the most complex FMS as indicated by the technical complexity (TC) index; has most machining centers per FMS; and the shortest pay-back time (PBT).

East European FMS tends to contain the most NC machine tools (NCMT); produce the largest number of product variants (PV); and have the shortest in-process time (IPT).

Table 5.5 Data comparison: East Europe, DMEs, and the USSR

Indicator	East Europe[a]		DMEs		USSR	
	No. of cases	Average	No. of cases	Average	No. of cases	Average
Machining centers per FMS (MC)	45	4.9	469	4.6	26	6.2
NC machines per FMS (NCMT)	71	8.6	576	7.2	45	8.3
Robots per FMS (ROB)	24	5.6	170	6.5	15	4.2
Technical complexity index (TC)	75	4.8	595	4.6	45	5.0
Product variants (PV)	56	203.0	437	149.0	31	110.0
Average batch size (BS)	41	382.0	192	127.0	25	308.0
Investments, Million $ (INV)	21[b]	4.0	263	5.9	9	4.7
Pay-back time, years (PBT)	29[b]	4.8	69	3.4	1	3.0
Reduction by a factor of						
Lead time (LTR)	21	2.9	82	6.3	-	-
In-process time (WIP)	29	3.5	44	8.0	2	5.0
Work-in-progress (WIP)	17	3.3	58	5.2	-	-
Personnel (PER)	31	2.3	111	4.5	29	2.7
Unit cost (UCR)	14	1.6	54	1.7	-	-
Increase by a factor of						
Productivity (PROD)	35	2.8	43	4.4	9	2.6
Capacity utilization (CAP)	20	1.8	59	1.9	2	1.7

[a] Excluding the USSR.
[b] Mainly CSFR installations.

Source: Tchijov & Sheinin (1991).

The developed market economies (for the most part OECD countries) possess more robots per FMS (ROB); manufacture in the smallest batch sizes (BS); have the largest average investment per FMS (INV); the greatest reduction in personnel (PER); the highest productivity (PROD); and the highest capacity utilization. Clearly the DMEs are the countries who are achieving the most flexible and the highest returns from FMS. Since the basic technologies themselves are now fairly standardized, two explanations are possible:

(1) That the extent and diffusion of computer hardware and software have been more rapid in the West. This has given an advantage to those countries, and only recently have the strategic constraints - usually as a consequence of US policy - been lifted, giving the formally communist command economies open access to such hardware and software, provided they have funds to purchase it.

(2) Perhaps of equal, and maybe greater importance is the infrastructural framework in place. Even the market driven economies of the West have had to re-adjust to rapidly changing world systems in order to meet increased competition. Low wage developing economies, emerging NICs; and most importantly the evolving information technology revolution has changed perceptions. Now it is not only the technology that is important, but also the way in which it is used.

5.5 Cost and Proliferation

One indication of trends in the costs of systems comes from analysis of the UK,[127] where the year on year cost changes in the systems being installed were calculated. These show a quite dramatic fall in the average cost of FMS/FMC systems from 1982 to 1986.

Table 5.6 Average UK System Costs 1982 - 1986

1982 = £2,453,398	n = 11
1983 = £2,450,484 (as a % of 1982 = 99.88%	n = 19
1984 = £2,071,653 (as a % of 1982 = 84.34%)	n = 13
1985 = £1,685,370 (as a % of 1982 = 69.70%)	n = 15
1986 = £1,127,887 (as a % of 1982 = 45.98%)	n = 26

Source: Haywood, unpublished data (1991a).

By 1986 the cost of the average FMS/FMC had fallen to approximately 46 per cent of the average costs in 1982, from almost £ 2.5 million to a little over £ 1 million.

Perhaps of equal interest is the gradual increase in applications over this period by new sectors. In 1982 there were applications in 8 areas. This was added to by 15 in 1983, 8 in 1984, 7 in 1985, and 10 in 1986. By the end of 1986, 43 different Standard Industrial Categories (SIC) at the four digit level were using FMS/FMC (Table 5.7).

Clearly the range of applications has increased rapidly - and not merely in the Mechanical Engineering sectors, which attract the most attention in the research field.

[127] Haywood, 1979a.

*Table 5.7 FMS/FMC by SIC and year of introduction in the UK**

Year	SIC	Application	
1982	3510	Motor Vehicles and Engines	
	3530	Motor Vehicle Parts	
	6148	Wholesale Distribution of Vehicles	
	3321	Metal Working Machine Tools	
	3640	Aerospace Equipment and Repair	
	3610	Shipbuilding and Repair	
	3275	Machinery for Woodworking/Rubber, etc.	
	3420	Electrical Lighting Equipment	
			n = 11
1983	3442	Electric Instruments & Control Systems	
	3205	Boilers/Process Plant	
	3283	Compressors and Fluid Power Equipment	
	3111	Ferrous Metal Foundries	
	3169	Finished Metal Products	
	3284	Refrigeration/Ventilation Equipment	
	3251	Mining Equipment	
	3289	Mechanical & Marine Engineering	
	4671	Wooden/Upholstered Furniture	
	3275	Footwear Machinery	
			n = 19
1984	3441	Telegraph/Telephone Equipment	
	3454	Electronic Equipment	
	3420	Electrical Equipment	
	3244	Food/Drink/Tobacco Processing/Packaging	
	3254	Construction/Earthmoving Equipment	
	3261	Precision Chains	
	4835	Plastics Processing	
	3276	Printing/Bookbinding/Paper Machinery	
			n = 13
1985	3222	Engineers Small Tools	
	2479	Other Glass Products	
	3251	Motor Vehicle Bodies	
	3120	Forging/Pressing/Stamping	
	2247	Other Non-Ferrous Alloys	
	3167	Domestic/Similar Metal Utensils	
	3301	Office Machinery	
			n = 15
1986	4532	Mens/Boys Outerwear	
	4539	Other Dress Industries	
	3230	Textile Machinery	
	4420	Leather Goods	
	3444	Components for Electrical Equipment	
	3620	Railway/Tramway Vehicles	
	3443	Radio/Electronic Capital Goods	
	2562	Adhesives/Sealants	
	2478	Glass Containers	
	3302	Data Processing Equipment	
			n = 26

* It should be observed that only new SIC applications for each succeeding year are noted. For example, the yearly list does not include the fact that new installations of FMS/FMC for manufacturing Motor Vehicle Parts (SIC 3530) occurred in each of the five years 1982-86, Metal Working Machine Tools in three out of the five years, etc.

Source: Haywood (1991a), unpublished data.

It is interesting that even in 1986 a range of FMS/FMC applications in 1986 in the UK in Clothing, Textiles and Leather goods had emerged, although no detailed information on these systems and their effectiveness is available.

5.6 FMS/FMC: A Brief Summary

FMS applications are the closest embodiments of full automation that are dealt with in the present report. There are a very few full CIM complexes but these are fairly inflexible and manufacture a very limited range of components and use a limited range of materials.

FMS is an answer to small batch production problems - which fail to achieve economies of scale - and which moves such production to a more flow-line process though, as yet, not many FMS are able to fully achieve true flexibility goals for which they are intended.

The cost of full FMS is still high and several million dollars is not considered to be a very high price to pay for one. However, there are indications that as the technologies evolve, as people become more familiar with them, and as diffusion increases, cheaper, less sophisticated systems (or FMC) are becoming more popular.

As with most other technologies, FMS has been installed first in the large companies in specific industrial sectors, e.g.,automobiles, aerospace, agricultural/earthmoving equipment, etc. Early FMS were not particularly flexible, or even economic, though systems are now becoming more rational due to longer periods of planning, a greater concentration on training for the people who run them, and more realistic goals being set.

Users have also been made aware of the fact that there are many intangible benefits of FMS, e.g., raising quality levels and shortening lead times may alter customers/potential customers perceptions of the company and thus increase orders.

The more tangible benefits include reducing costs, increases in equipment utilization rates, reduced inventory and work in progress, etc; and measures of these improvements have been indicated in this chapter.

Individual company improvements have also been highlighted e.g., Yamasaki, the Vought Corporation, Rover cars and Rolls-Royce engines, etc. There are, however, costs associated with the technology, e.g.,increased training outlay, (though we subscribe to the view that this is not really a cost but an investment in the future), increased costs in fixtures, jigs, tools, greater planning, system maintenance, etc. In many instances, because of the cost of a system compared with a conventional workshop, this involves multiple shift working.

Successful FMS/FMC use often entails dramatic changes in the way that companies operate. This may involve the breaking down of hierarchical or structural distinctions between jobs, the devolving of authority and responsibility back to shopfloor workers, much tighter links into suppliers and customers, and the adoption of a total quality approach to manufacturing.

The main component of growth up to the mid-1990s will be of rather simple and customized systems. It is likely that as more of the software, organizational and integration problems are resolved, that in the latter 1990s, rather more sophisticated systems will again emerge.

While machining systems will probably remain the main focus of FMS, increasingly attention will centre on assembly FMS which are likely to become widespread in the first decade of the next century.

As noted earlier, in the UK, FMS is now diffusing broadly through industrial sectors and this will continue to occur as the "philosophy" of FMS spreads, this will be as relevant to clothing, textiles and footwear, as it will to engineering, furniture making, injection moulding, foundries, etc.

Increasingly the world share of FMS/FMC will spread to new users as first the NICs and then other developing countries - including those East European countries experiencing market pressures in and from the OECD countries - adopt higher levels of FMS.

As a result of these trends, the early users of FMS, i.e., the motor vehicle, aerospace, machine tool industries, etc, will experience a percentage decline in world terms, but will still be major users of FMS.

The level of about 1,000 FMS in 1990 can be expected to increase to around 3,500 units by the year 2000 and reach approximately 5,000 units by 2010 (Table 5.8).

Table 5.8 FMS population forecast by country

	FMS populations, units			Distribution, per cent		
Country	1990	2000	2010	1990	2000	2010
Japan	370	880	1,200	30.3	25.1	24.0
USA	230	660	1,060	18.9	18.9	21.2
FRG	140	340	500	11.5	9.7	10.0
UK	110	240	250	9.0	6.9	5.0
Others	370	1,380	1,990	30.3	39.4	39.8
Total	1,220	3,500	5,000	100.0	100.0	100.0

Source: Tchijov (1991).

The environment for full FMS may not yet be in place in most developing countries and considerable efforts need to be made in improving educational and training systems at all levels, improvements also need to be made to logistical systems, and better access to financial resources needs to be achieved.

In relevant companies and industries that a limited approach to FMS/FMC might be appropriate and relatively simple, FMC might prove to be the best approach, both in terms of economic costs and benefits, and for its learning curve and demonstration effects.

6. Equipment Supplier Profile

An attempt has been made to evaluate the role of the supplier industry, the automation equipment manufactures, with regard to developing countries. This was done in order to establish if those companies - in the developed countries - had different policies in selling to developing countries; what relationship existed, whether licensing took place; what problems existed which presented barriers to sales; what national policies existed which aided or retarded sales, etc.

A total of 295 questionnaires was distributed to suppliers (from nine OECD countries) that were considered to have some of the prime suppliers of new technologies. These countries, and the response rates are included below.

Table 6.1 Responses to the supplier questionnaire

Country	Sample	Received by September 28, 1992				
		Total responses	Response rate (%)	Not usable	Completed	Completed rate (%)
UK	65	23	35.38	5	18	27.69
USA	51	24	47.06	8	16	31.37
Germany	61	16	26.23	3	13	21.31
Japan	45	9	20.00	-	9	20.00
Italy	23	7	30.43	-	7	30.43
France	17	-	0.00	-	-	0.00
Switzerland	11	4	36.36	1	3	27.27
Sweden	7	2	28.57	-	2	28.57
Netherlands	15	2	13.33	-	2	13.33
Total:	295	87	29.49	17	70	23.73

The response rate after one round of distribution plus one reminder was almost 30 per cent, and the useable questionnaires represented almost 24 per cent of the original sample. However, these rates were pulled down by a low response rate from companies in the Netherlands (13.3 per cent), and a zero response from companies in France.

Leaving these two countries out the rate rose to 32.3 per cent overall and 25.8 per cent for useable questionnaires.

6.1 Sector, Type of Equipment and Regions Supplied

Of the 70 respondents, 35 supplied equipment to the mechanical engineering sector, 26 companies supplied clothing and textiles equipment, and 18 to the electronics sector (Table 6.2). Another group of companies primarily supplied the chemical, food/drink processing, and transport sectors (between 11 and 14 companies).

Table 6.2 Industrial sector you supply to

Sector	Total	UK	USA	Germany	Japan	Italy	NL	Sweden	Switz
Mechanical engineering	35	8	5	9	7	2	1	0	3
Electronic	18	3	5	3	7	0	0	0	0
Textiles & Clothing	26	7	7	2	4	2	1	1	2
Footwear	8	4	4	0	0	0	0	0	0
Printing & Publishing	6	4	1	0	1	0	0	0	0
Pharmaceutical	9	4	3	0	1	1	0	0	0
Chemical	11	6	3	0	0	1	0	0	1
Food & Drink	14	7	4	1	0	1	0	0	1
Transport	13	2	4	3	4	0	0	0	0
Furniture	3	0	2	0	0	0	0	0	1
Other	16	5	3	2	2	3	0	1	0

As will be clear from the individual country columns many of these companies supplied a variety of industrial sectors. For example, 18 UK companies provided information for the survey, but these companies supplied a total of 50 sectors; for instance one company supplied the mechanical engineering, printing and publishing, and food and drink processing industries.

Although the sample is a relatively small one, it appears that Japanese (2.9), UK (2.8) and US (2.6) companies supply to a broad range of sectors, while German (1.5) and Italian (1.1) suppliers deliver to a rather more limited range.

As Table 6.3 shows, the sample contains suppliers of a broad based group of types of equipment. Three groups, machines tools, computer software, and textile/clothing equipment, each had 18 suppliers; with computer hardware, computer aided manufacturing (CAM), and computer aided design (CAD) also well represented, and in fact these may also be suppliers to the machine tools, or clothing and equipment industries.

Table 6.3 Products you supply

Product type	Total	UK	USA	Germany	Japan	Italy	NL	Sweden	Switz
Machine Tools	18	3	0	5	6	2	0	0	2
Robots	10	1	2	2	4	0	0	0	1
Autom Guided Vehicles	4	1	0	3	0	0	0	0	0
Computer Aided Design	12	3	5	3	1	0	0	0	0
Computer Aided Mfg	13	1	5	4	1	1	0	1	0
Computer Hardware	14	3	3	4	2	0	0	1	1
Computer Software	18	3	6	5	2	0	0	1	1
Printing Equipment	3	1	2	0	0	0	0	0	0
Textile & Clothing Eq.	18	5	3	2	4	1	1	1	1
Footwear Equipment	2	1	1	0	0	0	0	0	0
Other Equipment	35	9	11	3	4	4	2	2	0

Apart from the 10 specific categories, there were 35 companies covering a broad range of other equipment.

Germany was particularly well represented in machine tools, AGVs, and the whole spectrum of computer specific areas, as were the USA and UK. Japan was strongly represented in machine tools, robots and computer hardware and software.

There was good response from textiles and clothing equipment suppliers, with respondents from 8 out of the 9 countries. Footwear however yielded only one reply each from the UK and USA.

The regional distribution of the suppliers' markets is given in Table 6.4

Table 6.4 Regions you sell/license to

	Total	UK	USA	Germ	Jap	Ita	NL	Swed	Swit
North America	60	16	14	11	8	5	1	2	3
Japan	51	15	8	9	9	5	0	2	3
Other OECD countries	57	17	10	12	4	7	2	2	3
Asian countries	54	14	9	10	9	6	1	2	3
Latin America	47	13	10	11	2	5	1	2	3
Eastern Europe	47	15	9	9	5	3	1	2	3
Africa	39	14	7	8	0	5	1	2	2

With regard to Africa two clear results emerge. First, Africa is the least important market for these companies - lagging behind Asia, Latin America and Eastern Europe.

Second, that the UK companies, and to a lesser extent the German, American and Italian companies, supply relatively more to Africa than does the group as a whole. The Japanese companies who responded to the questionnaire do not supply at all to Africa.

6.2 Equipment Prices

The prices charged for equipment and software were very wide ranging and, because of the diversity of the sample, generalizations are difficult. For that group of equipment about which most information is available - machine tools, figures are given in Table 6.5. Some prices of CAD, CAM, and computer hardware and software, with one robot example are given in Table 6.6.

*Table 6.5 Machine tool prices (US$ '000)**

Equipment	Price
CNC single spindle	67
CNC lathes	71-85
CNC machining centres	71-710
CNC milling/boring	73-423
CNC lathes	85-310
CNC lathes	92-106
NC lathes	99-142
CNC lathes	113-135
NC single spindle	140
CNC E.D.M. (Ram)	141-280
CNC unspecified	142
CNC multi-spindle	184
CNC milling	190
CNC unspecified	200-280
NC lathes	248
CNC milling	250+
NC double spindle	254
CNC unspecified	330+
NC single spindle	340+
NC single spindle	420-560
NC milling	530

*Converted to U.S. dollars at current exchange rates (June 1991).

The 21 machine tool types represent the output of 6 machine tool companies (3 from Japan, and one each from the UK, Germany and Italy). Simple NC and CNC machine tools at the bottom end of the market, light weight and less sophisticated, can be purchased for around $70,000 - though as can be observed from the third item in the table very large and sophisticated machines can cost up to $710,000.

However, lathes, machining centers, milling and boring machines, etc, can now be readily purchased for under $150,000, and as noted earlier these machines with NC or CNC controllers can be four times or more productive than conventional machine tools. This means in capital terms that conventional machines need to cost between $17,000 and $35,000 to be able to compete in the $70,000 to $150,000 price range of NC/CNC.

The supplier data gives CAD in its simplest form for as little as $16,000; while software packages can be purchased in a range from $3,500 to $120,000.

Machine controllers are available for $9,000 to $15,000; and industrial computers from $4,000 to $100,000 in the one response received.

Table 6.6 CAD, CAM, hardware/software, robots (US$ '000)

CAD	16-100
CAD	50-100
CAD	70
CAD	120
	110-400
CAD/CAM (Hardware)	28
CAD/CAM (Software)	34
Software packages	3.5-20
Software packages	5
Software packages	10-120
Software packages	15-30
Machine controllers	9-15
Industrial computers	4-100
Robots (average price)	71

The one robot example is, as noted in the table, an average price so one assumes that approximately 60 per cent of this firms' robots are sold at or below this price of $70,000.

The prices of numerous other items of equipment were also obtained ranging from Printed Circuit Board (PCB) systems from $230,000 to $350,000; printing presses from $10,000 to $1,500,000; dyeing machinery $100,000; scanners $100,000 to $120,000; process vessels $16,000 to $45,000; inspection machines $3,000 to $25,000; unit process controls $8,000 to $25,000; and management information systems from $50,000 to $250,000. This list is not exhaustive.

Approximately half (50.9 per cent) of the sample companies increased prices by 10 per cent or less between 1980 and 1985; slightly more than in 1985/8 (46.4 per cent). Including the 11 to 25 per cent bracket the gap widened somewhat from 60.3 per cent in 1980/85 to 66 per cent in 1985/8. There was, therefore, a tendency for prices in the latter - and shorter - period to increase faster than in the early 1980s; just at a time when the financial problems of most developing countries were worsening. Since much of this technology would have required payment by OECD currencies, or via export credit guarantee schemes, the ability of developing countries to pay for these goods was worsening.

Table 6.7 Changes in prices 1980/5 and 1985/8 (per cent)

	1980/85	1985/88
+1 - 5 per cent	26.4	25.0
+6 - 10 per cent	24.5	21.4
+11 - 25 per cent	9.4	19.6
+26 - 50 per cent	13.2	0.0
+51 - 75 per cent	3.8	1.8
Unchanged	7.5	17.9
Unspecified increase	11.3	8.9
Reductions	3.8	5.4

At the other end of the scale there was at least a strengthening of the more competitive end of the range with almost 18 per cent of companies offering unchanged prices, or even reductions. In the latter case this was in one Japanese company manufacturing machining centers and lathes (reduced by 10 per cent 1980/5 and 20 per cent 1985/8), and one USA/UK company manufacturing textiles/clothing equipment (by 5 per cent, 1980-5 and 25 per cent 1985/8 in the US; and by 40 per cent 1985/8 in the UK).

Respondents were asked how they expected future prices of their products to change over a two year, then 5 year period. The accuracy with which these questions can be answered depends of course, on the level of planning and forward thinking in companies, i.e. medium to long term rather than short. Specific features of the replies, however, are of considerable interest. The results are summarized in Table 6.8.

For example, in Table 6.8 below, the 1991/3 period shows great conformity with the 1991/6 predictions, as far as increases up to 25 per cent are concerned. A total of 67.1 per cent expect an increase within this range for the first period, and 69.6 per cent expect an increase within this range during the latter period. This is not radically different to the earlier figures of actual increases during 1980/5 (60.3 per cent) and 1985/8 (66.3 per cent).

The major differences exist in the 6-25 per cent and unspecified increases bracket. There is a wide discrepancy which perhaps reflects market uncertainty.

Table 6.8 Price increases 1991/3 and 1991/6 (per cent)

	1991/93	1991/96
+1-5%	28.1	20.0
+6-10%	35.9	23.3
+11-25%	3.1	23.3
+26-50%	0.0	17.0
Unchanged	10.9	8.3
Unspecified increase	18.8	20.0
Reduction	3.1	3.3

One of the reasons for trying to establish data from suppliers was the hope of identifying regional variations in pricing. In the event, suppliers were quite open in saying, by a majority of 2 to 1, that they did differentiate by region (see Table 6.9).

Table 6.9 Does the price of your product vary by region?

	UK	USA	Germ	Japan	Italy	NL	Swed	Switz	Total
yes	10	6	6	5	1		1	1	30
no	2	5	1	2	3	1	1		15
sometimes	6	5	6	2	3	1		2	25
Total	18	16	13	9	7	2	2	3	70

Including with the "yes" answers those who concede variations on occasions, some 78.6 per cent of companies do - for various reasons - adopt differential pricing policies. Of these - leaving aside the last four countries, for whom the sample is small - 92 per cent of German companies, 89 per cent of UK, 78 per cent of Japanese, and 69 per cent of U.S. companies do discriminate.

This does not necessarily imply that they are taking larger profits, since there is a variety of factors which may cause differences in pricing. Table 6.10 below seeks to establish why prices vary.

Table 6.10 Why does the price of your product vary by region?

	UK	USA	Germany	Japan	Italy	NL	Sweden	Switz	Total
Transport costs	10	7	10	6	3	1	0	1	38
Other reasons	13	12	9	5	4	1	1	3	48

In almost half the sample the cost of transport was the prime reason for higher costs. Amongst the first six countries there was remarkable conformity, ranging from 43 per cent in Italy to 53 per cent in Germany who put transport as the main additional cost. Only Switzerland and Sweden were not in line with this - in Switzerland only 1 in 4 companies quoted this and in Sweden none.

Of the "other" reasons given, agents commissions, sales and market costs, and guarantees etc, were the most important (mentioned by 28 per cent of the sample); market competition - and what the market will bear (23 per cent): duties, taxes, credit and insurance (16 per cent), and service costs/ support (16 per cent). See Table 6.11 for a full list of causes.

Table 6.11 Non-transport reasons for price variations

Agent commissions, sales, market costs, etc.	28%
Market competition	23%
Service costs, support, e.g., engineers	16%
Duties, taxes, credit and insurance	16%
Training costs	7%
Local hardware, materials prices	7%
Currency fluctuations	5%

82 per cent of the rationale for higher prices lies with the first four items in the list. Training, and local hardware/materials prices were low in importance in these companies; and hedging against changes in currency exchange rates are almost as important as either of these two factors.

6.3 Trade with Developing Countries

Of 70 companies in the sample, 8 of them did 26 to 50 per cent of their trade with developing countries; and 20 (28 per cent) did between 11 per cent and 50 per cent of their trade with such countries. This means that quite a significant number of companies are involved in the supply of goods to developing countries. (Table 6.12)

Table 6.12 Percentage of trade with developing countries

	UK	USA	Germ	Jap	Ita	NL	Swed	Swit	Total
1 - 5%	7	7	6	2	1	1	0	1	25
6 - 10%	5	4	2	4	0	0	1	2	18
11 - 25%	4	4	0	0	2	1	1	0	12
26 - 50%	0	1	3	2	2	0	0	0	8
51 - 75%	2	0	1	1	2	0	0	0	6
76 - 100%	0	0	1	0	0	0	0	0	1

Contrary to what might perhaps have been expected, i.e. a large trade with developing countries by the UK, only 11 per cent of the UK companies have over 26 per cent of their trade thus placed.

Of the admittedly small Italian sample, 57 per cent supply over 26 per cent of the goods to developing countries; 33 per cent of Japanese companies and 38 per cent of German also have at least this level of trade.

What is apparent from Table 6.13 below however, is that developing countries are becoming more important to these companies. Of the 70 companies, 32 (46 per cent) reported increased trade in the last five years. Of these, Japan has shown the strongest growth with 78 per cent of companies expanding trade post - 1986; however as Table 6.4 shows, none of this has been with African countries.

Other expanding networks have primarily been Italy +57 per cent, and the USA +50 per cent. Germany has, in fact reduced its share with only 4 companies showing an increase and 5 reducing.

Table 6.13 Percentage change of trade with developing countries in the last 5 years

	UK	USA	Germ	Japan	Italy	NL	Sweden	Swit	Total
no change	6	3	2	0	0	1	1	2	15
up	7	8	4	7	4	0	1	1	32
down	2	1	5	2	1	0	0	0	11
no answer	3	4	2	-	2	1	-	-	12
Total	18	16	13	9	7	2	2	3	70

Future developments are expected to show almost a universal increase in sales to developing economies. (see Table 6.14)

Table 6.14 Expected percentage change of trade with developing countries in the next 5 years

	UK	USA	Germ	Jap	Ita	NL	Swed	Swit	Total
no change	4	2	3	0	2	1	1	1	14
up	10	12	6	7	2	0	1	1	39
down	0	0	2	2	1	0	0	0	5
no answer	4	2	2	-	2	1	-	1	12
Total	18	16	13	9	7	2	2	3	70

Nearly 56 per cent of these companies expect to expand trade with a range of developing economies, from NICs through to Least Developed countries. Japan again leads with 78 per cent, the US catching up with 75 per cent, and the UK re-emerging at 56 per cent, amongst the major countries.

In the light of earlier discussion on the infrastructural support needed to utilize new technologies, the question of what relationships these companies had in developing countries was examined. This was done by enquiring about licensing, cooperation, joint ventures, etc, and the data is included in Table 6.15.

Table 6.15 Business relations with developing countries

	UK	USA	Germ	Jap	Ita	NL	Swed	Swit	Total
Selling products	13	13	11	7	6	1	2	3	56
Licensing to firms there	2	3	3	2	1	1	0	1	13
Cooperation on project basis with local firms	3	3	2	0	2	0	1	2	13
Joint ventures with locals	2	2	3	2	1	0	0	1	11
Other types of cooperation	3	2	2	1	0	0	0	0	8

A variety of relationships exist ranging from 80 per cent selling hardware (as against software, services etc.), 19 per cent licensing, 19 per cent on collaboration, 16 per cent with joint ventures, and 8 per cent other forms of cooperation.

All of the sample countries had relationships that went beyond merely selling hardware to individual companies in the countries concerned. This is reflected by the fact that 45 of the 70 companies do have established local links - though this varies from local agents to sales offices, local parts suppliers, sister companies, liaison offices, joint venture companies, etc. The main links are contained in Table 6.16.

Table 6.16 Main links with developing countries

Agents/distributors/dealers	44%
Sales offices	28%
Own local service/maintenance facilities	16%
Joint venture companies	8%
Sister companies	4%

In spite of the fact that 64 per cent of the companies do have local links, these are for the most part merely local agents or sales offices (72 per cent). What might prove more conducive to the successful adoption of such equipment would be companies having their own local service and maintenance, or joint ventures or sister companies.

6.4 Developing Countries and Supply Problems

The next question is of spares or maintenance problems which might be present in selling to developing countries. Almost 39 per cent said that it does amount to a significant problem, and 24 per cent did not give a reply. Only 37 per cent thought that no problem existed in this field but this may be due to their own strong local presence on their part. (However as Table 6.16 shows, only 28 per cent of companies have sales offices.)

There are national differences however, with nearly half (44 per cent) the UK companies acknowledging problems; in contrast to Germany where only 15 per cent of companies express reservations.

Table 6.17 Do developing countries pose specific problems (spares, maintenance)?

	UK	USA	Germ	Japan	Ita	NL	Swed	Swit	Total
yes	8	5	2	2	1	1	1	1	21
no	5	8	5	3	3		1	1	26
sometimes	2	1	2		1				6
no answer	3	2	4	4	2	1		1	17
Total	18	16	13	9	7	2	2	3	70

Although almost 40 per cent of the sample faced problems - at least part of the time - this was not thought to lead to higher prices for developing countries, a somewhat surprising conclusion (see Table 6.18).

Table 6.18 Does this involve higher prices for developing than for developed countries?

	UK	USA	Germ	Jap	Ita	NL	Swed	Swit	Total
yes	6	4	3	3	1			1	18
no	8	10	9	5	5	2	2	2	43
sometimes	2								2
no answer	2	2	1	1	1				7
Total	18	16	13	9	7	2	2	3	70

Over 60 per cent of companies responded "no" to this question, and only 28 per cent thought it involved higher prices on a regular or occasional basis. However, a third of the UK, Japanese and Swiss companies did rate it likely that they would charge higher prices.

When asked how much higher prices would be, they responded as in Table 6.19.

40 per cent of the sample anticipated that problems posed by such factors as spare parts and maintenance might well increase prices paid by developing countries by between 6 and 10 per cent; a further 30 per cent considered it likely to be between 11 and 25 per cent higher for such countries.

Again this varied by country with one of the three Japanese companies saying over 11 per cent; and three out of four US companies saying over 11 per cent.

Table 6.19 On average how much higher would prices be?

	UK	USA	Germ	Jap	Ita	NL	Swe	Swit	Total
1 - 5%	2	0	1	0	0	0	0	0	3
6 - 10%	3	1	0	2	0	0	0	1	7
11 - 25%	0	3	0	1	1	0	0	0	5
26 - 50%	2	0	0	0	0	0	0	0	2
51 - 75%	0	0	0	0	0	0	0	0	0
76 - 100%	0	0	0	0	0	0	0	0	0
More	0	0	0	0	0	0	0	0	0

6.5 Licensing and Sales to Developing Countries

One way in which technology can be transferred to developing countries is by the licensing of established products for manufacture in those countries. If, for example, the manufacture of machine tools became a national goal - as it did in Brazil - then considerable learning curve benefits and diffusion factors reinforce the local development, knowledge by the use of such technologies. However, the survey results show low levels of licensing to developing countries (see Table 6.20)

Table 6.20 Licensing to developing countries

yes	18
no	48
no answer	14

Only 25.7 per cent did any licensing to developing countries, and an analysis of what products were licensed shows that only about a half of those would be likely to have any real down line benefits to those countries - such as diffusion and learning curve benefits associated with working with latest technologies and both in the product itself and the production processes needed to perform these tasks. 8 of the 18 companies licensed machinery manufacture, but this ranged from "the smallest and simplest machines" to CNC lathes and machining centers (one Japanese company).

Six companies licensed computer related and graphics products; but others included "staplers", "simple machine parts" (see Table 6.21).

*Table 6.21 Hardware/software licensing**

Dicing machines	1
Food/drink processing	2
Computer related (Hw/Sw)	6
Machine Tools	4
Textile/clothing equipment	5
Footwear machinery	1
Software related	4
Engines	1

*The total exceeds the 18 company sample because some companies license a variety of products

From the developing countries' point of view, the most useful licensing is probably that which promotes learning by doing and enhances skill levels. Among the licensed products reported were the following, which seem particularly relevant:

- textiles/clothing machinery;
- diesel engines;
- standard machine tools;
- computer hardware and software;
- machine tools, and computer hardware/software related systems.

In fact, these all came from German companies.

Other significant licensing included food/drinks processing equipment (UK and US); machine tools and textiles/clothing equipment (Japan); textiles/clothing equipment (Italy); and machine tools, computer hardware/software (Switzerland).

A variety of reasons were advanced in order to justify not licensing. These included:

- the products were too high technology;
- the products were too specific or too custom made;
- the low technical development of developing countries - no supporting industry;
- financial barriers, eg a lack of credit/hard currency;
- unwillingness to create local competition to own products;
- software security;
- limited demand in the region.

Of these factors the most often recurring ones are listed in Table 6.22

Table 6.22 Reasons for not licensing

Local/regional demand for product too low	11
High technology products/low technology infrastructure	10
Lack of local finance	6
Creating local competition to ourselves	5

Clearly low demand, and a high-tech product are by far the most important reasons for non - licensing. A virtuous circle of demand, and significantly improved infrastructure, e.g. education/skills, is required to induce such companies to increase their interest in licensing.

Somewhat surprisingly, in view of the previous section on licensing, local demand and the high tech nature of the product were not considered as relevant as barriers to sales. Here, finance related problems and import barriers accounted for 73 per cent of all the problems encountered. (Table 6.23)

Over half of the companies (54 per cent) were of the opinion that financial issues were of crucial importance in selling to developing countries. Almost a fifth of the sample cited import restrictions, such as, the "law of similarity", e.g., countries such as India and Brazil who apply strict laws preventing competition to local industry. Three companies specifically quoted India and five Brazil, as being extremely difficult to sell into - and that they were disinclined to continue to try.

Table 6.23 Main barriers to sales

High import duties, taxes, tariffs	28 per cent
Lack of foreign exchange	26 per cent
Import restrictions	19 per cent
Local availability of services (e.g., engineers)	7 per cent
Others	20 per cent

Protection of local industry creates difficulties if developing countries wish to use the latest equipment - and to learn from its use. For example, in Brazil up to early 1991 (the situation is still evolving) local machine tool companies were unable to buy the best machine controllers (usually Japanese and German) because of import restrictions. Meanwhile Argentinean companies (operating under favorable trading agreements with Brazil) were able to import such controllers for use on Argentinean machine tools and to sell into Brazil. While this was a policy designed to protect the Brazilian computer industry, it may have had a serious negative impact on the local machine tool industry.

However, overall the willingness to sell into all regions was quite positive (see Table 6.24 below). Although 17.2 per cent did not provide a reply, almost 56 per cent were willing to trade anywhere that market conditions allowed.

Table 6.24 Attitudes to trade by country/region

Will trade anywhere	55.7%
Will not trade in certain areas	27.1%
No answer	17.2%

For Africa the responses were quite encouraging. Not one company expressed the view that the area - or any individual country - was considered a least favoured market.

The main areas which were viewed somewhat unfavorably were the Middle-East (since the survey was carried out in February - May 1991, this is perhaps a reflection of the then current political situation), and Eastern Europe.

In the case of the Middle East it was the political environment which was most often quoted as a problem; and in Eastern Europe, the hard currency situation.

Other countries considered to be problematic for one or two companies were Taiwan - which was accused of "copying" and China - also for copyright infringements.

6.6 Country Policies in Developing Countries

This section examines policies adopted by developing countries which were likely to encourage suppliers to sell to those countries.

Again, perhaps not surprisingly in view of earlier findings, the financial environment was crucial. Half the companies cited the availability of finance, import duties, taxes and tariffs as the area which would most encourage them to enter developing country new markets to a greater extent. (Table 6.25). However, a further 35 per cent presented the view that a modernization of national structures, opening of markets, and political stability were prime requisites.

Table 6.25 Incentives to enter developing country markets

Finance, duties, taxes, tariffs	50.0 per cent
Modernization, open markets, stability	35.0 per cent
Others	15.0 per cent

Amongst the "other" group was expansion of demand, skills availability, and environmental protection.

The companies were asked what factors were most important in achieving success in selling into developing countries. Here the results ranged over a wide area, with the major factor (35.8 per cent) being the availability of strong local expertise, and good agents. (Table

6.26). This was followed by, again, availability of finance (14.9 per cent), offering a competitive price for the product, and the provision of technically advanced design and manufacturing possibilities.

Table 6.26 Reasons for sales success

Availability of local expertise/agents/skills	35.8%
Availability of finance	14.9%
Technically advanced design/manufacturing capability	12.0%
Quality of product	9.0%
Expansion of market	7.5%
Others	7.5%

Again local expertise and skills, collectively, emerge as important reasons for sales success, thus complementing the findings in the earlier discussions of developed countries chapters on the importance of skills and infrastructure for success in diffusion.

6.7 Latest or Appropriate Technologies?

The supplier companies were also asked which type of technology they sought to sell to developing countries (Table 6.27). Many of the companies were unwilling to sell/license latest technologies for a variety of reasons, largely the same as those noted in Table 6.22.

Table 6.27 Technologies you seek to sell/license to developing countries

	UK	USA	Germ	Jap	Ita	NL	Swed	Swit	Total
latest technologies	5	3	7	3	2	1	2	1	24
appropriate technologies	9	8	4	5	6	1	0	2	35

In general, the tendency was in favour of what were deemed to be "appropriate" technologies. There was a difference by country group however with almost two thirds (64 per cent) of sales by German companies, but only just over a quarter of sales by US companies (27.3 per cent), and a little under two fifths (37.5 per cent) of sales by Japanese companies being thought of as latest technologies.

As noted earlier, the German suppliers to developing countries are willing to sell/license the latest technologies, and 63.6 per cent of their goods were categorized in this way.

The reasons for opting for a largely appropriate technology approach to sales are contained in Table 6.28. Here again the rationale is largely focused on problems associated with maintenance, spares, servicing, technical back-up, and the fact the latest technologies are considered to be too high tech and too costly. Clearly these factors, and what the suppliers consider to be market need are the main criteria.

Table 6.28 Barriers to latest technology sales

Maintenance, spares and servicing problems	37.2 per cent
Lack of technical back-up	20.9 per cent
Perceived market requirements	18.6 per cent
Technology too high grade, and too costly	11.6 per cent
Fear of copying	7.0 per cent
Lack of logistics, e.g., power, communication	4.7 per cent

There is a small but significant group of companies who are concerned enough about emerging competition through copying of latest technologies, who therefore do not sell such products to developing countries.

There is also a small percentage of companies who feel that logistical problems associated with the need for regular and consistent supplies of electricity, and open communication systems are essential for the use of their latest technologies.

With regard to both developed and developing country markets, the benefits of the suppliers' products were largely considered to be the same. While there were marginal differences these were not thought to be very important. (see Table 6.29).

It should be noted that in the data collection in developing countries, reported later in this study, there was a clearly expressed preference for the latest as opposed to "appropriate" technologies.

The most important benefit was improvements in productivity, with 21.4 per cent of the suppliers citing this amongst other factors. Second came more effective cost structures (17.9 per cent), i.e., reduced material costs, shortened lead-times, etc. A close third was improvements in quality - both in the equipment being sold, i.e., better engineered and more reliable, and in the ensuing product deriving from this (16.7 per cent), i.e., greater repeatability of a higher standard of product.

Interestingly, although improved productivity was given most often by suppliers as the benefit of their products, there is a wide range of other proposed benefits on the basis of which supplier products (customer processes) are sold. Increasingly such factors as higher quality and reduced lead times are emerging as factors . This is much in line with the earlier findings on developed countries' use of new technologies.

Table 6.29 Benefits of using suppliers products

Increased productivity	21.4%
More effective cost structures	17.9%
Improved process and product quality	16.7%
More efficient manufacturing	9.5%
Reduced lead-times	8.3%
Market leadership/increased market share	6.0%
Reduced labour costs	4.8%
Improved process reliability	4.8%
Others	10.7%

6.8 The Supplier Industry: A Brief Summary

In general, Africa is the least favoured region for the sales of products of the companies contained in our sample. The Japanese companies have not exported to this region. (see Table 6.4).

Companies from countries with historical links with Africa, including Germany, Italy, and particularly the UK, area are fairly strong suppliers to Africa. In addition, however, almost half of the US companies exported to the region.

Almost two-thirds of the Italian companies conduct a considerable amount of their current business with developing countries (Table 6.12).

Developing countries overall are expected to become more important to the sample companies over the next five years (Table 6.14). The UK and US companies expect to increase trade with these countries quite significantly - perhaps more importantly 7 of the 9 Japanese companies expect to expand trade, though this is likely to be mostly with Asian developing countries.

In terms of the established relationships within developing countries, many companies have a rather formalized "hands-off" connection, i.e., their local representatives are agents, dealers, etc., and the companies themselves have not established collaborative, joint ventures, or sister companies; or do not have their own branch offices (see table 6.16).

About half of the sample companies found there were specific problems associated with selling to developing countries (Table 6.17) and these usually centred on low overall demand, the cost of agents fees, extra sales or marketing costs, etc; on maintenance or service costs (Table 6.11).

The main barriers to selling or licensing to developing countries were focused upon these factors, plus the feeling that the products were probably of too high a technology content to be used effectively, or a fear of copying, or because the logistical framework was inadequate (Table 6.28).

There was comparatively little interest in licensing more advanced products for manufacture in developing countries; though the German companies were a strong exception to this general rule (see text in Section 6.5).

The cost of the goods/services supplied covered a wide range but CAD prices (software less than US$ 3,500) and CNC machine tools prices have now reached relatively low levels which place them within reach of many smaller companies in the developing countries (Tables 6.5 and 6.6).

However, the prices of these goods overall have been rising during the last five years and prices are expected to keep increasing at about the same pace over the next five years.

7. The Costs and Benefits of Automation

Throughout chapters 2 to 6 frequent references are made to the costs and benefits of the use of automated technologies. It would therefore be inappropriate to simply re-state what has already been discussed there; even more importantly it would be inappropriate to remove such discussion from their proper place, i.e. in the context of the technologies they relate to. However, this short chapter synthesizes the information contained in other parts of the report.

7.1 Robotics

The cost of robots (using somewhat dated information) ranged from $15,000 in the Low-cost range, from $30,000 in the Medium-cost range, and $60,000 in the High-cost range. More typically -in the same three ranges costs were $20,000, $62,000, and $85,000 respectively (see Table 2.4). However, more recent data from the supplier survey in the preceding chapter indicates an average price overall of around $70,000 - which implies that perhaps 60 per cent of robots sold would be less then this price (see Table 6.6 and following text).

The cost may be dependent on the number of units purchased: the cost of a $60,000 base-price robot - assuming development cost decreases with multiple applications - can reduce by 35 to 58 per cent.[128] Since many developing country companies are not of a size to purchase 30 or 40 robots, they may be excluded from the market or have to pay a disproportionately high price per unit (see Table 2.13).

The benefits of robots are somewhat more difficult to quantify.[129] At high volumes of production, plant utilization may increase by 31 per cent; and at two shift low volume it would more then double (see Table 2.15).[130] Machine tending costs could be reduced by 93 per cent; material transfer by 56 per cent; spray painting by 40 per cent; inspection by 55 per cent, etc. (see Table 2.16).

Examples of individual applications reveal that about 25 per cent of final assembly at Fiat's Cassino plant is now automated using over 400 robots; and Volkswagen at Wolfsburg utilizes over 500 robots to assemble its Golf and Passat cars.

In the UK benefits generally attributed to robotics include a 66 per cent reduction in lead-times, work-in-progress, and inventory, and greater flexibility in product changes (see Table 2.17).

The labour displacement characteristics of robotics can be important: the high concentration on robotics in Japan and Sweden is to a major extent due to the need to free up skilled labour to move to other jobs - and the still low development of sensors and grippers, robotics is not likely to be very important for developing countries at this stage.

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128 Miller, 1989.

129 Miller, 1985.

130 Smith and Heytler, 1985.

7.2 CAD

CAD costs cover a very wide range, from as little as $5,000 through to $1 million. However, the bottom end of this market - based on personal computers - is becoming increasingly flexible, has very low cost software programmes, e.g. from $100 to $ 5,000, and is becoming much more user-friendly. PC based CAD often provides 70 per cent of the benefits for 20 per cent of the cost of more expensive systems.[131]

By 1985, around one-third of CAD was based on PCs and it was estimated that by 1990, 90 per cent of CAD/CAM, CAE seats would be using personal or desktop computers.[132]

CAD systems for the garment industry - now usually obtainable for less than $40,000 but depending on configuration - embodied all hardware and software costs, including: computer equipment, monitors, digitizer and plotter; with software programmes for pattern making, pattern digitizing, and full scale marker plotting.[133]

One PC system Microsoft Windows which is an IBM PC and clones programme, has a software price tag of $3,375. This brings smaller companies, including those in developing countries, into the computer marking age. It has been suggested that any company can have complete marking, grading and plotting (including hardware) for under $15,000.[134]

The benefits can be seen from examples, such as the Swedish ASEA company reducing design work which previously took 3,000 hours, to 40 hcurs using CAD;[135] and there are examples of productivity increases ranging from almost a three fold increase to a twenty fold increase,[136] and instances of a 100 to 1 saving in labour time associated with modifications to existing designs.[137]

In relation to industries which have formed the basis of industrialization in developing countries, i.e., clothing and footwear, CAD can have a significant impact on the cost of materials. Savings in raw materials can average 5 per cent - and in one instance to 9 per cent.[138] Since in these industries the materials used can comprise between 40 and 60 per cent of total costs, the savings that could accrue to developing countries could be dramatic, particularly if they have not developed textiles or leather industries and have to use scarce finances to purchase these materials from abroad.

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[131] Edquist and Jacobsson, 1988.

[132] Design Graphics World, 1985.

[133] Adams, 1988.

[134] Adams, 1988.

[135] Arnold (1984), Senker (1982), Kaplinsky (1983).

[136] Kaplinsky, 1983.

[137] Hoffman and Rush, 1988.

[138] Hoffman and Rush, 1988.

As the supplier survey also reveals (see chapter 6), CAD and associated software can now be purchased across a broad range. CAD systems ranged in price from $16,000 to $120,000; CAD/CAM hardware for around $28,000; CAD/CAM software from around $34,000. Software packages ranged from $3,500 to $120,000, with three of the suppliers providing software packages for $10,000 or less.

CAD seems to be an imperative requirement for developing countries. This is as a consequence of its relatively low cost; its skill saving rather than labour saving characteristics; its savings in material costs; and last - but not least - its crucial role in enabling developing countries to acquire their own design capabilities.

7.3 NCMT

NCMT technology is now long established and the relative costs in comparison with traditional machine tools has declined over the years. This, combined with a productivity capacity generally acknowledged to be of the order of four to one, means that developing countries with relatively high labour costs, for example, Mauritius, might well find its applications economically justified.

The benefits include manufacturing in what is essentially a one-off or small batch environment, in a more flow-line process. Since most production is of this nature - especially in small to medium sized enterprises - the economic and technical benefits are considerable (see Figure 4.2).

Productivity increase appears to be growing, with increases of 2 or 3 to 1 as early as the late 1970s / early 1980s.[139] Later observations suggest increases of 15 to 1 using N.C. lathes.[140] Other findings show that although capital costs were higher for CNC lathes, the total cost savings associated with floor space and labour were some 40 per cent - even for single shift working (see Table 4.15). For two shift working savings were even higher, 48 per cent.[141]

Changes in the relative price change of NC and non-NC machines also affect the calculations:

> "If we compare the prices of NC and non-NC machines by type [for example, NC lathes versus non-NC lathes (NMTBA, 1989)], the price ratio drops to three or four to one for lathes and to about three to one for boring machines in the mid-1980s. If we also take into account the higher productivity of NC machine tools (four times greater), we are able to conclude that since the mid-1980s NCMT implementation has become economically beneficial enough to be justified even by conservative 'cost minimizers'. This corresponds with an expansionary phase of the technology's 'life cycle'".[142]

As noted in chapter 4, NCMT is:

[139] Rempp, 1982.

[140] Rodger, 1986.

[141] Jacobsson, 1986.

[142] Tchijov, 1991.

(1) A technology which is skill saving, sometimes is adopted because of shortages of skilled labour.[143] For developing countries too, there are advantages to such a technology where skilled labour is just unavailable.

(2) It is not necessarily a labor replacing technology. While in instances, for example the UK, it has been used as a substitute for labour, in developing countries it may act to enlarge demand as a result of improvements in quality and productivity.

(3) It is now a relatively rational capital investment choice, as noted above by Tchijov, in regard to its unit trade-off with several conventional machine tools.

"The break-even wage for skilled workers, when the choice of CNC lathes becomes profitable, is fairly low, indicating that even if there is not an absolute scarcity of skilled labour the use of CNC lathes can be advantageous to investors".[144]

As with CAD, NCMT technology is imperative for successful industrial development strategies in developing countries. The adoption and implementation of NCMT also has very important learning curve and demonstration effects, as well as the economic, quality and productivity impacts noted above.

7.4 FMS and FMC

Although there are examples of FMS (pre-microprocessor control) dating back to the mid-1960s, it has only been in the last ten years that its full integrative, systemic impacts have been felt. Considered to be the first real move to computer integrated manufacturing, systems were expensive, sophisticated - and in many instances uneconomic.

In the last five years much more has been learnt about how to configure and run them successfully. Both hardware and software - but especially software - has evolved at a rapid rate.

Also as interest has grown amongst smaller companies across a wider range of applications; more companies have become involved, and simpler configurations of FMS and especially FMC have diffused - with subsequent reductions in relative costs.

Benefits have been estimated to average:

- 30 per cent reduction in labour costs;
- up to 15 per cent savings in materials;
- reductions of 50 per cent or more in WIP and inventory;
- a 30 per cent increase in machine utilization;
- a reduction in total production costs of up to 27 per cent, etc.[145]

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[143] Senker, 1983.

[144] Jacobsson, 1986.

[145] UN/ECE, 1986.

Lead time reductions averaging 74 per cent and WIP reductions of 68 per cent in the UK; and machine utilization increases of 74 per cent have been calculated for Sweden (see Table 5.1).[146]

A particular benefit of FMS/FMC in the developed countries has been the increase in the number of shifts that can be worked without increasing labour costs, i.e., by the introduction of an unmanned third shift. An analysis of FMS worldwide (IIASA database) showed that two thirds were running for three shifts, and that 72 per cent of FMS were autonomous enough to run during one shift in an unmanned mode.[147]

Particular examples of benefits include:

- The Rover car company in the UK reducing cylinder head machining from 648 to 72 hours; for camshafts from 200 to 48 hours; and for die blocks from 65 to 23 hours.

- Rolls Royce engines recovering a £4 million capital cost in the first year of operation - mainly as a result of an associated inventory saving of £4.5 million.

- JCB Transmissions, increased turnover by 30 per cent, and increased productivity by 50 per cent.[148]

- Yamazaki improved machine utilization of machines by 33 per cent - from even their high levels - and reduced floor space by two-thirds.

- And Vought Aerospace invested $10 million in an automated system which saved then $25 million on parts produced between 1985 and 1988. On traditional equipment manufacturing time would have been 200,000 hours, this was reduced to 70,000 - about one third.[149]

Both the costs and the benefits of FMS/FMC appear to be quite high. For developing countries the first may appear to be the major barrier to its use - therefore preventing the benefits from being obtained. However, there may well be fewer companies in the developing countries of the size or sophistication to use the larger/costlier systems.

Equally, consistent and adequate power supplies, and sufficient numbers of skilled operators, maintenance and systems people may not be available - and the latter was a major problem at the early stage of development in the OECD countries.

The full-blown FMS seen in major companies in the developed countries are not, at this time, applicable to developing countries - except for those with companies of sufficient scale of operation, with high levels of in-house skills, and well developed supplier links.

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[146] Haywood and Bessant, 1989.

[147] Tchijov, 1991.

[148] Bessant and Haywood, 1988.

[149] Bonetto, 1988.

Much more relevant are the stand-alone NCMTs with load/unload mechanisms automated; or the simpler FMC type of configurations. Even small to medium sized OECD companies, with not very high levels of in-house skills, have shown considerable improvements in performance using such technologies.

8. Product and Process Design

As discussed earlier in Chapter 1, industrial production can be divided analytically into three distinct phases: design, manufacturing and coordination.[150] In this division, design comprises all pre-manufacturing tasks necessary to identify, describe and prepare products for manufacturing as well as the identification of the requirements for operations regarding materials, components and sub-assemblies for production and materials management.[151] Design is the path through which innovation is transformed into manufacturing practice.

From the point of view of manufacturing, design is the starting point, and is more than just a pre-assembly function. It is the art of product conception itself, beginning with the definition of the future product's objective:

> "Being concerned with the whole coherence of the product to meet its objective, the task of design is to integrate all the determining parameters: the nature and characteristics of materials and components, ergonomics, quality, prices etc. This requires information queries, feasibility studies and up to the obtaining of prototypes ready for production. Design does not confine itself to the *product*, but it may also concern the related production *process* (engineering design)".[152]

Design can be called a kind of "discipline of industrial creation". It fulfills this function at several levels:

- "it questions the practice and efficiency of research (applied and technical);
- it questions the whole management of the firm, its internal organization, communications and compartmentalization of different services;
- leads to reassessment of the relationships of industry with its whole environment - users, suppliers, competitors".[153]

8.1 A Traditional View of Design

Design is actually a twofold function which includes the design of the products to be produced, and the design of the manufacturing process itself. However, in the traditional approach, the two design functions are regarded as separate. Either the process (including the machinery, factory lay-out, division of tasks and the organization for subassembly delivery) has been designed first, and products have to be designed so that they are possible and economic to manufacture in the pre-existing process. Or, products are designed independently, and the whole manufacturing process has to be designed according to the products' characteristics.

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150 Kaplinsky, 1985.

151 Langdon and Rothwell, 1985.

152 Aubert, 1985

153 Aubert, 1985.

The approach is related to the product life cycle theory. In the early phase of the life cycle, product design and marketing are the most dominant functions strategically. Manufacturing is considered to be at best strategically neutral. The ideal factory simply has no barriers to the introduction of a new product, and the manufacturing process can be adapted frequently to changes in product design. The task of manufacturing is to stay adaptable by retaining considerable looseness in production formats. The assumption is, that the organization can tolerate considerable looseness in terms of efficiency, delivery time, delivery dependability, or even quality dependability. The organization competes on product innovations, on the basis of novelty in product characteristics and product performance.

It is also assumed that the customer is willing to tolerate this looseness and that results such as low quality are in fact inevitable. Poor product quality and poor design quality are, in this early phase of the product life cycle, accepted as unavoidable. This implies that a lot of engineering changes are still necessary to adapt it to manufacturing and customers' requirements after the product has been introduced. There is very little interaction between the design department and non-physical manufacturing.[154]

When the product matures and shifts over its lifecycle the dominance shifts from product development to the manufacturing process. The focus of product novelty and performance becomes less important, while cost effectiveness and delivery performance become more crucial in the strategy of the firm. Product innovation becomes not only less important, but increasingly difficult as the whole manufacturing system is targeted at becoming more cost effective, and becoming dedicated to the specific product line and thus more inflexible. The relationship between product design and manufacturing is still sequential but reversed in direction: manufacturing determines the kind and magnitude of product innovation and design changes that can take place.[155]

As observed in the chapters on developed countries, this is precisely the direction in which current technologies are moving, i.e., in a systematic or "machinofacture" form which transforms "economics of scale" and "economics of scope" into an integrated whole.

Companies engaged in large-scale production, e.g.,motor cars, which have required flow-line production facilities are now able to produce many thousands of variations of the same vehicle in a "one-off" mode. One example of this is Fiat in Turin, where one line produces two different models, in many hundreds of variations of engines, colours, trims, etc. At the other end of the scale flexible manufacturing equipment, such as CAD, NCMT, FMS, etc. allow very rapid changeovers between one-off or small batch production. Increasingly production moves from the two ends of the manufacturing scale shown in Figure 4.1 towards the centre, with both forms of production, volume and variety, benefitting.

In the final phase of the product cycle, it was assumed, that only very minor changes in product design would take place. At this stage it is more a question of finding new, lower market echelons and cutting production costs as low as possible. In the traditional approach, this was usually the phase, when relocating production into low cost countries came into question. Thus, developing countries were "by definition" cut out of both innovative product design and production process design. Their role, in the global division of labour based on the

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[154] van Dierdonck, 1990.

[155] van Dierdonck, 1990.

idea of product life cycle, was to produce mature products with conventional manufacturing technologies and organizations based on the extensive use of cheap labour.

8.2 Changing Life Cycles and Design for Manufacturing

The changes in markets, manufacturing technologies and business strategies discussed earlier put an emphasis on the integration of different spheres of the manufacturing process. Functional integration - to gain flexibility, better control over manufacturing operations, cost efficiency and rapid response to market changes - has become one of the most important competitive weapons in manufacturing industry. With this shift of focus, the role of design, and the interrelation between the two design dimensions, change radically.

In product life cycle terms, the changes have two implications. First, life cycles are becoming shorter. In many sectors products become obsolete much earlier than before, though the reasons for this vary by sector. In the area of high technology it is above all a question of rapid technological change. Products are replaced by new ones, that show far better performance rates and are often cheaper. This is the typical case in, for example, computers and other advanced electronics. A personal computer is replaced by significantly more effective models within one or two years. In other sectors the obsolescence is often caused by issues more related to market tastes. Fashion changes, for example, have made the clothing industry life cycles very short indeed.

The other change affecting product life cycles is diversification, e.g.,the earlier Fiat case. Products are more diversified than ever before, and Henry Ford's comment on his early cars that "you can have any colour providing its black", is now completely and utterly without application for the modern consumer and producer. This is caused by changes in personal tastes and by market segmentation. This means, that in addition to shortening the "tail",the product life cycle itself will be cut. Before really reaching the maturity phase, the product will be developed into many variations for different markets. The versions for various markets, again, are developed according to their own lines, and diversified further.

From the product design point of view, life cycle developments mean that the need for product innovation and development does not really end at all. Individual product models are replaced by new versions before the product reaches maturity.

Coping with this kind of product life cycle anticipates a new approach to manufacturing and design and the integration of these two becomes essential. The manufacturing technologies have to achieve increased flexibility, as already discussed in earlier chapters. From a design point of view, this means a need to design products, that are easy to diversify and develop further without significant changes in the production process. From the integration point of view, the basic question is the manufacturability of the products designed and the flexibility of the production process in order to meet such product changes.

Design for manufacturing has been a central topic in business management literature in developed countries during the mid-1980s.[156] Design for manufacturing means, that many significant changes have to take place within product design. Among the main points are:

- a reduction in the number of parts of which the product is composed;

[156] Putnam, (1985); Whitney, (1988); Dean and Susman, (1989).

- an increase in the number of standardized parts;

- modular design which makes it easier to test, to build and to offer a broad product mix and yet to have low inventories and short delivery time;

- jigless production, i.e.,avoiding jigs and fixtures as much as possible in order to reduce set up times (or using jigs and fixtures with uncomplicated set-ups);

- taking into consideration the machine capabilities and the potential problems related to the use of certain parts or methods for assembling parts;

- using software that helps designers to evaluate the manufacturability of the design.

One conclusion is the need for increased cooperation between design, manufacture and other functions within the company. An example of this need in an acute form is given by this of a case of a company producing metal tube furniture for three market segments: (a) hospital furniture, (b) kitchen and canteen furniture and (c) style furniture tables, chairs, etc. for domestic living rooms; three product lines, that are quite different and related to different markets:

> "The market for hospital furniture was characterized by low volume, project type production, quantities and also specifications that were customized, and by short delivery times. In addition price could not be neglected because it was the deciding factor in choosing among competitive bids. The kitchen furniture segment was characterized by high volume, mature standardized products, production to stock and competition mainly based on price. The style furniture was characterized by low volume, high variety, frequent design changes and production to stock".[157]

The three segments suggest quite different and even conflicting sets of specifications for the design department. For hospital furniture, it was important for design people to understand the customers. For price and delivery reasons standardized components had to be used. For this, functional analysis was an important tool.

For the kitchen segment, production efficiency was the main issue. Therefore value analysis to substitute components with cheaper ones or ones easier to manufacture was an important requirement, as well as working closely with vendors.

For the style furniture market aesthetics, creativity, following fashion trends and being close to the market were critical.

With so conflicting a set of requirements, the company's design department found it hard to understand its own role in the competitive strategy. This contributed to the "stuck in the middle" position of the organization and subsequent financial difficulties.

> "This case illustrates that the design department not only should understand its strategic role, but also that in the case of conflicting roles one might think about 'focused design' organization in analogy with the concept of a focused factory. In order for strategy

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[157] van Dierdonck, 1990.

formulation to play its integrating role, especially between manufacturing and design, it is critical that both have a good and non-conflicting understanding of their role".[158]

This again emphasizes the need for a strategic integration of functions within a company. Within this integration, the role of design is quite crucial. Design can be regarded as having a very special status as the starting point for CIM.[159] This refers especially to engineering design. In this concept, the traditional roles of the two designing functions are reversed, where product design is largely subordinated to process design. The successful planning of a flexible manufacturing totality, is then the primary task giving product design either a narrow or a broad field to develop variations.

This analysis is, of course, from the point of view of planning very sophisticated production facilities especially within the capital goods sector. The model derived for estimating the basic competitive advantages in various product fields, however, provides tools with which to evaluate the role of design. The model is based on two dimensions, the complexity of the product (high - low) and the uncertainty of the market (high - low). This yields 4 basic types of competitive advantages and product fields. At one end are highly complex products in uncertain markets (a), at the other simple products with stable markets (b) two other categories are, simple products with uncertain markets (c), and complex products with stable markets (d) - these are the two transitional types (Table 8.1).

Table 8.1 Competitive advantages in various product areas

Competitive advantage		Product area	Examples
(a)	product performance	capital equipment, high technology	aircraft, production machinery
(b)	product cost	basic commodities	nuts, bolts, light bulbs,
(c)	rapid response	fashion articles	skate boards, fashion clothing
(d)	high variety	consumer durables	tv-sets, personal cars

Source: Brooks (1990).

One interesting point is that industrial sectors are actually changing their focal points. For example, the share of consumer markets with high variety and rapid response demands seems to be growing with further segmentation in the basic commodity markets. Thus, the number of products in category (b) - which largely responds to the old idea of products in the maturity phase of the product cycle - is diminishing, while the share of products in categories (c) and (d) are growing.

The focal points for business from the angle of technological development and applications of CAD and CIM technologies in the four product fields can be described as follows:

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[158] van Dierdonck, 1990.

[159] Brooks, 1990.

- In (a) extensive use of CAD and CAE are needed to engineer a complex product in order to achieve high levels of performance. Versatile machinery is needed to cope with a wide range of small batch manufacture and rapidly changing schedules.

- In (b) product design is quite simple, and emphasis is on capacity planning in order to achieve high utilization of machinery, good process control and control of logistics control. Automation of production (CAD/CAM) is mainly needed in developing (1) high quality tooling, (2) securing a stable quality of the products and (3) in gaining control over the whole production process.

- In (c) emphasis is on rapid and often innovative product design and - from the engineering design point of view - in logistical controls. The linkages in this type of production quite often consist of a very wide (and even rapidly changing) network of firms involved in the manufacture of the same product.

- In (d) quite sophisticated CAD for modular design of components is needed, with developed CAM linkages. In production design, the trend goes towards more flexibility, rapid changes and a functioning production network with JIT organization.[160]

The whole debate on design factors in products and processes is further extended by the concept of re-design. In many cases a product may have been manufactured in the same way - or with only minor changes - for many years. Since this has been the accepted norm, production managers have thought "it has always worked well this way, why change it". This is, of course, a blinkered approach to manufacturing since as we have emphasized here, the linkage between product and process design is tightening.

One example of this was found in Sweden, where re-design of an established product in order to manufacture the housing of a submersible pump by the use of a Flexible Manufacturing System, cut manufacturing operations by 47 per cent.

> "FMS revealed to us the importance of design for production even more than we thought possible. In one instance by simply evaluating the technology we reduced the number of operations needed from 95 to 50. It has forced our designers to design even more in collaboration with production, and increased the levels of knowledge in the firm".[161]

8.3 CAD and Design in Textiles and Clothing

The textiles and clothing industries are interesting examples from the design point of view. The textiles industry is, to a large extent, a technologically and organizationally rather stable and slowly changing process industry. It produces some final products for the consumer market, but the main products - yarn and cloth - are mainly inputs to the clothing industry.

New raw materials are continuously introduced to the industry, but the basic characteristics of the products do not change dramatically. However, fashion changes make the variations in the composition of product assortment very rapid. Design and choice of the

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160 Brooks, 1990.

161 Haywood and Bessant, 1987.

products to be manufactured are often imposed by the user companies. These clothing companies define exactly what kind of yarn and cloth they want. So the textile company's own role in product design is often limited to adaptations of the ready made design for their production facilities.

Thus, within a textiles company, engineering design is often more important than product design. The production processes themselves change only slowly,though incremental innovations that improve the speed and flexibility of the process and the quality of the products are continuously introduced to the industry. The design linking new machinery capabilities and product requirements is important, and results in product quality that is to a larger extent becoming a more important competitive advantage than production costs. One of the basic issues is to be able to satisfy the clothing firms' product requirements.

The clothing industry, on the other hand, is one of the most diversified industries. In the framework of Table 8.1, it is split into two categories, with one segment producing basic commodities with production costs as the main competitive advantage, and the other with fashionable goods with rapid response as the focal point of manufacture. In addition to these two segments, a third one could be added, that produces high quality clothing with characteristics that more closely resemble consumer durables than either basic commodities or fashion articles.

Design is important for all clothing categories, but it is the basic issue especially in the fashion segment, and in the fashion industry particularly because design is a highly integrative function. It does not necessarily integrate the functions within one factory, but between a wide network of textiles and clothing manufacturers, even retailers and fashion houses.

For example, intricate formal and informal links between the retailer, manufacturer, textiles merchant, subcontract units, and homeworkers have been found in a study of buyer-supplier relations (Chain A, Figure 8.1) in the UK.[162]

In a second, more formal relationship (Chain B) flexibility of response was much more constrained.

Chain A, in particular, contains the seeds of a highly integrated structure in which design of products and processes is crucial. Rapid links, rapid responses, and rapid changes are required by all the players since design is a function of all the participants.

In particular, there are pressures on the smaller firms as Figure 8.2 indicates, and the similarity to the discussion of pressures for change and systemic manufacturing in Chapter 1, bears a striking resemblance to pressures in the clothing industry.

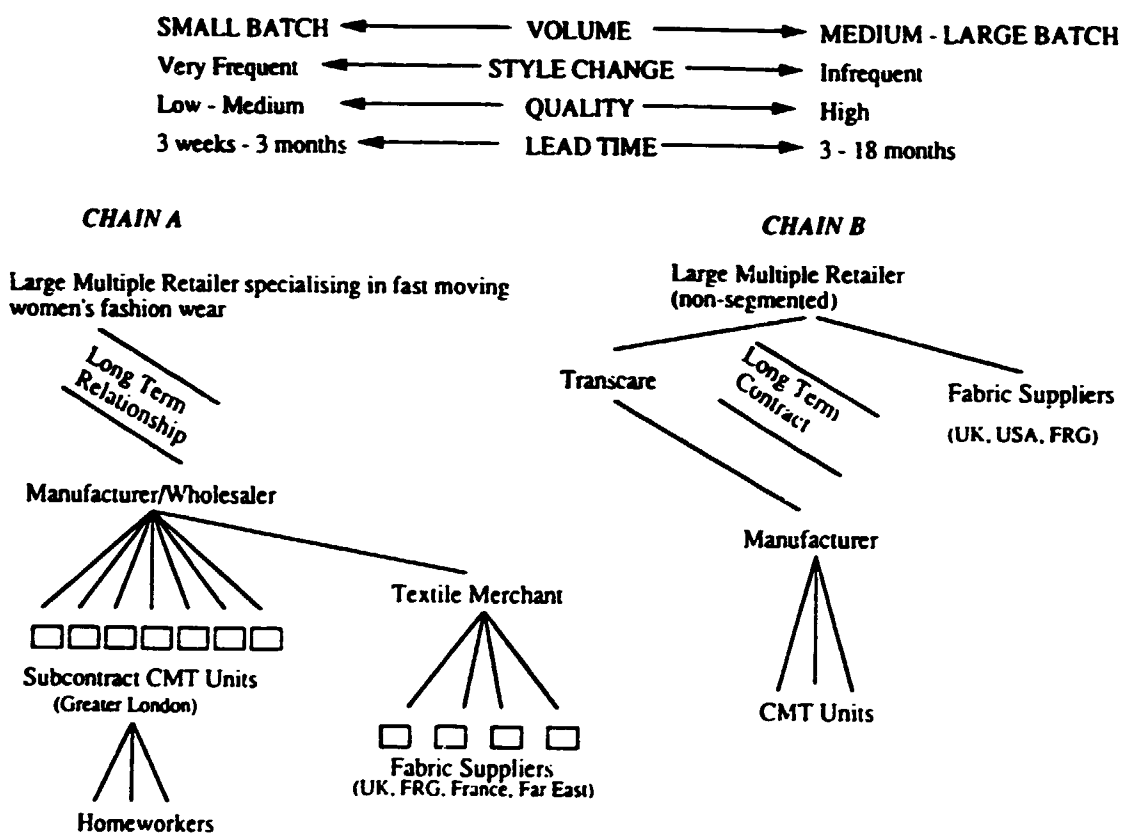
CAD and electronic data interchange (EDI) is becoming increasingly crucial in developing and retaining these links and relationships.

Thus, CAD has become a crucial tool both in facilitating the design of product variety and in integrating the production network. Another example on changes in the textiles sector

[162] Whitaker, Haywood and Rush, 1989.

in Italy in the mid-1980s[163] reveals some basic themes on the role of design and CAD in the modern textiles and clothing industry operating in the fashion market.

Figure 8.1 Comparison of supply chains



Source: Whitaker, Haywood & Rush (1989).

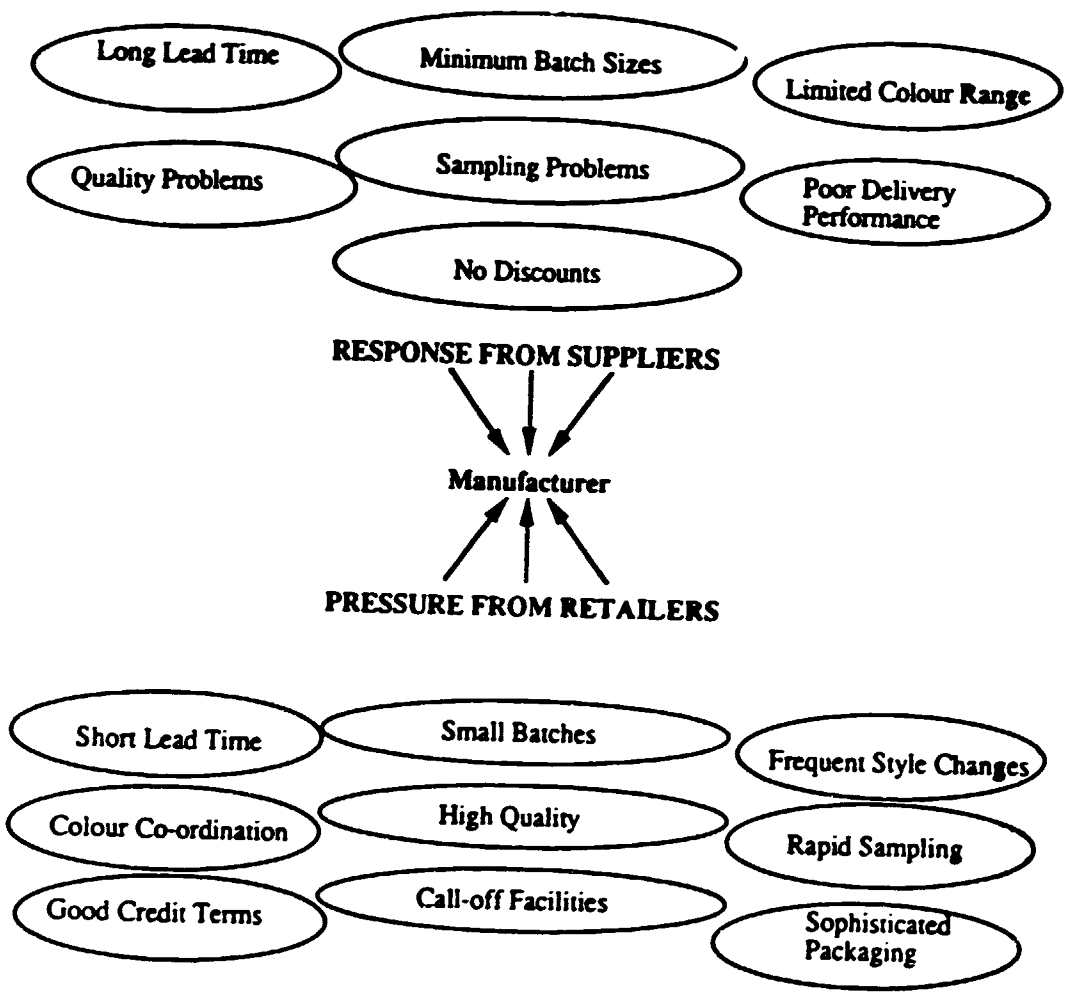
Designs for fall and spring fashion were presented twice a year, in February and August. Designers were expected to prepare samples of fabrics in a variety of possible weaves and colours. Preparing samples required weeks of interaction between designers, customers and producers. After samples were made, firms defined the product mixes they would offer the marketplace.

In this CAD is an irreplaceable tool. With it a designer could consider different weaves and colours before they were actually woven. Only 5 to 8 designs out of a hundred designs proposed would actually be produced. The cost of design was expected to be cut dramatically by CAD, but the most important advantage offered by the technology was the possibility to react

[163] Menichetti quoted in Jaikumar, 1986.

quickly in the marketplace. If particular designs met the approval of the fashion houses for their collections a firm could, using CAD, quickly make adjustments to its own offerings.

Figure 8.2 Mounting pressure on small manufacturers



Source: Whitaker, Haywood & Rush (1989).

To meet the requirements of the industry, CAD must be able to offer:

- fidelity in colour reproduction;
- resolution in hard-copy generation;
- sophisticated software capable of reproducing weaving effects and providing a feeling for texture;
- hardware to allow processing of a large volume of data; and
- accessibility to a variety of different users.

By the mid 1980s the possibilities of CAD in the textiles and clothing industries had improved remarkably, but the overall situation was still a little turbulent and changing rapidly:

> "CAD has not been able to deliver the wide variety of colour combinations we require, but I know that in the next few years we are going to have a system that will satisfy the demands of the industry. Changing the way of doing business is going to take a lot longer than the development of the technology. I need to create my own network of people who can exploit this technology...
>
> My business is to get things done as fast as I can - information from the market into Prato, what products the customer wants, which yarn, which composition, how it will look - then talk to the firms in Prato. There are about 100 firms that can produce yarn; if it is a specialty yarn, about ten firms can do it. Depending on the specialty, it is a different firm each time. I have to take feedback from them and send it back to New York, maybe with some modifications. With CAD I can greatly expand the alternatives I can propose and hope one is a hit!
>
> There is another programme undergoing experimentation in some dyeing houses in Prato. We are trying to apply new methods in industrial colour management based upon a better knowledge of the process. Using spectrophotometers for automatic colour measurement, we can today create programs for the right recipe for finishing that are quite reliable. These methods have been tested by several European companies, resulting in consistent savings in dyestuffs. What is appealing to me, more than the savings in dyestuff, is to be able to make the connection of colour management with CAD. We will then be able to be consistent between design and manufacturing.
>
> I am still at a loss as to how to create the capability to effectively exploit this technology. Do I need designers in New York as well as in Prato? What kind of a database do I need? How large must it be before it is effective? Do my suppliers have access to designs and patterns? If so, who? Should it be shared by everyone in Prato in a common pool, or should I restrict it to my own firm? Should there be a service company that provides CAD services to everybody? Should there be more than one such company?
>
> We are beginning a new epoch, and how we organize for it among ourselves is very important".[164]

Menichetti's description gives a good overview on the complexity of designs' role in fashion clothing. The crucial function of CAD becomes evident as well; also the integrative function played by a designer working with CAD and the use of comprehensive databases becomes quite obvious. However, the forms of organizing these wide production networks are still left open. Both the role of CAD and the new forms for organizing the clothing network will be discussed further in Chapter 16.

Since the mid-1980s the performance rates of CAD systems have increased remarkably and, as observed in Chapter 3, prices have reduced thus becoming well within the reach of developing countries. The concrete possibilities for using CAD in developing countries - as well as the supporting policy and infrastructural issues required - are discussed in more detail in the following chapters.

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[164] Menichetti quoted in Jaikumar, 1986.

9. Developed Countries: Organizational and Manpower Issues

Chapters 2 to 5 discussed at some length the experiences, economics, and diffusion of four technologies, robotics (IR), computer aided design (CAD) numerically controlled machine tools (NCMT) and flexible manufacturing systems (FMS), as applied in developed countries. This has been done largely in terms of the technologies, though some of the costs and benefits, barriers and potentialities of these production aids were also covered.

The considerable literature related to these technologies has also been emphasized. This will aid readers to follow up on the points raised: however the chapters are intended to be sufficiently self-contained to allow them to stand also.

This difficulty is that the technologies themselves represent only part of the problem of technical change. Later sections of this report cover other factors, e.g., organizational and structural changes required, the manpower, the logistical framework, the availability of financial resources, etc., as they apply to developing countries. The present chapter deals with three major issues in relation to the experience of developed countries. These are:

(1) Methodological and structural implications;
(2) Supplier relationships;
(3) Manpower, and skills issues.

They are essential features of the infrastructure for successful technology implementation.

9.1 Methodological and Structural Implications

The full strategic implications of automation need to be appreciated. Entering this technological minefield is not simply a matter of a short-term investment in one or two discrete items of equipment but rather a long-term philosophy involving technological and organizational components which need to be carefully linked to provide support for the overall business.

In evolving a strategy for computer-integrated manufacturing there are two possible routes. One involves what might be called the "techno-centric" approach which installs islands of automation based on advanced technology and gradually works towards linking these into a fully integrated continent - the "factory of the future". Here problems are perceived as principally composed of financial and technological elements and the dominant belief is that if enough resources are thrown at the problem it will be solved.

The second involves an "organo-centric" approach in which the process of technological innovation follows that of organizational adaptation. The pattern here follows roughly the prescription offered by Ingersoll Engineers: "simplify,integrate, computer-integrate" and implies an incremental approach based on low risk, high return organizational changes building up gradually to higher risk technological changes such as CAD/CAM and CIM.

In many instances, particularly so it seems in the English-speaking world, the general approach has been the first of these, the "techno-centric", which has dominated. In the early 1980s, for example, the instinctive reaction to what seemed an unstoppable wave of competition from Japan saw many countries/companies throw money into the technology option. For example, the Saturn project of General Motors. The inefficiency of early FMS applications in the US and UK has been commented on.[165]

The simplification of approaches to change in production methods is needed[166] and a more "organo-centric" approach which allows for a first, or at least joint, concentration on changes in the organizational/structural and technological fields.

One possible scenario for such change was offered earlier in Chapter 1 where it was suggested that moves towards a concept of the "factory of the future" should embrace all of these issues (see Figure 1.3).

This would involve moves towards the adoption of new technologies within an overall framework of change which involves changing methods and structures.

Methodological in the context of evolving better buyer/supplier relationships and the adoption of just-in- time methods in order to reduce work-in-progress and inventories; improved quality in order to satisfy customer demands; the adoption of group technology to improve the work-flow; a greater concentration on design-for-manufacture, e.g.,for too long, many companies have been producing goods inefficiently, and re-design along-side new technologies can be a powerful competitive tool.

This one aspect of organizational change comes with the adoption of different approaches to the layout and methods of production. Here the influence of Japanese manufacturing techniques can be clearly seen, with emphasis on simplification and planning to achieve smooth flow through manufacturing - to make batch processing resemble flow production as closely as possible. The precise configuration of layout and the range of techniques adopted vary, but in many firms technological change involving FMS is taking place in parallel with programmes for quality improvement, changing supplier and purchasing policies, and moves towards implementing a just-in-time philosophy both in purchasing and within the production process as a whole.

Similarly, structural changes which create barriers between functional jobs, together with horizontal hierarchies, have created inefficiencies which inhibit communications and industrial relations. These structural changes need to be implemented quickly and in tandem with the other two elements.

The move to FMS and other integrated automation technologies poses strong questions about the traditional pattern of functional specialization.[167] For example, there is a need for the design and production functions to work together to develop products which are suitable for manufacture on such systems. Such a design for manufacture philosophy is of particular significance.

There is a need for business systems engineers and manufacturing systems engineers, or put more crudely "businessmen" with a more detailed knowledge of production and 'production

[165] Jaikumar (1986) and Voss (1986).

[166] Ingersoll Engineers (1983) and Schonberger, 1982.

[167] Haywood and Bessant, 1987a.

people' with a more detailed knowledge of business.[168] The essence of such changes is to encourage coordinated skills. This requires the adoption of a single systems view of the enterprise and the scrapping of parochial boundaries between individuals and departments, shortened hierarchies, and broadening skills.

In many companies (Germany, Sweden, etc.) there are on average, only three or four levels of management down to the level of the shopfloor worker. This has many implications for border crossing between different functional specializations within management and this suggests that managers are better placed to have an all embracing knowledge of the products and processes employed within the company; a tendency made easier by the fact that graduates tend to be very broadly based throughout all functions of the companies, and not confined to the research and development or production engineering functions as tends to be the case in other countries, for example, in the US, UK, etc.; it is common to find six, seven or more layers of management. However, it is not merely the fact that there are flatter hierarchical structures to aid efficiency and communications, but that movement between levels is more apparent in the former countries.

This trend towards flatter and less structurally functional occupations is being accelerated as a result of the introduction of information technology and the organizational changes that this brings with both vertical and horizontal movement occurring.

Strategic change is also exerting pressures. While new technology and organizational structures are allowing greater control and information flows in companies the devolution of responsibility and the use of higher levels of skill on the shopfloor has also increased the pressures for organizational change.

FMS and its associated information technology gives the most senior managers a complete picture of the whole process from design and receipt of orders through manufacture and delivery. This increases pressure on middle managers who have traditionally been responsible for specific functional operations. Additionally, if sufficient confidence about their own abilities exists among senior managers it also affords the opportunity of devolving responsibility back to the shopfloor, in some senses standing the old Tayloristic concept of the division of labour on its head.

That this kind of managerial self-confidence exists in countries with a consensus style of industrial relations is evident from a number of examples provided by both managers and shopfloor workers.[169] In one instance established customers with urgent component requirements were allowed to bypass both managers and supervisors, and go straight to the appropriate shopfloor worker with design modifications that needed to be embodied, or to discuss technical or material problems, or even to introduce new and urgent orders. In another case operators working on an FMS who faced machining difficulties, perhaps because of materials problems, completely bypassed all internal and external company hierarchical structures and directly telephoned the responsible shopfloor worker in the supplying foundry to arrange for replacement castings. This resulted in replacement components being available within hours rather than the days that this would have taken by going through the formal procedures in an hierarchy.

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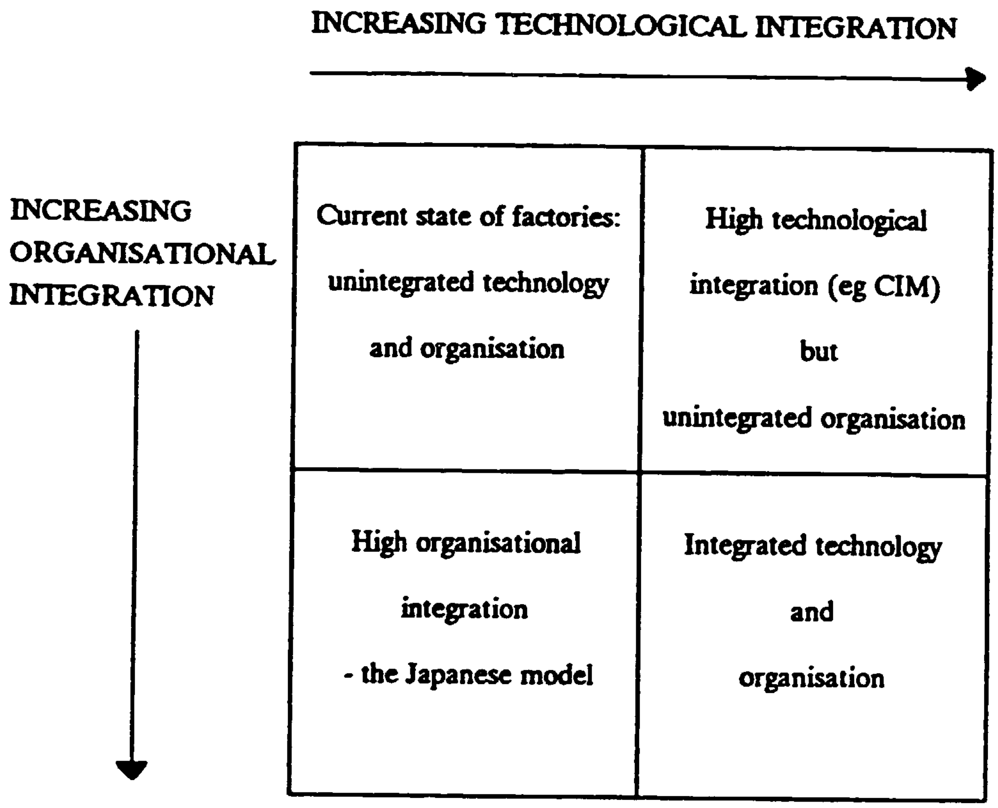
[168] Parnaby, 1986.

[169] Haywood and Bessant, 1987a.

Given the growing importance of reducing stocks and work-in progress, allied to just-in-time deliveries, this degree of confidence in managerial abilities, and those of their workers, will increasingly become a powerful competitive weapon.

One way of viewing the integration at all levels that are increasingly necessary is that provided in Figure 9.1. Here it is suggested that moves in a southerly then easterly direction might be implemented by companies who are not yet highly technology driven. The ideal goal,of course, being to end up in the south-eastern box.

Figure 9.1 Options on the road to integration



Source: Haywood (1988).

Failure to adopt such an approach suggests a risk that, far from being a highly integrated "continent" of automation, the "factory of the future" may instead resemble a loose "archipelago of islands", poorly joined together by an ad-hoc network of bridges and ferries and suffering from the inefficiencies, delays and frustrations associated with such a geography.

The UN/ECE report of 1986 highlights five decisive elements in the adoption of FMS, which are just as relevant to more general applications of new technology. These are:

(1) A decision to invest in FMS should be an integral part of a broader decision to adopt new organizations and managerial principles for the whole company.

(2) For the successful implementation and operation of FMS, it is also necessary to ensure the involvement of all groups of personnel within the company.

(3) In undertaking an investment appraisal of FMS, experience shows that it is difficult to measure and quantify many of the potential benefits.

(4) Most of the full FMS which are in operation today are tailor-made for the user; this results not only in unnecessarily high development costs but also in considerable compatibility problems when the time comes for the system to be expanded or linked to other systems.

(5) Problems arising in the implementation and operation of FMS do not usually derive from technical deficiencies but rather from inadequate planning and organization.

They note that three areas in particular should be given special attention, and at least the second and third of these are again of general relevance.

- sensor technology;
- software; and
- communication networks.

9.2 Some Country Comparisons

Some EC countries are clearly in a strong position to exploit flexible automation technologies -for example, Germany now has a relatively high rate of use of FMS, robotics etc, and can build upon its position of strength as a specialist machine builder. Its ability to develop alternative working practices and obtain higher levels of responsiveness and flexibility will depend less on the question of skills availability - with around 70 per cent of the workforce possessing some vocational qualification the FRG is well-endowed and the union with East Germany will swell still further the labour supply in skilled personnel - than on managerial attitudes towards changes in working practices.

Scandinavia has also demonstrated leadership in moving towards alternative models - ever since the Volvo experiments at Kalmar in the 1960s. Recent developments suggest that on a broad front a new model for manufacturing organization and management is emerging which marries highly skilled people, looser and more flexible work arrangements, with high levels of advanced manufacturing technology (AMT).

In the UK, on the other hand, as in the USA there are many barriers to change. In addition to the serious limitations imposed by the shortage of skills and inadequate investment in training, there is a strong traditional management culture which may not be capable of reacting fast enough to the challenge for greater flexibility and responsiveness. The dominance of the Ford/Taylor model in the UK and the US has been remarked upon elsewhere and it is significant to contrast this approach - which stresses a high level of functional differentiation and division of labour with other European approaches which embody more integrated forms. The concept of "Technik" as a unified view of manufacturing as a total system is one which is present in most continental European languages and culture but lacking in the UK and the USA.

Mechatronics is clearly not simply a collection of machines and computers but a much broader system including a key organizational component. Successful users are, above all, those firms which recognize this and manage such innovations as total systems. Contextual factors - like the layout of production, the choice of products to be made, the linkages between different support functions, the skills and work organization of those operating the systems - all have a bearing on how it will perform. Indeed, the benefits of FMS investment often come more from the organizational changes which it provokes than from the narrow set of physical equipment which is installed.[170]

Second is the point that mechatronics is a *configurational* technology[171] evolving and developing as a result of interaction between users and producers and during the long-term process of implementation. The centrality of organizational learning in this implementation process needs to be recognized.

In this respect Europe stands at something of a crossroads with regard to AMT. Investment in the physical elements of AMT has already been extensive but the promise offered by such innovations is often not fully realized. At the level of the firm there needs to be a shift to a longer-term strategic perspective on manufacturing, within which choices about the appropriate use of mechatronics technology and the design of matching organizational forms can take place. In particular, firms need to recognize that, in the emerging manufacturing environment, competitive advantage will depend increasingly on knowledge and skill and on intensive technical cooperation and networking both with users and with suppliers.[172]

9.3 Supplier Relationships

In fact one significantly important reason for introducing FMS, and a major reason for its success in Sweden, has been the relationship that exists between suppliers, customers and subcontractors. Long-term purchasing arrangements, economic and technical assistance, and frequent consultation, all establish a framework for increased production efficiency and reduced costs with high levels of quality. One subcontractor in Sweden had been supplying 40 different components to one customer for a period of at least ten years. These strong links may be illustrated by the following quotes made by company directors in Sweden:

> "For some time now we have had strong links into a more limited number of suppliers, often paying ourselves for the subcontractors costs in tooling or jigs. Cooperation is the keyword. If someone quotes too low a price for a job we would probably query it since it could lead to a lower level of quality that we desire.
>
> Although we are a fairly small company we have 300 established customers including some of the largest in Sweden, e.g.,Saab, ASEA and Volvo. These have mostly been long-term relationships and I would estimate that 95 per cent of Swedish companies have such long-term contacts with their customers and suppliers".

In Sweden many small to medium-sized companies in the subcontract sector have order books in the region of a rolling average of twelve months - in contrast to the UK where the

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[170] Jaikumar 1986; Tidd 1990.

[171] Fleck, 1988.

[172] Bessant and Haywood, 1991.

norm is something under three months.[173] In one instance a Swedish subcontract company representative noted that they already had 75 per cent of their order book filled for the coming year. Such continuity allows Swedish companies to have a longer-term planning horizon and facilitates the use of new and more expensive equipment with the knowledge that a return on capital invested can be made.

The use of new technology can also be due to the purchase of new equipment by the customer specifically for the use of the subcontractor. Several instances of such installations have been highlighted where expensive equipment had been installed for the duration of a contract (and was still in place after several years due to the follow-up nature of orders).

This infrastructural support is reinforced,in many instances, by direct assistance in the purchase of materials at preferential prices from other suppliers to the major companies.

All of these factors bring benefits to the subcontractor in terms of expanded time horizons and production possibilities; but also bring substantial benefits to the customer in the form of improved quality, reduced part costs and improved delivery times.

Swedish, German and Japanese companies with their long established and collaborative links between major customers, producers, and subcontractors could be in a much stronger position than many other countries in successfully achieving such integration. The consensus and codetermination approaches which bring together government, management and labour, makes this much more likely, whether the linkages are of a computerized or of a more informal nature.

9.4 Manpower and Skills Issues

One of the major findings derived from extensive research into the use of automated technologies, is that concerning the changes in manpower and skills. There seems to be a general opinion that FMS and automation as a whole will lead to a gradual transformation of employment structures.[174] The first observation which can be made in this respect is that indirect production/support work is increasing while direct work is decreasing (a shift from manual to mental work). This trend can be documented by both national and individual enterprise employment data.

A second observation is that automation is causing changes in skill requirements both in existing work and, in particular, in the new jobs created. Practical skills have to be complemented by a higher degree of theoretical skills in science and in modern technologies.[175] It is often stated that the new production technology requires personnel with multidisciplinary skills.[176]

The traditional work organization, characterized by specialization, fragmentation and narrowly-defined work tasks is, to a large extent, replaced with so-called flow-oriented work

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[173] Haywood and Bessant, 1987a.

[174] American Machinist, 1985; ECE, 1984.

[175] American Machinist, 1985; Ministry of Industry, Sweden, 1983; Hatvany et al., 1983.

[176] UN/ECE, 1986.

organizations where work is more broadly defined and carried out by teams of workers having multi-disciplinary skills;[177] and it was found that the use of modern technology, - and the efficiency with which it was used - depended very much on the skills of the people who used it, and the management objectives in applying the technology.

Profound changes in the types of workers and the levels of skills they employ can be expected in those countries or companies wishing to make effective use of information based technologies such as FMS. In Sweden in those companies adopting FMS, graduate levels, for example, have increased from just under 3 per cent of the workforce in 1981 to approximately 10 per cent in 1986.

In Sweden the rationale for the use of FMS as a major competitive weapon is that a combination of using the latest technologies and the continual, and increasing, upgrading of education and skills secures increasing company market share. One example of this latter trend in Sweden was that while approximately 75 per cent of school leavers currently went on to higher education in one form or another (in the UK it is estimated to be approximately one third of the workforce), it was planned that this would increase to 95 per cent by 1995. One company visited observed that already 55 per cent of its shopfloor personnel had technical high school training.

This combination of latest technologies integrated with high and increasing skill levels had led to an increase of 25 per cent in employment levels, in one company visited, and an increase of 250 per cent in productivity. In this same company, women represented 40 per cent of the workforce, with a substantial percentage of this being women employed in skilled production roles.[178]

One answer to the problem of successful utilization of FMS might lie in the approaches long adopted in Sweden where school children begin - at the age of 13 - to be introduced to, and start to make choices about, their future employment options. At this age they visit and work within local companies for at least one week per term to gain work experience; at 15 this increases to two weeks per term: and at 16 or 17 they have the opportunity to go on to a higher educational establishment, where they can receive a more occupationally oriented and technical education to provide them with the necessary skills for their future occupations.

The use of FMS has also led to a considerable coming together of those skills traditionally defined as direct (blue collar) and indirect (white collar). With the company becoming more computer driven white collar workers are becoming more involved with shopfloor work than ever before. While there are some problems of demarcation they are a minor problem and are increasingly being overcome.

One approach is to upgrade the shopfloor worker to do more organizationally and technically driven work, in other words to get the person with the machine or manufacturing knowledge to acquire computer or electronic skills rather than get the more academically qualified to acquire machining knowledge, since generally it takes much longer to acquire machining skills.

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177 UN/ECE, 1986.

178 Haywood and Bessant, 1987a.

Many companies - particularly in Sweden, Japan, and West Germany - have taken up the challenges of developing production processes that involve a strongly integrative technology and labour role. This follows what has been called computer and human-integrated manufacture (CHIM)[179] - rather than what has mainly been concentrated upon up to now in the UK, computer-integrated manufacture (CIM).

In a comprehensive survey (1200 manufacturing establishments) conducted bi-annually by the Policy Studies Institute (PSI) in the U.K, a distinct and increasing impact of micro-electronics technologies can be seen. The latest (1987) survey showed the following:

- In the UK manufacturing as a whole, nearly two factories in three are now using micro-electronics - more than three times as many as six years before. One in every eight is using it in its products and three out of five in their production processes.

- In 1978 barely 7 per cent of UK factories were using micro-electronics; now two-thirds are and there is only limited scope for further new users. In the course of a decade micro-electronics has grown from being a "new" technology to becoming a mature one.

- Applications in products are concentrated almost entirely in three industrial sectors: electrical, electronic and instrument engineering; mechanical engineering, and vehicles and aircraft.

- Applications in processes are spread more widely, with particularly high proportions in paper and printing; food and drink; and chemicals and metals; and particularly low proportions in clothing and textiles.

These were highlighted as findings of the fourth in a major series of reports examining the application of micro-electronics. Other factors included:

- Automation: Complex, advanced kinds of application are still rare, but their use is increasing and is associated with the greatest job losses.

- Key Skills: The most widespread obstacle, regarded as a very important difficulty by nearly half the user factories, is lack of specialist technical expertise.

With regard to the need for highly skilled personnel, including engineers, they were able to report that training had markedly increased, but despite having a well established university and polytechnic system the supply was not keeping pace with demand.

> "The number of engineers with relevant expertise has been rising fast, doubling between 1981 and 1983, and doubling again between 1983 and 1987. In each of the four surveys the user factories have said they would like still more - on average about 40 per cent more. Over half of the user factories still have none of these specialist engineers at all".

Clearly if a developed country such as the United Kingdom is facing problems of having sufficient experts to cope with the demands of automation, developing countries may face even

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[179] Haywood, 1988.

more severe problems. There is, of course, a question of scale involved here however, and a slowly growing automation sector in the latter countries may not put too much strain on the educational system. It is essential however, to be aware of the demands that will be put on the post-school leaving system, particularly at the university and technical levels.

In terms of real numbers of engineers, PSI note in their 1986 report:

"Although not sufficiently quickly to meet the demand, the number of engineers with the necessary expertise has been rising fast - from an estimated UK total of about 26,000 in 1981, to about 46,000 in 1983 and about 52,000 in 1985. The users in the 1981 survey reported having an average of 1.2 engineers per establishment when they work on microelectronics applications, but this had increased to an average of 6.3 by 1983 and has risen further to an average of 7.5 in 1985. However, because there are fewer engineers in the smaller establishments, when the sample figures are weighted for all UK manufacturing the average number per establishment using microelectronics comes down to about 2.9.

Rapid as the growth in numbers has been, it has at no point come near to meeting the demand. In 1981, user establishments on average wanted about 40 per cent more of these engineers than they had already, in 1983 about 40 per cent more than they had by then, and in 1985 they still say they want about 40 per cent more than the even greater number than they have now. And no doubt more still will be wanted in future years when additional establishments start using micro-electronics and when existing users extend the range and sophistication of their applications".

The PSI surveys contain a wealth of data on the spread of microelectronics in both products and processes. For processes, three tables are presented which emphasize the pervasiveness of micro-electronics application. The first shows applications by type of equipment. (Table 9.1). Applications in design were expected to increase by 236 per cent between 1983 and 1989 (136 per cent achieved between 1983 and 1987).

Applications in machine or process control already stand at 71 per cent and machine control alone at 64 per cent. Perhaps of most interest is that centralized machine control, integrated process control and automated handling were expected to reach 32 per cent, 36 per cent and 44 per cent respectively of all companies in the sample by 1989.

All of the applications imply significant advances in Robotics, CAD, NCMT, and FMS - the four technologies dealt with in earlier chapters. Given that the UK is thought likely to be one of the slowest adapters of automation among the OECD countries, this indicates that Japan, the USA, Germany, etc., are likely to become even more internationally competitive - with subsequent implications for the international division of labour.

Looking at changes in process applications alone, on a weighted average for all UK establishments, in total a clear doubling of applications emerges. (Table 9.2).

Table 9.1 Type of micro-electronics application in production processes: 1983-1985-1987-1989

(percentages of all establishments using each type of application)

Type of application	1983	1985	1987	1989 (expected)	1985-1987 (expected change)	1985-1987 actual change)	1987-1989 (expected change)
BASE	1200	1200	1200	1200	1200	1200	1200
Design	14	22	33	47	+10	+11	+14
Machine control (of individual machines)	42	52	64	69	+2	+12	+5
Process control (of individual items or process plant)	29	39	49	56	+2	+10	+7
Machine or process control or both	50	60	71	75	+1	+11	+4
Centralized machine control (of groups of machines)	9	14	18	32	+8	+4	+14
Integrated process control (of several stages of processes)	11	20	24	36	+9	+4	+12
Centralized machine control or integrated process control or both	15	25	31	47	+11	+6	+16
Automated handling (of products, materials or components)	15	22	29	44	+12	+7	+15
Automated storage	5	7	10	18	+7	+3	+8
Testing, quality control	22	35	45	54	+6	+10	+9
Centralized machine control or integrated process control or both and also design, testing and automated handling	2	4	8	18	+5	+4	+10

Source: PSI (1988).

Table 9.2 Extent of use of micro-electronics, 1981-1983-1985-1987, weighted for all UK establishments (column percentages of all UK manufacturing establishments)*

Process applications	1981	change 1981-1983	1983	change 1983-1985	1985	change 1983-1985	1987
BASE (unweighted)	1200		1200		1200		1200
(weighted)	41060		37085		33145		32001
In production already	18.0	+19.2	37.2	+11.4	48.6	+10.5	59.1
Under development	2.8	-0.1	2.9	-1.1	1.8	+1.2	3.0
Feasibility investigated	5.8	-2.5	3.3	-0.1	3.2	+0.1	3.3
Total	26.6	+16.7	43.3	+10.3	53.6	+11.7	65.3

* Excluding establishments employing less than 20 people.

Source: PSI (1988).

In fact the applications in production processes already reaches a level more than three times higher in 1987 than in 1981.

The final Table shows the level of applications by size of company, and it confirms the earlier discussions in this report regarding the adoption of automation by larger firms. (Table 9.3). Although 68 per cent of companies already used micro-electronics in their processes by 1987, there is an obvious progression by firm size. In those companies employing between 1 and 19 people only 18 per cent use such technologies and 45 per cent in the 20-49 range. With 99 per cent of firms employing more than 1,000 people the largest companies are almost five times more likely to use automation based technologies than the smallest companies.

Table 9.3 Extent of use of micro-electronics by size of employment (column percentages)

	Employment size								
Process applications	**1-19**	**20-49**	**50-99**	**100-99**	**200-499**	**500-999**	**1000-**	**Total[1]**	**Total[2]**
In production already	18	45	60	74	89	94	99	77	68
Under development	1	4	2	4	3	1	1	2	2
Feasibility investigated	3	4	4	3	1	1	0	2	2
Total	21	52	66	81	93	95	99	81	72

[1] Main sample, establishments employing 20 or more people.
[2] Extended sample, including also very small establishments employing 1-19 people.

Source: PSI (1988).

What are the consequences of these trends? If we note that the extent of automated processes are advancing across a broad range; and that the skills requirements are rising with them several points emerge. As the UN/ECE report notes:

"The Bureau d'informations et de prévisions économiques (BIPE) in France estimates that over the next 10 years the use of advanced manufacturing equipment will require changes in skills and qualifications in about 25 per cent of the jobs in French industry (ECE, 1985). In order to adjust to these changes in employment structure and the demand for new skills, individual enterprises together with national educational authorities must set up education and training systems in order to ensure the timely teaching of adequate skills to a sufficient number of personnel in industry and students at school. Frequently national educational systems have built-in delay factors, in the skills required in industry (Ebel, ILO). In order to reduce those delays, close cooperation between industry and national educational authorities is called for. The needs of industry must be expressed explicitly at an early enough stage for the educational systems to adjust to them".

Thus, in a rapidly changing technological environment several million people will require re-training to cope with those demands.

In a recent review of Mechatronics (the combination of mechanical and electronics equipment) in Europe, it was stated that:

"The extent to which mechatronics can be implemented will depend critically on the level of skills available in the labour market and places a strong emphasis on training. Occupational structures are changing considerably as a result of the introduction of FMS -

with a general cutback in the numbers of unskilled and semi-skilled functions, such as loading, unloading, transportation and progress chasing. A consequence of the declining numbers of direct operators and the need to maintain high levels of utilization and flexibility is that skill requirements change. Not only is there a need for higher levels of skill but also for greater breadth and flexibilityto move between and across skill boundaries (Senker 1985). Multiple skilling at all levels is increasing in importance and the portfolio of relevant skill is also changing, with increasing emphasis on preventive action rather than direct intervention, on diagnosis and problem-solving and on planning and programming".[180]

In conclusion some findings of the 1986 PSI report[181] for the UK are summarized, covering both positive and negative features.

The positive features observed are:

(1) The massive loss of jobs some have predicted has not so far happened.

(2) Until recently the direct displacement of jobs has been quite small in relation to total employment in manufacturing industry and to total unemployment from all causes.

(3) Even now the average number of jobs displaced per user establishment is only 2 or 3 a year.

(4) Any direct decrease in jobs in the establishments using microelectronics may well be offset by indirect increase in jobs elsewhere.

(5) Such job losses as there have been seem, on the whole, to have been acceptable to the people in the workplaces concerned because they have mostly taken the form not of dismissals but of natural wastage.

There are however, concerns for the future:

(1) Between 1983 and 1985 the total decrease in jobs has been much greater than that expected by industry - three times the level in the previous two years.

(2) The higher level of decrease may be explained in part by the effects of increasing adoption of more advanced systems, in which case further spread of their use may lead to further rises in the rate of decrease in jobs.

(3) The proportion of job decreases taking the form of voluntary redundancy rather than natural wastage has risen sharply.

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180 Bessant and Haywood, 1991.

181 PSI, 1986.

(4) The small average decrease in the number of jobs per establishment is a net figure which conceals much higher gross numbers of jobs displaced in particular cases.

(5) The new jobs becoming available are often of different kinds and in different places from the old ones and are therefore not necessarily within the reach of those displaced from the old ones.

(6) Continued acceptability of job shedding cannot be taken for granted if the rate of displacement continues to increase and if the background level of mass unemployment persists.

In spite of the negative aspects of the employment effects, the report argued for the adoption of new technology to maintain and improve international competitiveness:

"Falling behind in this would only lose more jobs to other countries which adopt the new technology more effectively".[182]

9.5 Organizational and Manpower Issues: A Brief Summary

As desirable as updating productions technology is, it cannot take place without a wide variety of other factors being brought into play.

While it is possible to attach quantitative "numbers" or "figures" to proposed new production systems, evidence has increasingly shown that it is the total environment in which it takes place that is an important factor in its successful use -- and that these may be quite qualitative factors.

Production techniques have been seen to be moving towards a more "knowledge" based setting; and the structures and methods coming to represent an "organo-centric" whole rather than a "techno-centric" one.

Long-term strategies have to be adopted, and for some developing countries this will mean decades rather than a few short years. The precedents are clear: Germany, Japan, Sweden, just three countries which are now successful in international terms have spent decades putting in place social systems which have created skilled, educated workforces capable of moving along consensus lines to highly developed economies. This provided the catalyst or "virtuous circle" for success.

Organizations, structures and methods can be changed only on the basis of such a bedrock, since reliance on the old Taylorist/Fordist model is no longer feasible with microelectronics based information technologies.

Changes in learning and skills are essential and this is only possible with a fully developed educational system at all levels, including vocational training.

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[182] PSI, 1986.

Such a total concept calls for:

- the development of coordinated skills;
- design and re-design for manufacture;
- a joint technological/organizational approach to change;
- closely coordinated buyer/supplier relationships; and adoption of JIT;
- allocating to the computer what it is best at, and to human beings what they are best at; etc.

The path to CIM can be summarized as "Simplify, integrate, computer-integrate".[183] Another summary derives from analysis of the Japanese approach to manufacturing:[184]

(1) Learn from others;
(2) JIT/TQC are imperatives for improvement;
(3) Production people must control quality;
(4) Non-Japanese can use Japanese techniques;
(5) Simplify plant configuration -- break down shop barriers;
(6) Labour flexibility is the key to success;
(7) Have your suppliers deliver at least once a day;
(8) Production managers and workers can improve systems themselves;
(9) Simplify and reduce, simplify and integrate, simplify and expect results.

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[183] Ingersol Engineers, 1983.

[184] Schonberger, 1982.

10. Developed Country Policy Issues

Despite the commitment of OECD countries to market mechanisms, they have increasingly intervened over the past twenty years in support of their national industrial structures.

Such support has ranged from subsidies to the primary sector through to large-scale incentives directed towards the development and diffusion of high technology sectors of the economy, e.g. micro-electronics, opto electronics, etc. In the latter case in part this is because the sheer scale of developments, and the integrative nature of the trends that have occurred -- particularly over the last ten years -- has been so profound that governments have been unable to remain aloof. Government policies to foster automation and the electronics sector in general, have included pre-competitive research programmes, support for inter-firm cooperation, special government procurement policies and cooperation on a regional level to join forces while removing inter-regional barriers to trade to enable companies to reach the necessary economies of scale. Setting of industrial standards and the active involvement of the national (or in the case of EC countries, the 'regional' industry) in this process has been another important field to strengthen competitiveness vis-à-vis third countries. In contrast to other sectors, companies in the electronics were in general allowed to merge and acquire other companies even though this appeared to run counter to officially proclaimed competition policy. Finally, so called "anti-dumping" measures have increasingly been used to fend off imports and protect the local industry.[185]

The scale of intervention has, however, been quite different according to application and country. It appears that although considerable sums of money were also provided in the UK and USA, for example, there was rather less centralized guidance of policy than that seen in countries such as Japan or Germany. Again, although Sweden provided some assistance to its infrastructure, its policies toward specific industries were much less interventionist than those of Japan and Germany.

This chapter attempts to highlight some of the specific policy approaches taken by individual countries. It also discusses some of the problems, reviews sectoral issues and diffusion, examines some of the skills/employment issues once again, notes the need for changing buyer/supplier relationships, and offers tentative conclusions on the policies adopted by these developed countries, with additional reference to some developing country issues.

10.1 An Introduction to Technology Policy Issues

Developments in micro-electronics and, in general, the information technology industries, have had a marked impact on industrial structures and technology policies in the OECD countries. As the Swedish Government Research Bill (1990) noted:

> "The development of information technology in recent decades has brought with it a shift away from a highly product-oriented society to one that is increasingly knowledge-oriented. This trend will be of crucial significance in the twenty-first century, heralding a revolution for the industrialized nations in the first place, but eventually also for the developing world".[186]

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[185] UNIDO, 1992.

[186] Government Bill (Sweden).

This raises issues concerning the framework for development in both the developed and developing world, and the interventions that might be expected from national governments.

> "The role of government as a source of information and analysis of industrial developments has been enhanced by the radical structural changes that have been integral to the process of trade expansion – e.g., the multiplication of new goods and services in the market as a result of technological innovation and the growing internationalization, through mergers and various forms of inter-firm linkages, of product development, production and marketing".[187]

Governments may adopt policies geared towards support for specific technologies or industries, become providers of information and analysis, and increasingly develop infrastructure, e.g., education, communications, transport, or a whole range of other policy instruments.

> "Effective government programmes have a number of common features despite different national institutional structures and economic performance. They include: high levels of out-reach (the large number of target firms which actually participate in programmes); relatively low levels of discrimination between applicants so that governments do not have to choose specific applications and technologies; market-driven support of activities such as the provision of initial consultancy; and attention to the infrastructure (technological institutions, technology suppliers, consultants, and inter-firm linkages) and to investments in the development of human capital (skill development, training and education)".
>
> The national industrial structure and structural relations within industry are key elements determining the rate of applications. Important structural elements include: the presence of strong firms in key fields producing (electronics, machinery, metals) and using (automobiles, defence) advanced automation equipment; close ties in some industrial sectors between technology generation and industrial use, either within the same firm or group of firms, or through efficient sales and applications intermediaries. Furthermore, the relations between industrial purchasers and suppliers are increasingly important.
>
> Overall, there are large advantages in expanding the diffusion and application of microelectronics to gain competitiveness, improve productivity and efficiency, and to broaden product range and capabilities. Governments have a strategic role to play in setting the general economic conditions which encourage diffusion, and in some cases increasing information and overcoming constraints on wider applications".[188]

But such social/political/economic/technological imperatives greatly complicate issues related to development, even within the highly industrialized nations.

> "...the rate of technical change in any country and the effectiveness of companies in world competition in international trade in goods and services, does not depend simply on the scale of their research and development and other technical activities. It depends upon the way in which the available resources are managed and organized, both at the enterprise and at the national level. The national system of innovation may enable a country with rather limited resources, nevertheless, to make very rapid progress through appropriate combinations of imported technology and local adaptation and development. On the other hand, weaknesses in the national system of innovation may lead to more abundant resources

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[187] OECD, 1990.

[188] OECD, 1989.

being squandered by the pursuit of inappropriate objectives or the use of ineffective methods".[189]

In the OECD countries, for example, programmes pursued by different countries to diffuse new technology have tended to follow four broad approaches

- to offset weaknesses in the economic/industrial sub-structure, i.e., poor balance in industrial firm size;
- to support the adoption of specific technology transfer between manufacturers and the user companies;
- to compensate for lack of information about technologies, i.e., to act as an information provider; and
- to improve the infrastructure by providing increased levels of adequately trained and skilled workers at all levels -- but particularly the technical, scientific and management levels.

"For the most part governments have embarked on longer-term support programmes with 3 to 7 year time horizons (the Danish, German, Swedish and UK programmes). Some minimum length of commitment -- three to four years -- appears necessary to develop smoothly administered programmes and to build confidence and reinforcing links between the diffusion agencies and industry -- particularly for SMEs. But it appears desirable to have some constraints on programme length to prevent long-term reliance on government support, to create a sense of urgency and competition among firms for support, and to avoid becoming locked into one mode of support when technological change is rapid and problems and priorities change ...

Targets: A major decision is where to target government assistance to realize maximum impacts: whether by industrial sector, by size of firm, or by other criteria. Programmes in Denmark, France, Germany, Japan, Portugal, Sweden and the UK gave priority to small and medium-sized enterprises (SME's), and in some cases to high potential, technically oriented owner-run firms. The German programme targeted smaller firms in technology-intensive machinery industries where small German firms have traditionally been highly competitive and where the challenges of new competition and the opportunities of micro-electronics applications are most keenly felt. But larger firms and more traditional industries can use adaptation and modernization assistance if they are slow to adopt the technologies on their own, particularly where there are structural factors inhibiting adoption and adaptation".[190]

10.2 Government Support Programmes

This section concentrates on support policies being utilized in a number of OECD countries namely the USA, Japan, Germany, France, the UK, Sweden, and Denmark. The analysis draws heavily on OECD (1989 and 1990) and Roobeek, (1990).

As far as can be established, recent policies directed towards improving the competitiveness of firms have tended towards five areas:

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189 Freeman, 1987.

190 OECD, 1989.

(1) Stimulation of research by establishing closer links between institutes of higher or further education (universities, polytechnics, technical high schools) and scientific research centres, and the individual companies.

(2) The development of industrial zones or science parks, in order that dissemination of modern techniques and ideas can occur.

(3) Modernization processes within the firm itself, e.g., research, organizational or structural changes, and training and education. Very often this type of support has been provided by offering tax/grant concessions to firms carrying out such activities.

(4) Support for applications of particular technologies, e.g., the UK's Microelectronics Application Project (MAP) or the German Special Programme.

(5) Attempts to strengthen the infrastructure via enhancement of the educational/skills base, etc.

These trends are reflected in Table 10.1 which shows how eight OECD countries have supported the diffusion of micro-electronics.

Table 10.1 Major activities supported by national microelectronics diffusion programs

Programme activity	Denmark	France	Germany[1]	Japan	Portugal	Sweden	United Kingdom	United States
1. Awareness activities:								
- general awareness	×		×	×		×	×	
- applications/demonstration projects	×	×		×	×	×	×	
2. Consultancy assistance	×	×	×	×	×		×	
3. Market identification, exploration and development	×						×	
4. Process development/process applications support	×	×		×	×	×	×	×
5. Product development support	×	×	×				×	
6. Enabling infrastructure/information channels for technology transfer:								
- publicly backed technology institutes	×	×		×	×	×		
- decentralized applications centres	×	×			×			
7. Enhance technology supply (upstream):								
- domestic technology supply capability		×	×	×		×		
- improve access to foreign technology suppliers	×							
8. Training programs for:								
- technicians/engineers	×	×		×		×	×	
- managers	×			×			×	
- shop-floor personnel (apprentices)								
9. Broad education programs (secondary, tertiary, adult education)								
10. Basic research support:								
- enterprises				×		×		×
- technology institutes	×	×		×	×	×		
- universities	×					×		×

[1] Special programme only.

Source: OECD (1989)

The next section discusses individual national support programmes and section 10.4 makes a number of general observations regarding groups of OECD countries.

10.3 National Policies in Seven OECD Countries

(A) Denmark

Approximately Dkr 1.5 billion ($145M) was allocated over the five year period 1985-89 in support for technological development (see Table 10.2). The average sum awarded to the 969 projects supported in 1985/6 was about Dkr 800,000 ($78,000).

Table 10.2 Technological development program: total budget 1985-89 and funds committed 1985-86, by type of activity

	Number of projects supported 1985-86	Funds committed 1985-86 (million DKr)	Total budget 1985-89 (million DKr)
Total	969[1]	782.6	1540
Support to individual companies for product & process development	508	219.1	560
Equipment grants to universities, know-how centres	45	126.4	200
Broad based support[2]	416	437.1	780
of which			
a) Microelectronics systems R&D	105	169.3	250
- general R&D	63	92.3	140
- project ESPRIT (EEC)	42	77.0	110
b) Increasing use of microelectronics within firms	259	231.3	475
- specific IT use	120	121.2	215
- public awareness	25	15.3	25
- demonstration	23	11.4	25
- consulting assistance	15	22.9	75
- training	38	38.7	85
- importation of technology	38	21.8	50
c) Other activities	52	36.5	55
- technology assessment	15	12.8	25
- pilot/test projects	37	23.7	30

[1] Excluding approximately 350 initiated consulting assistance tasks.
[2] General projects in technological institutes, joint projects by groups of firms and industry associations.

Source: OECD (1989).

Of the total sum, roughly one third (Dkr 560M) was devoted to support to individual companies to develop both products and processes, and a slightly smaller sum (Dkr 475M) to support the increased diffusion of microelectronics. Ranking third in importance was support for R&D in microelectronics (Dkr 250M); equipment grants to universities or other knowledge centres ranking fourth in importance (Dkr 200M).

Assistance to individual companies provided grants worth 40 per cent of direct project, or 50 to 75 per cent of project risk capital.

Since the range of industries in Denmark is not as wide as in many larger countries, the 1985/86 assistance was somewhat more focused on a smaller range of sectors (Table 10.3).

Table 10.3 Technological development program: distribution of funds by sector (per cent)

	Technological development program: 1985-86			For comparison: 1985	
	Total	Industrial R&D fund loans	Product development grants	R&D personnel	R&D expenditure
Food, drink, tobacco	5.4	24.8	1.2	6.8	8.3
Textiles, clothing	2.8	5.0	2.6	0.3	0.4
Wood, furniture	3.6	2.9	5.5	0.6	0.5
Paper, printing	0.9	5.2	0.1	0.2	0.2
Chemicals, plastics	4.5	-	3.9	22.5	24.4
Metals, machinery	16.3	14.6	24.1	43.8[1]	42.6[1]
Electronics	21.9	28.3	23.2	10.9	9.6
Software	13.	13.5	32.0	n.a.	n.a.
Other	31.6[2]	5.7	7.4	15.0[3]	14.0[3]
Total	100.0	100.0	100.0	100.0	100.0
Total value (million Dkr)	782.6	119.5	99.6		3,217

[1] Includes electrical machinery and instruments.
[2] Includes equipment grants covering all activities.
[3] Includes small enterprises.

Source: OECD (1989).

The outreach of the programme has been quite extensive with approximately 33 per cent of companies with more than 200 employees and around 20 per cent of companies with less than 50 people taking part. Eighteen per cent of firms (1000 out of 5500) were directly involved in the Technological Development Programme developments, demonstration and joint programmes.

However, barriers to effective use were extensively found among the many firms taking part (Table 10.4).

> "A significant number of firms (36 per cent of introducing firms, 20 pe...) had encountered unexpected problems in introduction. Over one-th... ith problems encountered these problems in training staff, one-fifth had a sho... of qualified labour and one-quarter had organizational problems. Technical problems were common in almost two-thirds of firms with problems (see Table 10.4). In general, 40 per cent of firms reported limitations and bottlenecks when introducing new technologies. Shortage

of qualified labour was the overwhelming general limitation (57 per cent of firms), followed by financial problems (22 per cent)".[191]

Table 10.4 Problems encountered when introducing new production technology: 1986 (percentage of firms reporting problems)

Technical problems	64
Delays in supplying equipment	50
Training staff	34
Organizational problems	25
Shortages of skilled labour	22
Application of new materials	8
Other	9

Source: OECD (1989).

Potential users of technology who received government assistance in their efforts to upgrade their products and processes received help from a wide variety of sources – though by far the highest percentage came from the suppliers of the equipment.

Table 10.5 Sources of advice and information when investing in new process and production technology: 1986 (percentage of firms)

Suppliers	67
Private consultants	28
In-house	22
Universities, technology information centres etc.	22
Technological service institutes	20
Customers	4
Other	8

Source: OECD (1989).

For the rest, private consultants, in-house expertise, universities or information centres, and technological institutes ranked fairly evenly.

[191] OECD, 1989.

(B) France

France has always been known for its relatively strong interventionist approach in industrial policy (the so-called "Colbertism")[192] which also included technology policy. French public policy has been built upon two basic pillars. The first is support of national industry through grants, forced reorganization and public procurement policies; the second has been the development of international connections, to obtain appropriate technology.[193] Since the early 1980s, the French have sought to provide assistance to industry through both product and process stimulation. (On the product support side, the "Products Using Electronic Components Programme" (PUCE) was started in 1982 and by June 1986 had received funds equal to US$ 7.2 million (FF50 million at FF6.9 to the $)).

The support to process innovations was provided under the National Computer-Integrated Manufacturing Agency (ADEPA) programme. This is not a financial institution but a technology assistance operation, and is intended to aid -- primarily -- small- to medium-sized enterprises to modernize using computer integrated equipment and methodology.

ADEPA provided funds of around FF 210 million in 1984/5 (just over $30 million) and supported 1959 systems, of which about half were in the electronic and machinery industries.

Two major benefits (in terms of additionality) arose as a result of this support:

(1) It brought forward in time investment that would probably eventually have been made; 37 per cent of the companies would have deferred the investment without support.

(2) More importantly perhaps, it resulted in upgraded investment, i.e. more sophisticated and automated processes were introduced; 70 per cent of companies noted this (OECD, 1989).

As the OECD report observes:

> "ADEPA has two important features: the quality of technical assistance; and the flexibility it enjoys as a quasi-public agency in implementing technology transfer and managing government incentive schemes for SMEs. This structure, in which manufacturers, consumers, trade associations, employers, trade unions and government are represented, is an effective channel of consultation between industry and government. It also has staff of the necessary calibre (professionals with a strong practical background in manufacturing automation), and a pragmatic approach with which to help SMEs when modernizing their technology. It has an important role to play in boosting intangible investment in training, software, and marketing where small firms have been weak...
>
> Other measures have also been introduced to promote and motivate the growth of venture capital in the area of new technologies. More emphasis is also being given to promoting intangible investment (training, software, marketing) and to the internal re-organization required to effectively integrate new innovations and production processes into existing firm structures".

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[192] UNIDO, 1988b.

[193] UNIDO, 1985.

Apart from these two recent support programmes, France has - as was pointed out earlier - a long history of support to industry. The support to the electronics industry, information technology and industrial automation goes back at least to 1966 with the Plan Calcul. A major characteristic of the Plan Calcul was the policy of supporting "national champions". The impact of the three successive "Plan Calculs" up to 1982 was however an excessive support for mainframe computers to the detriment of components, peripherals and small computers.[194]

In the late 1970s, the Programme Télématique (telecommunications) dominated research activities. It was however only in the 1980s that automation integration has been pursued, starting with the "Filière Robotique" (1981) and the Machine Tool Programme (1981-1984). In 1983, public authorities in France launched the Plan d'Action Filière Electronique (PAFE). The programme covered a wide range of fields and could be regarded at the time as by far the most comprehensive of any European programme in this area. Within this programme, there was a micro-electronics plan, a plan for passive components, a PUCE (chip) programme (so that small- and medium-sized firms could introduce French electronics components into their products), a super-calculator plan called Marisi, an imaging plan, and finally the "productique" plan for modernizing industries.[195] The "Plan d'Action Filière Electronique" had the objective of making France the world's third largest electronic power after the USA and Japan.

Overall, there seems to have been a certain concentration in telecommunications, telematics, professional electronics, medical electronics, and the space industry. For industrial applications, the programmes concentrated on the use of electronics in textiles, garments and the capital goods sector, including machine tools, robotics and flexible manufacturing equipment.[196]

Specifically focusing in on these integrating technologies (NCMT, Robots, CAD, FMS, etc.) the subsidies since the mid 1970s have been quite heavy, totalling FF 7,856 million, with almost 60 per cent of this total going to the 1981-1984 Machine Tool Programme and the 1982-1985 Plan Productique. It also included FF1,2000 million for the Fonds Industriel Modernization (FIM which operated from 1982 to 1985 providing soft loans for purchasing robot equipment.

France's efforts at the national level lost however some of their momentum towards the end of the 1980s. Natio. al efforts - although remaining strong by international comparison - have been complemented by various EC programmes in the late 1980s and 1990s. Amongst the various programmes which touch on electronics and automation, ESPRIT, the European Strategic Programme for Research and Development in Information Technologies, has been the most prominent one.[197]

(C) Germany

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[194] UNIDO, Survey of Government Policies in Informatics, (UNIDO/IS.526), Vienna 1985, p. 28.

[195] UNIDO, 1988b.

[196] UNIDO, 1988b.

[197] UNIDO, 1988b, p.189.

one might expect. Since the creation of the BMFT (the Federal Ministry for Research and Technology) in 1972, Germany has de facto a single office to assist and guide Research and Development in German enterprises.[198] The situation is however complicated by the activities of the 'Länder' (prov... es), which also play a role in fostering research in the German provinces. The main objective of Germany's policy in electronics has been to attain technological independence by developing a strong domestic industry in specific market niches. In practice, public policy in Germany operates through a loose form of consultation among industry, government and unions rather than through formal institutional arrangements. Support for large-, medium- and small-sized companies is a key aspect of German policy and contrasts with previous policies which tended to support and build up "national champions".[199] At the same time, however, government allowed - disregarding overall tight merger control legislation - takeovers for companies to build up their cross-sector technology bases. The most striking example was the merger of Daimler Benz and the defence and aerospace giant MBB.[200]

As with France, the German (pre-unification) focus has concentrated on three or four areas. We are concerned here with process technology utilizing micro-electronics and information technology rather than support for new materials or bio-technology.

German support started at around the same time as in France. Between 1971 and 1988, Government subsidies in the field of micro-electronics and information technology totalled DM 11,942 million. The largest subsidy - DM 3,00 million - went to the Information Technology Plan which ran from 1984-1988. In addition, DM 2,700 million was spent on R&D support for data processing between 1974 and 1982. Between 1967 and 1979, Germany had three successive informatics plan. In 1971, it started with Data Processing Programmes; in 1974, it launched its first five-year plan (1974-1978) for electronic components (Elektronische Bauelemente) followed by a micro-electronics programme (Zeitungsplan Mikroelectronik) from 1979-1983. In 1984, came the unified information technologies plan (1984-1988) and postal services, and for the 1984-1987 period, a special programme for industrial automation (DM 530 million) was launched aimed at the introduction of CAD/CAM to medium-sized enterprises, the promotion and development of robots and the promotion and development of flexible manufacturing systems.[201]

In the 1980s, the focus of the programmes shifted further towards application and development while pre-competitive research was left to EC programmes. At the same time, the overall outlays of the German government and regional governments favoured basic research and joint international projects, cutting back funding of commercial research. Over the 1980-1990 period, Germany's R&D outlays rose to $55 billion or 2.9 per cent of gross national product, from $33 billion or 2.6 per cent of GNP.[202]

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[198] UNIDO, 1988b, p. 185.

[199] UNIDO, 1985.

[200] Business Week, 1990a.

[201] Arnold and Guy, 1986.

[202] Business Week, 1990b, p. 69.

While government has provided substantial funds to increase modernization, it is clear that industry itself has responded positively to this stimulus, bringing forward investment more than double that provided by the state.

One specific example of support is the Special Programme on the Application of Micro-electronics. This was a somewhat similar project to the UKs Micro-electronics Application Project (1978-84) – see section (F).

The Special Programme had three main aims:

- to increase micro-electronic applications, both product and process based;
- to improve the position of the domestic components industry;
- to stimulate the use of micro-electronics amongst the capital goods manufacturers.

The budget for the programme, 1 January 1982 to 31 December 1984, was DM 450 million (US$180 million at DM 2.5/$). Support was on a subsidy basis for 40 per cent of development costs and 20 per cent of associated investment. Maximum subsidy DM 800,000 per applicant. The distribution was (DM million):

1982	1983	1984	1985
89.2	153.3	127.1	23.4

A total of 1,740 firms received grants to develop micro-electronic applications in 2,340 projects. Over 60 per cent of the target population of 5,000 firms using micro-electronics or considering using micro-electronics knew of the scheme.[203]

Table 10.6 Summary of federal funds allocated for research, development and applications in micro-electronics and information technologies

	Expenditures 1984-1988 (million DM)
Expenditures	
a) Special applications micro-electronics: (1982-85)	393
b) Special applications components:	
Sensors/microperipherals	320
CAD for ICs	90
Key micro-electronic components	90
Submicron technology	600
New materials technology	200
Integrated optical systems	90
c) EDP:	
CAD for computer/software	160
Computer architecture	160
Knowledge processing, pattern recognition	200
d) Software:	n.a.
e) Industrial automation:	
CAD/CAM, robots, university-industry cooperation	610

Source: OECD (1989).

[203] OECD, 1989.

In evaluating the success of the scheme it was found that it had a major impact on bringing forward investment both in time and increased sophistication, with most firms citing the assistance as crucial to their involvement.

Almost 90 per cent of the participating firms reported the venture to be technically successful -- though the smaller firms faced greater funding and market problems.

"Most firms thought the Programme was a success (93 per cent thought that assistance had paid off), with firms reporting positive effects on internal structural change, improved R&D financing, and positive impacts on firm finances and the establishment of new firms. The programme led to extension of the product range (23 per cent), improvements in product quality (22 per cent), and turnover increases (13 per cent)".[204]

The success of such government support programmes is thought to depend on four major ingredients:

(1) The degree of simplicity in administering the scheme, i.e. the use of existing professional organisations -- industrial engineers.

(2) A very simple application and approval system.

(3) A concentration on specific industries (precision equipment, machine manufacturing, and industrial electronics), and on the small- to medium-sized enterprises.

(4) A constant and on-going evaluation procedure.

Government subsidies for integrating technologies also started earlier than in France, which is perhaps a reflection of German strength and concentration in the machine tool, CAD, etc, industries. For example, a subsidy of DM 40 million was provided between 1974 and 1979 for the development of robot technology. Between 1974 and 1988, a total of DM 2,200 million was provided by the German Government in the form of subsidies for robotics. The two largest components were the BMFT Programme for Manufacturing Technology, comprising three parts with total funding of DM 675 million between 1984 and 1988 and a Microperipherals programme making available a total of DM 865 million between 1985 and 1988 for sensors, intelligent components etc.

Machine building and precision equipment are traditional mainstays of German industry and it is not surprising that efforts have concentrated on these areas. The Japanese challenge has been successfully withstood, with the German machine tool industry expanding more strongly than that of Japan in the 1980s and defending its position as the world's second largest producer after Japan, with a share of 24 per cent of total world exports. Between 1985 and 1988, the German machine tool industry more than doubled its volume of business from US$ 3.2 bn to US$6.8 bn while the Japanese industry increased its turnover by 60 per cent from US$ 5.3 bn to US$ 8.6 bn.[205] This success went hand in hand with the intensification of government efforts to improve the supply side

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[204] OECD, 1989.

[205] UNIDO, 1990b, p.139.

The 'Fertigungstechnik' programme launched in 1984 was designed to bolster the national machine building and robot industry and extensive funds have been made available for this programme. Its main target group consisted of small- and medium-sized firms in the machine building sector.

One of the prime objectives of the 'Fertigungstechnik' programme was to disseminate robots, CAD/CAM and flexible automation, though research institutes are also engaged in designing quality control machines for flexible production systems.

A further CAD/CAM programme has been set up worth DM 250 million. The close collaboration between industry, techno-scientific research institutes, universities and government has helped to reinforce the industrial and scientific base for developing robotics.[206]

The success of German support for industrial development has clearly stemmed from established strengths; i.e. machine tools, equipment embodying high value added, such as precision instruments; simple-to-administer schemes; particular types of company, specifically small- to medium-sized; and an established, highly skilled workforce, working in collaboration with technical institutes and other research bodies.

(D) Japan

At the heart of Japan's efforts to improve the technology basis of Japanese industry, one finds the MITI. The MITI (Ministry of International Trade and Industry) was founded in 1949 and given powers to control not only external trade, exchange rates, capital investments, and joint ventures but also transfer of technology.[207]

In the 1960s the MITI encouraged the major Japanese manufacturers to establish a joint research institute, The Japan Information Processing Centre, which, jointly with the MITI's own laboratory, established the Super High Performance Electronic Computer Development Project (1966-1979) funded with US$ 28 million, which laid the foundations of Japan's success in the field of electronics and automation. This programme was launched in preparation for foreign investment liberalization, scheduled in the late 1960s.[208] Under the program, the government identified projects based on close consultation with industry, universities and national laboratories. The criteria for selection of projects were:[209]

- a high social return;
- inability of private enterprises to undertake such projects because of the size of the investment, the time lags and the high risks involved;
- projects utilizing technologies that did not require extensive basic research;

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[206] Roobeek, 1990.

[207] UNIDO, 1988b, p. 179.

[208] The World Bank, 1989e.

[209] Peck and Tamura, 1976.

- projects to be carried out in cooperation with universities, government laboratories and industry.

As early as 1956 and 1957, two laws were passed to promote the engineering industry and the electronics industry. In 1971, these two laws were integrated into a new law (Kidenho) for promoting specific engineering and electronics industries. Special targets were the computer industry, integrated circuits and magnetic disk industries.

Together MITI and the NTT (an enterprise created by the Ministry of Posts and Telecommunications to carry out research) have originated most major R&D programmes in the field of electronics, thus enabling Japanese industry to acquire state-of-the-art know-how. The NTT was more oriented towards specialized telecommunications applications, whilst the MITI was primarily concerned with informatics. Although there was no direct financing for firms participating in this research, there were significant indirect subsidies by way of issuing of contracts.[210] Thus, in 1978 orders from the NTT represented 10 per cent of Japan's total consumption of semiconductors.

As with all three preceding countries – and subsequently Sweden and the UK – Japan has focused its support upon small- and medium-sized enterprises and also, mainly amongst larger firms, upon pre-competitive collaboration. The MITI was thus behind the setting up of the VLSI (Very Large-Scale Integration) Research Association, formed in 1975 by the five largest computer manufacturers (Fujitsu, Hitachi, Mitsubishi, Nec and Toshiba, subsequently joined by Oki and Sharp in 1979).[211] The structure of horizontally and vertically integrated industrial groups has enabled those enterprises to follow long-term strategies even if this meant losses in the early years of production. De facto cross subsidization within these groups has been a further element of the Japanese approach, with the government helping those large groups by means of public procurement.[212]

Nevertheless, support to small- and medium-sized firms has also played a crucial role. Incentive schemes include fiscal support for conditional loans for R&D projects (around 50 per cent of R&D cost, which must be repaid according to the profit generated by the technology or the success of the development project.), soft loans to cover around 50 per cent of costs of marketing new technology, etc.[213]

Small- and medium-sized enterprises are extremely important to Japan in general and to the industrial sector in particular, accounting for nearly 51 per cent of manufactured exports and 72 per cent of employment in the manufacturing sector. Although a substantial gap in productivity and wages still exists between large enterprises and small- and medium-scale enterprises, the latter have kept up with rapid technological advances.

> "Small and medium enterprise policy in Japan is delivered through an incremental series of policy measures announced in general "laws" and implemented through the existing support infrastructure. Unlike the more precisely defined policy delivery systems described

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[210] UNIDO, 1988b, pp. 179 f.

[211] UNIDO, 1988b, pp. 181.

[212] Kommission der Europäischen Gemeinschaften, 1991, p. 19.

[213] World Bank, 1989e, p. 49.

in the European case studies, the Japanese system to re-orient small enterprises towards a greater use of microelectronics, particularly in production technology, operates through a widely applied ongoing system of central government and prefectural modernization, upgrading and guidance networks, financial incentives (loans) and taxation expenditures (special depreciation and tax deductions)".[214]

Japan's prefectural governments play a major role in administering information programs. Regional research and testing institutions funded by the prefectural governments provide technical guidance and testing services, and disseminate information on new technology through publications for SMEs. They also sponsor meetings among SMEs from different business sectors to create opportunities for active technology transfer and exchange.[215]

Table 10.7 Budget expenditures for small and medium enterprise policy (general account expenditures, billion ¥)

	1983	1984	1985
Ministry of International Trade and Industry			
Japan Small Business Corporation	76.3	60.3	49.5
Policies on Small Enterprises	38.0	39.5	41.0
Training and guidance	7.8	9.2	10.4
Modernization and upgrading	9.7	9.9	8.9
Other systems: largely financing subsidies	44.5	46.9	41.2
Sub-total	176.3	165.8	150.9
Ministry of Finance			
Small Business Credit Insurance Corporation: capital contribution	55.5	51.0	43.0
Other	7.5	9.0	18.4
Ministry of Labour	3.4	3.4	3.8
Total	242.7	229.2	216.2
Share in total general account outlays (per cent)	0.48	0.45	0.41

Source: OECD (1989).

In general four types of policy are pursued in Japan:

- In order to modernize industry which has failed to adopt best practice techniques;
- To correct imbalances in business practices;
- To encourage development and growth in the small- to medium-sized companies;
- To assist companies facing financial and investment barriers.

[214] OECD, 1989.

[215] World Bank, 1989e, p. 35.

In order to provide this support, Japan has developed what is probably one of the most comprehensive programmes among OECD countries. Between 1975 and 1992, the government provided subsidies totalling 663.2 billion for micro-electronics and information technology, including components of Y 120 billion for the Paperless Office programme, which runs from 1984 to 1993 and promotes the automation of patent supply and fact finding and Y 100 billion for the 5th Generation Computer Project, which ran from 1982 to 1991 and under which the government provided 50 per cent of total cost of Y 200 billion. It was Japan's programme to develop a fifth generation computer which prompted other industrialized countries to follow suit. Japan unveiled the plans for a fifth-generation computer system at the end of 1981.[216]

The support provided falls into three main areas:

- Manpower and skills infrastructure. Extensive training programmes have been developed, in particular for the smaller companies, and administered by the Japan Small Business Corporation which was founded in 1980. This provides training at all levels and includes both technical and organizational elements. The demand for such training is very heavy.

- Special programmes aimed at the diffusion of specific technologies, such as Flexible Manufacturing Systems, Robotics, etc.

- The establishment of collaborative networks concerning research developments, in high-cost, high-technology areas (see Tables 10.8a and 10.8b).

One specific project which will have some bearing on some developing countries, is the Automated Sewing System project. Scheduled for completion in 1990, there are as yet no concrete details of the results. However, with a goal of reducing the time taken for sewing preparation, assembly, fabric handling and system management by one half, the implications should be very significant for developing countries. Some 28 enterprises took part in the programme, most of them medium-sized companies. The project was funded to the extent of ¥10 billion ($67 million at ¥150/$).[217]

Table 10.8a Ongoing national research and development projects - large-scale projects (million Yen)

Project name	R&D period (FY)	Total R&D expenditure (estimates)	Budget for FY 1987
Manganese module mining system	1981-91	20,000	819
High-speed computer system for scientific and technological uses	1981-89	23,000	2,947
Automated sewing system	1982-90	10,000	1,301
Advanced robot technology	1983-90	20,000	2,425
Observation system for earth resources satellite-1	1984-90	23,000	3,142
New water treatment system	1985-90	11,800	2,123
Interoperable database system	1985-91	15,000	1,055
Advanced material processing and machining system	1986-93	15,000	1,100

Source: OECD (1989).

[216] UNIDO, 1985, p. 21.

[217] OECD, 1989.

Table 10.8b Completed national research and development projects - large scale projects (million Yen)

Project name	Period (FY)	Total expenditure	Outline of project
Super high-performance electronic computer	1966-71	10,100	Large-scale computer system with super-high performance.
Desulphurization process	1966-71	2,700	i) Efficient removal of the SO_2 contained in the gases exhausted from power plants or other; ii) Direct removal of sulphur from heavy oil.
New method of producing olefin	1967-72	1,200	Economic production of olefins by direct cracking of crude oil instead of using naphtha.
Remotely controlled undersea oil drilling rig	1970-75	4,500	Remote-control oil drilling rigs for under-sea use.
Sea water desalination and by-product recovery	1969-77	7,000	Economical large-scale production of fresh water and economical by-product recovery technology.
Electric car	1971-77	5,700	Various types of electric car to replace ordinary vehicles in urban areas.
Comprehensive automobile control technology	1973-79	7,400	Integrated control technology with a view to relieving traffic congestion, reducing automobile pollution and traffic accidents, etc.
Pattern information processing system	1971-80	22,100	Computer technology for the recognition and processing of pattern information such as characters, pictures, objects and speech.
Direct steelmaking process using high-temperature reducing gas	1973-80	14,000	Direct steelmaking technology aims at a closed system which uses the heat energy from a multi-purpose, high-temperature, gas-cooled reactor in the steel making process.
Olefin production from heavy oil	1975-81	14,200	Technology for manufacturing high-value-added olefins (ethylene, propylene, etc.) using a high sulphur-content heavy oil fraction (asphalt), which is difficult to desulphurize, as the raw material.
Jet engines for aircraft	1971-75[a] 1976-81[b]	6,900 12,900	Research and development on large-scale turbofan engine designed for use in commercial transport in the 1980s.
Resources recovery technology	1973-75[a] 1976-82[b]	1,300 11,400	R&D on technical systems for the disposal of solid urban waste, centered on resource recycling for promoting the efficient utilization of resources and facilitating the smooth application of solid urban waste treatment.
Flexible manufacturing system complex provided with laser	1977-84	13,500	R&D on new, automatic, integrated production systems that are flexible and provide quick through-put in the manufacture of small batches of machine components.
Subsea oil production system	1978-84	15,000	R&D on an efficient system for subsea oil production which would be applicable to the continental shelf and slope surrounding Japan to deep sea oil fields.
Optical measurement and control system	1979-85	15,700	R&D on an optical measurement and control system permitting massive volumes of data, including picture images, to be measured and controlled in adverse environments.
C_1 chemical technology	1980-86	10,500	R&D on processes for producing basic chemicals such as ethanol, ethylene glycol, olefins from C_1 compounds such as CO from natural gas, coal, etc.

[a] Phase 1. [b] Phase 2.

Source: OECD (1989).

On the specific integrating technologies noted for France and Germany, Japan spent ¥63.5 billion (about $425 million) from 1974 to 1990. The largest part of this support -- by far -- was that allocated to the promotion and use of robotics. The Japan Robot Leasing Company, for example, receives an annual subsidy of Y 24.7 billion to provide loans, in particular for SME in order to encourage diffusion of robotics.

Table 10.8c Japanese Cooperative R&D Projects in Software Technology

Period	Project/Organization (total yen funding)*	Objectives and Outcomes
1966-1972	Japan Software Company (2 billion)	Common development language and basic software for different architectures. Complete failure.
1970-1982	IPA Package Effort (10 billion)	70 packages developed. Very limited usage.
1971-1980	PIPS Project (22 billion)	Pattern-information (graphics) software, mainly for Japanese language processing. Several products commercialized. Links with Fifth Generation project.
1973-1976	Software Module Project (3 billion)	Applications development. Little coordination. Complete failure.
1976-1981	Software Production Technology Project (7.5 billion)	Automated and integrated factory tool set and modularization techniques for batch environment. 20 discrete tools finally developed by individual firms.
1981-1986	Software Maintenance Engineering Facility (SMEF) Project (5 billion)	Interactive, UNIX-based tool set for maintenance and development. Improved experience level of Japanese firms with UNIX.
1984-	TRON Project (company funds)	Development of a standardized architecture and operating system for multiple levels and types of computers. Some products announced. Promising idea despite competition from other standards.
1985-1989	Inoperable Database System Project (1.5 billion)	Network to link work stations using OSI protocols. Improvement of interface standards likely.
1985-1989	FASET Project (2.2 billion)	Development of CASE tools for automated code generation from formalized specifications. Promising goals but limited participation.
1985-1990	Sigma Project (25 billion)	Development of UNIX-based support tools as well as reusable code and packages, for a national network. Major dissemination of existing practical technology.
1982-1991	Fifth Generation Computer Project (50 billion)	Development of knowledge (logical-inference) processing and parallel computing hardware and software. Major long-term advances possible in Japanese AI capabilities. Short-term potential for software automation and reuse support. Limited commercial applications, however, and lukewarm support from major companies.

*In 1989 currency, approximately $7 million = 1 billion yen. AI = artificial intelligence; CASE = computer-aided software engineering tools; FASET = Formal Approach to Software Environment Technology; IPA = Information Processing Promotion Agency; OSI = Open Systems Interconnection; PIPS = Pattern Information Processing System; TRON - The Real-time Operation System Nucleus.

Source: Michael A. Cusumano, *Japan's Software Factories: A Challenge to U.S. Management*, Oxford University Press, 1991.

Japan's attempts to encourage the diffusion of automation techniques are summarized in the 1989 OECD report:

"In the small- and medium-sized firm sectors, policies are part of a long-term general effort to improve their performance through guidance and advisory services, training, and a series of investment and R&D-related incentives. Support for the development of technologies with commercial potential has mainly benefited larger firms through the extensive series of cooperative R&D projects. These increase the technological level of participating firms and increase the stock of technology that is potentially available for wide applications.

Incentives have been aimed at improving the structure of investment in SMEs, to encourage greater investment in more advanced equipment. Investment in advanced manufacturing equipment (NC machine tools, robots, CAD/CAM equipment) by SMEs is already reasonably high -- Secretariat estimates suggest that it was around 5.5 per cent of their investment in machinery and equipment in FY 1984, compared with the average for all firms of around 6 per cent -- but over two-thirds of this is concentrated in machine tools. Government policy has aimed at increasing investment in more advanced equipment and computer-based systems.

A number of general factors are of key importance in assisting the diffusion of advanced manufacturing technologies. These include:

- Inter-firm links between large firms and their sub-contractors, and between equipment suppliers and purchasers. Large firms demand high levels of quality control, rapid delivery, and some product development from their sub-contractors.

- Firm-based training is widespread and training is a continuing process. Technical graduates tend to learn new skills on the job and supplement them with short specialized external training courses;

- The general educational level is high, providing a highly adept and literate work force who can cope with new technologies;

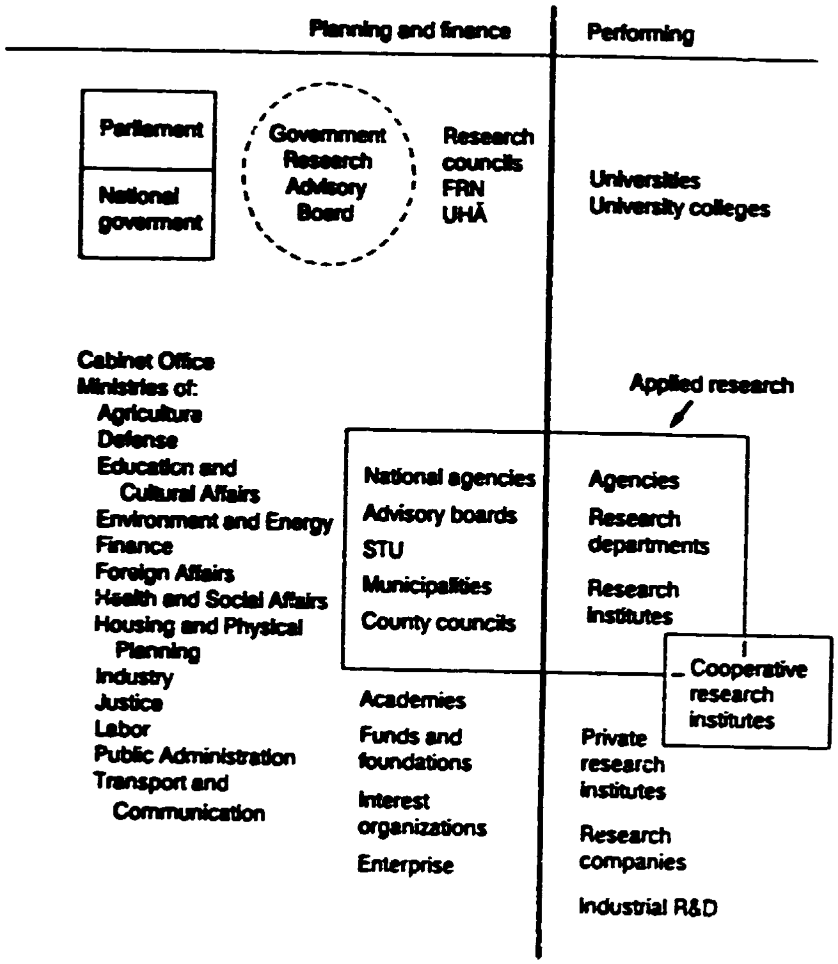
- The investment propensity in advanced manufacturing technologies is very strong. Investment is primarily aimed at ensuring quality and reliability and saving skilled manpower resources. Firms have long-term planning horizons and see training, development and investment as essential factors underpinning competitiveness".

(E) Sweden

Government support for the diffusion of new technology in Sweden was not centralized, but tended to be administered by individual ministries, with the Ministry of Industry the main funder.

In 1985 public sector funding of R&D amounted to some SK9,807 million with by far the largest part of this, SK6.232 million (64 per cent), going directly to the higher education sector (see Figure 10.2). Public funding (SK9.807 million) was approximately 38 per cent of total spending on R&D in 1985, which was down by about 2 per cent (from 40 per cent) on the preceding year.

Figure 10.1 The Swedish R&D system



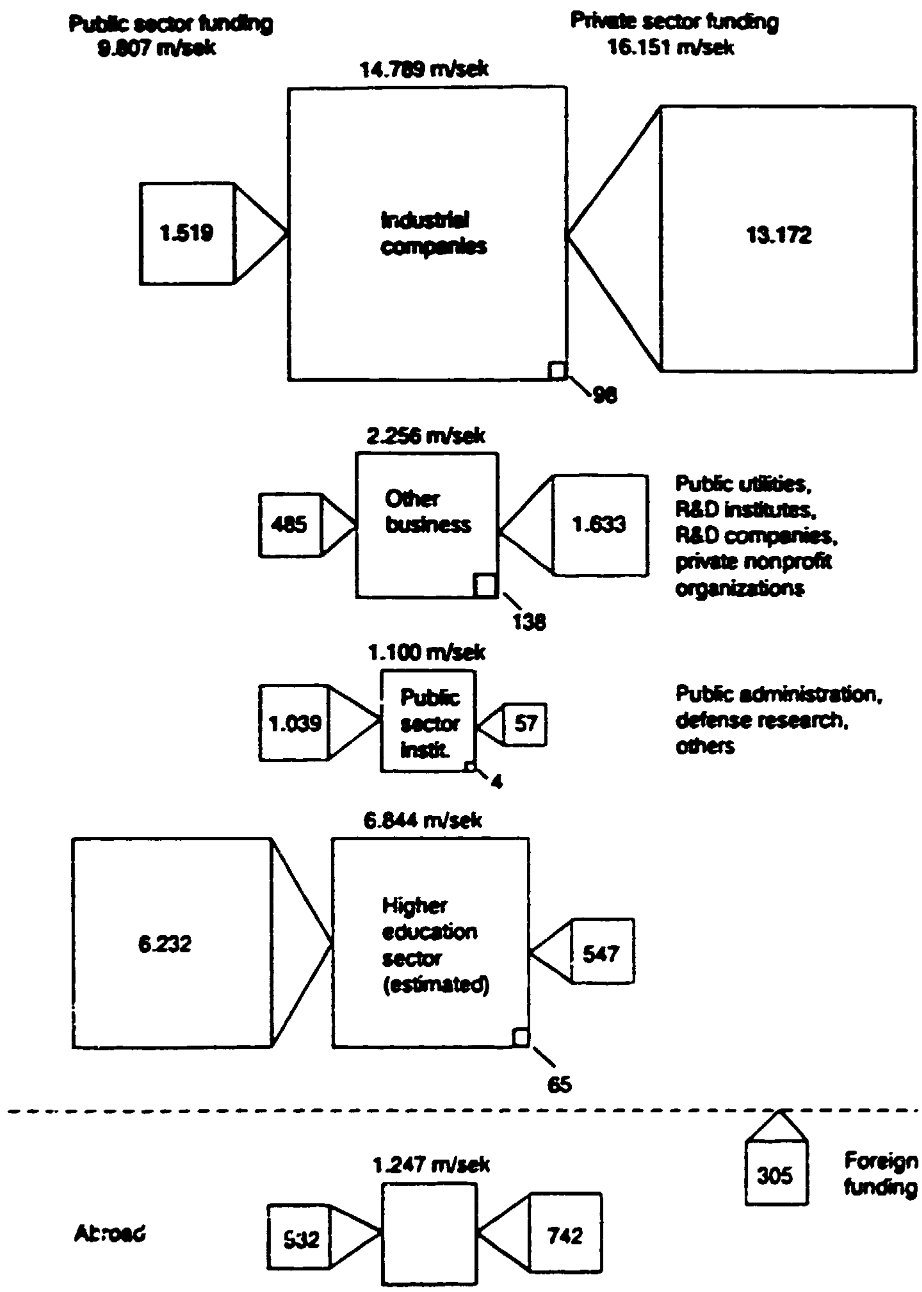
Source: Dyring (1985).

The State is considered to have the primary responsibility for funding basic research – and more importantly perhaps, the training of the research workers.

"Total central government allocations for R&D in fiscal year 1987-88 amounted to SEK 12,300 million. Of these, approximately SEK 5,500 million were assigned to general scientific development, primarily university and research council funds.
The Research Bill of 1987 provided for reforms adding up to SEK 1,200 million over three years, over and above compensation for inflation. This means a permanent rise of SEK 500 million in the level of research allocations. These resources are channeled primarily into

higher education, with the emphasis on recruiting new generations of researchers, and to work in certain priority areas of research".[218]

***Figure 10.2** Total R&D in Sweden, 1985 (social sciences and humanities investigated only in higher education), in SEK million*



Source: Fact Sheets on Sweden (March 1989).

[218] Fact Sheets on Sweden, March 1989.

The growth rate of R&D in Sweden under such a stimulus has been high in comparison with most other OECD countries -- about 11 per cent per annum during the 1980s. R&D costs in relation to value added in the business community have 2.5 per cent compared with 2.2 per cent in the U.S., 2.3 per cent in Germany and 1.8 per cent in Japan.

> "In both 1977/78 and 1986/87 approximately 43 per cent of state funding for research and development went to the 'promotion of general scientific development', i.e. government appropriations for research at universities and colleges (including government payments to the health authorities under the agreement on medical training). Defence accounted for the second largest share of state R&D allocations, with around 25 per cent in both 1977/78 and 1986/87. Defence R&D is thus on a large scale, and to a substantial extent it is performed outside the higher education sector".[219]

R&D for defence has been high and even increased in importance in 1987/8, as Table 10.9 shows.

Table 10.9 ***R&D funds in the central government budget, fiscal year 1987-88, according to purposes***

Purpose	SEK Million	Percent
General scientific development	5530	45.0
Defense	3308	26.9
Energy and water supplies	643	5.2
Transport and telecommunications	502	4.1
Industrial activities	450	3.7
Working environment, occupational health and safety	322	2.6
Space activities	315	2.6
Agriculture, forestry, hunting, fisheries	287	2.3
Physical administration, public services	267	2.2
Public administration, public services	220	1.8
Health and medical care	117	0.9
Housing environment, land-use planning	115	0.9
Education	84	0.7
Social welfare, social environment, social security	51	0.4
Culture, media, leisure	48	0.4
Research on the earth and atmosphere	30	0.2
All purposes	12,288	100.0

Source: Fact Sheets on Sweden (March 1989).

One of the main instruments in encouraging technical advances is the National Board for Technical Development (STU). This plays a strategic role in industrial development providing:

- long-range broad based research support;
- the allocation of venture capital;

[219] Government Research Bill 1989/90:90.)

- the provision of advisory services;
- an information source;
- help in technology procurement.

STU grants in 1983/4 by type of recipient is listed in Table 10.10.

Table 10.10 STU grants 1983/84, by recipient

Recipient	Percentage of total amount	MSEK	No. grants
Universities and university colleges	30	202	960
Cooperative research institutes	21	142	239
Companies with <5 employees and individual investors	11	74	817
Companies with >5 employees	16	108	331
National government agencies	9	61	258
Development comp >5 employees	7	47	209
Sectoral organisations	6	40	174
Total	100	674	2,988

Source: Dyring (1985).

The Cooperative Research Institutes (see Figure 10.1) figure prominently in STU work and particularly in relation to CAD/CAM, FMS and Robotics. These institutes provide research, consultancy and advisory services.

In developed countries in general the OECD (1989) has noted:

> "Government technology procurement is not aimed solely at the purchase and application of advanced microelectronics in industry. However the importance of electronic applications in defence and public procurement and the role of the state as a demanding purchaser of high performance equipment has influenced the development of electronic-based products and underwritten investment in advanced manufacturing equipment to enable supplying firms to meet exacting technical performance requirements".

The extent of support for integrative technologies and the importance of STU in administering these policies is evident from the generous government subsidies for robitics, CAD/CAM and flexible automation. For example, in the four year period from 1984 to 1987, the Swedish Board for Technical Development (STU) spent SK 317 million on programmes in manufacturing techniques and CAD/CAM.

> "The main programmes in the fields of robotics and CAD/CAM/CIM are coordinated by the STU. Universities conduct much basic applied research in close cooperation with industry. Dissemination of advanced FMS equipment among medium-sized and small companies is strongly encouraged both on the part of the Ministry of Industry and through STU-priorities".[220]

Evidence of government commitment is also clear from its Information Technology Programme (ITP), to which a total of SK 1,110 million was given over between 1987 and 1990, with the emphasis on micro-electronics, systems engineering, and the application and diffusion of information technology. Prior to the ITP, the government funded a National Micro-Electronics Programme from 1978 to 1987, with total funding of SK 560 million. This included extra investment in education, fundamental research, applied research and 50 per cent subsidies on purchases by industry of new industrial development technology.[221]

Government policy, not just in micro-electronics or I.T., is an attempt to cover a wide spectrum of support starting from the development of skills, through research subsidies, and government purchasing (the defence industry). Also of importance have been consultancy for small- and medium-sized enterprises, and support for intangible assets, such as marketing, work organization; and the development of human capital.

(F) The United Kingdom

In common with most other developed economies, the UK has had a major series of support programmes for industry since the late 1970s. These have ranged from support for the newly emerging integrated circuit manufacturing company INMOS; through to individual support projects, such as, the Flexible Manufacturing Systems (FMS) scheme; to large overall programmes, like Alvey which was aimed at advanced technologies such as 5th generation computers and a direct response to similar efforts undertaken by Japan. With funding of £ 200 million, the Alvey programme has been very ambitious. However, since the UK has a very large armaments industry a great deal of the funds for the latter programme was diverted into military technology. As the Alvey programme is rather upstream of the market, promoters are in a good position to explain that concrete effects will not be felt immediately on the market or in British industry.

First efforts to assist the British industry outside the military field date back to 1956, when the Post Office aided the electronics industry by forming the Joint Electronic Research Committee to coordinate the efforts made by British industry. In informatics, the public authorities favoured the creation of ICL and then consistently supported it until its merger with STC in 1984.[222]

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[220] Roobeek, 1990.

[221] Roobeek, 1990.

[222] UNIDO, 1988b, p. 187.

The Ministry of Industry, and bodies such as ACARD (Advisory Council on Applied Research and Development) and the Technology Group have been important instruments of public industrial policy. Later, the Alvey Committe became the main body responsible for encouraging coordinating and supporting fundamental research (directed towards 5th Generation computing) and providing the main strategic guidelines for long-term development.[225]

The Microelectronics Application Project (MAP), mentioned earlier in the chapter, was launched in mid-1978 as an attempt to promote microelectronics in both products and processes. The target companies were the smaller ones with less than 200 employees. It operated by encouraging companies to look at microelectronic applications by paying $4,000 towards the cost of hiring a consultant, and by a grant of 25 per cent of development costs of any products involving microelectronic applications.[226]

Of the £63 million spent on the project from 1978 to 1985, 62 per cent was devoted to project development goals, with the remainder fairly evenly split between consultancy (MAPCON) 14 per cent; training 8 per cent; and raising company awareness, 11 per cent.

MAP activities fall into four basic categories. These are:

- Increasing industrial awareness of the implications and benefits of microelectronics;
- Providing assistance for the development of training courses in microelectronics techniques;
- Supporting micro-electronics consultancy. Costs of independent expert advice on the feasibility of applying micro-electronics are subsidized; and
- Providing project development support to firms for applications of microelectronics technology.

An initial budget in 1978 of £55 million to be spent over six years was increased to £85 million in 1982 (US$149 million at £0.57/$). Through to 1985 expenditures were:

Table 10.11 MAP expenditures, 1978-1985

Activity	Current annual expenditure (million £)	Total expenditure (million £)
Awareness	0.7	7
Training	1.3	8
Consultancy support (MAPCON)	1.7	9
Project development support	11.0	39
Total	14.7	63

Source: OECD, 1989.

The programme included:

Awareness: These activities are designed to alert industry to the possibilities of microprocessors – both in products and in processes. MAP provided funds to organizations for the purpose of

[225] UNIDO, 1985, p. 35.

[226] UNIDO, 1985, p. 34.

running seminars, workshops and conferences increasing awareness of micro-electronics. MAP also provides an information service.

Training: This project paid up to 50 per cent of the costs for developing courses conducted by education and training institutions (universities, polytechnics, colleges of higher and further education and commercial training bodies) in micro-electronics techniques. This included the purchase of hardware/software used in the training, staff training, etc.

Consultancy: This project paid up to £2,500 of the cost of employing outside experts to carry out the feasibility studies on the use of micro-electronics. Support of up to 50 per cent (maximum £1,500) could also be given for follow-up studies.

By the mid-1980s, over 7,000 applications had been received and over 4,000 firms benefited from the MAPCON programme. The cost of this was some £10.1 million.

Investment support: MAP was targeted at small- to medium-sized firms, although larger firms could also receive support. Grants were awarded for investments embodying micro-electronics of up to 25 per cent of costs, normally between £10,000 and £125,000.

By mid-May 1985, support for investment had reached the following:

Table 10.12 Project development support

Applications received	2,743
Offers of support	1,431 (52 per cent of applications)
Projects completed	769
Government funds committed	£53 million
Maximum grant size	£125,000
Median size of grants	£40,000 - £50,000

Source: OECD (1989).

The MAP scheme was probably one of the best known in the UK and was widely used. As with the other countries covered in this chapter there were a number of important successes derived from the scheme. The main features of the scheme were:

- its general diffusion to small/medium-sized firms for consultancy purposes;
- little government choice in which technologies to support;
- it was a very wide-ranging programme dealing with both products and processes, but dealt with through one central agency;
- of a long-run nature 1978-85 (seven years);
- as with the German equivalent (S P) it was continuously and continually assessed and evaluated.

In a study of the MAP scheme conducted by the Policy Studies Institute and the Centre for Business Research it was found that many boards of directors, in deciding whether to invest the necessary additional finances in microelectronic based technologies, did so because of the fact that the Government being prepared to support the project gave it some form of official 'seal of approval'.[225]

Another success story in government support policy was the Flexible Manufacturing Systems (FMSS) scheme. Launched in 1982 and running until 1986, it provided £35M of support which was then topped up by a further £20M in 1984. In an assessment of the scheme carried out by the Centre for Business Research in 1990, a number of additionality criteria were adopted.

> "To the extent possible, the analysis takes account of additionality and internal displacement effects in calculating the net gains to the firms in the sample. Here we provide a breakdown of additionality (as indicated by the firms) within the 31 firms in our Scheme-user sample under the following categories):
>
> 1 -- wholly additional;
> 2 -- accelerated;
> 3 -- increased scale;
> 4 -- upgraded;
> 5 -- non-additional.
>
> As illustrated in Figure 10.3, it was the 'accelerated' category which included the majority of cases (52 per cent). Of these, 75 per cent were able to specify the degree of acceleration, which ranged from 3-6 months to as much as 5 years. Three-quarters of these firms, however, claimed that the projects were brought forward by between one and three years.
>
> The second most frequently mentioned category was those projects that were 'up-graded' or more innovative as a result of the scheme. Within our sample, 32 per cent declared that without the grant they would have introduced some form of stand-alone equipment. Although some of these firms will also be included within the increased scale of investment category (23 per cent), all of these firms fulfilled the requirement of integrating previously distinct manufacturing activities and would not have done so without the encouragement of the Scheme.
>
> Sixteen per cent of the sample indicated that the investment was wholly additional, and only one firm (3 per cent) admitted that the project was non-additional in any way. Although 'additionality' is a necessary criterion for selection under any DTI scheme, the percentage actually fulfilling this requirement appears to be somewhat higher for the FMS-Scheme than some evaluations have found. In this evaluation the fact that the majority of the firms were quite specific in their acceleration or the up-grading from stand-alone to integrated equipment, leads us to conclude the declarations of additionality made by the firms might only be slightly exaggerated."
>
> "In terms of fulfilling the DTI's requirements that the projects must, in some way, be additional to what the firm would have done without the grant, the selection of projects for support certainly appears to meet this requirement.
>
> When examined by the total size of projects, it was the smallest projects (under £200,000) for which acceleration was again the most frequently mentioned category -- at 67 per cent. A similar percentage for the category of acceleration was also found for the smallest-sized grants (up to £100,000). While it might be expected that grant size would correlate with total project size, this is not necessarily the case, given the chance from 33 per cent to

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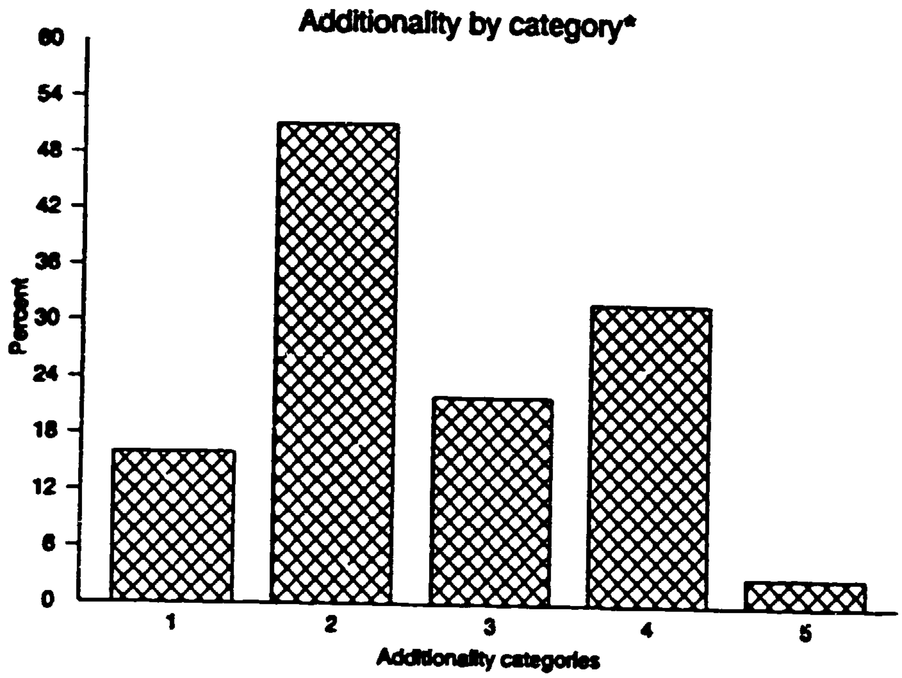
[225] Northcott et al., 1985.

20 per cent maximum grants between FMS 1 and 2, and the fact that grants ranged from as low as under £100,000to over £1 million".[226]

Figure 10.3 Additio ality criteria



* Several firms appear in more than one category - usually increased scale and upgraded - resulting in total percentages for the five categories which add up to more than 100%.

Source: Rush, Hoffmann & Bessant (1990).

The researchers also described a number of other successful outcomes of government policy arising from this scheme:

- it markedly affected the diffusion of the technology;
- learning by doing rose in almost all the firms in the sample (31);
- the demonstration effect to other companies was high - support for systems was conditional on open access to other interested companies;
- it stimulated the adoption and manufacture of FMS equipment in the UK supply industry – around 30 per cent of the installed equipment was from UK suppliers; and 4 of the 6 supplier firms interviewed had around 25 per cent of their sales from FMS related products.

Total UK government support for the integrated technologies alone has been quite extensive, and between 1978 and 1989 amounted to some £418M ($211M at $1.70/£).

[226] Rush, Hoffman and Bessant, 1990.

"The United Kingdom cannot rely on a strong machine building industry. In contrast to its American and West German counterparts, the British machine building industry is heavily concentrated, with six enterprises accounting for over 50 per cent of national output. With the exception of the defense sector, Britain's base for manufacturing robots is brittle. It does, however, enjoy considerable potential in the fields of software, sensors and artificial intelligence. Close collaboration in these fields between universities and industry has been actively stimulated. In the 1970s, British governments mainly tried to stimulate innovation through general measures. The DTI channels R&D funds into various schemes such as CAD/CAM, CAD/MAT, CAD/TES, FMS as well as into Industrial Robotics schemes. These programmes, all strongly orientated towards dissemination, were recently grouped under the "Support for Innovation" (SPI) umbrella. The British government often supplies only a relatively minor proportion (20 to 30 per cent) of the total costs of investments in capital goods and R&D".[227]

(G) The United States

In the United States a somehow different approach is taken to micro-electronics (as to industrial policy in general):

Federal Government involvement is somehow restricted to the field of military and aerospace. However, these two fields were strong enough to give the US electronics industry the necessary support to develop in the first place.[228] The pressing military demand for firing tables or aircraft profiles was one of the origins of the progress from electromechanical calculators to electronic computers. The various US forces signed major contracts with several universities, giving an impulse to a movement which resulted in the development of ENIAC, the Electronic Numerical Integrator and Computer in 1946. The Department of Defense ordered from IBM and Burroughs in 1951 the Semi-Automatic Ground Environment or SAGE system, intended to protect the US from surprise aerial attack. This was at the time an enormous programme of US$ 1.6 billion for seven years which brought a number of scientific breakthroughs. In 1965 the Federal Government paid out US$ 200 million in contracts on informatics research, representing a third of all the research expenditure of the manufacturing sector.[229]

However, "the United States does not have specific Federal programmes aimed at diffusing and applying microelectronics widely in industry. It does, however, have a range of general policies which are aimed at improving industrial performance, increasing the conduct of research and development, and promoting the transfer of Federally developed R&D to industry. Most of these policies take a simple and non-interventionist form, to enable wide coverage and participation and to reach the very large number of industrial and research participants in a large and diverse country. Direct programmes to promote advanced technologies have been left largely to individual states where a multitude of high-technology programmes have been introduced".[230]

In many instances US policy is focused upon: tax credits; the National Aeronautic and Space Agency (NASA) -- which provides considerable spin-off benefits to the commercial

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[227] Roobeek 1990.

[228] UNIDO, 1985, p. 14.

[229] UNIDO, 1988b, p. 174.

[230] OECD, 1989.

aircraft industry as well as the electronics industry; the addition of overhead charges (3.5 to 4 per cent) to contracts to cover R&D; support for national organisations supporting the development and diffusion of new technologies, e.g., the National Centre for Manufacturing Services (NCMS), the National Technical Information Service (NTIS) or the Office of Productivity, Technology and Innovation (OPTI), etc.

One of the main tax incentives has been the Research and Experimentation Tax Credit scheme to help companies develop new technologies. The major users of the scheme have been Metals and Machinery, Chemicals and Rubber, and Transportation, Communications and Utilities. The Metals and Machinery sector claimed more tax credits than both of the next largest users together ($298 million to a collective $265 million).

A second tax scheme was the R&D Limited Partnership, to encourage the development of new technologies. In 1983 these represented about 2.25 per cent of the $44 billion spent on R&D by private companies.

The NASA spends about $500 million per annum on R&D of a commercially usable nature. While OPTI is the main channel for efforts to diffuse such technologies as FMS, in part it does this by a leasing or time-share basis.[231]

To separate out the data is difficult, particularly because of the importance of the US Department of Defense and its impact on technology diffusion. The Department of Defense developed into a kind of American MITI which was not only responsible for military defense. When the progress of the Japanese electronics industry began to disturb the American authorities, the Department of Defense was given permission to reactivate its research activities by launching a number of new programmes from 1978 onwards. In 1980 it was the VHSIC (Very High Speed Integrated Circuit) plan for the period 1981-1987 with about US$ 1 billion of projects centred on integrated circuits and processors. This plan was subsequently integrated into the Strategic Defense Initiative (SDI) or 'Star Wars' programme for which US$ 25 billion were devoted for the 1984-1990 period. The Defense Advanced Research Projects Agency (DARPA) implemented at the same time another very ambitious programme, the Strategic Computer Programme, with US$ 1 billion for the period 1984-1990.[232]

Estimates made by Annemieke Roobeek[233] speak of a total support for the micro electronics area in a narrow sense of US$ 1.6 billion for the 1978 to 1989 period (see Table 10.22). She estimated that around US$ 4000 billion annually was spent on indirect support for computer technology and micro-electronics. Of this US$ 4 billion, the main components were US$ 542 million for R&D of 1.25 micron chips and pilot production lines, both as part of the first phase of the VHSIC and as non-VHSIC activities; US$ 340 million for the second phase of VHSIC for pilot production lines and the development of 0.5 micron chips; and US$ 500 million for the Department of Defense's 'n' generation computer project. Purchasing policy and tax conversions were also employed to encourage the production and use of technical and scientific equipment.

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231 OECD, 1989.

232 UNIDO, 1985b, pp. 174-176.

233 Roobeek, 1990.

NCMT, Robotics, CAD and FMS. The role of each of the armed forces is clear in the development and diffusion of these technologies. For example, the Air Forces ICAM programme costing $211 million between 1978 and 1985; the Navy's programme on advanced applications of artificial intelligence and robotics – $600 million (1984-88); and the D of D Mantech project costing $834 million (1980-84).

> "The United States occupies a leading position in software for CAD/CAM/CIM but its robot manufacturers are coming under increasing pressure from foreign competitors. Joint ventures, such as the collaboration of General Motors with the Japanese Fanuc, are being set up to meet this challenge. But the American machine building industry, an important supplier and user of robots and CAD/CAM equipment, is losing ground (US Department of Commerce, 1984). For years, the industry has faced sinking orders, hitting rock-bottom in November 1986 with the number of orders falling below 32 per cent."[234]

There are, however, some signs of cooperation among US producers and private sector organizations outside the influence of the US Department of Defence which was nevertheless given government support. The defence and space programmes contributed greatly to the early development of the semiconductor industry, but it has been noted by the President's Commission on Industrial Competitiveness that this no longer pushes civilian research and development sufficiently.[235] Two projects launched in 1981-1982, by reason of their size, are a reference point concerning the change in the American mentality in this respect. One project was launched by the major informatics manufacturer Control Data in January 1982, and the other during 1981 by IBM.[236]

The project launched by Control Data, the Micro-electronics and Computer Technology Corporation (MCC) is a private non-profitmaking association, the partners in this being companies which supply research workers for a joint laboratory. The patents belong to the association. For the first three years only the participating companies can use them. Then licenses are granted and the participants share the expenses with the association. It is thus a regrouping to share R&D costs which under the official anti-trust legislation could constitute a distortion of competition. The government has however made it clear that it would not impede such private sector initiatives.[237] The National Cooperative Research Act of 1984 officially gave legal status to this type of association to carry out joint research. About 40 such associations were registered in the 1980s.[238] At the same time, government indirectly favoured the development of the informatics industry in general by application of anti-trust legislation to constrain the entry of AT&T and IBM into the merchant market.[239]

The other project, launched by IBM, resulted in the creation in 1982 of the Semiconductor Research Corporation (SRC). This non-profitmaking association has as its

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[234] Barber, 1986.

[235] UNIDO, 1985, p. 14.

[236] UNIDO, 1988b, p. 177.

[237] Kommission der Europäischen Gemeinschaften, 1991, p. 19.

[238] UNIDO, 1988b, p. 177.

[239] UNIDO, 1985, p. 15.

objective the coordination of research on semiconductors to be carried out in cooperation with universities and private laboratories. Its objective was *inter alia* to build a pilot centre capable of producing the 16 Mbit memory and to design a 1 Gbit memory.

Apart from less stringent rules on competition in a number of selective cases to foster research while applying more stringent rules in other cases to give assistance indirectly to smaller producers in the field of electronics, the American "industrial policy" also concentrated on trade questions. US civil private sector research is indirectly given an incentive of potentially larger profits and shorter pay back periods by opening up global high-tech markets for US producers. The 'Omnibus Trade and Competitiveness Act' of 1988 gives American authorities the right to press third countries on opening their home markets to US products, thereby threatening third countries with the closing of the US market if they do not comply with US demands.[240]

10.4 A Developed Country Overview of Policy

The preceding section dealt at some length with policy issues pursued by seven OECD countries. These reflected a considerable number of similar approaches, but also some significant differences, for example, the very high emphasis placed in Sweden on the role of higher education, compared with a somewhat lesser emphasis in the UK.

This section gives a broader picture of trends across a variety of countries and, in so doing, highlights the importance of:

- education, training and skills;
- research/industry links;
- consultancy services;
- information promotion;
- technology availability and support;
- technology evaluation.

As observed from the individual countries covered in 10.3 (A) to (H) above, all of these factors have been important criteria in the development of efficient and effective government policies. Clearly merely to have a policy on the introduction of new technologies -- particularly those based on micro-electronics -- is not sufficient. Because of the radical nature of the integrative and "systemofacture" changes that have occurred during what has been called the "Second Industrial Revolution", all the evidence points towards a much more comprehensive package of initiatives to support industrial development. Moreover, despite the stronger infrastructure in most of the OECD countries, there have still been problems in many countries in adapting to the organizational and structural changes required.

Skills and training are particularly important, not only for scientific-technical and managerial personnel, but also shop floor personnel. Training needs include:

- Familiarization with technological advances;

- Technical aspects of product and process design, implementation, maintenance and operations;

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240 Kommission der Europäischen Gemeinschaften, 1991, p. 19.

- Organizing and managing production and other firm functions to take advantage of flexible manufacturing capabilities;

- Changes in work organization and task structures, and labour/management relations.[241]

Similarly, the importance of high quality consultancy services, feasibility studies, advice, and evaluation services has proven to be invaluable -- particularly to the small- and medium-sized companies which represent a considerable amount of output and employment, and which do not possess the in-house capability to conduct these themselves. This is not to suggest that consultants are the only path to success, since there have b many expensive failures by consultants who did not understand or appreciate the problems of their clients. However, it is clear from the example of the use of the Verein Deutscher Ingenieure (VDI) (the German Engineers Association) as the focus for the administration of that country's Special Programme, (including the provision of consultancy and development services) that this has been a major factor in its success.

These factors were also evident in the provision of consultancy services in the UK for the MAP programme -- the equivalent to the Special Programme:

In Sweden, the interface between state and industry has -- as noted earlier -- been focused to a considerable extent on research institutes and universities.

> "The growing cooperation between state and enterprise has many facets. Emulating foreign examples, Sweden has acquired a number of science parks and innovation centres adjoining higher education establishments. This brings education closer to the practitioners' everyday scene and research closer to applied questions.
>
> Many of Sweden's science parks are concerned with information technology, biotechnology and microbiology. But materials science and engineering are also being made a subject of this kind of cooperation.
>
> Various procedures have been developed for cooperation between universities and enterprise. Companies can commission research from higher education establishments. Industry can also finance associate professorships, i.e., pay for contributions to research education made by qualified persons from other sectors of the community. In return the higher education establishment can "lend" researchers to small and medium enterprises for limited periods".[242]

Another element was the widespread availability of a growing range of technology options, internationally sourced, i.e., the profusion of CAD suppliers in the late 1970s and 1980s. This allied to enhanced buyer/supplier relationships and the provision of expert maintenance of increasingly integrated technologies, e.g., FMS, which called for rapid software development, was another crucial element in government policy making.

However, given the importance of all of these factors, it is the general conditions within each individual country which set the framework for their development policies. The OECD

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[241] OECD, 1989.

[242] Dyring, 1985.

suggests that the actions of governments are constrained/guided by factors falling under seven headings. An annotated summary follows:

(1) *The Industrial Structure*. For example, the existence of national "champions" in certain key industries, such as electronics, machine tools, precision instruments, etc; linkages between these prime manufacturers and the main users; and strong and consistent buyer/supplier links.

(2) *The Market Orientation of Firms*. In particular, their competitive environment and their entrepreneurial drive towards the use of microelectronics in both products and processes.

(3) *Labour acceptance / Labour markets*. Here, the whole field of industrial relations and the development of company and country policies on conflict or consensus politics emerges, e.g., the Swedish or German consultation approach, or the US, French, or UK conflict driven ones. The consensus models may provide a much stronger base from which to utilize new technologies. Within this category it is also obvious that the availability of highly skilled and motivated workers is an imperative for success. The existence of a high-wage culture geared towards producing for either a strong home market or in rich markets internationally with quality goods is not a barrier to success.

(4) *The Technological Infrastructure*. Here the existence of an industrial sector well linked to educational, research, and consultancy services, as in Japan, Germany, or Sweden, is an advantage not currently enjoyed by many developing countries.

(5) *Financial and Fiscal Incentives*. All of the industrial countries covered in the first half of this report enjoy the luxury of well developed financial sectors, the existence of venture capital (some more than others), the ability to secure funds from international bodies (International Monetary Fund, World Bank, etc.) Most, if not all, offer fiscal incentives to encourage the adoption of new ideas and technologies, e.g., the U.S.

(6) *Government High Technology Programmes*. It is clear, particularly from the evidence compiled by Roobeek (1990), that all the OECD countries have developed programmes of support to encourage the adoption of high technology and R&D activities. Even the defense and aerospace activities of the US, Sweden and the UK have provided important spillover effects into the commercial field.

(7) *The Macroeconomic Setting*. The size and structure of the individual economy, its demand, growth potential, profitability, and general health will, to a considerable extent, influence the policies adopted and the rate of diffusion of technology.

As the OECD's report notes:

> "The interaction and importance of these general factors will determine the strategy which governments adopt when they orient industry policies towards diffusion. These interactions also determine the effectiveness of diffusion policies".[243]

[243] OECD, 1989.

Table 10.13 Typology of industrial policy characteristics of seven OECD countries

Policy aspects	USA	Japan	FR Germany	France	UK	Sweden	Netherlands
Relative importance of post-war policy choices	big; TNCs formed the base for expansion abroad	big; MITI acted as visionary force	big; consensus on renewed industry as base for expansion	big; establishment of national industrial base	small; continuation of pre-war aspirations	big; expansion of state intervention in industry and social welfare	big; large scale industrialisation was pushed strongly
Policy response to post-war internationalisation	export expansion direction Western Europe	export with closed national boundaries	free trade in favour of the large enterprises	state intervention and limited expansion	free trade, but also oncoming protection	free trade and strong domestic competition	free trade in favour of TNCs
Implication of post-war internationalisation on national industry	strengthening of TNCs and weakening of domestic industries	challenge of technical-advanced industry	strengthening of large companies and upgrading smaller companies	building up of advanced industrial industries for protected markets	further weakening of industry and low growth	expansion of export and strong domestic demand	expansion of shipbuilding, agriculture and chemical industry
Wider context of decision making	hegemonial policy formulated by politicized administrators	MITI-apparatus still acted as 'Ministry of War'; war economy	corporatism based on national cohesion	'L'etat developpeur'; elitist, central state	strong institutions, but weak in directing industry	small, central government with many intermediary links	strong expansion of government competence in various fields
Influence of social and political context of industrial policy	strong management culture and varying influence of trade unions	vision development by top management; top-down consensus building	cooperation social partners; room for open discussions	limited influence of social organizations outside elites	stress on protection of existing employment	open discussion context; combination technology and humanization	limited influence of trade unions; dominance of commercial spirit
Learning curves and patterns of industrial policy	from free trade to protectionism and bi-lateral trade agreements	from free trade to forced opening of the domestic market	free trade in combination with open domestic market	openness of domestic market is politically negotiable	from free trade to protection, to open, deregulated market	international openness	international openness
Characterization of post-war industrial policy	uncoordinated, covert industrial policy	very coherent industrial policy	coherent social and industrial policy	political dirigism	politically caprious industrial policy	constructive socio-industrial policy	stable, moderate interventionist policy

Source: Roobeek (1990).

So, what have been the post-1945 industrial policy characteristics of several of these countries?

The matrix shown in Table 10.13 indicates that virtually no two countries have adopted the same approaches, the same policies, or exist in the same social, economic and political framework. Consequently, a variety of options are open to potential followers. Clearly the concept of "contingency theory"[244] is as relevant to countries as it is to organizations.

The policy instruments that have been employed by these countries have varied though, in general, the awarding of grants or loans has been the favoured medium, as shown in Table 10.14.

Table 10.14 Government policy instruments used to support industrial R&D: 1985-86

	Policy instruments (approximate share of 1985-86 expenditures in brackets)
United States	tax concessions (65%), grants (35%) (procurement)
Canada	grants (100%) (tax concessions not included)
Japan[a]	'Consignment' subsidies (40%), tax concessions (35%), grants (25%), equity capital (from 1985) (2.5%)
EC	grants (100%)
Belgium	n.a.
Denmark	grants (some repayable) (80%), loans (20%)
France	grants (50%), repayable grants (25%), tax concessions (from 1984) (25%)
Germany	grants (90%), tax concessions (10%)
Greece	grants (infrastructure development) (100%)
Ireland	grants (100%)
Italy	loans (90%), grants (10%); programs cover mixed grants + loans + equity capital + contracts
Netherlands	grants (50%), loans (40%), mixed grants+loans (10%)
Portugal	soft loans (100%)
Spain	grants (100%)
United Kingdom	grants (65%), mixed grants+loans (35%)
Austria	grants+loans (50%), tax concessions (from 1986) (50%)
Finland	grants (37.5%), loans (40%), tax concessions (from 1985) (22.5%)
Norway	grants (100%)
Sweden[b]	grants (70%), loans (30%), guarantees (1%), tax concessions ceased 1983/84
Switzerland	grants (100%)
Turkey	n.a.
Australia	tax concessions (from 1985/86) (70%), grants (30%)

n.a. = non available.

[a] 'Consignment' subsidies involve research commissioned by central government from private industry associations, groups of private firms and government laboratories in national cooperative research projects such as the Large-Scale Projects, or the 5th Generation Computer Project.

[b] Excluding technical R&D support appropriations which go to private industry as well as to universities and to government-backed institutions via the National Board of Technical Development, STU.

Source: OECD (1990).

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[244] Child, 1977.

Looking at support for R&D activities -- the building blocks of technological advancement -- the allocations by business enterprise, non-profit making institutions, higher education and government vary significantly from country to country. Icelandic enterprises provide only 15.4 per cent of R&D, compared with around 75 per cent in Switzerland; and government sponsored R&D varies from a low of 4.4 per cent in Sweden to a high of 60 per cent in New Zealand. R&D in the higher education field ranged from 11.5 per cent in Turkey through 13 per cent to 14 per cent in the United States, Germany, the United Kingdom and Switzerland, to almost 35 per cent in Austria (Table 10.15).

Table 10.15 R&D in the OECD countries by the sectors in which it is carried out

Country	Sector in which R&D is (% share) carried out			
	Business enterprise	Private non-profit institutions	Government	Higher education
United States	71.1	3.0	12.3	13.6
Japan	66.8	4.0	9.1	20.1
FR of Germany	73.1	0.5	12.9	13.5
France	58.7	1.0	25.3	15.0
United Kingdom	63.4	3.4	20.1	13.1
Italy	53.9	0.0	23.9	19.2
Canada	53.2	1.1	23.3	22.4
Netherlands	56.2	2.3	18.3	23.2
Sweden	68.0	0.2	4.4	27.4
Switzerland	75.0	5.0	6.0	14.0
Australia	32.0	3.0	37.0	28.0
Belgium	71.5	4.3	5.4	18.8
Spain	58.0	0.0	25.3	16.7
Turkey	74.2	0.0	14.3	11.5
Austria	54.8	1.9	8.4	34.9
Norway	62.7	0.7	14.4	22.2
Yugoslavia	54.2	0.0	26.0	19.8
Finland	60.9	0.6	19.5	19.0
Denmark	55.3	0.8	19.5	24.4
New Zealand	25.0	0.0	60.0	15.0
Portugal	28.0	5.0	39.0	28.0
Ireland	51.7	1.2	27.7	19.4
Greece	25.0	0.0	53.0	22.0
Iceland	15.4	6.3	48.3	30.0
OECD	68.0	3.0	14.0	15.0

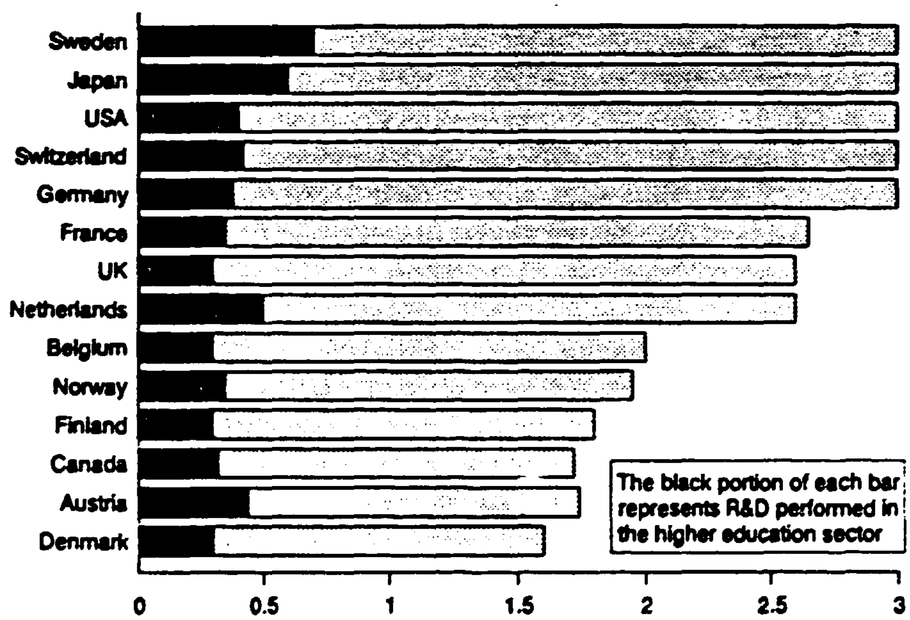
Source: Swedish Government Bill (1989/90:90).

As the Swedish Government Bill reports:

"In the first half of the 1980s, R&D expenditure in most OECD countries rose faster than the overall rate of economic growth, measured in GDP terms. Average GDP in the OECD area as a whole increased by 2.6 per cent, while R&D expenditure grew by an average of 6 per cent. The share of GDP accounted for by R&D thus increased, in some cases very strongly. Of the larger countries, only the UK and Canada had slow growth in research spending.

It is common to regard R&D funding as an *investment* and to compare this investment in knowledge with investments in real capital, i.e., buildings and equipment. In 1985, for the OECD area as a whole, R&D expenditure corresponded to about 11 per cent of real capital investment. The proportion has increased in most countries. Four countries, the FRG, Sweden, the US and the UK, had particularly high ratios of 14-16 per cent. However, this was partly due to weak expansion of investment in real capital, especially in the United States and Britain. Japan has invested heavily in both knowledge and real capital, which could be taken to mean that Japan is better placed than other countries to translate R&D results into innovations and to take advantage of technical advances".

Figure 10.4 R&D expenditure in certain OECD countries as a percentage of GDP



Source: Swedish Government Bill (1989/90:90).

Perhaps of greater interest is the allocation of support provided by government according to industrial sector. From Table 10.28 it is clear that expenditure on Aerospace is a major focus in at least three countries, the US, France, and the UK, with 76.2 per cent, 59.6 per cent and 62.7 per cent respectively being government funded.

However, such support is now starting to transcend national borders, and particularly in certain key areas, the EC has responded to increased pressures from US defense-funded projects and the Japanese government's long-term strategies guided by MITI by developing extensive technology programmes, as Table 10.17 indicates.

Table 10.16 Industries which have well above the manufacturing average share of their R&D financed by government (most recent year available)

	Manufacturing average (%)	Manufacturing industries (percent) Important non-manufacturing in brackets []
United States 1985[a]	33.2	aerospace (76.2%), electrical group (40.3%) [services]
Canada 1985[b]	9.0	aerospace (29.7%), instruments (16.7%) [engineering services]
Japan 1987	1.6	ships (36.6%), petroleum refineries (5.2%), other transport (4.8%) [mining, utilities]
Belgium 1987	4.0	ships (32.7%), aerospace (27.9%), metal products (15.4%) [agriculture, engineering services]
Denmark 1987[a]	6.1	transport (85.2%), paper & printing (20%) [other services, communications, engineering]
France 1987	23.6	aerospace (59.6%), electronics & components (36.7%)
Germany 1985[b]	12.6	other transport (44.4%), ships (39.5%), ferrous metals (28.3%) [engineering, other services, utilities]
Ireland 1986	13.8	non-ferrous metals (50.9%), ships (49.3%), motor vehicles (44.5%), wood & furniture (34.8%), ferrous (32.1%), transport (28.6%) [agriculture, construction]
Italy 1988	17.1	ships (42.2%), transport (41.4%), ferrous metals (39.3%), aerospace (33.7%) [agriculture, construction, other services]
Portugal 1986	2.5	fabricated metal products (12%), machinery (11.2%), chemicals (5.5%) [mining]
Spain 1986	10.2	aerospace (49.2%) [engineering, other services]
UK 1985[a]	24.2	aerospace (62.7%), machinery (34.2%), electrical, electronics & components (29.6%)
Austria 1985	3.9	transport (12.1%), wood & furniture (10.2%), instruments (8.5%), non-ferrous (8.3%), ferrous metals (8.2%) [agriculture, engineering, mining]
Finland 1987	4.4	other manufacturing (12.3%), non-ferrous metals(9.7%) [mining, engineering, services]
Iceland 1983[b]	7.4	fabricated metal products (28.3%), electrical machinery (17.1%)
Norway 1987[c]	12.3	machinery (36.2%), electronics & components (26.7%) [communications, utilities, engineering services]
Sweden 1987	11.0	wood & furniture (48.3%), other transport (33.5%), motor vehicles (16.9%), electronics & components (16.2%) [agriculture, utilities]
Australia 1986[a]	5.6	aerospace (21.4%), drugs (15.0%) [utilities, engineering services]

[a] Industry total excludes agriculture and mining.
[b] Industry total excludes agriculture.
[c] Industry total excludes mining.

Source: OECD, 1990.

Returning to questions of employment and skills, the increasing importance of R&D and the adoption of new technologies, and their link to employment and skills is emphasized in a Swedish Government Bill.

"According to the National Industrial Board's study, only the most R&D intensive firms managed to maintain their level of employment.

There is a strong trend indicating that a growing share of the industrial workforce will in future be employed in advanced technology sectors.

In addition, there was a very sizeable difference in productivity between companies with high and low levels of R&D. What is more, over the period, firms not involved in R&D activity increasingly lost ground to other companies, at the same time as resources were transferred from low-productivity businesses, those without R&D, to higher-productivity firms, i.e., those with a high R&D intensity. Finally, the Board studied the relationship between R&D intensity and export success. The data analyzed showed clearly that the proportion of output accounted for by exports covered positively with R&D intensity".

"Investment in R&D is essential to companies wishing to maintain and strengthen their competitiveness and thus contribute to favourable development of the Swedish economy. International studies also suggest that R&D will become increasingly important, since it is predicted that competitiveness will in future lie in a company having capabilities in several technologies or combined technologies, such as mechanical and electronic engineering, or optics and electronics".[245]

This is strongly supported by evidence from the OECD which recognizes that skill shortages and the structural changes being undergone as a result of these new automation technologies are principal barriers to their introduction:

"In France, Germany and the United Kingdom, lack of expertise was rated as the most important problem by the majority of establishments when applying microelectronics in products and processes (Table 10.30). In Austria in 1986, 78 per cent of surveyed firms saw the need for higher qualifications and a different mixture of skills as one of the principal effects of introducing microelectronics. This had risen sharply from 48 per cent in a similar survey in 1983. In Italy a survey of thirty enterprises adopting flexible automation technology in 1986 found that the most important obstacles affecting diffusion were shortages of technological skills (70 per cent of cases -- mainly shortages of design capabilities and skilled machine operators) and organizational problems (66 per cent of cases -- mainly problems with production organization and programming/software). Industrial relations issues and financial problems were of lesser importance. In Japan, over 70 per cent of Japanese firms surveyed in the 1982-1983 period reported that difficulties in adaptation and changes in the substance of work were greater than in the past, and that the impacts of microelectronic-based technologies were increasing the importance of technicians and technical training".

"Another series of surveys of Japanese firms showed that almost two-thirds of industrial workers affected by the introduction of new automation technologies (in 12,200 manufacturing establishments) saw vocational training as their most important concern. Two-thirds of establishments which had problems with introduction viewed the acquisition of new technical skills as their most serious problem and foresaw skill shortages as a future impediment to the introduction of new manufacturing technology. Over three-quarters of firms which foresaw problems when introducing office automation equipment identified the acquisition of new technical skills as the most important one".

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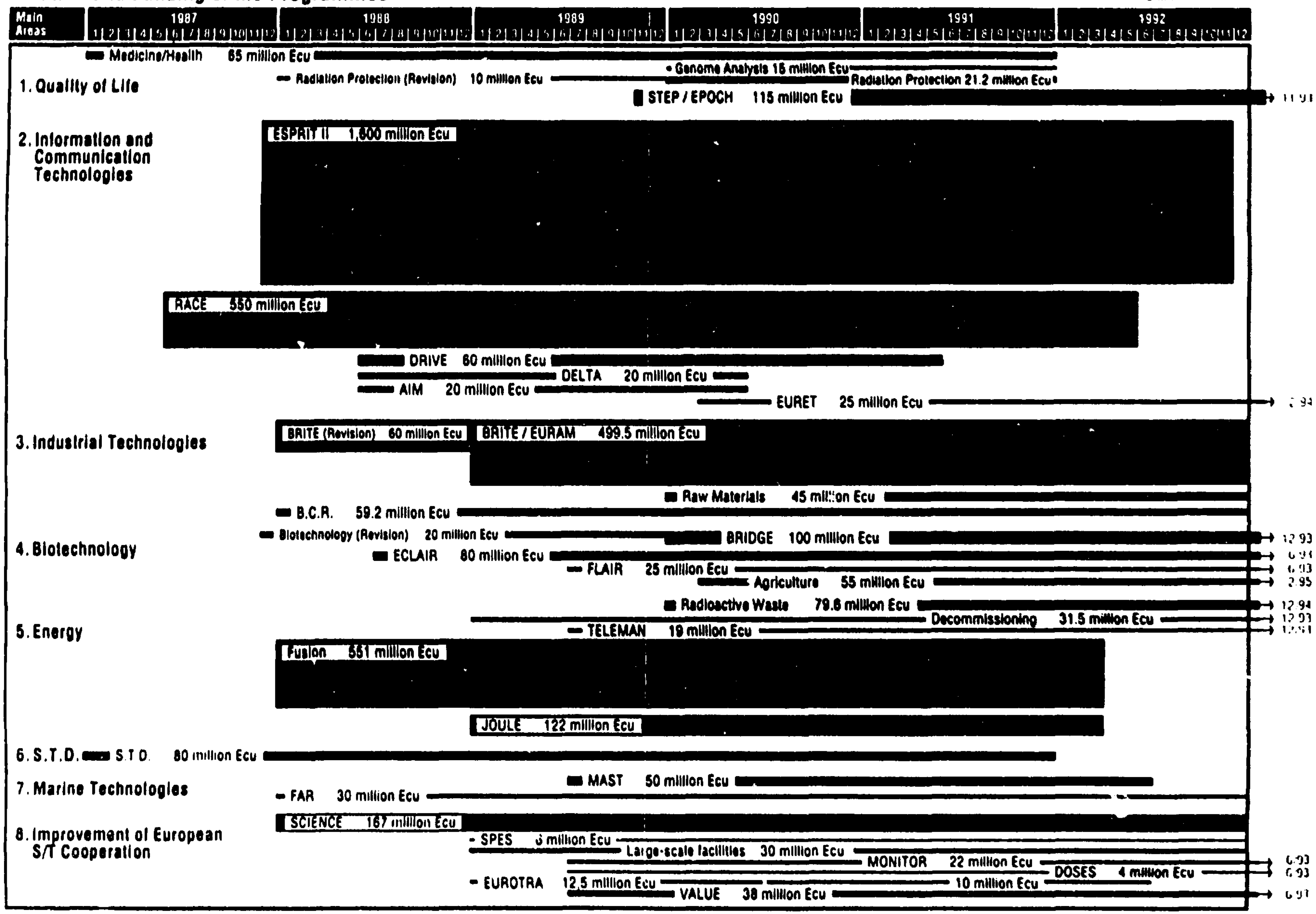
[245] Swedish Government Bill 1989/90:90.

Table 10.17 European Technology Programmes

Duration and Funding of the Programmes*



* Joint Research Centre not included

Table 10.18 Main advantages and problems in use of microelectronics (percentages of sample), 1983

	Product users			Process users		
	France	Germany	United Kingdom	France	Germany	United Kingdom
Lack of people with expertise	58	65	50	51	54	43
Problems with software	10	38	14	11	27	16
High costs of development	30	34	38	24	23	25
General economic situation	26	25	45	23	19	42
Lack of finance for development	18	23	30	19	17	29
Problems with microprocessors/components	9	19	9	4	14	7
Problems with sensors	9	17	11	8	16	14
Higher production costs	19	17	18	15	12	15
Opposition from shopfloor/unions	16	17	6	15	14	8
Difficulties of communications with subcontractors or suppliers	6	15	9	9	13	10
Opposition in management	1	6	4	2	4	5
Opposition from other groups in firm	3	3	4	2	3	4

Source: Northcott, et al. (1985).

The Japanese experience with respect to a comprehensive programme of education and training, both at the general and the vocational levels is important.

> "The combination of a high level of general education and scientific culture with thorough practical training and frequent updating in industry is the basis for great flexibility and adaptability in the workforce. The Japanese system of industrial training is distinguished further by its close integration with product and process innovation. The aim is to acquaint all those affected by technical change with the problems that are likely to arise, and give them some understanding of the relationship between various operations in the firm. This again greatly facilitates the horizontal flow of information. Thus the 'systems' approach is inculcated at all levels of the workforce and not only at top management level. Obviously, the availability of a large number of good-quality professional engineers, not just in research and development, but in production engineering and management generally has played a vital part in the enormous Japanese success in the import of technology, the redesign of processes and products, and increasingly now in autonomous innovations".[246]

Table 10.19 indicates that for the UK the problem has become worse over time with regard to lack of skills.

[246] Freeman, 1987.

Table 10.19 Main difficulties of microelectronics users (all United Kingdom manufacturers, per cent)

	1981	1983	1985
Lack of people with expertise	40	39	46
High costs of development	29	29	32
Lack of finance for development	29	30	28
General economic situation	40	43	26
Problems with software	12	14	13
Problems with sensors	9	10	11
Problems with microprocessors/components	8	7	9

Source: Northcott (1985).

Given these problems, even in highly developed economies, what is the answer? The OECD suggests an even greater effort is required, and that this will be increasingly the case.

"Develop a more technologically skilled work force

Goals include development and expansion of:

- A managerial cadre able to understand and capitalize on the enhanced production capabilities and the wide range of new products possible with micro-electronics applications;
- Engineering capabilities to design, install and utilize new or improved production processes and organizational approaches, and to design new products incorporating micro-electronics;
- A skilled technical and shop floor work force able to use and maintain new production methods, and to participate in the effective development and production of new and improved products; and
- Research staff in industry, research institutes and universities able to conduct basic and applied research and to provide training and consulting resources on micro-electronics and micro-electronics applications".[247]

10.5 Developed Country Industrial Policies: A Summary

New technologies, and in particular those based on microelectronics and IT, have increasingly been seen by developed countries as a means to increase their international competitiveness and to regain the initiative against low wage competition.

[247] OECD, 1989.

The use of Computer Integrated Manufacturing (CIM) combined with new organizational forms and new materials has increased dramatically in recent years. This has become part of the motivating force for increased R&D.

Concurrent with this have been closer links between the sub-contract and the user/supplier industries in general.

Taken together these factors have pushed government policy towards a variety of responses:

(1) to reduce the cost of R&D carried out by enterprises;
(2) to share the risks associated with high R&D investment;
(3) and by the creation and support for schemes designed to increase awareness of new technologies, and establish demonstration sites.

Developing countries are ill-placed to respond to such pressure:

> "Research is an important key to economically weak nations overcoming their development problems. As is stressed in funding requests from such bodies as the Swedish Agency for Research Cooperation with Developing Countries (SAREC), the economic crisis and the heavier burden of debt have left the developing countries feeling increasingly compelled to give priority to immediate economic and social needs. Recruitment of young research workers is slowing down and awareness about international R&D and ways of adapting it to local conditions is deteriorating. This inadequate research capability fundamentally undermines the scope for domestic control of development".

However, it is precisely the time when investment in technology has increased pressures for similar changes in developing countries that the costs of investment has increased:

> "The cost of capital has risen sharply since the latter half of the 1980s. For a variety of both macroeconomic reasons and international factors, these costs look set to remain high throughout the first half of the 1990s (at least), and the financial markets appear to be moving towards a general consensus in this respect".[248]

This has occurred as the debt servicing burden has reached a point where merely the interest on loans is taking virtually the whole of the export earnings of many developing countries. Also the sheer size and complexity of many of these integrated technologies requires their long-term planning, and a major restructuring of organization, within companies and industries.

> "*Investment* in modernization and upgraded technologies has reshaped entire segments of the technological bases of several industrial branches (by the simultaneous introduction of new materials and computer-assisted design, for example). The increase in investment in innovation and modern technologies has been a major factor in the exceptionally high levels of investment noted in the recent phase of the business cycle. This growth in investment and the pattern of its distribution throughout the national and international economy are currently providing the main impetus behind the restructuring of manufacturing industry".[249]

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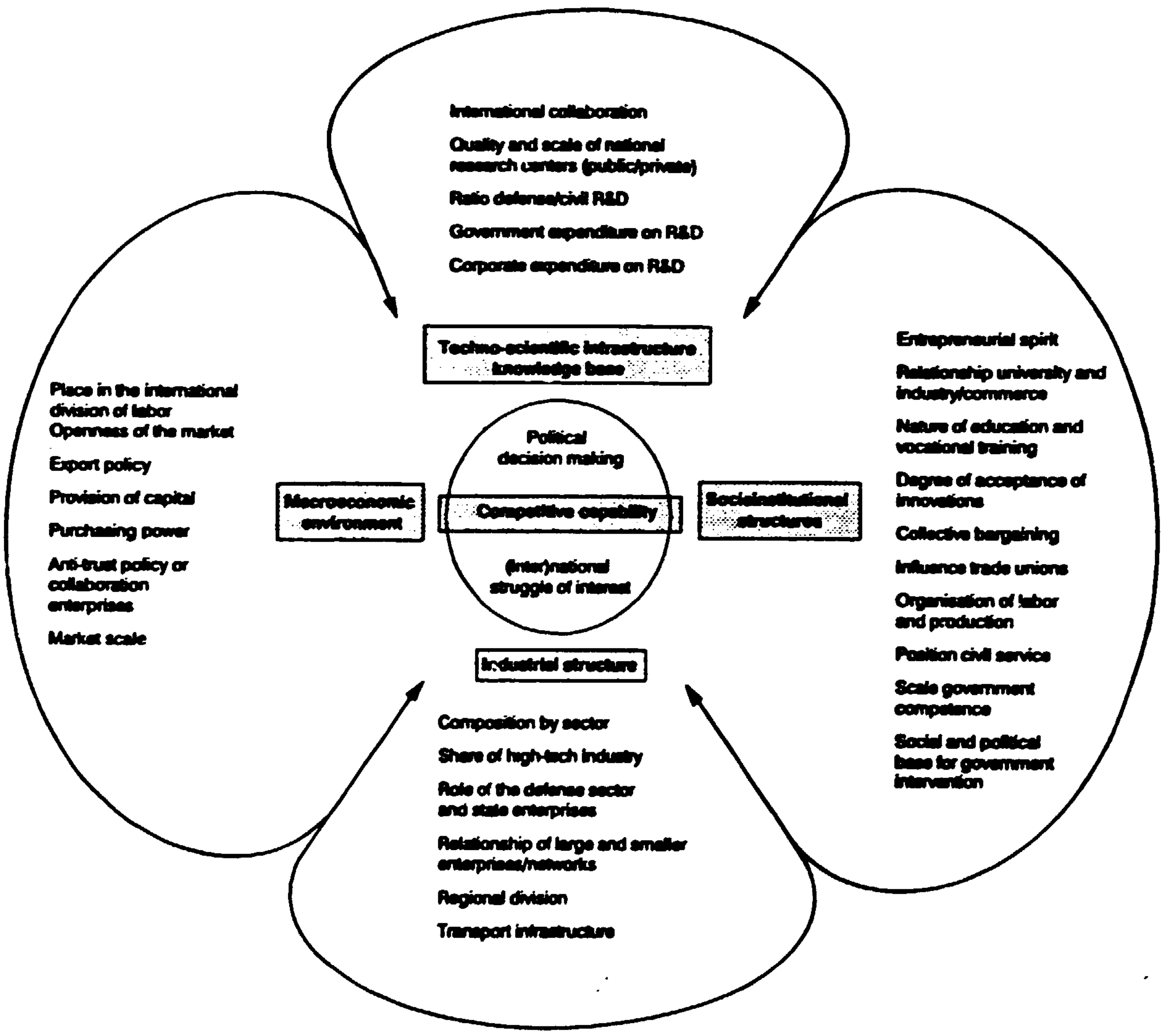
[248] OECD, 1990.

[249] OECD, 1990.

However, the diffusion of certain technologies has resulted in certain economies of scale, e.g., NCMT, and in other instances software advances and less sophisticated computer systems (largely based on PCs) has resulted in low cost CAD being available. Both these technologies -- NCMT and CAD -- are now quite viable for developing countries with the appropriate infrastructures.

Figure 10.5 is a diagram which encompasses many of the features discussed in this chapter on government policy for technology diffusion (Figure 10.5).[250]

Figure 10.5 The clover diagram



Source: Roobeek (1990).

[250] Roobeek, 1990.

This shows clearly the inter-relationship between:

- the techno-scientific infrastructure;
- the macro economic environment;
- socio-institutional structures, and
- the industrial structure

In each of these individual countries this can be a major determining feature in developing the competitive capability, both in the national and international fields:

> "Not heavy funding, but a strong industrial and institutional base is therefore the key to successful technology policy and enhanced competitive capability. A flexible automation programme will yield far greater competitive advantage in a country like West Germany, which enjoys a relatively specialized industrial structure, a highly advanced technological and scientific infrastructure as well as trade unions who do not instinctively reject new production methods, than in a country like the Netherlands whose machine tool industry is far less developed. On the other hand, the Netherlands stands to reap more extensive international benefits from an agriculture-orientated biotechnology programme than does a country like Sweden. In other words: a technology programme should as far as possible link up with the healthy and dynamic sections of the existing industrial structure or build on a certain knowledge base if it is to bear fruit. This does not mean that new initiatives should not have a chance. However, there must be a receptive base for these new developments".[251]

It is clear that although the provision of funds through grants/loans, development of contacts between higher education and research establishments, and industry, and other financial inducements have been very important in the majority of OECD countries -- money alone is not enough.

What has proven to be important is how the schemes have been administered, simple application and evaluation procedures, and selectivity of specific programmes to support. Most of these factors are presented briefly and concisely in the 1989 OECD report:

Table 10.20 Programme and policy approaches and priority areas to promote diffusion

- Awareness campaigns to build interest in microelectronics technology;
- Technical and management assistance to individual firms (particularly small firms) through subsidized consulting, feasibility studies, technology implementation assistance, and market exploration;
- Technical and research support for product development or for process improvements to individual firms or consortia of firms;
- Support for market-oriented technological institutions which provide consultancy services to individual firms and groups of firms, training courses, and contract research services;
- Develop capabilities of the domestic technology supply system, for example microelectronics design and applications capabilities, software development, original equipment manufacturing capabilities;
- Training and development of skilled manpower, especially technical and managerial training;
- Support applied research and applications development by university or government laboratories.

Source: OECD (1989).

[251] Roobeek, 1990.

11. Developing Countries: Development Theory and Practice

This chapter summarizes some basic development theory ideas from a number of sources,[252] and tries to see how these theories have work2third worlded, in principle, by looking at the case study countries. The role of direct foreign investment is also discussed since this affects both development and dependency.

11.1 Development Theory

The basic approach to economic and technological development of less industrialized countries was based on the so-called modernization theory, often attributed to Rostow (1960). Mjoeset (1985) argues, that the theory represents the typical US view on postwar problems in relation to the de-colonized Third World. Every nation would run through a series of stages: the traditional, the preconditional, the take off and the drive to maturity, finally ending up in "high mass consumption', the generalized American way of life.

The stage of growth theory was quickly opposed by scholars taking a Third World point of view.[253] They argued that any kind of stage theory was futile, since the periphery had been influenced by the core during the whole colonial period, even in those countries where colonialism was informal. Even in the period of de-colonization, Third World nations were linked to the core through the asymmetric structure of the world market. The Third World supplied the core with cheap raw materials receiving advanced products in return, with the West reaping all the positive linkage effects. The products returned to the Third World were mainly luxury products and military equipment.

In the case of machinery, both the economic one-sidedness and the low qualification of Third World labour forces would hamper industrialization. The only viable alternative was to de-link from the unequal exchange of the world economy, following the strategy of self-reliance.

The modernization/dependency quarrel polarized the debate as one between "internal" and "external" determination of development. There have been, however, attempts to specify the combination of such different factors by emphasizing more the institutional issues related to development or underdevelopment.

For example, the French regulation school accepts, on the one hand, the basic criticism of modernization theory.[254] On the other hand, the simple exogenous explanation of 'development of underdevelopment' is rejected. It is impossible to reduce such a complex phenomenon as unequal development to the international division of labour as the sole encompassing explanatory factor. This is done for example by Froebel et al. (1977), who emphasize the emergence of worldwide markets for cheap labour as transport technology improved and fragmentation of production processes is facilitated. The developing countries have not been just passive objects of the developed worlds' actions.

It is important, first, to take account of the specific development phase of the global economy, and to scrutinize national conditions for growth and development. The upturn in

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[252] Rostow, 1960; Mjoeset, 1985; Frank, 1979; Lipietz, 1984; etc.

[253] Frank, 1979..

[254] Lipietz, 1984.

developing countries' industrialization has been linked to the crisis of Fordism in Western market economies, which changed the conditions for profitable manufacturing and activated the search for cheaper production locations.[255] Lipietz also looks at discrete conditions in the relevant developing countries focusing on the specific relations between social forces, which determine domestic industrialization strategies.

The mid 1970s economic crisis according to Lipietz was triggered off by a temporal fall in the rate of profits. Production and investment slowed down in the developed market economies. At the same time, the first oil crisis caused chaos in balance of payments relations, and OPEC-surpluses were channelled into the Eurodollar market. Banks competed to supply credits to developing countries, which increased their demand for important Western industrial goods and increased debt burden.

An acceleration in outward investment from developed countries occurred and developing countries' industrialization got a new boost. But with the second oil crisis and the new downturn in 1979/80, the international debt crisis has caused a strangulation of these processes of industrialization, which, especially in the African case and to some extent the Latin American case, is still continuing. The individual country groups developments are, of course quite different.

The importance of a wide setting of political, cultural and specific economic factors - not only the socio-economic basic structures as in Lipietz' interpretation - in explaining the developing countries problems in reaching the "modernization" path of economic development is also emphasized by many other institutional economists, e.g.:

> "Institutions can have the effect of either facilitating or retarding economic growth. The choice of appropriate political institutions, rules and policies enhances economic growth. Moreover, by affecting resource mobility and the incentives for innovation and accumulation, institutions may induce or hinder economic efficiency in the allocation of resources and growth. Institutions affect growth also through their effects on expectations, social norms and preferences. Expectations are, of course, subjective, calling attention to the importance of perceptions and the way in which they are formed rather than only to the objective factors that are included in traditional economic analysis. Social norms can also play an important role in affecting the extent to which growth enhancing activities can take place. For example, religious norms may either encourage or inhibit money lending and entrepreneurial activities. This calls attention to the role of preferences in institutional change and development."[256]

The more institutional approach avoids the simple reductionism of most world-systems approaches and the basic modernization theory. Admittedly, that modernization reflects a real trend in the postwar Western world. But the replication of this model in the developing world is quite difficult. The fundamental institutional settings do not necessarily follow the rationale of western modernization, and on the other hand, the influence of the developed world is - on a rather unequal basis - affecting their economies.

Actually, even Rostow in his original book waters down the slogan of "self sustaining growth", though he provides no systematic theory that would help in explaining why this modernist surge came about in the West, but is being hampered in the Third World. By

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[255] Lipietz, 1984.

[256] Nabli and Nugent, 1989.

devising aid as a policy towards developing countries, Rostow tacitly admitted that the take off was no self evident process, but based on institutionalized inequality.[257]

Developing countries do not form a coherent group. They show very differing developments, and these differences cannot be explained by any one common pattern. Especially if the central role of institutional development is recognized, the analysis should be very country specific. At a more aggregate level, however, developing countries are often separated into four groups of countries:

(1) the large Latin American countries,
(2) the South East Asian NICs,
(3) the OPEC countries,
(4) the least developed countries.

Lipietz' analysis (ref; Mjoeset, 1985) covers the first two groups. Both groups of countries originally started out in the post-war era by relying on a strategy of import substitution. With the decline of developing countries' terms of trade this strategy became less viable.

Other problems included a relatively short history of industrial experience and narrow domestic markets. Lipietz regards the import substitution strategy as no more than a caricature "sub-Fordism" in which neither the labour process nor the patterns of social demand are substantially transformed.

As a response to these problems and the general failure of import substitution techniques, the Latin American countries opened their large domestic markets for more foreign investments while maintaining high tariff barriers. A wave of US investment followed beginning in the early 1960s, concentrated upon some of the standard Fordist production lines (chemicals, automobiles, durable consumer goods). The relatively large strata of middle classes was the basic economic force behind the demand for Fordist products in Latin America.[258] This succeeded for a while, and the period between 1967 - 1973 has often been called the era of Latin American "economic miracles".

The fact that working class mass consumption still was largely restricted indicates continued barriers to the full emergence of Fordism. The largest Latin American country, Brazil, is a good example of limited Fordism and restricted mass markets. Of the population of 150 million, it is assumed that only about 60 million form the real market, while the others are living either outside the formal economy, or whose demand is limited to the basic necessities of life.

The East Asian NICs were smaller economies without attractive domestic markets, the Republic of Korea being the largest with a population of roughly 40 million in the late 1980s. Thus the countries had to rely more on export oriented industrialization, and, to attract foreign firms and technology, they had to offer very cheap wage labour. As a response to the developed countries economic crisis of the 1970s, many firms moved parts of their production to these countries.

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[257] Mjoeset, 1985.

[258] Mjoeset, 1985.

Some scholars have claimed that the low qualification of the labour force was a problem. An even more important issue may be, as Lipietz points out, the high work ethic and motivation in the countries - based on patriarchy and traditional, religious norms - are the ultimate qualification for the type of simple Taylorist production processes then evolved in these countries.

However, the success of this strategy has been focused on several specific factors with a very strong state supervisory role, for example, the Export Processing Zones, and exerting political control and strong discipline over workers. According to Lipietz the typical NIC pattern amounts to a "19th century Island" in the 20th century. Neither the production process, nor the pattern of consumption are transformed, and a draconian Taylorist form of exploitation may provoke social unrest.

Hence, both groups of countries made great efforts to increase the technological level of production in the 1970s, to increase wages and to subcontract the more simple production processes to second generation NICs. This is a trend towards what Lipietz dubs "peripheral Fordism": it requires a certain level of labour force qualification, but at a comparatively low wage. Furthermore it requires closeness to large markets.

Our Latin American comparator country, Brazil, is a good example of Lipietz' peripheral Fordism: Despite having one of the largest gross national products in the world as we noted above, a very large proportion of the population is excluded from the market due to very low incomes - sufficient only to meet the basic shelter, food and clothing need. The mass markets have been created to a limited extent, and for a limited middle class, only.

The East Asian NICs are more problematic, and Lipietz' interpretation simplifies their development. Again, the overall institutional set up is more complicated. The NICs have developed their education systems, created research institutes and been to some extent able to follow the Japanese development strategy based on incremental innovations, learning by doing and development based on continuous technological renewal, both in terms of sophisticated production processes and new, more high quality products. The case of the Republic of Korea will be discussed in more detail in Section 12.7.

In discussing the crisis of Fordism and peripheral Fordism, Lipietz refers to the Ford Motor Company as the pioneering enterprise in finding new solutions for the industrial problems in developed countries. Economies of scale were achieved by locating plants in countries such as Spain and Mexico - and thus very near to the developed countries main markets - and negotiating a certain ratio between suppliers to local markets and re-exports. This development seems to be associated with a drive towards fragile democratic experiments. At the same time, some of the NICs - for example the Republic of Korea - launched large state supported and debt-financed investment projects in heavy industries.

Since the late 1980s trends in the industrialized core must again be taken into account. The deepening crisis of Fordism in the late 1970s and problems in establishing the new micro-electronics based trajectories of development spurred increased Western protectionism against Third World latecomers. Western demand for crucial developed countries' exports slackened, monetary policies changed, and under increasing competition in home markets protectionism and trade barriers were erected. The skyrocketing international interest rate increased the debt burden of Third World countries. Export surpluses are now scarcely sufficient to pay the interests on escalating debts. The situation is especially bad in the Latin American countries.

The approach referred to above does not offer any theory of development stages. This means, that - contrary to Rostow's or traditional Marxist theories - it is not implied that all countries must pass through all the same stages of development. For example, all least developed countries do not, by any inherent law of development, have to go through all the phases of industrialization. Even if they have not really gone through the industrial revolution, they might well gain benefits from the "information technological revolution". It may even offer them new possibilities to find new development paths.

The basic focus in Lipietz' approach is on the wage nexus, which emerges as the key to the fate of "Fordist tendencies" in developing countries. From this point of view it is necessary to trace the prevailing relations of social forces, to judge whether the present structural crisis will produce the new institutions capable of consolidating a new coherent regime of total regulation in the developing countries.

Lipietz argues that the globalization of continued neo-liberal austerity policies will create severe problems for countries trying to develop peripheral Fordism. Traditional Keynesianism is no longer a viable alternative, it is a policy rather more dependent on the postwar upturn and linked to the institutional framework of what he calls, monopolistic regulation. When this regime of regulation is no longer able to secure coherent total regulation - in a new, more flexible economy with less hierarchical and more networking relations between organizations - the corresponding policies will not work either.

Lipietz' analysis is, in many respects simplified and one dimensional. However, he is right in rejecting the simple "modernization" and "dependency" views. The developing countries situations are more complicated. Institutional settings and technological change has also been given a more central and more independent place in the development discussion than is usually the case. The role of technology and the possibilities of a more technologically driven development path is outlined further by neo-evolutionary and institutional economists.[259] This approach will be discussed more in Section 12.3 and 12.4 in the context of technology policy issues and an evaluation of the case countries policies.

11.2 Sectors and Firms in Techno-economic Development

Flexible automation and other new production technologies are usually discussed only in the context of advanced industrial countries. This is because the technologies are usually related to the most rapidly growing sectors of the economy, typically electronic and mechanical engineering. The technologies are, however, even penetrating sectors with static or declining markets and production volumes in the developed countries as has been noted in the first half of this report.

In these old branches the environment where new technologies are introduced is often very different to rapidly expanding industrial sectors. They are also sectors important in developing countries. It is through these industrial sectors, that new technologies often affect developing countries more than through the sectors on the edge of technological development.

Industrial branches can be divided into three categories according to their role in technological development:[260]

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[259] Clark and Juma, 1987.

[260] Perez, 1986.

(a) the carrier branches making the most intensive use of the new technologies, are the best adapted to the ideal organization of production, and induce a great variety of investment opportunities upstream and downstream. They form the dynamic core of new technological development.

(b) the motive branches produce the new technologies, and maintain and deepen their relative cost advantages.

(c) the induced branches make use of the new technologies at a slower rate. Broad diffusion is attained only when the necessary social and institutional innovations have opened the way for the upswing and the generalization of the new technological style.

In the context of the micro-electronics revolution, the electronics and related sectors are the motive branches, and metal working industries the most important carrier branches. But the relative supremacy of the new technological regime is spreading wider to more and more induced branches.

However, it is not only the characteristics by sector which are the most important factors directing the possibilities of technological development. The course of change depends finally on the investment and production decisions of individual firms, which are the crucial actors in the economy.

Thus another three-way classification is of firms which may be classified as supplier dominated, production intensive, and science based firms:[261]

(a) Supplier dominated firms are typically small and found in traditional manufacturing and non-manufacturing sectors. Most technology comes from suppliers of equipment and materials. Appropriation is mainly non-technical and in-house technological skills are weak. Few product classes are therefore technologically proximate or related, although some firms do contribute to their own process technology, and therefore have some technological capacity to diversify vertically upstream.

(b) There are two complementary and inter-linked types of production-intensive firms: scale-intensive and specialized suppliers. Scale-intensive firms are typically producers of bulk materials through continuous processes, or consumer durables through mass assembly. Cost-cutting through the exploitation of economies of scale and learning defines the dominant technological trajectory so that firms are typically large. In-house production of engineering activities is essential, given that process technologies are complex, interdependent, difficult to operate but capable of continuous improvement. These production engineering activities make diversification vertically upstream into process equipment a technologically proximate activity.

Scale-intensive firms live in symbiosis with specialized suppliers of production equipment, control instrumentation and (more recently) software. In such specialized suppliers, technological trajectories are strongly oriented towards product performance and reliability,

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[261] Pavitt, 1984.

given the scale and interdependence of the production systems to which they contribute. Technological inputs come from in-house design and development activities and from the design, development and operating experience of scale-intensive users. Since these users are also continuously seeking improved production technology, equipment suppliers can remain relatively small and specialised. Technologically related products are equipment and instrumentation where specialised suppliers are able to apply their existing design skills in other applications.

(c) Science based firms are found primarily in the chemical and electrical/electronics sectors. Their technological trajectories are defined by the numerous and pervasive product-market opportunities exploitable through in-house R&D, on the basis of science based techniques. Successful innovative firms can grow large through entry into technologically related product markets. They also accumulate skills related to synthetic chemicals and electrically and electronically based consumer durables.

According to these categorizations, textiles, clothing and footwear sectors are induced branches with primarily supplier dominated firms. Machine suppliers have significant influence on the firms' technological development, and in-house R&D is rather modest in the sectors, directed mainly on incremental process developments and improving cost effectiveness. Within these sectors, flexible, microelectronics based automation has so far changed the mode of activities less than for instance in mechanical engineering.

But the situation is changing: in the traditionally quite automated textiles sector, growing flexibility is introduced into machinery; in clothing, CAD/CAM has already, since the 1970s changed the pre- and post-assembly phases of production significantly; and even in shoe manufacturing more microelectronically controlled machinery is available.

The core of flexible automation is, however, the integration of individual activities within factories and firms as well as between companies as we noted in our discussion in Chapter 1. New organizational forms based on integrative ideas are changing traditional branches even without introducing much new technology. Subcontracting relations and distinct cooperative contracts upstream and downstream in the production chain are changing the conventional structures within branches. Firms are increasing their flexibility by using both flexible machinery and by improving the overall flexibility through keen cooperation with other firms.

In integrating business activities organizational innovations are often more important than technological ones. This is highlighted by developments in the clothing industry. The sector was described above as an induced branch where machine suppliers dominate the technological development, and in-house R&D is modest, in other words as a sector lagging technologically behind. But from the point of view of organizational innovations, the sector has actually been in the leading edge in developing new flexible business organizations based on interfirm networks and comprehensive subcontracting linkages. The Italian company Benetton is often used as a paradigmatic example of the new production mode, side by side with the most sophisticated electronics and mechanical engineering companies using the newest production technologies.

When it comes to hardware, the sector is very supplier dominated. However, the business organization, the ways of using technology and the incremental developments in machinery are developed in firms within the sector. The outcome in industrial activities are, then, both original and highly developed, in fact models for many other industrial sectors. From this angle, the clothing industry is a very innovative sector, but with low spending on research and development.

In textiles, clothing and footwear the development of production technology has, however, advanced at a somewhat slower pace than in many other branches. These industrial branches still rely mainly on the old comparative advantages and benefits of mass production technologies, and - especially in the case of clothing and footwear - on cheap labour. This means that the sectors in developing countries still have a little time before full automation becomes a major development in the developed countries.

However, as already noted in this report, automation is accelerating in these sectors. The central role played by organizational innovations in clothing also means, that developing countries have to put more emphasis on institutional behaviour and organizational practice in their industrial firms.

11.3 The Case Study Sectors: Textiles, Clothing and Footwear

The production of textiles, clothing and footwear has gradually moved from developed countries to developing. The most important developing country production areas in these sectors are in Eastern Asia, Southern Europe, Mexico and a few other Latin American countries. In contrast, the sectors have diminished in most developed countries through to the early 1980s, though as discussed further in Chapters 15 to 17, they may have passed an inflection point in the mid 1980s.

For many developing countries, these sectors have been important areas of industrial development. For example, the rapid industrialization of Mauritius has mainly been due to the expansion of these sectors, so much so that a diversification strategy out of clothing has been envisaged as a central target in the National Development Plan:

> "Since textile and clothing have now become sensitive product areas, policy will be aimed at encouraging investment in non-textile sectors with emphasis on products and production processes involving more sophisticated technology. This will be reflected in the investment promotion strategy. Investment schemes will be introduced to encourage investment in the new areas of interest. For the immediate future, the sectors that have been selected for special incentives are leather, printing, jewellery as well as "haute couture".[262]

This shift may also be influenced by another feature of the sectors development. When economic development accelerates and wages rise, the production of textiles, clothing and footwear - at least for mass markets - becomes less attractive. There is, thus pressure to shift the focus of production to other industrial sectors or to higher, more demanding value-added market segments with higher profit expectations.

Developing countries' competitive advantage in these sectors has been based on low wages. Is this changing? Developed countries have allocated relatively large resources to developing both production technologies and new organizational forms to improve flexibility that could surmount the benefits of low wages. There are examples of success on this. In clothing, the Italian networking fashion companies are often mentioned.

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262 Ministry of Economic Planning and Development, 1988.

Thus it is not only a question of manufacturing technologies, but on new, segmented and rapidly changing markets and new production and marketing organizations as well. Could these changes diminish the role of developing countries as a source for cheap production for developed countries markets? Or could the developing countries gain new benefits by introducing more automated flexible technologies? The East Asian NIC countries are already moving in this direction, labour intensive, simple, mass production is being moved to other less developed countries in the area, and the NICs are automating their own production.

The African case is, however, more problematic. The Sub-Saharan African countries especially have not been able - particularly in terms of exports - to benefit from the advantage of cheap labour. Multinational companies in these sectors have not established significant production in these sectors in SSA countries, and the local firms are seldom internationally competitive. They have, in general not gained from the relocation of textile, clothing and footwear production from developed to developing countries.

In this sense, Mauritius is a clear exception. It has, to some extent, been able to follow the path of the NICs in developing a rapidly growing exporting clothing industry. The Mauritian case is included as part of the examination of technological development of the respective sectors which is contained in detail in Chapters 15 to 17.

11.4 The Role of Direct Foreign Investment

Direct foreign investment has been a key issue in the industrialization of developing countries, in both positive and negative ways. It has often contributed substantially to the evolution of industrial structures, but it has also supported the creation of patterns of dependency.

The origins of extensive direct foreign investment go back to the early 1960s in the industrialized world, when rapid post-war industrial growth ran into problems of labour scarcity. Countries responded to the challenge of increased foreign competition and rising labour costs with different strategies. US firms responded by moving the most labour intensive phases of production to low wage regions, first in the United States, and later in the developing world. The European companies more often preferred importing cheap labour to work in domestic factories. The Japanese encountered the problem somewhat later, and answered it mainly by automating production processes.[263]

In the early 1980s some 2 million people were employed in off-shore assembly operations worldwide with an annual output of $ 15 billion. Off-shore assembly grew from 4 per cent of total US imports in the early 1960s to almost 10 per cent in the 1980s.[264] Eleven developing countries account for 75 - 80 per cent of world off-shore assembly output primarily in the production of electronics goods, and three quarters of all off-shore assembly of electric and electronic goods is concentrated in five countries. The most important off-shore assembly sites for US firms are Mexico with over $ 3 billion (28 per cent) followed by Malaysia's $ 1.4 billion (13 per cent) and Singapore's $ 1.3 billion (12 per cent) worth of electrical and electronics goods.[265]

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263 Sanderson et al., 1987.

264 Grunwald and Flamm, 1985.

265 Sanderson et al., 1987.

Table 11.1 Foreign investment inflows 1983 - 1988 (US$ billion)

Country/region	Year						Annual average	
	1983	1984	1985	1986	1987	1988	81-83	83-88
Developed countries	33.5	38.6	35.7	63.6	94.5	118.8	35.3	70.2
Developing countries	10.4	12.0	13.3	13.9	23.6	25.1	13.2	17.6
Africa	1.2	1.4	2.6	1.8	2.2	2.9	1.4	2.2
South-West Asia	4.7	5.1	4.6	5.7	10.1	12.3	5.0	7.6
Western Asia	0.3	0.7	0.4	0.3	0.2	0.4	3.7	0.4
Latin America	4.0	4.7	5.6	6.1	10.8	9.3	6.3	7.3
Oceania	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1
Eastern Europe	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.02
Total	43.9	50.7	49.0	77.5	118.1	143.9	48.6	87.8
African share of total	2.7%	2.8%	5.3%	2.3%	1.9%	2.0%	2.9%	2.5%

Source: Tolentino (1990).

Africa has, however, never been an important target for off-shore manufacturing or any form of direct foreign investment. The African share of all foreign investment inflows during the 1980s has fluctuated on the average between 2 and 5 per cent of the world total foreign investment.

The targets of off-shore manufacturing may, however, be quite diverse. The 'original' aim was to re-import sub-assembled parts back to final assembly and markets in the States. This is still the dominating pattern for American corporations. The US firms locating plants in low wage countries are mainly the large multinationals.

The Japanese pattern of off-shore manufacture is quite different. It has never been as important a strategy for companies as in the US and the targets are also different. Firms have located plants mainly in the low labour cost areas in neignbouring East Asian countries. In doing this, the firms have not applied any extensive foreign sourcing strategy. The firms often have only a few foreign plants. For example, Japanese plants in the Repulic of Korea are in most cases the only foreign establishments of these firms.[266] The large Japanese corporations, on the other hand, prefer establishing plants in the US and West Europe.

The volume of Japanese foreign investments in Europe and the USA has grown remarkably since the late 1980s. Japanese enterprises have been acquiring both important corporations - such as Columbia Broadcasting Corporation, bought by Sony - or entering in joint ventures with Western corporations. The latter strategy has been typical in the automotive industry, for example, with production sites in USA and/or the EC.

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266 Sanderson et al., 1987.

In the Japanese case, the main target is not to re-import to Japan. Choosing foreign plant sites and partners in joint ventures - both in the Asian NICs and in Europe/USA - is more often motivated by the desire to gain access to new markets. The strategy is supported by the US and EC trade policies, for example, the regulations on the local content of products sold in their markets.

The European off-shore establishments (outside Europe) are still of minor scale compared to the US and Japan. They represent a mixture of the two strategies, with greater focus on the Japanese one. European firms are using off-shore manufacturing more often in the traditional industrial branches than in the high tech area. The operating mode is quite different in these cases: for example, textiles and garments manufacture in low labour cost countries is usually not carried out by foreign establishments of European firms, but by independent local subcontractors.

With regard to current technological developments it has been suggested that these may alter the patterns discussed above. For example, the evolution of flexible manufacturing automation has generated speculation about the likelihood of capital-labour trade-offs significantly reshaping the development prospects of low-wage areas, redirecting future factories to areas of abundant, secure and low cost capital.

Mexico has been cited as retaining its cost advantage for all volumes considered for the range of generally less sophisticated products currently assembled there. However, for volumes exceeding 310,000 units per year, US flexible assembly begins to show lower unit costs than manual assembly in Singapore. Transportation costs and local production are the dominant factors traded off against the lower wage rates.[267]

Will the increased automation cut down on off-shore assembly? So far the evidence is contradictory. On the one hand, it has meant the return of some manufacturing to the United States, while on the other hand, the US$ 9.5 billion value of US off-shore assembly in the developing countries, up from $ 6.2 billion in 1980 shows that developing countries are playing an increasingly important role in assembly and manufacturing of many goods including, electrical and electronics products.

But reverse examples do exist. The main motivation for repatriation have been the desire to reduce inventory and transportation costs in addition to moving production closer to the end market in order to be more responsive to customers, and in particular, to meet delivery deadlines without maintaining costly inventories.

New automation technologies introduce changes into existing capital/labour relations. Analysis of costs of various stages of the pre-assembly, assembly and post-assembly operations in the garments industry in a broad range of countries shows clearly how automation has influenced the international division of labour.[268]

For a no tariff, no time cost, no robotics scenario, Jamaica ranked 1st in all three areas of production for the US market (see Table 11.2), China 5th in all three categories, and the US itself only becomes competitive in the pre-assembly stage at number 9.

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[267] Grunwald, 1985.

[268] Mody and Wheeler, 1990.

Table 11.2 Women's high style printed polyester dress: competitive advantage estimates

	No tariff, no time cost, no robotic production				
Rank	Pre-assembly	Assembly	Post-assembly	Cost	Time
1	Jamaica	Jamaica	Jamaica	4.88	42
5	China	China	China	4.96	67
9	US	Jamaica	Jamaica	5.15	47
11	Korea	Korea	Korea	5.21	66
15	Korea	China	China	5.24	77
33	Korea	Jamaica	Jamaica	5.44	72
35	China	Jamaica	Jamaica	5.44	72
46	US	China	China	5.57	97
73	US	Korea	Korea	5.82	96

Source: Mody and Wheeler (1990).

However, with robotics the US clearly emerges as number 1 in pre-assembly, and none of the low wage countries or NICs is able to challenge them (see Table 11.3).

Table 11.3 Women's high style printed polyester dress: competitive advantage estimates

		Robotic production			
Rank	Pre-assembly	Assembly	Post-assembly	Cost	Time
1	US	Jamaica	Jamaica	5.43	38
3	US	China	China	5.83	88
11	US	Korea	Korea	6.12	88
27	Jamaica	Jamaica	Jamaica	6.44	41
31	China	China	China	6.50	66
37	US	US	US	6.56	10
49	Korea	Korea	Korea	6.78	66
53	Korea	China	China	6.78	76
85	Korea	Jamaica	Jamaica	7.02	71
87	China	Jamaica	Jamaica	7.04	71

Source: Mody and Wheeler (1990).

In this scenario when US firms automate, developing countries may suffer the direct loss of jobs and revenues associated with the automated sectors and processes. For the moment manual assembly may be the least cost alternative in, for example Jamaica, China or Korea, but flexible automation technologies are gaining ground for a wide variety of products. It is important to recognize that the industries of the future will have different staffing and manpower requirements than did the factories of the past and that the employment generated by them is of quite different nature than in conventional manufacturing.

From this point of view, even the NICs face serious problems. If they fail to keep pace with new manufacturing technologies they risk falling behind, and in the absence of stringent protectionist policies, may lose domestic and export markets to more efficient competitors.

It should be noted that cheap labour is by no means the only important factor when thinking about multinationals relocation to off-shore assembly. Location of production sites involves a most complex decision making situation, since decisions for relocation are not made on a daily basis, and this means that changes in prevailing patterns cannot be very rapid.

Many of the most successful multinational production sites in developing countries have in fact developed into rather complex entities with many tight - production, cultural and market - contacts to the local and regional environment. This connection is not easy to sever. It does not seem likely that all of the multinationals production sites in the most advanced NICs would have remained as isolated islands of low cost labour assembly. It is more likely, that many connections to the local and national environment at various other levels have been established.

Of course locational decisions also depend on governmental policies towards direct foreign investment in the respective countries. Policies vary. Some developing economies - for example Hong Kong and Singapore as noted earlier - have been very open to multinationals, others have restricted foreign industrial activities to special "free zones" or within a definite scope of industrial branches. Most African countries have in the past been even more negative towards foreign production sites. Even in cases where the formal policy has not been hostile to foreign investment, the actual policy has made the repatriation of revenues, or acquiring import licenses difficult and hindered foreign investment. An important share of foreign capital and foreign connection has in fact been established through international development aid connections.

The African situation is, however, changing rapidly. Many countries are trying to attract foreign capital by facilitating investment and foreign trade regulations and establishing tax free export production zones. The success of Mauritius, which has drawn praise from a variety of sources, including the World Bank, has served as an example in this sense, though even here there was a marked inability to attract the major multinationals to the country due to the small scale of the market.

Some countries have also tried to link locally operating foreign firms more directly to national development plans, while others have counted more on the direct employment and multiplier effects caused by investments. Countries with modest resources and less to offer have less countervailing power and are not very likely to be able to set conditions on the operations of large foreign enterprises, if they want to attract them.

This may imply that already the so-called second tier NICs - not to speak of the least developed countries - will have difficulties in the future in trying to attract and keep foreign investment in the country. For them, cheap labour may be the only asset to offer to multinationals. However, the share of labour costs in all costs is going down in most industrial sectors in the developed countries. As noted earlier in the US direct labour costs represented less than 10 per cent of sales in most industries.[269] Thus the attraction value of cheap labour only is diminishing. In addition to this, the prevailing multinationals assembly sites in Africa are either few, or culturally isolated from the local environment. If connections to the local industrial

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[269] Skinner, 1986.

environment are few, it becomes easier to relocate establishments if the present location countries cannot develop the comparative advantages they have to offer.

Thus, even from the direct foreign investment point of view, there is a pressing need to establish basic development policies that rely less on prevailing comparative advantages, such as low cost labour, and which create new directions and initiatives. In this, more technology driven development paths may have a lot to offer.

11.5 Development Theory and Practice: A Brief Summary

Theories of development have broadened and deepened considerably in the last twenty years.

Industrialization was regarded as the key influence on international markets and general economic prosperity in the developing countries in the years immediately after World War II, though for a long time domestic demand was more important than exports in almost all of these countries.

The growth of industrial capacity mainly started in the 1960s. During the next decade the phenomenon came under discussion in developed countries where it was often seen as a possible rival to their industrial growth. The new developments may not have been posing really fundamental new problems to the world economy, but the new growth and increase in exports from the developing countries emerged at the wrong time, at a time of slow growth and high unemployment in the developed countries.[270]

Development in the 1980s proved this to be at least partly true: it has not been so much a question of a general industrial take off of developing countries, but rather a clear split within the group. While a small group of NICs in East Asia and a few other countries have started rapid industrial growth, some others - mainly African countries - have actually declined in this sense.

Total industrial development, measured by the growth of value added, has been faster in developing countries taken as a whole than in advanced market economies both in the 1960s and 1970s. The figures for the 1970s and the 1980s (Table 11.4) show that the difference in growth has been widening.

Table 11.4 Growth of manufacturing value added by economic grouping (per cent)

Period	Developing countries	Planned economies	Advanced market economies
1970-79	7.3	9.6	6.2
1980-89	5.8	7.0	3.0

Source: Ballance & Sinclair (1983).

[270] Ballance and Sinclair, 1983.

Taking a closer look at a time series for distribution of world value added between different groups of countries (Table 11.5), the picture becomes clearer. The share of developing countries has been growing since the early 1950s, but it has mostly been a question of growth within a small group of most advanced countries: the 13 countries grouped here as semi-industrialized countries count for most of the growth, and the top 8 of the countries have in fact been responsible for about 70 per cent of the total developing countries manufacturing value added by 1980.

One of the main results of this growing industrial strength of the SICs and/or NICs has been a re-evaluation of the concept of the "Third World" as a common - factual and/or politico-ideological - entity. Many of the most advanced developing countries have more in common with the industrialized North than with most African states. This distinction has also affected the theories of industrial development and international industrial relationships. As discussed above, both the general modernization theories based on neoclassical economics and Marxist inspired dependency theories, have been largely swept aside with the growing recognition of the increasing disparities between these countries.[271]

More detailed analysis is needed, since the aggregate figures do not reveal much about the changes. It is always a question of concrete development in real historical settings. A lot of the change occurring is due to technological development and the closing of the technology gap between developing and developed countries. The following chapters make some illustrative excursions into some of the main issues in the evolution of industrialization in developing countries especially from the point of view of technology in development.

Table 11.5 Estimated shares of world MVA

	1938	1948	1953	1963	1970	1975	1978	1980
Advanced market economies	61.0	72.2	72.0	77.3	73.4	67.5	66.8	65.2
of which: - old centres	41.0	58.7	55.2	46.1	39.6	35.7	35.0	33.4
- recently industrialized	13.8	6.5	10.4	22.9	25.8	24.2	24.5	24.3
- others	6.2	6.9	6.4	8.3	8.0	7.6	7.3	7.7
Centrally planned economies	34.5	22.1	23.2	14.6	17.8	22.6	22.9	23.8
Developing countries	4.5	5.7	4.8	8.1	8.8	10.0	10.3	11.0
of which - SICs	3.3	4.0	3.2	5.5	6.0	7.0	7.2	7.7

Definitions of areas:

- Old centres: Belgium, France, Luxembourg, Netherlands, Norway, Sweden, UK, USA, Germany/FRG.
- Recently industrialized: Greece, Ireland, Israel, Italy, Japan, Portugal.
- SICs (semi-industrialized countries): Argentina, Brazil, Colombia, Egypt, Hong Kong, India, Malaysia, Mexico, Philippines, Singapore, Korea, Thailand, Turkey.

Source: Ballance & Sinclair (1983).

271 Harris, 1986.

Industry in developing countries has been mainly labour intensive manufacturing, but the product mix began to diversify significantly in the late 1970s, with some countries achieving notable gains in electronics related products and certain other categories of non-electrical machinery (agricultural and textile machinery, machine tools). The growth in these sectors has been dominated by the four NICs (Taiwan, Korea, Hong Kong and Singapore), but both in garments and electronics some other countries, such as Malaysia, Philippines and Thailand, have made important progress as well.

The main markets for these developing country products have been in the developed countries. In some product categories these countries have been very dependent upon retailing access to OECD markets, for example, Mauritian exports to the US and the EC. During the 1970s policies in many developing countries were drafted in the direction of a wider product mix aimed at OECD markets. In developed countries this has led to counteractions, pressured especially by leading domestic firms. The consequence has been quota limits and raised levels of tariffs for developing country products. It became increasingly difficult to sustain the high rates of export expansion, quite apart from the problems posed by technological development.

The most important industrial sectors from the point of view of the present study, technological development and especially new, micro-electronically controlled manufacturing technologies are:

(a) Electronics - computers, consumer electronics and semiconductors. This sector is at the heart of the new technological paradigm. Semiconductor assembly has been one of the main fields for multinationals off-shore assembly and in consumer electronics and computers many domestic developing country firms have shown success.

(b) Machines, machine tools and other metal products, mechanical and engineering industry. These sectors, producing the capital goods for other sectors form - together with some parts of electronics - the actual core of technologically dynamic industry which becomes a focus for learning curve benefits, and acts as a prime diffusion factor in spreading new technology through industry.

(c) Textiles and garments industry. This sector is the most typical branch for manufacturing based on cheap labour resources. The production technology shows somewhat slower change in manufacturing technologies.

(d) Vehicles are, so far, the manufacturing sector where advanced flexible automation technologies are used most widely. There is a quite extensive vehicle production capacity in many developing countries, and although, for example, cars are mainly produced for domestic markets, some NICs have shown quite remarkable success in exporting vehicles (for example, the Republic of Korea).

The developments in garments and textiles are discussed in detail in Chapters 15 and 16. The other sectors will be dealt with in Chapter 18.

12. Developing Countries: Industrial and Technology Policy Issues

African countries have typically - regardless of their political system and ideological emphasis - a rather centralized system for long term policy planning. This even applies for the most market economy oriented case country in our study - Mauritius - with its quite comprehensive three year national development plans. The countries usually have national plans for five year periods and sometimes specific longer term development plans. In the newly independent Namibia, the planning organization is only now being established.

The main policy focus is on long and medium term targets. The long term policy is, however, only partially achieved. There are often quite drastic shifts both in focal sectors and targets for development from one plan to another. In addition to this, the five year plans are not always in line with either the longer term development programs or the actual short term policies carried out. This is documented for example by the contradictions in the Tanzanian five year plans and longer term development programs.[272]

12.1 Basic Problems of Policy Making in African Countries

A frequent comment on policy implementation in most countries visited was that in reality the governmental policy making is guided by short term considerations without deeper consideration of a longer time span and more sustaining development. The general rhetoric in planning documents is often far from the reality of policy execution.

There are two basic explanations for the weakness in the practice of long term policy making. Both themes came up constantly in discussion with policy makers in the countries visited:

(1) The dependent nature of local economies and their consequent heavy integration in the international system.

(2) Limited domestic resources, in terms of finances and/or human skills and expertise.

To a large extent these are both facts: the economies in the countries are - to a varying extent, of course, - quite dependent on international capital and trade connections. In consequence, autonomy in local decision making is reduced and the scope for actual policy implementation is limited. The situation has been worsened by the deepening economic crises which have made it necessary for the countries to borrow ever more heavily from foreign countries under progressively more unfavourable terms. This has again weakened the level of local autonomous decision making. This means that the environment for policy making has been weak and has worsened over time. With limited control over the material and economic base, there can hardly be independent local decision making by the national governments.

On the other hand, views on "dependency" have lately changed somewhat. Countries that used to be more or less hostile to foreign capital - Tanzania, for example - are becoming more positive regarding joint ventures or more direct types of foreign investment. In other countries (Kenya etc.), it is a more central problem to keep foreign investors in the country by introducing new policy measures making it easier to repatriate profits and making import regulations for export production more flexible. Kenya is also trying to follow the example of Mauritius by

[272] Mlawa, 1990.

establishing tax free export producing zones. These aspects in policy do not, of course, fully counteract the restrictions on autonomy in policy formulation.

From the technology policy point of view the question arises as to what extent policy makers and planners in government appreciate that policy aimed at technological renewal can in fact be used as an instrument to achieve and consolidate autonomy in local decision making for economic self reliance and national development. This theme will be taken under more detailed discussion later in the chapter.

The unavailability of certain resources is also quite significant when considering financing such policies. In relation to skills, education and expertise, the picture is multifaceted. Especially from the technology policy point of view, skills, technological and managerial capability are crucial for sustained development. In most of the countries studied, there does not appear to be an absolute lack of people with higher university degrees. It is more often a question of the composition of skills - defining what skills are really needed for techno-economic development. Also, lower levels of education may be suffering at the expense of higher levels in certain countries, and not only in Africa. For example, in Brazil 70 per cent of the educational budget goes to the university sector.

The problems in skill composition relate to the national training and education systems, which are considered in detail in section 13.4.

12.2 Industrial Policy and Manufacturing Development

Industrial development has been central in almost all African development plans at least up to the early 1980s. And, of course, industrial development has been extensively examined in mainstream analyses and theoretical insights of the development literature. However, in many recent documents, the role of manufacturing has played a minor, if any, role. This applies especially to World Bank studies.[273] Even in national development plans the role of industry has been less emphasized lately than a decade ago. Agriculture is again being given the role of the sector with most potential in many developing countries.

The total MVA of manufacturing in all Sub-Saharan Africa (Nigeria excluded) came, in the mid 1980s' up to the level of Indonesia, Turkey or Finland. Between 1965 and 1985 the ratio of MVA to GDP for countries in Sub-Saharan Africa (SSA) has remained at a level of about 10 per cent, while it has risen from an average of 20 per cent to 30 per cent for all developing countries (World Bank 1988). This means that African industrial development has fallen back in relation to other developing countries.

However, the decline began in the 1970s and it was only in the 1980s that the growth of MVA fell dramatically - in the whole SSA area to an annual average of 0.6 per cent between 1980-1987 from an average of 4.9 per cent in the 1970s.

There have of course been important differences in performance trends. From 1965 to 1987 the combined MVA of Cameroon, Côte d'Ivoire, Ghana, Kenya, Nigeria, Zambia and Zimbabwe rose from 31 per cent to 66 per cent of the total MVA of SSA.[274]

[273] World Bank (1989a and 1989b).

[274] Riddell, 1990.

What then could be the main causes for the varying performance? Are there any clear policy related issues that could explain the success of a very few countries in the region?

The predominant source for manufacturing growth in all SSA countries has been domestic demand. This - as well as analyses of interlinkages between different sub-sectors[275] - suggests that a major factor behind growth has been the existence of an environment conducive to steady expansion or growth outside the sector itself.

However, remarkable national variances exist. In Kenya as well as in Botswana and Zambia the role and influence of management has been crucial in explaining short-term success but a more long term failure to sustain industrial expansion. In Kenya the shortage of engineers and technicians has been a major cause of the failure to expand the industrial base[276]. Yet for both Kenya and Zimbabwe, good production engineers in the textile sub-sector have been a major factor in creating international competitiveness.

In Kenya, and some other countries, pressures to expand the manufacturing sector too rapidly in spite of the inadequate domestic skills and markets and an unreliable supply of inputs led to an uncoordinated establishment of enterprises and a number of substantial industrial failures, often concealed.[277]

One conclusion from all the different examples is: a complexity of factors other than broad macroeconomic policies and incentives have played a crucial role in both restructuring the expansion or deepening of manufacturing, and has constrained development.

Import substitution has been a main policy target in most countries in the area. The main ingredients for success, where import substitution has succeeded and even led to a more export promotion type of policy focus, may be summarized as follows:[278]

- rather heavy government support for industrial promotion and expansion,
- a sustained period without balance-of-payments problems;
- a long period of overall growth and continued diversification in the rest of the economy;
- a fairly developed and efficiently operating supporting physical, transport and financial infrastructure;
- a developed capital market;
- high levels of local management and engineering skills, knowledge of production processes and ability to adapt machinery to local conditions;
- international confidence in the economy leading to inflows of foreign investment and technology;
- trade agreements which ensured relatively captive neighbouring and large markets for goods;
- tariffs and quantitative restrictions which provided protection to newly established firms;

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[275] Riddell, 1989.

[276] Coughlin and Ikiara, 1988.

[277] Coughlin and Ikiara, 1988.

[278] Riddell, 1990.

- and, in the case of some firms, the payment of subsidies.

In the case of Zimbabwe, success in import-substituting industrialization was the convergence of many supportive elements for long periods of time, together with the ability of both the government and manufacturers to adapt as circumstances, internal and externally induced, changed.

Of the countries studied in detail from this report, Mauritius came nearest to meeting these conditions. Highlighted by many international agencies (World Bank, UNIDO) as a recent success story, and a model for other African countries, Mauritius has seen unemployment cut from 27 per cent in 1983 to less than 2 per cent in 1990.

The official Per Capita Income (PCI) of US$1,777 in 1989, is estimated to have risen in the following two years and to be approximately $2100 in 1991. At this level Mauritius has a PCI approximately the same as Brazil - which possesses a GNP in the top ten of the world.

Much of the success of Mauritius in reducing unemployment and raising PCI has centred on policies of export promotion rather than import substitution. The small population does not give much scope for any significant increase in domestic demand. Strong growth has occurred over an approximate seven year period as a result of policies to attract manufacturing industry to the country.

A major contribution in this context has been the clothing industry. For example, 81 per cent of employment in the manufacturing sector in the Export Processing Zone is in wearing apparel - with knitwear representing almost half of this. Mauritius is, in fact, the third largest exporter of knitwear in the World.[279]

In order to improve value added, on a national basis, the textile industry has been strongly expanded recently and one highly automated company we visited was in a position to supply half of the textile requirement for the whole of the Mauritius clothing industry.

However, most SSA countries have continued to pursue import-substituting industrialization with little success and little development has occurred in recent years.

In the mid-1980s, almost exactly half of manufacturing in SSA was concentrated in the food, beverages, textile and clothing branches, only 8 per cent in chemicals and 10 per cent in the manufacture of machinery and transport equipment. Little structural change has taken place in the post-independence period. This is also shown in the "P/AC" ratio (production per apparent consumption, Table 12.1): in many product groups, the ratio has actually gone down since the 1970s. Plenty of scope is left for further import substitution in the whole SSA area.[280]

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[279] Mauritius Export Directory, 1989/90.

[280] Riddell, 1990.

Table 12.1 Production as a percentage of apparent consumption, 1973-75 to 1981-83, various products

Selected products	Share of SSA countries in the sample (per cent)		Production/apparent consumption (per cent)	
	1973-75	1981-83	1973-75	1981-83
Milk/Cream	22	11	36	26
Butter	74	68	82	64
Vegetable oil	99	99	110	90
Cotton woven fabric	73	79	86	91
Footwear	66	61	93	106
Soap	48	71	91	90
Cement	92	90	79	74
Nitrogenous fertilizer	98	99	18	13
Phosphatic fertilizer	92	99	26	20
Pig Iron	96	86	10	11
Angles, shapes & sections	58	44	15	19

Source: Riddell (1990).

With regards to exports, there has been an absolute decline in manufactured exports in fixed price terms for a majority of countries in the area, even for the above mentioned "successful" cases, Botswana and Mauritius being the only real exceptions. The main reason for this is that manufacturing industry in SSA is not internationally competitive.[281] It never was - and has become ever more high-cost over the past 20-30 years due to rising levels of protection, persistently overvalued exchange rates and quantitative restrictions placed on competing imports.

Quite obvious policy conclusions from this are: priority should be given to reducing tariffs, eliminating quantitative restrictions and ensuring that there is a far closer alignment between nominal and real exchange rates. However, this is not enough. Until the mid to late 1980s little effort was put into promoting manufacturing exports, especially to destinations outside SSA. The target of manufacturing was to supply goods predominantly for the domestic and regional markets in the attempt to replace imports and hence reduce the overall import bill.

This is quite true for most of the SSA countries though notable exceptions exist. Kenya, Zimbabwe and Mauritius have, since the mid 1980s, seen an expansion of non-traditional manufacturing exports as a result of explicit export promotion policies and the establishment or extension of export incentives.

Botswana is another exception, its success in manufacturing exports has been predominantly due to the overall - and open - trade and tariff policies. The same is true for Mauritius as well. This liberal policy does not necessarily fit well for the other SSA countries. In Botswana and Mauritius there has always been a 'climate' for exporting and entrepreneurship. Their non-traditional exports mainly comprise a small variety of goods, but not even Botswana has managed to break out to wider markets for manufactured exports. Less than 5 per cent of

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[281] Riddell, 1990.

the non-beef manufactured exports of Botswana go outside Zimbabwe and South Africa. Mauritius has succeeded to a much greater extent in selling into developed country markets.

Would the liberal, non-interventionist policy, recommended, for example, by the World Bank, create more domestic competition? Could it remove the power and control of large firms in particular industrial sub-sectors by encouraging competition and lead to rapid expansion of manufactured exports? Recent cross-sectional evidence supports the view that such an approach would actually be counter-productive (Jebuni et al., 1988). Botswana's experience would tend to confirm that a liberal trade and tariff regime is inadequate to induce the creation of a strong manufacturing sector capable of competing internationally.

Neither the non-interventionist policy nor the "industrialize at all costs" approach seem to be appropriate in the SSA countries. Industrial development can only be furthered by a type of intervention which is conscious of the need to have more industry and the need to encourage more efficient industry. One test for this growing efficiency is a growth in the number of internationally competitive products manufactured.

There is a need for a more complex range of policies aimed at raising productive efficiency, into which a set of broad macroeconomic policies need to be placed. A package of factors which would include a number of directly interventionist initiatives, might include the following: more appropriate machinery, better management capabilities and techniques, expanded research and technological capabilities, innovative ways of increasing labour productivity, systematic attempts to enter new non-domestic markets with higher quality products packaged more attractively, attempts to reduce comparative transport disadvantages and the provision or extension of export credit guarantees and facilities to minimize foreign-exchange risks.[282]

The experiences from policies towards manufacturing from at least Kenya and Zimbabwe (as well as Botswana and Zambia) in the 1990s point to the following.[283]

- factors other than price play a major role in determining the extreme variations in efficiency occurring within different industrial sub-sectors, in particular the role of management, machine design and engineering skills play a critical role in explaining these differences;
- sustained manufactured exports require far more than short-run cost advantages;
- management and machinery choice questions are vital to the creation of viable industries;
- sheltered regional markets can assist the drive to create efficient manufacturing units;
- the development of manufacturing depends critically upon the presence and promotion of an adequate base of domestic skills;

[282] Caulkin, 1989; UNIDO, 1989; Riddell, 1990.

[283] Riddell, 1990.

- sustained import substitution and the development of linkages between sub-sectors of manufacturing and between manufacturing and other productive sectors are unlikely to be developed without recourse to specific incentives and industrial promotion activities which need at least medium-term financing;

- a liberal trade regime is not a sufficient condition for efficient manufacturing production.

To this list of criteria can be added that of quality. In an increasingly competitive world the role of quality in products has increased and will continue to increase in importance. In order to maintain or improve exports to other countries, particularly the developed world, quality of products will rank at least beside price factors.

For example, Mauritius exports the vast majority of its manufactured goods to the European Community or the United States. One way it can increase the value of its exports is by moving up-market into "haute couture" clothing. Both policy makers and companies are aware of this and making the necessary adjustments.

It has been suggested that African countries should actually reject both the old import substitution approach to industrialization as well as the market determined export oriented approach in favour of a three-pronged approach to industrialization. Policies to promote the expansion of non-traditional manufactured exports, and a more systematic approach to further import substitution, need to be implemented in conjunction with policies which seek to raise the efficiency of existing manufacturing enterprises. Such an approach would need to be sensitive to market signals, but not shunning either the explicit promotion of industry or interventionist policies to enhance the expansion of manufacturing industry and the furthering of inter-linkages with other sub-sectors of the economy.[284]

This kind of policy, one that seeks deliberately to expand rather than to lead to the contraction of the industrial base provides a far more politically attractive future than those promoted by the international institutes in the 1980s. There is no doubt that the World Banks policies for industry in SSA have met with stiff resistance in many countries, thus raising the question of their feasibility. For example in Nigeria, Kenya and Zimbabwe opposition to industrial policies based on openness and liberalization has either delayed or led to the watering down of such policies and proposals.

In the kind of policy described above, foreign aid resources could play an important part in assisting the promotion, expansion and restructuring of the manufacturing sector. Examples could include the following:[285]

- funding and perhaps helping to execute sectoral and firm-based studies of inefficiencies, particularly of intra-firm differences;

- helping to establish training assistance programs for manufacturing;

- assisting in expanding the technical skills base of the sector;

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[284] Riddell, 1990.

[285] Riddell, 1990.

- identifying weaknesses in management and entrepreneurial skills and providing both stop-gap replacement and the training of indigenous staff;

- providing help in building up a domestic competence to assess reinvestment needs and appropriate machinery purchase;

- assisting in promoting and sustaining manufacturing export programs including pinpointing gaps in product range, product quality and packaging;

- monitoring current and anticipated trends in world trade in manufactures;

- encouraging the more rapid inflow of appropriate private foreign investment into the manufacturing sector in SSA.

In addition to these specific industrial policy measures, financial and trade policies are important for industrial development. In the case study countries, the interviewed policy makers' complaint focused constantly on problems related to import and export regulation, and foreign currency allocation and payment arrangements. Import regulation on many necessary intermediate goods, raw materials and modern machinery proved out to be especially problematic in Kenya. For example in respect of computers, the problem relates back to the outdated UNCTAD classifications of trading goods, on which the national import restrictions and customs regulations are based. Computers and much other equipment necessary for modern production are classified within categories with very high import tariffs.

12.3 Technology Policy Objectives in Developing Countries

The experience of industrial development in the 1980s and conclusions on policy discussed above quite often pointed towards technology related issues. A deeper look at technology policy objectives and measures is therefore necessary.

It has been suggested that policy makers, particularly in the poorer developing countries, frequently do not recognize the crucial role of technology in the development process. Even when policy statements attesting to its importance have been issued, they are often not backed up by the political commitment necessary to see that the policies are implemented effectively. Existing institutions for science and technology policy are too often either ineffectual or are biased in their activities more towards basic scientific than technological problems. In the latter case there seem to be an assumption that the development of technology will somehow automatically follow from that of science.[286]

Of course, many developing country governments are totally concerned with the short term problems of trying to manage the economy under conditions of severe resource constraints. Thus the development of technology policy has, understandably, received little attention. However, it is a mistake to believe that the severity of the crisis has no effect on technological questions. For example, the lack of foreign exchange restricts some governments' ability to import essential inputs, intermediate goods and spare parts. Because of the lack of these inputs,

[286] Hoffman, 1986.

capacity is underutilized and many plants are virtually closed down. Plus, plants have been established a number of years ago and do not incorporate very sophisticated technologies.[237]

In many cases the spares and intermediate goods necessary to run the plant could have been produced locally. If past policies had been directed towards the systematic development of a capability among local firms and the producer enterprise itself to supply spare parts and inputs, the effects of the crisis would arguably have been somewhat mitigated. Thus what seems to be a problem caused by lack of financial resources is due to the failure of government and managers responsible for industrial develcpment to effectively accumulate human and technological resources.

Government policies towards technology transfer may often be focused on increasing their productive capacity as cheaply and quickly as possible, with little effort put into acquiring technological capacity along with the productive capacity. Recipient firms obtain the hardware and some operator training but rarely acquire the underlying know-how and expertise required to improve and adapt the imported techniques. Many problems arise as a result of this failure to use the technology transfer process as a learning mechanism.

Also, the performance efficiency of an imported plant often declines over time - whereas in developed countries the performance efficiencies normally increase. The difference between the two situations is caused almost entirely by the lack of an indigenous, in-plant technical change capacity. By not striving to maximize the learning component of the transfer process, the countries are missing enormous opportunities to develop technical change related capabilities to improve the efficiency of existing plants. In addition to this, they are also losing the possibility of participating in design and engineering, in the local fabrication of plant and equipment and often, particularly in the poorer countries, to develop managerial capabilities.

What is particularly important here is the failure to develop a "design-consciousness". Without this many companies - and countries - will remain as "screwdriver" based, ie. they will not create own products, but will assemble or perhaps license goods designed in the developed countries, with consequent implications for less value-added earnings on products.

The importance of design and re-design was noted in chapter 8. An example from Mauritius may highlight the importance of these factors:

A structural engineering company was awarded a contract in Mauritius. They had the fabrication capabilities, but the torques and stresses implicit in the final constructions were beyond their design capabilities.

A French engineering company carried out the design work and took a large fee for doing so. By the time the project was completed, the consultancy fee - together with the labour and material costs - had taken up almost the whole contract fee. What had been a potentially lucrative contract now merely broke even.

The point of this story is that with a relatively low cost CAD system and appropriate software package - together with a skilled operator - the project could have been highly profitable for the company. Not only this, but with such a system in place this could create demand for the company as the service they provide increases overall demand and profitability.

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[237] Hoffman, 1986.

Governments in some developing countries have adopted a great variety of technology related policy measures in their efforts to industrialize. It is hard to draw any simple conclusions or argue for straightforward causal relations between the actual development and the prevailing policy. Only in a few developing countries have industrial and technology policies been clearly formulated and documented. This seems to be particularly true regarding the introduction and diffusion of new technology into the countries. The more coherent policy efforts, which are anyway few, concentrate on the development of the electronics sector and to a lesser extent on the use of computers or on the information technology sector. Singapore, Malaysia and India have, however, made some efforts in this field.

It is perhaps only in some of the most successful newly industrialized economies - the East Asian NICs and a few Latin American countries - where the governments have formulated long range programs to support technological development.

The technology policy approaches used in development can be categorized into four types (Table 12.2).[288] The policies adopted in African countries does not fit too well with any of the categories. They mainly appear to follow the technology dependency type, even though the formal targets are more in line with the technological self-reliance type. In many respects, factual policy measures are in practice a mix of laissez faire and dependency types.

Table 12.2 National patterns of technology development policies in developing countries

Type of pattern	Imitative learning type	Technological self-reliance type	Technological dependency type	Laissez-faire type
Countries	Korea, Taiwan, (Japan)	India, China	Some Latin American, Hong Kong, Singapore	Resource abundant developing countries
Technology acquisition mode	Imitation	Indigenous development	Joint ventures	No typical modes
Focus of technological efforts	Active learning for internalization of acquired technology	Acquiring in-house technical capability	Gradual enhancement of local capability and independence	No distinctive policy
Motive of development	Import substitution & export increase, high learning motivation	Indigenous supply for local needs, self supporting nationalism	Utilizing foreign technology	Nothing particular
Role of Government	Regulation of imports, active industrial policy & intervention	Active promotion of basic & applied research	Bureaucratic industry regulation	Laissez faire
Problems encountered	Lack of raw material technology & technical core	Low speed of early technological development	Brain drain & heavy foreign dependency	No comparative edge

Source: Lee et al. (1988).

[288] Lee et al., 1988.

In a developing country context, technology policy has to have quite different objectives than in the developed countries. The possible methods available for technological development are summarized in table 12.3. In countries such as the East African case countries, technological development is mainly taking place through imported technology - international technology transfer - and incremental domestic innovations. The role of formal technology transfer is usually seen as crucial; joint ventures are perhaps not as central as in more industrialized countries. However, in the African context the widespread actions of various donor countries and companies often resemble a joint venture, where the representatives of the recipient firm and the donor tackle the development problems in cooperation.

Table 12.3 Methods of technology development available in developing countries

Performer of technology development	*Method of technology development*			*Origin of resources*
Joint venture	Technology acquisition through establishment of joint venture			Outside resources of firm
Local firm	Adoption of foreign technology (technology transfer)	Formal transfer	Licensing-in Purchasing technology OEM production	
		Non-formal transfer	Subcontracting Purchasing of capital good Imitation	Inside resources of firm
	Indigenous R&D			

Source: Lee et al. (1988).

In a setting like this, the main policy targets are to manage the technology transfer process efficiently and to assimilate the technologies imported - through more formal transfer or through the actions of donors - successfully into the existing structures in a way that could contribute to a sustainable, dynamic technological and economic development.

The three primary objectives for technology policy in East Africa have been given as:

(1) management of the international technology transfer process;
(2) execution and management of technical change;
(3) acquisition and accumulation of technological and managerial capability.[289]

The management of the international technology transfer process is of considerable importance. The process involves a number of closely related processes from the international search for possible technologies to the actual implementation of the new technological system.

[289] Mlawa, 1990.

For example, the system to be transferred has to consist of both physical (machinery, equipment) and human (skills, experience) sides of the technology. The latter is crucial for the local technological and managerial capabilities. The technologies acquired from abroad also have to be appropriate to the recipient economy - appropriate in terms of market size, product type, resource use, etc.

These aspects highlight the phases preceding the definite choice of the technology to be transferred: a detailed international search for, identification and examination of the possible technologies, and alternative sources for them.

The next phase consists of negotiating and bargaining with the chosen suppliers. It is not only a question of acquiring the technologies on the best possible financial terms, but also to the minimization of restrictive clauses and other negative aspects often associated with technology transfer contracts. Substantial supportive services should be included in the contracts as well.

In the final phase the new technological systems have to be relocated and implemented into the existing production systems. This is a complex and time consuming process, ranging from the physical movement of the new technologies to the actual start up of the new facilities, This includes a set of operations from labour force training to various incremental innovations within the factory and elsewhere in the firm needed to adapt the new technologies and the organization into one another.

Here the local availability of supplier support is a central factor. This can take the form of engineers from the supplier company, or local engineers trained to maintain and repair the equipment that is being installed.

Similarly, the availability of spares and components for the equipment is a crucial factor. In every country visited there were examples encountered of delays running into months in repairing vital pieces of production equipment.

Sometimes these delays were consequent upon equipment supplier incompetence or lack of interest, sometimes due to the costs of buying the necessary replacement part, or the charges for bringing engineers from the suppliers - almost always one of the developed countries. Sometimes the problem was due to the bureaucracy involved in simply moving parts/components through the respective country's customs system. In such cases, a vital part was delivered within days by the equipment supplier, but it then took weeks if not months to clear through customs procedures and bureaucracy.

The second major objective of technology policy is the execution and management of technical change on initially imported production techniques. To be productive, the new systems have to be integrated within the production structures of the importing economy. A crucial aspect of this assimilation process is the performance of various technical changes on the original designs of the imported systems. This usually takes place as incremental technical changes, for example, by a series of modifications and alterations.

Through these changes the technical system will become better adapted to the prevailing conditions - skills, material inputs available, market structures etc. - of the recipient economy. As an outcome, the efficiency and productivity of the technical systems will be improved.

Over a long time span, the accumulation of incremental technical change improves the overall performance of the production system; in terms of steady improvements of labour and machine productivity, energy and material usage, reduction of downtime and wastage rates. In addition and complementary to international technology transfer, this kind of technical change is another important way to improve production technology and production efficiency, productivity and competitiveness. Execution and management of incremental technical change is thus a primary objective of technology policies in developed countries.

Efficient management of both the technology transfer process and domestic technical change depends on relevant technological and managerial capabilities in the importing country. The acquisition and accumulation of these capabilities should be a key technology policy objective in the less developed African countries. The technological and managerial capabilities needed in this context can be divided into three main categories: investment, production and innovation capabilities.[290]

Investment capability includes:

(a) project management i.e. the ability to organize - and to oversee - the activities involved in establishing and expanding major production facilities;

(b) project engineering i.e. the ability to provide and synthesize information needed to make technology operational in a particular context;

(c) the ability to coordinate and supervise hardware and software suppliers and civil construction contractors;

(d) a capability for embodying technology in physical capital - abilities for site clearing and preparation, construction, plant erection and the manufacture of machinery and equipment;

(e) start up capabilities - capabilities for staff training, achievement of planned efficiency levels etc.

Production capability consists of production management and production engineering. The former includes the ability to oversee and improve on the operations of established facilities and later the ability to obtain and act on information required to optimize operations.

Innovation capabilities are relevant for creating and carrying out new technical possibilities through to economic practice. This covers the whole area from invention and innovation to subsequent alterations and improvements, modifications and adoption of the production system.

Technological capability lies at the heart of successful technological - and hence industrial and economic - development. It is through mastery of the technical basis of production that many of the increases in production efficiency arise. However, the accumulation of technological capabilities is far from automatic or costless. Capabilities accumulate through experience, experimentation, conscious efforts and allocation of money and people to solve technological problems.[291] The methods used to acquire technological capabilities are many, and a dynamic capability for development can only arise from a multiple mixture of various

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[290] Dahlman et al., 1987.

[291] Dahlman et al., 1987.

methods such as institutionalized education, formalized training programs, learning-by-doing, technological apprenticeship programs, learning-by-researching and reverse engineering.[292]

In the context of a country, the three broad technology policy objectives - management technology transfer, management of technical change and accumulation capabilities - have to be adapted to the local conditions. This pre-supposes the monitoring of basic technological and managerial problems, action programs to solve them, and a relevant institutional set up to carry out and execute the tasks.

12.4 Technology Policy in the Case Countries

Technology policy as an independent policy is rather new - more or less a product of the late 1960s - even in developed countries. Thus it is not surprising that in most African countries explicit technology policy is of a very recent origin. The importance of technology has, however, been noted in various documents in East African countries. For example, a Kenyan government document states:

> "Science and technology provide the knowledge with which to identify development opportunities and to increase growth rates by making capital and labour more productive".[293]

The role of science and technology is characterized in a rather similar fashion in the first five year plan of Zimbabwe, and in a Tanzanian government document on Science and Technology policy:

> "The medium term objective is to develop and strengthen an endogenous scientific and technological capability, in terms of human resources, institutions, information collection and dissemination. This endogenous scientific and technological capability will constitute the basis for the attainment of long term development objectives of science and technology".[294]

> "A realistic Science and Technology policy for Tanzania therefore, must, above all, reflect the key role that science and technology will play in bringing about rapid social and economic development and subsequent realization of self-reliance. Furthermore, a realistic science and technology policy must also not lose sight of the fact that both agricultural and industrial development are very important sectors in the socio-economic development of a nation and that the state of industrialization and productivity in agriculture are a good indication of the level of both technological and economic development".[295]

Many steps towards formulating a policy in relation to acquisition, use, and development of science and technology for economic and social development have been taken. The countries have all established their national councils for Science and Technology policy or corresponding bodies. The organizations have formulated the official targets and institutional frameworks for technology policy. Various research institutes have been established in all the countries. Plenty

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[292] Bell, 1984.

[293] Republic of Kenya, 1986 .

[294] Republic of Zimbabwe, 1986.

[295] United Republic of Tanzania, 1985.

of flaws can, however, be found in the policies: they do not cover the basic objectives of development technology policy.

The main criticisms of East African technology policies - based on official documents of technology policy institutions - can be summarized in five main issues:[296]

(1) Technological needs and problems in the economy are discussed inadequately. A logical starting point for formulating policy is the identification of the technological problems the economy faces. However, the factual techno-economic problems have not been monitored in the technology policy documents, or it has been done on a very superficial level only.

Even in a country like Zimbabwe, where the needs for technological renewal have been studied, the results of the studies have not been used for policy and planning purposes. The need for technology policy was usually based on truisms about the importance of technology, on very general macro economic considerations and on broad sectoral objectives.

(2) The linkage between technology and development is understood poorly and the theory on the relations between technology and development on which technology policies in these countries are based is particularly weak.[297]

Criticism of Kenyan policy can be well generalized to the other East African countries. The policy documents have no informed discussion on the main sources of technology, on technology transfer and development, on the role of technology in economic development or on what needs to be done in order to efficiently manage the process of technology transfer. There are no considerations of the need for developing skills, expertise, and institutions. No discussion whatsoever is carried out about what might happen to the imported technical systems after they have been installed, or on the effects of technical changes on improved manufacturing performance, e.g. on unit costs, product quality or production reliability. All of these are factors which, as we saw in the earlier chapter on developed country policies, were important for technological success.

The assumptions of prevailing macro economic theory are a partial explanation for this. The economic policies in East African countries are based on conventional economic thought which gives technology a very limited role. It does not offer any tools for a deeper analysis of technology in society. Thus recognition of the high importance of technology for development takes the form of rather superficial statements based on a very vague understanding of technological development.[298] This should come as no surprise, since even developed countries have only relatively recently focused attention on technical change as a prime mover of economic development.

(3) No clear priorities have been developed for technology policy objectives. In addition to the ad hoc manner in conceiving policy objectives, there is also an obvious lack of a clear sequence of the objectives outlined. This is especially evident in the Tanzanian case: both general and sectoral objectives are simply

[296] Komba, 1990; Mlawa, 1990; Mlawa and Sheya, 1990; Juma, 1990 and Juma et al., 1991.

[297] Mlawa, 1990.

[298] Juma, 1991 and Mlawa, 1990.

listed without any order of importance, as targets of equal weight.[299] In a country with scarce resources prioritizing objectives would be even more necessary than in more affluent countries.

(4) Programs for concrete action are missing. Based on poor monitoring of technological problems, vague theory and unclear, unsequenced policy objectives mean it is not easy to formulate clear action programs. Technology policies in Kenya, Tanzania, Zambia and Zimbabwe have been described as badly operationalized with no real action programs generated.[300] Policy documents concentrate on broad statements like 'there is a need to control the technology transfer' with no concrete implications on why and how to do it.

For example, when discussing the priorities and action programs for technology transfer, the basic Tanzanian technology policy document simply states:

> "Government may, from time to time, identify and notify such areas of national priority in respect of which procedures would be simplified to ensure timely acquisition of the required technology".[301]

The lack of an action program limits the usefulness of the policy documents and puts into question the feasibility operationability of technology policy.

(5) The institutional structure is inappropriate. Many institutions for Science and Technology policy have in fact been established in East Africa during the last two decades. However, because of the poor understanding of the linkage between technology and development, the institutional structures are unsatisfactory.

The following weaknesses became evident from the interviews with researchers and policy makers in Kenya, Tanzania, Zimbabwe, Ethiopia, Namibia and Mauritius. The findings are supported by the observations of Mlawa (1990) and Juma et al. (1991):

(a) There are too many scientific institutions in relation to the technological ones. This institutional set up reflects a more general bias of East African science, technology and research policies. Too little concern is given to serious technological study, technical training and education, while more basic scientific research and higher scientific education is given priority in allocating scarce resources. As noted earlier this is also true for Brazil.

The scientific bias on research is contradictory to the logic of technological development in the East African countries where most technological development takes place through minor changes and incremental innovations. This does not benefit from highly specialized talents and basic research. It needs considerably more general technical assistance, basic technical capabilities, and the overall mastery of all the technical and economic aspects of the production process. The problem is accentuated by the educational systems emphasis more

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299 Mlawa and Sheya, 1990.

300 Mlawa, 1990.

301 United Republic of Tanzania, 1985.

on general arts than technical skills. The educational issues will be discussed in more detail in chapter 13.

The reality of these problems were confirmed by the case companies visited. Their technological problems were by no means of a scientific or theoretical nature. They were mostly lacking the everyday capabilities for technology and production management and engineering ranging from shop floor to higher management. These kinds of activities need a different set of supportive institutions than those currently existing in most Eastern African countries.

(b) The research institutes often deal with issues that have very limited relevance to the technology policy problems of the country. In most Tanzanian research institutions it has been noted that:

> "An enormous amount of scientific knowledge - mostly about behaviour of insects, animals, plants etc. - has been generated. Yet the transformation of such plant and animal entomological scientific knowledge and information has not been a major concern of many such local 'technology development' institutions".[302]

The point made here is that even very basic research in biological and natural sciences could be turned into technological practice. Biotechnology developments could actually offer a wide area of applications to the African countries. Biotechnology is more knowledge than capital intensive, and the African countries have an impressive nature supplying the genetic and other biological raw materials. The possibilities of biotechnological development for Africa although of extreme interest and offering tremendous possibilities is not a subject of this study, but is discussed in detail by, for example, Juma (1989).

(c) The focus of activities in most technology policy institutions seems to be on controlling activities. For example, the Tanzanian National Centre for Technology Transfer, a recently established institution, has as its broad objective to monitor and control international technology transfer. The need to handle the transfer process is urgent, but the objectives of the Centre are almost solely bureaucratic efforts such as controlling, venting and registering transfer contracts. However, what efficient management of the transfer process needs is the development of relevant skills and expertise for the efficient handling of the various tasks and decisions at all the stages within the complex transfer process, not the creation of bureaucratic institutions to scrutinize transactions. The poor results of creating centralized administrative institutions to manage the problems of international technology transfer have already been well documented e.g. in the Latin American context.[303]

(d) The objectives of institutions often overlap: there is no coordination, nor clear division of tasks, nor cooperative directives for the organizations, which leads to a waste of resources. For example, the main function of most "technology development institutions" in Tanzania seems to be to carry out and coordinate scientific research work and provide consultancy and advice to the Government on matters related to industrial development and management. The objectives

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302 Mlawa, 1990.

303 Camp and Mann, 1983.

of the institutions are, as a rule, described very broadly and no real division of tasks exists.

This problem has been noticed in some official policy documents. For example, the Zambian development plan states:

"The research funding and administrative arrangement through individual ministries of Government or managements of individual parastatal organizations without reference to overall national research requirements, has led to uncoordinated national research activity.... In some cases, especially in the rural sector, this has led to undesirable duplication of effort and spread of limited resources".[304]

The shortcomings of East African technology policies have been summarized as follows: if the theory of science, technology and development is weak, technology policy based on the theory cannot be expected to be anything other than unclear, ad hoc, and thus difficult to operationalize. Science and technology policy has usually too high and too scientific targets, it is irrelevant to real economic and social problems and the conversion of research results into economic reality has not been thoroughly thought through.[305]

Technology policy seems to be considered in a rather subordinate role in the countries under study. In spite of all the emphasis in official documents on the importance of technology, the actual economic policy seems to ignore technology. It is usually seen more as a creator of unemployment than a possible generator of development and economic renewal. In some countries, more policy measures against than for technological development may have been introduced. The strict import regulations and high tariffs on computer hardware imposed by Kenya are good examples of this. The attitude originates from misconceptions on the effects and possibilities of computer technology, and basically, on poor understanding of the role of technology in economic development.

Perhaps the one exception to this is Mauritius. Policies towards new technology are generally favourable in both government and company circles; in terms of encouraging its adoption via new companies and within existing companies.

However, even here there are problems. For example, although wishing to encourage the entry of new high technology industry in Mauritius, there are few examples of specific support programs, either in terms of diffusion of knowledge about technologies, e.g. CAD, NCMT, or specific purchase support programs.

A policy of establishing a "drop-in" site which would contain several CAD systems or several NCMT, for a demonstration of their potential might reap significant gains in terms of upgrading their diffusion.

Such a site could be an "off the high street" one in the capital Port Louis, or Curepipe. Given that the island is a small one, distance would not be a major factor preventing people from visiting; and it is possible that the suppliers of such equipment would provide the equipment free or on-loan if they saw the potential for future sales. The latter could, incidentally, also form the basis of an approach to suppliers by the educational institutions of

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[304] Republic of Zambia, 1989.

[305] Mlawa, 1990.

African countries, since this method of securing new technology is quite widespread in developed countries.

12.5 The Need for a Systemic Technology Policy

The resources of East African countries are very scarce. This means that they have to identify a few systemic technology policy measures that can be used to stimulate and promote the development of indigenous technological capability and to manage efficiently the international technology transfer and adaptation process. Such measures are policy interventions which have the capacity to achieve systemic gains by reorganizing the economic system as well as the institutional set up with minimal investment, administrative requirements, staff and infrastructure.

The main factors behind systemic technology policy measures are information flow, technical content and institutional networking. This kind of approach differs from more conventional policy formulation strategies in the sense that it utilizes the synergistic links between sectors. It is a systems approach instead of relying on linear causal relations.[306]

Technology policy formulation has to be closely linked to prevailing trends in international techno-economic development and the related institutional arrangements. The current emphasis on technology as a tool for international competitiveness makes it increasingly difficult for most African countries to acquire emerging technologies. Although some of the experiences of other countries may be relevant to Africa, it is important to place these in the context of emerging design trends and institutional arrangements relating to access to technology and the related information.

Conventional technology policy formulation has been characterized by the enactment or publication of distinct laws or policy papers. The situation is changing, and policy formulation has to become more a dynamic process guided by continuous review, analysis and research conducted by a wide range of institutions. The process requires continuous research and monitoring of both national and international trends in technology.

Table 12.4 provides a checklist of policy measures used in different countries to facilitate technological development. The feasibility of these measures depends largely on the current technological level of the country, existing institutional arrangements and their flexibility, and on the internal capacity to implement such policies. Not all measures identified on the list are transferable to the African context. For example, measures related to direct financial assistance for R&D may not be suitable, especially given the current pressure on the African countries to reduce their public expenditure and rationalize public sector operations. Though as we saw in chapter 10 this type of support was large, and growing, in the developed countries.

One of the main problems of technology policy in Africa is the absence of experience in this field. The checklist of policy options is too long, and therefore a country usually has to start with a few policy measures likely to stimulate supplementary initiatives in related areas. In this respect, a few policy measures which are linked to the local generation of technological and managerial capability would be a vital starting point. In addition, supplementary measures need to be introduced to deal with the external environment, especially in the case of international technology transfer.

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[306] For a more detailed discussion, see Juma, 1990 and Juma et al., 1991.

Table 12.4 Governmental technology and innovation policy measures

Measures	Examples
Procurement	Central and local government purchases and contracts, public corporations, R&D contracts, prototype purchases, setting design criteria, choice of priority for technologies
International trade	Trade agreements, technology acquisition agreements, tariffs, foreign exchange regulations, export compensation, import subsidies, licensing
Public enterprise	Innovation by publicly owned industries, setting up of new industries, pioneering use of new techniques by public corporations, participating in private enterprises
Scientific and technical	Research laboratories, support of research associations, learned societies, professional associations, research grants
Education	General education, universities, technical education, retraining
Information	Information networks and centres, libraries, advisory and consulting services, databases, technology monitoring, liaison services, public awareness
Financial	Grants, loans, subsidies, financial sharing arrangements, venture capital, provision of equipment, buildings or services, loan guarantees, duty and customs remissions, export credits
Taxation	Company, personal, indirect and payroll taxation, tax allowances, tax exemption for private foundations
Legal and regulatory	Patents, utility models, plant breeders rights, environmental and health regulations, contractual arrangements, conventions, inspectorates, monopoly regulations
Political	Planning, regional policies, honours or awards for innovation, encouragement of mergers or consortia, public consultation, creation of new institutions, setting up of research funds, initiating legal reforms
Public services	Purchases, maintenance, supervision and innovation in health service, public building, construction, transport, telecommunications, infrastructure
External relations	External aid, technical assistance, local and external training
International relations	Sales organizations, trade and diplomatic missions (science and technology attaches), technical cooperation, research representatives

Source: Juma et al. (1990).

This approach is based on the view that the introduction of a systemic policy measure may redirect the entire institutional terrain towards a more technology driven development and enable the economy to adjust to new technological imperatives. The problem is how to determine the effectiveness of the policy interventions. The following are some possible criteria:[307]

(1) The intervention must be associated with guaranteed or regularly available financial resources.

(2) Resources should not be associated with strict guidelines on returns and profit rates.

(3) The administrative requirements of the policy measures must be simple and easy to translate into technical criteria.

(4) The systemic policy measure must link with a wide range of other complementary policy measures.

Public procurement, foreign exchange management, financing local research, intellectual property protection and institutional collaboration have been identified as the main fields to start developing a systemic policy approach.[308] Measures for technological capability development, all the way from capabilities for developing technology policy formulation to the shop floor capabilities of actual technology implementation and operation should be given very high priority.[309]

To give a wider view of possibilities for a systemic, long-term approach to technology policy, the following subsections highlight the main themes to technology policy in Japan and the Republic of Korea.

12.6 Systemic Technology Policy: the Japanese Example

Japan and the East Asian NICs are usually taken as examples of a successful, technology driven path from underdeveloped to industrialized countries. In the Japanese case - which has to a large extent served as a model to the NICs - the most important features are the long historical perspective, the central role of government, specific firm organization, and various other social (often education-related) innovations.[310]

The historical perspective is crucially important. Features, that are usually related to the Japanese technology and industrial policy of the 1970s were actually there already in the early decades of the 20th century: government aiming actively towards industrial modernization, education seen as a key factor in this, a focus on international transfer of technology and further development of imported technology, keen cooperation between government and large corporations, etc.

The role of government, centred in the role of the Ministry for International Trade and Industry (MITI), is a second important point:

[307] Juma, 1990.

[308] Juma, 1990.

[309] Mlawa, 1990.

[310] Freeman, 1988.

"The not-so-invisible guiding hand of MITI shaped the long-term pattern of structural change in the Japanese economy and this influence was largely exerted on the basis of judgement about the future direction of technical change and the relative importance of various technologies. The central point of interest is that in the immediate post-war period, after an intense debate, Japan specifically rejected a long-term development strategy based on traditional theory of comparative advantage".[311]

This decision was critical in steering Japan to the technology driven path of development.

"Some of these advisors (of MITI) were engineers who had been drawn by the war into the management of public affairs. They were the last people to allow themselves to be guided by the half-light of economic theory. Their instinct was to find a solution for Japan's post-war difficulties on the supply side, in enhanced technical efficiency and innovations in production. They thought in dynamic terms. Their policies were designed to furnish the drive and to raise the finance for an economy that might be created rather than simply to make the best use of the resources then possessed".[312]

Thus MITI started considering a very long term technology policy decades before its western counterparts. MITI saw the promotion of the most advanced technologies with the widest possible long term world market potential as one of its key functions. Technological development was largely based on reverse engineering - assimilating and improving upon imported technology. This involved trying to manufacture a product similar to one already available on the world market but without direct foreign investment or transfer of blue-prints for product and process design. The method had several major consequences for the Japanese system of innovation:

"(1) Japanese management, engineers and workers grew accustomed to thinking of the entire production process as a system and of thinking in an integrated way about product design and process design. This capability to redesign an entire production system has been identified as one of the major sources of Japanese competitive success in industries as diverse as shipbuilding, automobiles and colour television.

(2) Japanese engineers and managers grew accustomed to the idea of using the factory as a laboratory. The work of the R&D department was very closely related to the work of production engineers and process control, and was often almost indistinguishable. The whole enterprise was involved in a learning and development process and many ideas for improving the system came from the shopfloor.

(3) Reverse engineering in such industries as automobiles and machine tools also involved an intimate dialogue between the firm responsible for assembling and marketing the final product and numerous suppliers of components, sub-assemblies, castings, materials and so forth. The habits, attitudes and relationships engendered during this prolonged, joint learning process did much to facilitate the high degree of cooperation with subcontractors which finds expression, for example, in the "just-in-time" system.

(4) The emphasis on high quality of products which is a characteristic of Japanese technology policy also owed much to the experience of reverse engineering. In the 1950s, the first production models, whether in automobiles, TV sets or machine tools, were often of relatively poor quality. A determined effort to overcome these defects led to a widespread acceptance of such social innovations as "qualitycircles" (originally an American

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[311] Freeman, 1988.

[312] Allen 1981, ref. Freeman, 1988.

innovation) and to the development of greatly improved techniques of quality control not simply at the end of the production run but at every stage, including all components from subcontractors".[313]

Comparing the Japanese method of technology transfer to the methods used on the one hand in the Soviet Union, and on the other hand in many developing countries, the Soviet Union was also engaged in large scale development based on imported technology and reverse engineering. However, much of the responsibility for diffusion and development rested with central organizations and institutes. Thus, much of the "technological learning process" took place in the central institutes rather than at enterprise level, and acute problems were experienced in the transfer of technology from the specialized R&D institutes to factory level management.

In developing countries, technology is very often transferred either through subsidiaries of multinational corporations or by importing "turn-key" plants designed and constructed by foreign contractors. Neither of these methods is likely to result in a process of technology accumulation in the relatively passive recipient enterprise.

The third central feature, is the specific firm organization with large conglomerates and vertically integrated groups of companies. This 'Keiretsu' firm organization has a specially important role particularly in relation to technology, finance of long term investment, and world marketing strategies and networks.

"From the standpoint of the firm, by forming or joining a group, it can economize on the transaction costs that it would have incurred if the transaction had been done through the market, and at the same time, it can avoid the scale diseconomies or control loss which would have occurred if it had expanded internally and performed that transaction within the firm".[314]

The final, but not least important feature of the Japanese innovation system, is the education and training related social innovations. It is not only a question of highly qualified research and development personnel - although the number of university trained electrical engineers was already higher in Japan than in the USA by 1973[315] - but of an overall high skill level of labour, based on thorough basic education and continuous further training and education.

There are two remarkable features in the Japanese education and training systems: first, the absolute number of young people acquiring secondary and higher levels of education is among the highest in the world. Second, the scale and quality of industrial training carried out mainly at enterprise level is high. The second feature goes back to the efforts of assimilating foreign technology. For this purpose, some large Japanese firms had extensive high level technical training already before the First World War. In general,:

"The combination of a high level of general education and scientific culture with thorough practical training and frequent up-dating in industry is the basis for flexibility and adaptability in the work-force and high-quality standards. The Japanese system of industrial

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313 Freeman, 1988.

314 Goto 1982, ref. Freeman, 1988.

315 Lemola, 1990.

training is distinguished further by its close integration with product and process innovation. The aim is to acquaint those affected by technical change with the problems that are likely to arise, and give them some understanding of the relationship between various operations in the firm. This again greatly facilitates the horizontal flow of information. Thus the "systems" approach is inculcated at all levels of the work-force and not only at top management level".[316]

The story of Japanese innovation policy highlights the key features of a systemic approach to technological development means: long term targeted development based on capability building, learning by doing and motivated commitment by all the actors involved, from workers in the simplest shop tasks to top management. It requires a coordinated policy on both governmental and enterprise level, but the firms are always the final decision making and responsible parties. At the governmental policy level, it also means the replacement of development based on self-evident ("natural") 'comparative advantages' with more demanding long term development targets based on comparative advantages created by capability building.

12.7 NICs on the Japanese Path: the example of the Republic of Korea

The policies for technological development in East Asian NICs (Republic of Korea, Taiwan Province, Hong Kong, Singapore) are far from straightforward copies of the Japanese pattern, and there are many fundamental differences. None of them has such a long term, uniform policy as Japan. Even the basic conditions differ. For example, unlike Japan, only the Republic of Korea with a population of over 40 million has been able to rely on domestic markets. The case of industrial and technological development in the Republic of Korea can be taken as an illustrative example of the NICs technology policies.

The Republic of Korea is considered by some analysts as the only one among the East Asian NICs that has the manufacturing base to produce high value added products sufficient to sustain high growth rates during the 1990s (Rushing & Brown, 1986). So far, its industrial performance has been quite outstanding. In 1953, agriculture produced some 47 per cent and manufacturing under 9 per cent of the GNP. In 1981 the comparable figures were 16 and 30 per cent.

The structural shift is evident in terms of labour force as well. In two decades, the share of agriculture was halved and the industrial share grew from 9 per cent to 20 per cent (Table 12.5).

Table 12.5 The breakdown of labour force between agriculture and manufacture in the Republic of Korea in 1960 and 1982

Year	Labour force in	
	Agriculture	Manufacture
1960	66 per cent	9 per cent
1982	33 per cent	20 per cent

Source: Rushing & Brown (1986).

[316] Freeman, 1988.

The manufacturing sector has also gone through a transformation: the contribution of heavy and chemical industries to total industrial output, 23 per cent between 1953 and 1955, was 29 per cent from 1960 to 1962 and 42 per cent from 1974 to 1976. The share of the engineering industry in manufacturing value added (Table 12.6) has risen from under 11 per cent in 1960 to over 25 per cent in 1982.[317]

The figures on exports are even more impressive. In the early sixties, the ratio of exports to GNP was only 4 per cent. Twenty years later the ratio had risen to 40 per cent. This means that the growth of exports attained an average rate of 35 per cent a year from 1962 to 1982. During the same period, the share of manufactured goods in exports rose from under 20 per cent to over 90 per cent.

Table 12.6 The share of engineering sector of the Korean manufacturing industry MVA, 1960-1982

Year	Share, per cent
1960	10.7
1963	10.2
1966	14.3
1969	14.0
1975	16.3
1979	24.2
1982	25.3

Source: Jacobsson (1986).

The background to industrialization in Korea

Until 1945 Korea was a part of the Japanese Empire. One effect of this was to introduce modern administration, monetary, railway and education systems. By 1945 about 25 per cent of the population had acquired some formal education.

Between 1910 and 1940 manufacturing output increased on average by 10 per cent per year, and the composition of manufacturing output also changed - light industry (food and textiles) declined as a proportion of the total from 72 per cent to 45 per cent between 1926 and 1939. Exports became important, with about 2/3 of manufacturing output exported, mostly to the rest of the empire.

In 1940 there were about a quarter of million Koreans employed in factories, another couple of million Koreans living in Japan and possibly another million in mainly industrial occupations in Manchuria. In fact - Korea seems not to be a particularly "new" industrial country.

When the war ended, the old business and technical class in Korea either went to Japan or was deprived of their positions in society. Korea lost external markets and raw material imports through the collapse of the imperial trading system. Heavy industry and mining remained in the North part of the country while the Southern administration inherited two

317 Jacobsson, 1986.

thirds of the population, nearly half the arable land, 70 per cent of rice growing areas and much of the light industrial capacity.

After the Korean war the crippled Republic of Korea economy was supported only by massive United States military and civil aid, as well as tight economic controls including protection against imports. The years between 1961 and 1979 were characterized by the "economic miracle" and an increasing export orientation - which was partly due to decreasing United States aid. Export was not an alternative to import substitution. In 1973 the Government introduced the Heavy Industry, and Chemicals Plans.

Since 1979 the government has drawn back from its strategy of creating a heavy industry base - which had created a set of uneconomic industries - and was obliged to begin measures of liberalization. It was partly an attempt to open the country to American imports in return for retaining access to US markets. Pruning was now aimed at concentrating resources on a few key heavy industries (which, however, were not chosen by simple deductions of comparative advantages). The economy had become much more complex than a couple of decades earlier, and it was no longer susceptible to the crude imperatives of public policy.[318] Also the substantial business class evolved during these decades were unwilling to accept governments unilateral definitions of the nation's interest. The building of an independent national economy - albeit, of a special export-oriented kind - now had to give way to an increase in the integration with the world economy.

The development of single industrial sectors in the Republic of Korea

(a) Shipbuilding

In the early 1970s government policies focused on the shipbuilding industry. The aggressive and optimistic plans could not be realized because of the oil crisis. By the early 1980s, the shipbuilding industry was in severe difficulties, though these have now been largely overcome. The most important shipbuilders are Hyundai, Daewoo, Samsung and Korean Shipbuilding.

In 1986 Japan built 5.87 million tons of the total of 7.95 million tons of new ships in the world. According to more recent statistics, (The Association of Japanese Ship Exporters, 1991) the Republic of Korea overtook Japan in the first quarter of 1987 as the largest shipbuilder in the world, receiving orders for 1.04 million tons, while Japan's were for 0.91 millions. The Japanese share of world ship orders (in total 3.44 mt) was 26.5 per cent, while the Korean share reached 30.2 per cent.

In spite of this success, employment has been substantially reduced with a total of 20,000 persons having been displaced in the Korean shipyards. More reductions are anticipated. This indicates that technological advances in the production process as well as continual organizational adaptation has occurred. Particularly so, since the scope of activities in the main shipyards has been further widened, with operations outside shipbuilding, e.g., building "oil boring rigs", steel constructions, and nuclear power stations.

[318] Harris, 1986.

(b) Automobile manufacture

Automobiles have been the latest and most spectacular achievement of Korean export industries. Even as late as 1986, there were doubts about the possibilities of Korean car exports:

> "As the (automobile) market never expanded as rapidly as hoped. And exporting was more difficult than expected. This left the industry in a tight position that was unlikely to improve much before the end of the 1980s".[319]

A recent forecast draws a very different picture: Korean annual vehicle sales are expected to rise to 3.4 millions in 2010, from the level of 977,000 in 1990. The growth rate is higher than in any other country. This would raise the national vehicle fleet from 3,2 millions in 1990 to 24,8 millions in 2010.[320]

Thus, the domestic market is estimated as increasing the demand for Korean made cars dramatically. In the late 1980s exports were far more significant. In 1986 Hyundai exported 160,000 "Excel" cars to the United States.[321] Three years earlier Korean car exports to the US reached a total of 65 cars. At that time, the Republic of Korea was the 20th on the list of world car manufacturers behind, for example, Argentina, Spain and Poland.

Already by 1984 Hyundai had introduced the "Pony" into the Canadian market and 80,000 of them were sold in the first year. It immediately overtook the Japanese in car sales figures and jumped to the top of the list of imported cars.[322]

For 1987, the export expectations of Hyundai were 330,000 of their total output of 610,000 cars. In total the Korean car manufacturers expected to export some 680,000 cars, two-thirds of their total production.[323]

The plans released by the five key auto firms in the second half of 1988 point to an expansion in vehicle production capacity from the late 1988 level of 1.7 million units to around 3.4 million units in 1993 - a doubling of capacity in just five years. Hyundai is planning an increase of 47 per cent, which would give it about 42 per cent of Korea's total output by 1993. Daewoo foresees an expansion which would more than treble the capacity, giving it also about 42 per cent of total South Korean car manufactures.[324]

Hyundai started car making in Korea 19 years ago by assembling cars for Ford. When the company wanted to start the manufacture of domestically designed car types Ford canceled the cooperation. The Japanese company Mitsubishi came in as a new partner, started to

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[319] Woronoff, 1986.

[320] The World Vehicle Market, 1991.

[321] Helsingin Sanomat, 19.7.1987.

[322] Insinööriuutiset, 28.1.87.

[323] Helsingin Sanomat, 19.7.1987.

[324] O'Brien, 1989.

subcontract parts, and also became a co-owner with a 7.5 per cent share of the mainly family owned company.

Two other car manufacturers, Daewoo and Kia, are also aiming at foreign markets. Their export strategies are quite different to Hyundai's. While Hyundai has built its own sales organizations and is marketing the cars under the company name, Daewoo and Kia are focusing on joint operations with American companies. Daewoo is partly owned by General Motors, and its "LeMan" cars will also be sold in the US as Pontiacs. Kia is cooperating with Ford (with a 10 per cent share) and using the Ford sales organization for its "Festiva" cars.

Daewoo's strategy may be the most successful in opposing the protectionist measures taken by the US government. Hyundai, on the other hand, is trying to cope by building an assembly factory in Canada. The factory scheduled full capacity output in 1991 with a capacity of 100,000 cars annually for the North American market. Hyundai is also considering direct investment in the USA.

Daewoo, Hyundai and Kia - which are conglomerates operating in many fields from shipbuilding to electronics - are extremely important for the Korean economy, with their car manufacturing divisions alone accounting for a quarter of the country's GNP. Their car exports are also responsible for a first time ever export surplus in the Korean economy. The Korean surplus in trade with the US was $5.7 billion in the first three quarters of 1986.

Trade with Japan, however, was almost as much in deficit as the trade with US was a surplus. The Korean trade deficit was US$4.6 billion with Japan. Technologically the Korean car industry is quite dependent on Japan. Japanese firms are also the most important parts suppliers for Korean car manufacturers. Conversely, Japan has kept its market strictly closed to Korean cars - only at the beginning of 1991 was a Korean manufactured vehicle, a US licensed military Jeep, imported to Japan. Since the late 1970s there has been a shift towards US components, partly because of the US trade regulations.

The Korean car manufacturers have not been at the leading edge of production technology. In 1987 the president of Hyundai corporation, Chung Se Yung, admitted that their car manufacturing technology is "not at the level of Honda". But an executive of the car factories, H.B. Suh added, that "from the US automobile industry Hyundai has, however, nothing to learn any more".[325] From the early 1990s on, there has been little to learn from the Japanese either, and Hyundai's success has continued.

During the 1980s the Korean car manufacturers did not target the European markets at all. Since 1990 the situation has changed, and Hyundai especially has been aggressively marketing personal cars, now domestically designed models, to the European market. They are hitting the market segments held so far by Japanese cars, but with clearly lower market prices.

(c) Electronics

The Korean "electronics revolution" has been quite extensive, too. Korean companies have plunged into the semiconductor business with assistance from United States companies because Japanese firms refused to cooperate. There are many interesting examples of technological development. For example, the textile company, Kolon International Corporation,

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[325] Helsingin Sanomat, 19.7.1987.

started making TVs and other consumer electronics, and then added cooperation with Fanuc by starting a joint robot-making company in 1983.

Government plans up to 1986 foresaw a fast increase of high technology industries. R&D investments rose rapidly; and Korea is also seeking membership of the OECD. In Daeduck Science Town 11 research institutes have been established employing 3,600 researchers. The Korea Advanced Institute for Science and Technology (KAIST) has 1500 researchers. KAIST is carrying out R&D projects for example in the fields of electronics and industrial automation.

Efforts to develop technology are mainly carried out by local capital, since foreign investors have become more cautious after labour discontent in the early 1980s, with many foreign companies leaving the country. This is particularly true of Japanese companies who feel threatened by Korean competition.[326]

(d) Industrial automation

As Tables 12.7 and 12.8 show Korea shows a very much higher penetration of NCMTs, CAD and robots than many other developing countries with similar industrial development, though it falls behind the OECD countries. The relatively low figure of industrial robots in Table 18.7, however, reveals that the industrial structure in the early 1980s was rather labour intensive.

Table 12.7 Approximate stock of electronically controlled capital goods in some countries, 1981-1983 (units)

Country	Technology		
	CAD	NCMTs	Robots
Argentina	10	350	..
Brazil	15	834	50
FR of Germany	375	42,500	4,800
India	28	378	20
Korea	33	1,344	35
Sweden	208	5,100	1,850
UK	620	25,000	1,753
USA	6,600	102,000	8,000

Source: Edqvist & Jacobsson (1985).

The indicators in Table 12.8 show that the Republic of Korea is at a level more clearly in line with some developed countries, both in the diffusion of CAD and NCMTs.

The diffusion of CAD is very high in the Republic of Korea, with its use mainly being seen as a means of catching up with the industrialized countries. The breakdown of CAD use by sector is given in Table 12.9.

[326] Junne, 1986.

Table 12.8 An indicator of the intensity of use of electronically controlled capital goods - the number of respective technologies divided by the value added in the machinery and transport equipment sector in 1980 (in 1975 prices) - in some countries

Country	Technology		
	CAD	NCMTs	Robots
Argentina	3	103	..
Brazil	1	67	4
FR of Germany	6	658	74
India	8	118	6
Korea	38	804	21
Sweden	33	809	293
UK	32	1,302	91
USA	47	729	57

Source: Edqvist & Jacobsson (1985).

Table 12.9 Areas of application of CAD in the Republic of Korea in August 1984

Area	Systems		Companies	
	No.	per cent	No.	per cent
Shipbuilding	14	22	7	15
Mechanical	12	19	10	21
Electronics	11	17	10	21
Construction	4	6	3	6
Plant Engineering	15	24	10	21
Other (archit, educ etc.)	7	11	7	15
Total	63	99	47	99

Source: Edqvist & Jacobsson (1985).

In spite of the rather good educational system in the Republic of Korea, there is a shortage of skilled personnel, in particular of experienced designers and draughtsmen which has retarded the diffusion of robots especially. Robots are still mainly substitutes for unskilled or semi-skilled labour, which is a further factor slowing the diffusion. Application problems have often been quite severe and local engineering capability does not yet exist to solve common application problems. External help from suppliers is often difficult to obtain when dealing with imported apparatus.

(e) The Korean machine tool industry

In 1982 there were 91 firms registered as metalcutting machine tool makers in the Republic of Korea. Most of them were very small, and firms with less than 200 employees accounted for 43 per cent of the gross output in 1982. The sector employs about 15,000 workers.[327] Domestic production consists of more than 50 types of machine tools (parts included): NC and CNC lathes, machining centres, automatic de-burring and tapping machines,

[327] Jacobsson, 1986.

grinding machines, horizontal boring and milling machines, and precision electrical discharge machines.

Up to the mid-1970s the industry was fairly small and exports were insignificant. In the late 1970s, the industry went through a period of explosive growth. Production rose from US$ 5.2 million in 1971 to US$ 178.4 million in 1984; and only 17 per cent of the total value produced was exported. In 1988 the production figures were up to US$ 597 million, but value of domestic demand was actually much higher.[328] Thus the fast growth of machine tool production has been based on the rapidly growing domestic markets.

In 1988, the domestic demand for machine tools in South Korea was US$ 1189 million. That is clearly more than in other developing countries - twice as much as, for example, in Brazil - but still below the OECD countries, corresponding to about 31 per cent of the Italian and 47 per cent of the German demand. The ratios have, however, changed rapidly. In 1984 Korean relative levels were only 21 per cent of the Italian and 36 per cent of the German.[329]

The first NC machines were produced by Wachon Machinery Works Company in 1977. Programs for NC devices and the relay circuits for control devices were developed in cooperation with the Korean Advanced Institute of Science and Technology (KAIST). Since then, the production and demand for CNC has grown dramatically.[330] Demand was expected to grow to about 490 units by 1988. That would mean a doubling of the market in comparison with 1984. In 1989, however, the stock of NCMTs was still very small, only about 10 per cent of the level in Italy, Germany or the UK.[331]

Table 12.10 Production, trade and size of the local market for CNC lathes in Korea, 1981-1984 (units)

Year	Share of CNC machines in lathe				
	Production	Exports	Imports	Consumption	Total inv. (per cent)
1981	84	46	26	64	37.7
1982	222	138	18	102	21.2
1983	233	65	47	214	28.6
1984	268	127	107	248	41.4

Source: Jacobsson (1986).

The growth since 1984 has been significant. In 1988 Korean NCMT production reached 2119 units.

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[328] UNIDO, 1990b.

[329] UNIDO, 1990b.

[330] Jacobsson, 1988.

[331] UNIDO, 1990b.

"After the mid-1980s, the machine tool industry expanded rapidly aided by the Government long-term development plan. From 1986 to 1989, the Korean industry expanded dramatically and the increase of investment by engineering industries provoked a surge of machine tool consumption while the increase in wages led to an increased demand for factory automation. The domestic production was insufficient to keep up with the surge of demand and imports have represented 50 per cent of apparent consumption in 1988 (30 per cent in the late seventies)".[332]

In 1985 there were five firms producing CNC lathes in Korea. They were Daewoo Heavy Industries Ltd., Tongil Co., Whachon Machinery Works Co., Kia Machine Tool Co., and Korea Heavy Industries Ltd.[333]

In mid-1980 the government provided funds to promote the purchase of domestically-produced machines. The government program was designed to spur investment in plant and equipment on the part of the machinery industry. The government initially allocated $88.9 million of general national investment funds, plus $49.3 million for small- and medium-sized firms, and $65,8 million went to industrial banks for their machinery funds. Another $164.6 million was added later to the program.

In 1981 the government provided a number of incentives to spur investment in machinery including tax credits, R&D assistance, grants and low cost financing. The Korean governments targets for the metalworking machine tool industry in 1986 included production value added at $950 million and exports - including metal forming machinery - totalling $550 million, or 57.9 per cent of production. 60 per cent of the machine tools currently in use in the Republic of Korea are domestically produced.

Explaining the development

In the first phase of accelerated export production in the 1960s the theory of comparative advantage appeared a plausible explanation of the process. Up to the present it might also be applicable to a major part of Korea's exports: textiles, garments, partly electronics. But the most spectacular successes (shipbuilding, steel, and manufactures of steel) are mostly the result of comparative advantages created by governmental decisions and policies, not by free market forces.

In sum: while the backbone of export performance of Korea might be attributable to a genuine comparative advantage, the second generation of growth industries seemed more likely to be the products of government policy. There were problems in both respects. Lower-cost producers affected the basic exports; in less then a decade, China expanded its garment exports so swiftly that it became the fourth largest exporter among developing countries. Koreans have estimated that Chinese wages are 30 per cent to 40 per cent below the Korean level. Also, the new industries directly affected old-established sectors of production in the industrialized countries, evoking protectionism in the richest markets.

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[332] UNIDO, 1990d.

[333] US, 1985.

The main reasons usually given for Korean economic and technological development can be grouped under four headings:[334]

- low wages;
- governmental policy;
- US aid or
- investments of multinational corporations.

(1) Low wages? Since low wages are general in developing countries, the Republic of Korea's advantage is limited. Korean wages were not the lowest in the world at the beginning of their fast growth period, and they have increased faster than in most developing countries - in real terms by over 7 per cent per year since the sixties. However in automobile manufacturing, for instance, the wage level in the Republic of Korea is obviously considerably below the Japanese level, which has given them a real relative advantage in relation to Japan in competition on the American markets.[335]

(2) The interaction of government policy with social factors: a high propensity to work and save? The government created a "free trade" regime for exports. This, with incentives, labour policy, and an exchange rate which much of the time reduced the price of exports and made imports relatively expensive. The Republic of Korea has subsidized exports and redistributed income domestically in order to cheapen exports in a way that might be called "artificial". However, the timing does not completely fit this explanation. Export expansion began in 1959 whereas the policy changes to export growth occurred later. The Republic of Korea did not pursue simple export promotion, and to this day it uses import substitution as a tactic of forcing industrial growth.

(3) US aid? US civil aid was very important in the financing of the infrastructure and education. However, the accelerated growth came later and was partly the result of attempts to cope with declining US aid. It may have been a necessary condition of development, but not the entire one. However, as we have continually emphasized in this report, education and skills and the infrastructure have been crucial to international competition and the time lag may be commensurate with long-term change in these areas.

(4) Investment by MNCs? In fact, the Republic of Korea is not a notable recipient of foreign investment. Foreign investment as a ratio of GNP between 1972 and 1976 in Korea was 5.5, in Brazil 9.6, Colombia 10.6, Taiwan 6.2 and Turkey 10.5. The volume of foreign investment does not correlate with the scale of exports - in 1980, Brazil with the largest volume of foreign investment had exports of $9.2 billion, the Republic of Korea $19.2 billion.

Furthermore, foreign investment followed accelerated growth rather than preceding it. The largest foreign investors by nationality were Japanese companies (with 61 per cent of the total in 1978, 48 per cent in 1984); and their entry came after the normalization of Korean-Japanese relations between the two countries in 1965. There were many small- and medium-

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334 Harris, 1986.

335 Helsingin Sanomat, 19.7.1987.

sized companies for whom one Korean plant was the sole overseas investment of inward investment, and usually these were operated jointly with a Korean partner. The large MNCs were rather limited in this context. In the 1970s and 1980s Korean companies seemed to be replacing some of the largest Japanese operations in the field of electronic goods. Investors from outside the Republic of Korea actually came after growth began and were heavily concentrated in particular fields.

The pioneers in the first half of the sixties were Koreans. In other sectors of key export production at different times - ships, footwear, iron and steel, metal manufacturing, non-metallic minerals, rubber goods, precision instruments, wigs, plywood - there were no foreign companies involved.[336]

It is quite obvious that all the above explanations played some role, but none of them was the effective cause on its own. There was an interaction between a peculiar and temporary set of conditions in Korea and new phases in the external environment: the Republic of Korea was not manipulated from outside, but did exploit changing opportunities.

The "take off" to sustained growth and international importance was not based on any "natural" comparative advantage, even if the advantages were exploited. A key factor in the development model has been, as in Japan, the creation and development of new, dynamic advantages, defined as targets by governmental policy and induced by various policy options, measures and even more straightforward administrative directives. In this, a long term development of capabilities and learning from imported foreign technology have been crucial factors. An important background factor enabling the development path has been the national educational and training system, which largely resembles the Japanese model. US financial aid has also enhanced the development of the educational system.

There are also other important features in the institutional set up contributing to the Korean success. Large conglomerates are the backbone of the economy; the pattern resembles the Japanese Keiretsu-system, but the conglomerates are often both tighter as organizations, and more directed by governmental regulations and directives.

12.8 Mauritius on the NICs' Path?

Both the Japanese and Korean examples emphasize the importance of long term systemic policy based on capability building. There are, however, some background features facilitating the formulation of long term policies, that are important in the NICs but not present in most developing countries. Common features among the developing countries that have had some success in industrial development (the NICS, India, Brazil), in contrast to African and other less successful developing countries may be summarized as follows:[337]

(1) All these countries share a long-standing culture associated with writing and printing.

(2) They all have a scientific past at the interface of traditional methods and European science, sometimes with a scientific heritage that is much older than European science.

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[336] Woronoff, 1986.

[337] Salomon, 1990.

(3) Unlike most other ex-colonies they have all been industrialized to some extent for almost a century, and have had the apparatus for advanced training, backed by a long tradition of scientific and technical exchanges with research institutions in the industrialized countries.

(4) In one way or another they all operate some sort of state capitalism, and the government at the highest level has long been aware of the role of science and education in development.

(5) In their education and research effort they all show a determination to break free from their dependence upon the industrialized countries.

The shared features shown above reveal the importance of time and continuity in building the academic and industrial institutions capable of creating the conditions for learning, and capability building, necessary in developing relative technological autonomy. Thus systemic technology policy is not only *technology* policy, it is more a long term comprehensive policy for technology driven development.

In the African environment, Mauritius has often been compared to the NICs. Indeed, in many respects the success of the island resembles the East Asian development. Similarities can be summarized as follows:[338]

(a) economic take off has been fuelled by a favourable conjunction of circumstances and events;

(b) the societies have been socially and politically reasonably stable;

(c) there has been a consensus among political and economic elites on an outward-looking, export-driven macroeconomic approach to development.

The favourable conditions in the case of Mauritius are represented, for example by its status as the first associate member of the EEC, which has resulted among other things in a highly favourable guaranteed price for the main export product, sugar. As a very small country, Mauritius is not seen as a notable economic competitor in the global market by any of the developed countries.

Socially and politically Mauritius has not been absolutely stable, but the situation has been far more balanced than on the African continent generally. The island has been inhabited only from colonial times and then by very different ethnic groups. The political stability arises from a rather long parliamentary and democratic tradition on the island, which has also resulted in a rather consensual view on development targets.

One additional difference to African nations in general is the rather comprehensive and effective educational system in Mauritius. It has been derived as a combination of positive elements of both the British and the French systems inherited from the previous colonial powers.

But there are clear differences between Mauritius and the NICs as well. Development in Mauritius is based more than in any of the NICs on foreign capital and activities in the EPZs.

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[338] Kearney, 1990.

The rapidly expanding sectors are also technologically rather mature, and narrow. There are not many linkages from the EPZ located exporting firms to the core of the local economy, which is still mainly based on sugar products. In spite of the rather effective educational policy, the research, innovation and technology policies are modest in relation to the NICs. Development on the island has not yet been based on ideas of technology driven development which are central in the NICs. It could be argued that the future development of Mauritius is critically dependent on the country's ability to steer towards a more research and technology oriented development path.

12.9 Developing Country Policies: A Brief Summary

Building up a systemic, long term technology policy is by no means an easy task. From the African countries point of view, there are almost too many gaps. The creation of a more technology driven development path has to be started from an analysis of targets, possibilities and resources available. This is always a country specific task. But some general conclusions on the possible measures to be taken can be drawn from the policies adopted in the industrialized countries (see chapter 10) and the experiences of long term policy built up in Japan and the East Asian NICs.

(1) There is a need to reorganize a variety of public technology policy institutions. They should be dealing with tasks more relevant to local economic and technological development and this should be done in more intense cooperation with individual firms and other economic actors. This implies more cooperation between universities, research institutes and firms. Common projects with concrete development targets where all types of institutions are involved are often the best form for cooperation. It is also important that all participating organizations have their own interests built into the project.

(2) There is a specific need to spread information on the use and possibilities of new technologies. This could be done through, for example, establishing specific "information technology centres" with differing targets, e.g.,CAD centres. There are many possible alternative ways to organize this kind of centre, but it is important that they are in close contact and cooperation with educational and training institutes as well as with firms.

(3) Companies need direct aid in getting information on production technology developments and making technology acquisition decisions. This could be arranged for example through sectoral research institutes, branch organizations or parastatal holding companies by employing personnel specialized in information gathering and creating contacts to sources of technological information abroad. The specialists should carry out contract tasks to individual firms, help them both in creating contacts to technology suppliers and in technology contract issues.

(4) Quite similar aid is needed by firms in technology assimilation and adoption matters. In this case, however, the need is for highly specialized knowledge on production technologies and for long term support, which starts long before the actual implementation of new technologies and continues until the new systems have been totally incorporated into the everyday activities of the firm. This kind of aid may, in many African cases, be only available through foreign donors.

(5) Even more general awareness programmes on the effects and possibilities of technological development are needed. They should be associated with an open and wide social discussion on the themes of technological development.

(6) Companies also need more direct financial aid in technology acquisition this means facilitating regulations on foreign currency in production technology matters. New production technologies are, however, means to make the economy more effective and productive and thus creating new possibilities for economic growth and increased exports.

It is not only a question of easier access to foreign currency for buying new production machinery; as important is the need to make customs procedures less complicated, less bureaucratic, and faster.

(7) For capability building it is important, that local firms are deeply involved in every technology transfer case, even when foreign donors are completely responsible for the process. Technologies imported should be "appropriate" in at least three senses: they should fit to the existing production processes in the recipient organization, they should raise the technological level of the organization and serve as a basis for capability building, learning and further technological development, and, third, they should support the macro level national development targets. The last topic may often include, for example, the target of diminishing the variety of machine types and makes in the country.

13. Developing Countries Infrastructure Issues

Both the discussion on technology policy above and the experience from developed countries stress the importance of infrastructure for technological development. The importance of logistical systems on the one hand, and human skills on the other, are critical for developments in manufacturing technologies. Logistical infrastructures are physical conditions for setting up modern production facilities, and human skills are critical factors for using them. Four main concerns on infrastructure are the following:

(a) the physical infrastructure for communication (road, rail, air and sea communication);
(b) energy and water supply;
(c) telecommunication networks;
(d) education and training systems.

In the following, these issues are discussed largely in relation to findings in the African case study countries.

13.1 Physical Communication

Physical communication is more or less a basic condition for all economic and industrial development, but there is need for a more sophisticated physical infrastructure when more developed production technologies and production organizations are adopted. For example, frequent airline services become more important with tighter connections to productive networks abroad and the growing importance of exports. And when more complex production structures and technologies are used, more accuracy will generally be needed in such transportation systems.

In interviews in the case countries, physical communication networks were very seldom mentioned as a major problem. This is, of course, relative to the technological and organizational level in the firms visited. The fact that road networks satisfy current needs does not mean that the same networks would be good enough for firms operating within more tightly linked productive networks or companies with very regular contacts abroad.

Road transport is not without its problems. Even though the roads in all the case countries - perhaps with the exception of Ethiopia and Tanzania - are quite reasonable, transportation is often not possible. The reasons for this are more in the realm of technology and industrial policy, i.e.,there are not enough trucks and lorries, and the existing ones are often unusable because of a lack of spare parts and flaws in the service and maintenance organizations. These were aspects that became especially obvious in Ethiopia, Tanzania and Zimbabwe.

In these countries the problems in road transport have created large horizontally and vertically integrated production facilities. This is counter to the visible trend to the undeveloped countries economy of smaller, less hierarchically connected small firms and operational units with more flexible network types of interconnections. Thus the transport conditions may, in the long run, become an obstacle for developing more modern firm structures or other economic institutions needed for a flexible economy.

Railroads have been of considerable importance especially for countries without their own seaports. These also pose problems, but again it is not so much a question of the rail networks as such, but of the transport equipment. There is not enough capacity, and the equipment available is quite often unusable, again because of a lack of spare parts and poor maintenance. Rail transport problems were mentioned especially in Zimbabwe and Tanzania. In Tanzania there were quite considerable problems on the Tanzania - Zambia railway (TAZARA), which is Zambia's main export route. Sea and air transport were not mentioned as a problem in these two countries.

Also in regard to transport issues, the small island of Mauritius is a clear exception. There is an extensive road network, some 1,880 kilometres of bitumenized road representing a road density of 1 km/km^2, including 33 km of motorway with further expansion planned.[339]

There is no railway system in Mauritius. The only previous rail lines were those used to transport sugar cane from the fields to the processing factories. However, the government has considered investing in a monorail system linking the major towns to ease a growing road congestion problem, e.g.,an estimated total of 105,000 vehicles by 1990. Mauritius currently has one international airport in the south of the island, which is served by 15 airlines with over 144 flights per week.[340] Cargo traffic grew by almost 220 per cent between 1984 and 1987, and was forecast to grow from 6,000 tons in 1984 to 25,000 tons in 1990. Plans are advanced with regard to a second airport in the north of the island. This would help to cope both with the increasing airfreight and the growth of tourism (193,000 arrivals in 1990).[341]

The island has one main harbour with three deep water quays, one mooring dolphin, a fishing port and one of the largest bulk sugar terminals in the world.[342] Some 600 ships per year, averaging 15,000 tons use these facilities. An estimated 2.8 million tons of cargo was envisaged by 1990 with 10 per cent being containerized.[343]

Mauritius is a positive exception when it comes to the condition of physical transport among our case countries. This is partly due to the small size of the country and the close proximity of townships and production sites.

Namibia has few transport problems, but has the general handicap that it is far from most markets.

Generally it may be concluded, with regard to physical transport, that there is a lot to do in developing road and railroad networks in the case countries, but the main problems are on supplying sufficient and satisfactory transport equipment for both road and rail transport. This again, is partly a question of finance and import tariffs - to ease the import of new equipment - and partly a maintenance problem.

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[339] Europe Yearbook, 1990.

[340] O'Brian, 1989.

[341] PCGlobe, 1991.

[342] National Development Plan, 1988-1990.

[343] O'Brian, 1990.

International transport problems were less related to equipment than to import/export regulations, long waiting times in customs and the large quantity of goods which disappear from, for example, port warehouses.

13.2 Energy and Water Supply

Energy and water supplies are basic infrastructure needs as well. Water supply was seldom a problem with the exception of a few local cases - and mainly during the dry season - when some textile mills with fairly high requirements had occasional problems with water supply. In Zimbabwe rationing of water supply caused some problems. Water is not over abundant in Mauritius either, where the situation may become more critical if industry continues to expand. This is also true of the comparator country Brazil.

However, from the point of view of more automatic production technology, water supply is not an area of specific concern and the needs are not likely to change remarkably with more developed technologies. An exception may be Namibia, where water is often in short supply. Marble mine uses a highly automated cutting system. The cutting machine is water cooled and because of shortage, the water is re-cycled.

Energy - electricity - supply seems to be a more critical problem and even an obstacle for automation technologies. Generally, a steady flow of electricity is especially important for all process technologies used in textiles or paper mills. In addition, all electronically controlled machinery may suffer badly from fluctuating energy. Cuts in supply may cause severe losses in terms of machine utilization rate, in some cases even in information loss, and in damaged equipment should the power fall below certain critical levels.

Interviews revealed that fluctuations and cuts in energy supply were especially problematic in Tanzania. In many regions supply cuts were daily causing important reductions in capacity utilization. The need for their own electricity generation facilities to offset the cuts was high, but these kind of arrangements were not possible for most companies. Highly automated machinery is practically impossible to use without a relatively stable supply of electricity. For further automation, the supply of electricity is one of the main obstacles in the physical infrastructure. Electricity supply in Namibia is good, with occasional surges in the municipal supply in Windhoek. This may also be true for Brazil, where due to the current national economic problems further development work on hydro-electric schemes was stopped recently.

13.3 Telecommunication

Telecommunication networks are growing in importance. They constitute the basic 'life lines' of modern production technology, from intra-factory connections to international networking linkages. The state of telephone networks varied highly in the case countries. While Ethiopia and Mauritius - Namibia too - seem to have only minor problems with telecommunications, Tanzania and Zimbabwe had rather severe ones. The worst was the Tanzanian situation, where telephone lines out of order was almost more a rule than an exception.

Poor international contacts are often created by non-automated telephone centres and sometimes by bureaucratic procedures for making the calls.

While international networking was very good in Mauritius and Brazil, it was quite often very difficult to establish a telephone link with other towns - or regions.

The problems in keeping telecommunication networks working quite often relates to unavailable technical skills and bad maintenance. This was the experience from companies interviewed in both Kenya and Tanzania: the repairing of a broken line often takes an extremely long time. Now, when the telecommunication networks are slowly being modernized, it is quite important to establish corresponding maintenance organizations with skilled technicians.

Unproblematic telecommunications are a basic condition for the wide use of more sophisticated technologies which require fluent communication. The main problems in keeping the telecommunication order again relates back to more basic industrial, technological and skills policies: there is a need for more modern telecommunication equipment, a system to produce maintenance skills and a workable maintenance and repair organization.

13.4 Education and Training

The importance of productive skills, managerial and technical capability and other dimensions of human capital have been highlighted consistently, both in earlier chapters concerning technological development and developed countries policies, and above in the chapter on technology policy. From the angle of flexible automation the labour force skills are at least as important as the technologies themselves.

Acquiring the relevant skills for technological development is, as discussed above, a complicated matter. The roots are in the national education system and the curricula. However, the theoretical and basic qualifications, while necessary, are not sufficient in themselves. Most skills needed are of a more practical nature and highly specific in relation to the technology, organization and firm in question. To acquire these skills there is a need for specific training courses, apprenticeships, and learning by doing.

It is quite evident that skill problems are among the most important obstacles for more sophisticated production technologies in our case study countries. Even now, when technologies in use, on average, were far from the leading edge, there was actually quite a consensus among industrialists as well as policy makers and researchers on the lack of relevant skills in all the countries studied. The lack of relevant skills - and even, the ability to use the skills in fact supplied, e.g.,by equipment manufacturers or aid givers - ranges from shop floor technicians to all levels of management. The only instances of companies with only minor skill problems, were companies that had themselves arranged comprehensive training programs - often including periods of study abroad - for all levels of manpower.

Table 13.1 gives information on the background of basic production skill problems in the African countries. The volume of secondary education in Africa lags far behind the European countries. For example, in Kenya only about 10 per cent of primary school leavers obtain any post-secondary education, and Kenya is a country with a far better secondary education system than most other African countries. Attendance at secondary education has also grown remarkably in Zimbabwe since independence in 1980.

Table 13.1 The number of students in secondary education and the share of secondary vocational education in four case countries

Year	Mauritius		Kenya		Tanzania		Zimbabwe	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
1975	65.1	1.6	241.0	2.3	62.0	0.0	68.7	1.9
1980	81.9	0.3	428.0	2.0	78.7	0.0	74.7	1.0
1985	72.6	1.2	457.8	1.7	92.9	0.0	481.7	0.0
1986	70.7	1.4	479.9	1.3	102.2	0.0	537.1	0.0
1987	71.9	1.2	544.7	1.0	..	..	584.0	1.9
1988	73.3	1.3	563.4	1.6	..	..	640.7	1.7

(a) Number of students in secondary education, in thousand.
(b) Share of students in vocational secondary education, percent.

Source: UNESCO (1989).

The education system is most highly developed in Mauritius. Education is free at all levels; and an overall level of literacy of 85 per cent exists - for the under 30s it is a remarkable 95 per cent, compared with between 30 and 70 per cent in other African countries[344].

Primary school enrolment stood at 89 per cent and secondary school enrolment at 45 per cent in 1987.[345] Currently, there are places for 1300 students at the University of Mauritius which has expanded rapidly in recent years (less than 400 students in 1988 when university education still had to be paid for). The average enrolment rates for African countries have been below 70 per cent in primary and about 23 per cent in secondary education.[346]

Between 3 per cent and 4 per cent of Mauritius Gross National Product is devoted to the educational sector; though there are a considerable number of private schools which indicate that the total public and private investment in education might be almost double this figure. In the educational field, Mauritius seems to be following the example of East Asian NICs in emphasizing both high quality primary education for all and broad opportunities for - free - further education. There still remains, however, problems in vocational education since too little focus has, in the past, been laid on expanding and raising the quality of vocational education in the country. Although the government started its first "Industrial Trade Training Centre" in 1969 (with ILO support) there was a feeling they had not been the major success hoped for, and in the late 1980s a new "Industrial and Vocational Training Board" was added. In order to develop a clearer industrial training strategy, a study was carried out by Bheenick and Hanoomanjee

[344] UNIDO, 1989b.

[345] World Bank, 1989b.

[346] UNESCO, 1989b.

(1988). A new and comprehensive educational and training initiative was proposed which, if successful, may solve any remaining skills problems in Mauritius (see Figure 13.1).

Tanzania has achieved considerable success in providing basic services for its population. This applies to education as well and an estimated 20 per cent of the national budget is currently allocated to education.[347]

Primary education is compulsory and in principle free. Although education in Tanzania is controlled by the state, there are also some private schools, mainly at the secondary level, established according to conditions issued by the Ministry of Education. Even university education is free, with only a charge levied for board and lodging (World Bank 1989c). However, the overall level of university education is not very high. There are only 2 universities with slightly less than 3,500 students in total.[348]

Adult - male - literacy is on a high level in Tanzania in comparison to the African average of 49 per cent. The figures for Tanzania in the early 1980s range, depending on the statistics used, between 62 per cent and 83 per cent.[349]

However, due to the economic crisis and lack of resources, primary school enrolment has shown tendencies to decline. It stood at 69 per cent in 1984, and declined to 66 per cent 1987, only slightly above the African average of that year (EIU, 1990i). As a proportion of the school age population, the total enrolment at primary and secondary schools, taken together, increased from 27 per cent in 1970 to 58 per cent by 1981, but then declined to 43 per cent in 1986.[350]

One explanation for this is, that the real per capita expenditure on education has been reduced by one third since the mid 1970s. Funding deficiencies are the greatest in the case of teaching materials and maintenance of furniture and buildings.[351]

Among the major issues facing education in Tanzania are the quality of education and the pressures to increase the low transition rate from primary to secondary education (only 5.2 per cent in 1985, about one third of the average African rate). On the other hand the costs of university education are very high. As an outcome of this, the teacher/student ratio is excellent, 1:3, better than twice the Sub-Saharan average.[352] One consequence of this education policy has been that the output of qualified engineers is quite high. Many, however, work in public administration and not in the manufacturing sector. At the same time, technological skill deficiencies on the factory level are pressing. Generally there seems to be a relatively wide gap between highly qualified Tanzanians on the one side and the technological level of the mainly unskilled or semi-skilled workforce of many enterprises on the other.

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[347] Tanzania, 1990.

[348] PCGlobe, 1991.

[349] UNIDO, 1989B; Tanzania, 1990; EIU, 1990i.

[350] Tanzania, 1990.

[351] World Bank, 1989c.

[352] World Bank, 1989b.

Both in Zimbabwe and Namibia the adult literacy rate is also above the African average - approximately 76 per cent and 73 per cent, respectively. Zimbabwe has one university with almost 8,000 students, while Namibia has three very small university institutions with altogether roughly 500 students.[353]

The Ethiopian literacy rate is extremely low, only 5 per cent. About 3.9 per cent of GNP is spend in education, and there are 22 universities with 18,500 students. With 59 per cent, the Kenyan literacy rate is a little above the African average. There are 4 universities with about 10, 000 students in Kenya.

However, the main problem of the education systems in the Sub-Saharan African countries may not be the overall volume of education or even the size of secondary education. Column (b) in Table 13.1 shows, from the point of view of industrial development, the real problems. Secondary education is almost completely of a general "arts and sciences" nature and the share of vocationally oriented education has not reached 3 per cent in any of the countries. This is extremely low. The corresponding share is radically higher in the developed countries: about 36 per cent in Germany, 24 per cent in France, about 14 - 17 per cent in Japan. Even in the United Kingdom, which has served as the model for the education systems in most case study countries - and where formal vocational education is modest - the share is about 9 per cent. In the Republic of Korea, a country largely following the Japanese development path, the share has been between 16 per cent and 20 per cent in the 1980s.

In African countries, the vocational content in primary education is also very limited. The curricula in primary schools leads to examinations that in turn are designed to select the few persons lucky enough to obtain secondary education. Education in primary schools generally leads the pupils to expect white collar jobs. This does not serve as a preparation for life which the majority of children will actually live as adults.

The educational systems in African countries have generally been inherited from the previous colonial powers, usually Britain or France. Although some countries have made attempts to reform these systems, little has in fact been done:

> "The school systems remain European-oriented, with the focus still on competitive examinations. In former Anglophobe Africa some school systems still write English certificate examinations, and where local examining boards have been established they are mere carbon copies of these British systems, such as the West African Examination Council, or the now defunct East African Examination Council. The curricula continues to stress the skills required by the bureaucratic sector while the desperately needed vocational and technical skills receive insufficient attention. Educational systems of the colonial days survive virtually intact. Few if any attempts have been made to develop full scale re-socialization programs".[354]

There are explanations for this. In colonial times, vocational training was at the centre of the primary school curriculum. This was heavily opposed by Africans, motivated by the view that such curriculum was designed to provide inferior education for Africans to hamper their political advancement. This attitude prevails even today, though perhaps more motivated by social class structure than by racial sentiments. The elites tend to oppose vocational reforms

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353 PCGlobe, 1991.

354 Sifuna, 1990.

at least so far as their children are concerned - this is little different to their model in England where private education for those children whose parents can afford it, still pay for their children's education in the belief (probably correct) that this will ensure their place in the upper echelons of society. For non-elites, on the other hand, sending children to school is a major investment. They do not see much sense in them learning practical skills that could as well be taught at home, they expect that education will lead to salaried jobs. So actually no social group is really backing educational reforms geared towards more vocationally oriented systems.

This means that vocational education in the East African countries is mainly provided by the large companies with enough capital - and foreign finances - to do this. The situation is most unsatisfactory, in most developed countries raising the level of vocational secondary education is one of the central concerns associated with developing manufacturing technologies and technological change generally.

In response to the need, the vocational content of primary education has been increased. In the new Kenyan "8 - 4 - 4" (primary - secondary - tertiary) system the new eighth year of primary education is more vocationally oriented. The other reason for the one year lengthening is, that primary school leavers have been too young for working life, which has lead to a very high number of unemployed and often socially disoriented youth.

Criticism of vocational training in primary schools is based on fears that the teaching of basic skills will become hampered and no practical skills will really be learned. It is argued that the assumption of pre-vocational skills taught at primary level would improve the employability of school-leavers has never been tested.[355] However, interviews with Kenyan industrialists do not confirm this. As a rule they emphasized that standard seven year leavers are not recruited any more, because they are too young and not very well oriented towards work or the vocational training supplied within the companies. The eight year primary education is, to a growing extent, becoming a basic condition for employment in the industrial sector.

The volume of vocational education has also been extended in Kenya. Presently there are 15 governmentally maintained national technical secondary schools, 3 self help technical secondary schools, 35 schools with industrial education programs offering carpentry and metal work, 130 schools offering agriculture, 35 business and 106 home science education.

However, experience from these schools has not been very good, according to one source with employability after school leaving not much improved and these schools even being seen as unwise investments. But such criterion would have to be examined in more detail.[356] The interviews with industrialists and policy makers in Kenya seem to point to the quality of training and teaching in the institutions.

Especially because of the lack of a trained workforce, graduates from technical schools are usually employed in supervisory positions. As such, they are expected to be qualified as foremen and for other supervisory tasks. However, experience on the abilities of these graduates has not been very positive. Examples from two Kenyan textile and clothing factories show that newcomers from schools were quite incapable of supervisory jobs without very detailed supervision and guidance themselves. They were very knowledgeable about the

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[355] Sifuna, 1990.

[356] Sifuna, 1990.

practical aspects of actual work, and might have been good practical trainers for the small-scale rural textile/clothing industry, but not at all for supervising large-scale manufacturing.

As a consequence of the above, large companies often put technical school graduates in the same categories with primary or general secondary school leavers. This means that they have to be trained to their tasks from the beginning.

The same three main problem fields which exist in secondary education are also relevant in university and other higher education institutes:

(1) a lack of finance to provide university education generally;
(2) faculty structure biased towards arts and basic sciences at the expense of technology;
(3) limited relevance of qualifications learned in relation to the needs in economy.

The total supply of higher education is quite modest. Even in the best case the number of tertiary students in 100,000 inhabitants is far behind the average level of 2,000 to 3,000 in European developed countries - or in East Asian NICs where the ratios are on the same level (Table 13.2). In Tanzania and Namibia the situation is much worse with the ratio reaching only 21 and 2, respectively.

Table 13.2 The number of tertiary students per 100,000 inhabitants and the number of university students abroad in five African countries

Country	Number of tertiary students per 100,000 inhabitants[a]	Number of university students abroad[b]
Zimbabwe	396	2,225
Mauritius	149	2,250
Kenya	107	6,619
Ethiopia	66	7,967
Tanzania	21	2,165
Namibia	2	..

[a] Source: The Economist (1990).
[b] Source: UNESCO (1991).

To obtain a comprehensive picture of the extension of tertiary studies, the number of students abroad should be added to the number of domestic students. Figures here are on a level quite typical to (non East Asian) developing countries in general, and much lower than figures in OECD countries. Column 2 is somewhat under estimated, since information from the Soviet Union is missing. The Soviet Union has traditionally been an important supplier of education to developing countries.

However, the total amount of university graduates is not necessarily too low. For example in Kenya, there is even some unemployment of university graduates. The structure of education varies a lot by country, but generally the share of engineering is quite low, especially bearing in mind the total number of students. Even in Kenya, where the share is highest, shortages in the supply of engineers was constantly mentioned as a problem and a constraint for technological development in the companies interviewed. And as will be recalled from earlier chapters, a shortage of engineers, technicians, etc, is as big a problem in the developed countries as it is for the developing ones.

The basic problem, however, is in the content of education and the skills learned. The most common problem related to personnel and the work force in general which were mentioned by firms interviewed in all the countries visited, were skills for management, both for technical and business management. It became perfectly clear, that graduates from university had very limited capabilities for management positions, from supervisory tasks to department heads. It took a long time for companies to train graduates in good business practice.

Table 13.3 Third level students in five African countries, 1986/1987 (per cent)

Field of study	Ethiopia (1989)	Kenya (1989)	Mauritius (1989)	Tanzania (1987)	Zimbabwe (1989)
Business	24.7	5.8	28.0	7.1	10.6
Natural sciences	7.1	9.6	2.5	3.0	2.0
Mathematics & computers	2.8	0.1	5.0	0.2	0.3
Engineering	10.3	4.0	11.2	10.9	5.3
Trade, craft, industrial programs	1.5	0.4	..	24.7	0.5
Other areas	53.6	80.1	53.3	54.1	81.3
Total number of students	33,486	22,840	2,179	6,071	55,047

Source: UNESCO (1989).

With the information available, it is quite difficult to evaluate the underlying problems. It seems at least partly to be a question of the nature of university studies in the countries. Universities are rather isolated, cooperation with private companies is rare, and students get very limited business practice.

13.5 Manpower and Labour Policies

Manpower questions, generally, seem to be the main concern in the East African countries. Mauritius is the only one of the case countries, where unemployment is not a central policy concern.

For the other African countries, the creation of new jobs has been formulated as a main target for industrial and economic policy. The direct implications of this aim are a heavy emphasis on very labour-intensive production methods, negative attitudes to all technologies expected to diminish the need for human labour, and a wage policy supporting the comparative advantage of cheap labour. In this kind of a labour policy concept, human labour is seen more as a mass than a specific resource. Policy outlines like this, however, also cause problems.

For example, difficulties in management were discussed above in the context of the educational system. They have a background in the more general manpower policy setting as well. The problems of organization and management in Sub-Saharan African and other countries on the same level have been summarized as follows:

> "Any kind of a 'scientific' approach to management is lacking; diagnosis and factual analysis are largely absent; decisions are taken on the basis of hunches and intuition; adequate information on which to base the decision-making process is not available; responsibility and authority are heavily centralized; both in small and large private establishment, with a slightly reduced degree of centralization in the latter; where there is some delegation, it is based less on merit than on considerations on family, ethnicity, caste and class; there is a premium on obedience and ritual rather than a critical judgement; the myth of a "powerful" person who is credited with the ability to achieve results in situations where others cannot, still persists. In contrast to private establishments, public sector enterprises show a good deal of delegation of responsibility, but without accompanying delegation of authority; middle managers shy away from accepting responsibility and exerting real authority for fear of being penalized if they make mistakes. The impersonality of public sector and state organizations inhibits the fostering of personal loyalty to one's work, colleagues and institution".[357]

This criticism may be rather too sweeping - and exceptions exist, of course - but the interviews in firms and with researchers in the case study countries largely support his considerations. Even for a highly qualified university graduate it may be difficult to change the rules within the existing, largely traditional enterprise cultures. Thus the critique on education may only be partially targeted, the actual practices in firms may suffocate attempts to use modern management skills, and the existing organizational structures and behaviours within firms may pose the real obstacles for developing management practices.

This leads to the organization, management, skills and other manpower related issues. They are core areas of success in modern manufacturing. Introducing highly automated machinery may turn out to be counterproductive if these are not correspondingly taken care of. In the case study countries, many individual enterprises were found where the training of the labour force and the building up of efficient management and organizations had been seriously considered. These types of companies had an infrastructure that could be adapted for production with more advanced technologies.

These few examples represented, however, only a minority of the leading edge of the most aware companies and there are plenty of opposite examples. As a rule, firms that had fewer contacts with developed country firms or aid projects also seemed to be less advanced in this respect. The main problem is that there are only very few conscious public policy measures, awareness campaigns or development programs, aimed at aiding firms in organizational renewal, management development and other problems related to the manpower aspects of technological change.

One central lesson from introducing advanced production technologies in developed countries is the importance of labour involvement and motivation, as noted in earlier chapters. Successful implementation of highly sophisticated technology is in most cases highly dependant on a motivated work force, from shop floor to top management.

In African companies visited, lack of motivation was often mentioned as a main reason behind low labour productivity. A set of reasons can be found behind this belief, and some of these are directly policy related.

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[357] Bhagavan, 1990.

The manpower and labour market systems in most case countries - especially in Tanzania and Ethiopia - are very regulated. It is difficult to introduce any sanctions or incentive schemes. For example, in Tanzania bonus systems cannot be introduced without a special government permit.

Even when applied, the benefits are minor: in general bonuses are linked to higher production volumes, which again are more dependent on raw material supplies, energy inflows, and machine maintenance, than on the direct contribution of production workers. On the other hand, it is almost impossible to fire an unproductive worker.

The main reason for low labour productivity and lack of motivation can, however, be found in the wage nexus. In the whole region, wages are generally below the subsistence minimum. Workers and their families simply cannot survive on the wages paid alone. This seemed to be true for shop floor workers and higher managers. The outcome of too low wages is that people have to have other sources of income. This may take the form of other work, either on the labour market or as small-scale family farming, the informal sector, or straightforward corruption.

Whatever the extra income may be, the consequence is that an important share of a persons energy, interest and involvement is aimed on things other than his official work. The second source of income may need more concern, because it usually is less regular and less self evident than the secure salary job. Even basic interest in, motivation towards, or respect for, a job that does not give the minimum income needed in daily life cannot be very high.

In some countries firms can solve the problem by simply paying higher wages. This was the case, for example in Kenya and Zimbabwe, where a few companies mentioned lesser motivation problems due to wages above average. Another thing usually referred to as raising the level of motivation and involvement was training. Companies investing more in training their labour force expressed less motivation and productivity related problems. The problem is more difficult in countries like Tanzania where firms have very little freedom of decision making in this respect. Salaries are set centrally and considerable bureaucratic operations are needed to make an exception.

Welfare problems are also related to this, for example the poor level of social security. In a traditional society, social security was actually provided by family, village and tribal systems and within the immediate living environment. In the present African reality, this is much less the case. The traditional connections are broken to a growing extent, and people cannot rely on old family/tribal connections as much as they did, especially in an urban environment. This raises the need of governmentally provided social security to a new level.

It is not only or in the first instance a question of social equality or human rights factors. The examples of Japan and the NICs showed that successful technological and economic development is also dependent on social and political stability and to consensual decision making. These cannot be achieved in countries, where social inequality is unduly present, and causing potential reasons for unrest. Studies on national innovation systems and long-term economic growth also show that success in economic and technological development very often goes hand in hand with a more even spread of social and economic welfare, and social equality.

13.6 Developing Country Infrastructure: A Brief Summary

The main conclusions on infrastructure development arising from the case company visits and literature discussions are:

Physical and telecommunication issues

Functioning physical and telecommunication infrastructures are among the basic conditions for technological development. In this respect, there is much to do in the case countries. These problems have usually been recognized as well, and it is more a question of money than will to develop them.

From the automation point of view, the necessity for a reliable electricity supply must be emphasized. This is obligatory for a wider spread of any kind of more advanced, electronics based technologies. Computers and sophisticated production machinery can be damaged by interruptions and fluctuations in power supply. Only large firms are capable of overcoming the problems of, for example, voltage fluctuations in electricity by company internal arrangements. Smaller firms are completely at the mercy of the public supply system.

Up to date working telecommunication systems are at least as important. Here the need for centrally provided systems is self evident for large firms as well. Building up a reliable telecommunication network with a possibility to further enlargements and a rapid diffusion of telephone apparatus should be a primary infrastructure building task.

Education and training

Even though education systems in most African countries have expanded remarkably during the years of independence, the systems as a rule, are not up to the requirements of modern industry. There are too few institutions for vocational education, the vocational content in the curricula is generally too low, and the facilities for teaching technology are not adequate. Higher education, though often quite extensive, is focused in general on "arts and sciences" subjects not giving entirely satisfactory qualifications for graduates aiming towards industrial management or research positions.

Thus there is a need to:

(a) considerably expand the system for vocational education in the most important fields of economy in the case study countries.

(b) update the technical facilities for teaching, especially for teaching computer related subjects. The general level of computer literacy - even familiarity with computers - is all too low to meet the needs of modern economy; and trainers are often poorly qualified.

(c) to narrow the gap between industry and educational institutions. This could be done for example by introducing elements of the central European dual education system to vocational education. In this case students would be alternating between school and factory; practical training would be given in the factory and theoretical teaching explaining the things learned by doing in the school. This is in fact already being done within many large firms, but there is a need to introduce similar arrangements into the formal vocational education system.

(d) Even higher education should be linked better with practice. This means that, for example, university students for management and technology should spend more time in industrial firms during their study. In order to learn in practice about new production and management methods, the students should also be able to spend some time abroad in advanced companies. This, again, is already done by the most aware African companies, but there is a much wider need for spreading knowledge about industrial changes to the future management and technical personnel in the countries.

(e) The training furnished by companies is quite extensive in most case countries, in fact it is often the only vocational education available. With developing the general educational system, the intra-firm training should a) be linked better and more tightly to the general education system, b) be geared more towards a system of further education.

While intra-firm training is actually possible only for large firms, there should be more publicly aided systems for training the personnel of small firms. This could be done by either opening the training institutes of large firms to other companies, or by establishing cooperative training centres financed by various companies with public aid. This kind of training centre could operate, for example, in the context of and using the facilities of the technology demonstration centres proposed in the previous chapter. This kind of model - based on cooperation between public authorities, local companies and technology suppliers - has proved to be rather successful, for example, in Sweden.

Manpower and labour policy

There are many difficulties with the basic manpower policies in the countries. In spite of the very high priority of employment in policy documents, the policies are not necessarily the best possible ones for reaching this target. For example, the extensive fear of labour replacing technology may, in many cases, lead to the complete obsolescence of industrial branches and exclusion of them from international markets. This is certainly a danger when cheap labour is no longer the main competitive weapon and the quality standards demanded on the market can only be assured by technologically more developed production facilities.

Especially the reluctance to utilize computers, which is evident in some countries, may turn out to be harmful from the employment point of view. The experience from developed countries shows that computers have, through the reorganization of economic structures and job practices, in fact created more new jobs than destroyed. Their ability to facilitate operations and open new economic opportunities exceeds the negative effects, though wholly new industries or occupations may be created (see for example Chapter 1), implying significant structural adaptation.

From the manpower policy point of view, the main conclusions are:

(a) Individual firms should have more freedom to decide at the company level on wages, incentives and sanctions, and other issues related to the use of manpower.

(b) Firms should be supported and encouraged towards manpower development, both in terms of training and organizational development. The motivation of the labour force depends not only on economic incentives, but as well on work content and skill related issues. Experience from developed countries shows that in general, motivation to and involvement with work increases with the growth of freedom and decision making over one's own work. High motivation correlates also with skills; people with a thorough mastery of their task are more motivated than people uncertain about their abilities with the job.

Some of the large firms visited during the project understood these matters quite well. The possibilities for more advanced manpower - and organizational - development were, however, limited, partly because of governmental regulations, partly because of economic constraints, and partly because of narrow managerial skills, knowledge and experience on possible alternative ways in manpower development.

One of the basic policy tasks, therefore, is to spread more information on the possible benefits of manpower development and new organizational forms. This, in turn, requires more information gathering, research work and creation of contacts to companies in developed countries that could serve as examples in this respect.

(c) A general increase in the wage level to raise living standards and create domestic demand is needed. This can, however, only take place hand in hand with an overall growth in productivity. The productivity, in turn, can be increased by a general raising in the technological and operational standards of the economy.

14. The Case Study Countries

A number of issues are examined in this report, in connection with both developed and developing countries. However, special attention has been given to Ethiopia, Kenya, Tanzania, Zimbabwe, Namibia and Mauritius with Brazil as a comparator.

The African case study countries are all from the Sub-Saharan region and, with the exception of Namibia, in Eastern Africa. The countries have, however, quite different backgrounds and histories of economic development, but are generally - in terms of economic structure and market status - fairly comparable. Perhaps the one exception is Mauritius which is geographically isolated from the African continent. It is also a small country, both in terms of population and area. Economically it is the obvious African success story of the late 1980s. In this sense it is an interesting comparator to the other African countries who have faced growing economic difficulties during the same decade.

Namibia is a slightly problematic case country. It is a country with a very large land area, small population, and recent independence. The implication of the first two aspects is that the economy is small in many terms, and regionally decentralized. Because of the latter aspect data concerning Namibia is fairly sketchy. This makes it quite difficult to include the country in statistical comparisons. Because of the fact that Namibia achieved independence only recently, both the economy and the administrative structures are only now being formulated, and development policies are not yet clearly drawn.

Ethiopia poses different types of difficulties. The country has been involved in a civil war since the late 1980s. This badly affected the performance of the economy. With the end of the war in the summer of 1991, there was a change of government and drastic alterations in the policies and the economic system of the country may be expected.

Mauritius is taken as a specific example of successful export oriented policy. The Lomé Convention and various other general issues relevant from the point of view of exporting from developing countries are discussed in the context of Mauritius.

Kenya is regarded as the most developed country on the East African continent, and the country shows interesting long-term development trends with periods of both success and failure. The country has applied rather regulated, import substitution oriented trade policies in the past, but these policies are undergoing change.

Tanzania, Kenya's neighbour is one of the poorest in the world, which previously adopted very strict socialist policies. The policies are, however, changing rapidly and the country shows some interesting recent developments.

An overview of the countries is given in Table 14.1, which presents some of the main economic indicators.

Zimbabwe has one of the most important and diversified manufacturing sectors in Africa, with considerable export success also. The manufacturing base is however in need of refurbishment and technological upgrading.

Table 14.1 Case study countries: Main economic indicators, 1990

COUNTRY	Area '000 km	Population ('000)	Urbanization[2] per cent of population	Total GDP curr Mill US$	GDP/ capita curr US$	MVA curr Mill US$	MVA/capita curr US$	MVA/GDP (per cent)	Exports of goods and services as percent-age of GDP	Exports of manu-factures as percent-age of MVA[1]
Ethiopia	1,222	50,970	12.7	6,038.7	118	642.0	13	10.6	10.2	87.8
Kenya	580	24,030	23.0	8,771.9	365	861.8	36	9.8	25.5	111.4
Mauritius	1.86	1,070	42.3	2,485.4	2323	472.4	441	19.0	70.5	223.1
Namibia	824	1,780	56.1	1,882.2	1057	76.6	43	4.1	51.4	n.a.
United Republic of Tanzania	945	25,630	31.4	2,542.4	99	104.8	4	4.1	21.6	196.1
Zimbabwe	391	9,370	27.1	5,322.3	568	1,403.6	150	26.4	35.9	114.0
Brazil	8,512	150,370	76.1	473,696.6	3750	154,435.2	1027	32.6	7.2	22.0

Source: UNIDO Database

1) 1989, except for Namibia, for which no export data are available.
2) World Bank, Social Indicators of Development 1990

14.1 Kenya

Kenya is an East African country with an area of 582,646 km^2, a population of approximately 24 million and an annual population growth rate 4 per cent. (REG Database). Since independence in 1963 Kenya's economic performance has been quite good, especially in comparison to neighbouring countries, though the high population growth has partly eaten away the fruits of this development.

Manufacturing industries account for only about 12 per cent to 13 per cent of GDP, but the sector has been quite dynamic and is a major contributor to the country's economic performance. With a GDP per capita of nearly 370 US$ (1990) Kenya is on the upper end of the low income developing countries and is considered to be the most industrially developed country in East Africa.

In the first three development plans (1964 - 1978) the Kenyan industrialization strategy was based on an import substitution policy. The results were a rather encouraging rate of growth, broad diversification, and an increasingly inward looking manufacturing sector with decreasing export volumes since 1973. In the third development plan it was declared that:

> "Sustained industrialization depends on the ability of manufacturing enterprises to maintain internationally competitive costs and quality. While temporary protection may be required by industries with high initial costs and inexperienced personnel, those that would need permanent protection are a drain on the economy. Enterprises that can compete only within a protected market do not have much scope for expansion".[358]

In spite of this the import substitution strategy was not changed, partly because of the boom in coffee and tea prices in the world market. However, the fourth development plan (1979-1983) made a cautious shift from import substitution to export promotion policy and mentioned amongst the objectives was "to reduce protective barriers enjoyed by industries under the pretext of infant industry arguments".[359] The fifth development plan incorporated a number of economic reform measures associated with IMF programmes such as curtailment of public expenditure, up-grading of the interest structure, tightening of monetary policy, greater surveillance of public enterprises, import liberalization and increases in agricultural producer prices.

After a decline in GDP growth to the level of 1.5 per cent in the early 1980s, the overall economic policy change proved to be successful, and growth rates climbed to around 6-7 per cent in the latter half of the decade. This is a level far ahead of most other Sub-Saharan countries. The policy emphasis of the early 1990s, according to the sixth development plan, is to further support diversified export growth and to give the private sector a greater role in the economy.

In spite of the relatively good economic performance, technology policy has played only a minor role in Kenya. For example, a technological capability and industrial skills index of developing countries estimating the skill intensiveness of engineering products, ranks Kenya in 61st place out of 79 countries. Kenya is thus not only behind countries such as Hong Kong, Brazil and Mexico, but also behind Tanzania, Mozambique, Zimbabwe and the Central African Republic. And, according to the same index, Kenya has not progressed technologically as fast

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[358] Government of Kenya, 1974.

[359] UNIDO, 1988.

as many other developing countries.[360] On the other hand, Kenya does produce her own cars and despite high tariffs Kenya has already started to play "a leading role in Sub-Saharan computing".[361]

The Government has specified the following "core industries" that are considered essential for the formation of a strong and sustainable industrial base in Kenya:

- metallurgical industries centred around iron and steel production to provide a wide range of materials required by the engineering industry;
- a capital goods industry for the production of a wide range of machine and hand tools for use in the industrial and agricultural sectors including spares for the manufacture of machine tools and dies;
- chemical and biotechnological industries to provide fertilizers, pesticides, industrial process chemicals and packaging materials;
- pharmaceutical industries;
- local resource based industries, especially those using wastes and by-products as well as agro-industries, including the processing of oilseeds, coffee, tea, pyrethrum, sugar, grains, hides and skins and dairy products; and
- telecommunications and information processing industries including the assembly of microcomputers and telecommunications equipment.[362]

These industries are seen as vital in forging the necessary linkages between the industrial, agricultural and communications sectors, and the Government is - according to the National Development Plan - willing to take firm measures in the form of various incentives designed to promote their development.

The actual structure of the manufacturing sector in Kenya is currently quite different. Table 14.2 shows the structure of industrial output.

Table 14.2 The structure of industrial sectors in Kenya in 1987, per cent of output

Sector	Share of output (per cent)
Food processing	59.1
Beverage and tobacco	7.8
Textiles and clothing	7.6
Leather and footwear	1.4
Wood and paper	3.3
Plastics and pharmaceuticals	3.2
Basic chemicals	2.7
Cement and glass	0.2
Iron and steel	9.0
Electrical and transport	5.7

Source: Ministry of Planning and National Development (1989).

360 UNIDO, 1990c.

361 AED, 9 April 1990.

362 Ministry of Planning and National Development.

The food processing sector makes up the bulk of manufacturing activities in Kenya. Food processing, beverages and tobacco account for more than two-thirds of all manufacturing activities, followed by iron and steel (9 per cent) and textiles and clothing together with leather and footwear (9 per cent).

It is interesting that in the sixth national development plan the growth rate of industrial output from 1987 to 1993 has been projected at 6.7 per cent per annum - and the rate is the same for each sub-sector. This indicates, that although core industries to receive special support have been identified, no structural change is expected to occur.

The unemployment rate is about 13 per cent and without an annual employment increase of 3.4 per cent, the projections foresee an unemployment rate of around 20 per cent by the year 2000. This means, that the Government has put a heavy emphasis on job creation and on the use of labour intensive methods. One implication is that automation in Kenya can only be justified on the grounds of increased quality and increased competitiveness which will eventually lead to more productive employment within the manufacturing sector.

Exports and trade policy

The total export/GDP ratio for Kenya amounts to just 11.2 per cent (1988), but more than 45 per cent of those total export earnings are accounted for by just two agricultural products, coffee and tea.[363]

The largest export market for Kenya (1989) has been the EC (43.9 per cent) and within the EC it has been the UK (19.5 per cent) followed by Germany (8.7 per cent).[364] According to other sources, the share of the EC (1988) is closer to 48 per cent; followed by African countries (26 per cent), the USA (5 per cent), Japan (1.5 per cent). Within Africa, the largest market has been the PTA zone (nearly 19 per cent) whereby Uganda accounted for 9 per cent of total exports, followed by Tanzania with 2.6 per cent.[365]

Most exports to the EC are still agricultural products, mainly coffee and tea (Central Bureau of Statistics, 1989). Exports of manufacturing goods have been quite negligible, with the exception of refined petroleum which represents the majority of manufacturing exports. For example, only 3.7 per cent of the total output of textiles and clothing was exported in 1985.[366]

But Kenya's manufacturing exports are not only relatively small, they have been declining for some time. An analysis of the sources of growth of the Kenyan manufacturing sector (covering the years 1976 to 1984) shows that out of 19 sub-sectors of manufacturing only four (beverages and tobacco, non-electrical machinery, plastic products and clothing) have not seen negative growth rates in exports of manufactured goods. For example, exports of machinery & transport equipment declined from 40 million US$ in 1980 to 14 million US$ (1984) before increasing again to 24 million US$ by 1987 (World Bank, 1988a). Growth of the manufacturing

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363 IMF, 1990a.

364 EIU, 1990d.

365 Central Bureau of Statistics, 1989.

366 UNIDO, 1988.

sector has thus in the past resulted from import substitution and from an increase in the domestic demand but not from manufacturing exports.[367]

Generally the Government of Kenya has started to change the trade policies away from the formerly strong emphasis on import substitution towards a more liberal trade regime. The National Development Plan (1989-1993) e.g., states:

> "The industrial and commercial sectors combined have witnessed fast growth. This impressive performance resulted from the industrial strategy of import substitution propped up by high protective tariff walls and administrative controls adopted at Independence. This strategy has resulted in considerable lowering of the country's dependence on imported consumer goods. The next phase of our industrialization will be spearheaded by a strategy of export promotion of consumer and intermediate goods while at the same time laying the base for the eventual production of capital goods
>
> and
>
> The current import policy based on high tariffs and quantitative restriction typified by import licensing and foreign exchange rationing is too restrictive to allow for competition. Government will therefore continue during the Plan period to make a comprehensive review of the Tariff structure with a view to lowering tariff rates generally and to achieve equitable levels of effective protection".[368]

Import duties are an important source of government income in Kenya. Of total government income, import duties accounted for 16.5 per cent of the total government income in 1987/88. If sales taxes on imports are added, the share increases to 29.2 per cent.[369]

Prior to the 1988/89 Budget, there were 23 different tariff categories ranging from 10 per cent to 170 per cent plus a number of specific duties and a duty free category.[370] The top rate was then reduced to 135 per cent. For example, the import duties for an average PC were at the level of 120 per cent in 1990), while components and spare parts were subject to a 35 per cent levy.[371]

The amendments to Customs Tariffs, announced by the Minister of Finance in his budgetary address to Parliament in July 1990, were the following:

- Import duty on raw material, intermediate goods and spare parts will fall for the second year by 5 per cent;

- The top rate of 135 per cent on dutiable items will be replaced by a top rate of 100 per cent;

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[367] UNIDO, 1988.

[368] Ministry of Planning and National Development, 1989.

[369] Central Bureau of Statistics, 1989.

[370] Ministry of Planning and National Development, 1989.

[371] Minshull, 1990.

- Tariffs will replace quantitative restrictions on a range of products;

- Rates of import duty according to whether items are assembled or kit form will be rationalised;

- To encourage reforestation, duty on imported pulp wood falls from 20 to 10per cent;

- To encourage exports, import duty on a number of items with export potential will be reduced (e.g., raw skins and hides);

- Amendment to encourage the local manufacture of spare parts for vehicles;

- Duty exemption on industrial machinery will be raised from KSh 5 million to KSh 20 million.[372]

In addition to import tariffs there have been various non-tariff trade barriers. It is a government intention to replace the non-tariff trade barrier system in the long run with custom tariffs. The import licensing system has already been modified and the number of goods which can be imported more or less automatically was increased from 803 items to 1121 items between 1984 and 1987.[373] Nevertheless, the deterioration of the current account and the severe foreign exchange shortage that Kenya was experiencing in early 1991, will not lead to an abolition of the existing system in the very near future.[374]

Foreign investment

In the past, Kenya was known for its relatively liberal foreign investment policy. That competitive advantage has, however, over the years lost some of its former significance as other African countries have also started to follow the example of Kenya. Therefore Kenya has recently undertaken several changes in order to regain and increase its competitive edge in attracting more foreign investment.

The legal framework for foreign investments are the Foreign Investment Act and the Investment Protection Guarantee Act. According to these acts, foreign investors enjoy the right to repatriate both the capital invested and all profits or dividends. In order to increase the safety of foreign investment even further, Kenya has recently become a signatory to the Multilateral Investment Guarantee Agency, which is affiliated to the World Bank.[375]

However, the repatriation of profits often encounters long delays which tend to reduce the overall profitability and attractiveness of foreign investment projects in Kenya. Previously, investors even had to deposit their profits in low interest frozen accounts while awaiting foreign

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372 Saitoti, 1990.

373 UNIDO, 1990c.

374 AED, 7 January 1991.

375 Saitoti, 1990.

exchange, sometimes for years. Now they are permitted to invest in deposit accounts at market interest rates.[376]

Due to this change in policy, direct investment after having fallen from the late 1970s to the mid 1980s increased again from a low of US$ 3.9 million in 1984 to US$ 68.8 million by 1988.[377] However, the absolute level of direct investment is still rather modest. In addition, in the past decade the number of US multinationals with investment in Kenya has halved.[378] UK firms top the list of foreign investment with assets of about US$ 1,600 million followed by the USA, Germany, France, Italy and Japan.[379]

As it is the Government's declared intention to make foreign investment more attractive in the future, one of the measures taken will be to speed up the allocation of foreign exchange for the purpose of profit repatriation.[380] Currently the repatriation of dividends can take up to two years.[381] Delays in repatriations of profits and dividends are to be cut to one year.[382] The Kenyan Association of Manufacturers calls, however, for the establishment of a system through which allocations for the payment of dividends and repatriated profits should be made possible within 6 months.[383]

In the past the incentives to foreign investment consisted mainly of tariff protection, input price controls, duty drawbacks, investment subsidization, access to domestic credit, one step licensing and sanctioning, etc.[384] However, some of the typical incentives for Kenya, such as tariff protection or input price controls, are likely to lose their importance as Kenya is moving towards a more liberal trade policy and towards the abolition of the system of price controls. Although the corporate tax rate was reduced in 1991 from 42.5 per cent to 40 per cent it is still relatively high. On the other hand, with the new legislation, which defines the withholding tax (15 per cent on dividends and 10 per cent on interest earned) as a "final tax", the overall tax burden has indeed declined.[385] Nevertheless, the incentive (especially for transnational companies) remains to transfer profits abroad by selling at low and buying at high prices from other foreign subsidiaries.

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[376] UNIDO, 1990c.

[377] IMF, 1990a.

[378] EIU, 1990c.

[379] AED, 23 July 1990.

[380] UNIDO, 1990c.

[381] AED, 3 September 1991.

[382] Kweyuh, 1990.

[383] EIU, 1990d.

[384] UNIDO, 1989a.

[385] African Business, August 1990.

With the creation of the Investment Promotion Centre in 1988 the time required for clearing new investment requests is claimed to have been reduced from several months to just two weeks.[386]

The two latest schemes to promote investment and export capabilities are the Manufacturing Under Bond Scheme and the Export Processing Zones (EPZs) Scheme.

The scheme was worked out in 1987/88 and allows for the import of inputs (equipment and raw materials) free of duty as well as the local purchase of inputs free of sales taxes provided the eligible production facility is licensed entirely for export production.[387]

The major objective of the scheme is to stimulate industrial growth by giving manufacturers incentives to produce for export rather than to limit themselves to producing solely for the domestic market.

Up to May 1990, however, only 3 companies were actually fully operating under the 'Manufacturing under Bond' scheme (Fine Garments Kenya, Hercules Mills and Brother Shirts) and only 7 companies by the end of September 1990.[388] A total of 23 companies (with a potential to create some 2,900 jobs) have so far been approved as satisfying the conditions laid down by the authorities out of a total of 41 firms that have been attracted by the scheme.[389] Among the companies approved have been garment manufacturers such as Yuken Textile Industry and Kyu Garments as well as automobile manufacturers like General Motors Kenya or Associated Vehicle Assemblers.[390] Still, actual operations for many companies has not started yet and some firms have even become reluctant to enter the operating phase in the near future.

The high expectations for the Manufacturing Under Bond scheme do not seem to have been realized so far. The main deterrents have been bureaucratic delays and high fees, but also the wait and see attitude of many companies which have been more interested in the overall even more favourable "Export Processing Zone" scheme which was expected to take off by June 1991.

The creation of an "Export Processing Zone" (EPZ) scheme was announced in the National Development Plan (1989-1993). An EPZ comprises an area, either near an airport or a seaport provided with various physical, communications and service facilities and customs offices. The entire production from the zone remains strictly for the export market. In the initial phase, EPZs have been planned near Nairobi's Jomo Kenyatta International Airport and near the Port of Mombasa.[391] A third EPZ will be sited at Athi River. Water supply and other amenities have already been made available for the planned sites with the assistance of

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386 EIU, 1990b.

387 Ministry of Planning and National Development, 1989.

388 Africa Analysis, 28 September 1990.

389 African Business, May 1990 and October 1990.

390 EIU, 1988.

391 Ministry of Planning and National Development, 1989.

the World Bank's International Development Association (IDA).[392] So, investors wishing to set up shop under the EPZs will have virtually all the important infrastructure ready for them. These include factory premises, electricity, water and telephone lines. They will only need to pay the rent.[393]

Investors under the EPZs must manufacture goods only for export. If a local firm wants to purchase goods from any of the three zones, it will have to apply for an import licence and a foreign-exchange allocation to "import" the goods.[394]

Investors in the EPZ will be exempt from exchange controls, certain taxes and fees. Among the incentives being offered to EPZ developers are:

- a duty and tax-free access to inputs;
- a 100 per cent write-off of investment costs;[395]
- a 10-year tax holiday and thereafter only a 25 per cent income tax for the following 10 years;[396]
- non-resident investors are to be exempted from withholding tax on dividends for the first ten years;[397]
- tax accounts for the investors in the zones are to be maintained in foreign currency, with the consent of the Central Bank of Kenya and the Commissioner of Income Tax;[398]
- and what seems to be even more interesting, operators have the right to keep the foreign exchange generated from the sales of their products.[399]

The operational phase of the EPZ scheme was expected to begin in June 1991. The number of applications as of Oct. 1990 was about ten. Among them is a popular international sewing and knitting equipment company which is at present represented locally by agents. However, as of Oct. 1990, the bill to start the EPZ scheme had not yet been debated in parliament.

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392 African Business, October 1990.

393 African Analysis, 28 September 1990.

394 Njujuri, 1990.

395 AED, 18 June 1990.

396 ARB, 31 July 1990 .

397 AED, 18 June 1990.

398 Njujuri, 1990.

399 African Analysis, 28 September 1990.

14.2 Tanzania

Tanzania has a population of about 26 million and an area of 945,090 km^2; annual population growth is 3.4 per cent.

Tanzania is classified as one of the least developed countries and economic development has been slow. After the 1967 Arusha Declaration, Tanzania followed a policy of socialism and self-reliance which led to widespread nationalization and inward looking economic policies in the early 1970s.[400] The industrial sector became dominated by mixed companies in which the Government had a majority shareholding. Many other companies were owned through the National Development Corporation in close cooperation with the Ministry of Industries and Trade. Rigid systems to control prices, wages, investments, and foreign trade as well as an administrative system of allocation of foreign exchange were introduced.[401]

The Second Five-Year Plan (1969-1974) also proved to be too optimistic (Carroll, 1990c). However, the situation became worse after the oil price shock of 1973 and the severe food grain crises which followed the 1974/75 drought.

The economic situation worsened so drastically between 1979 and 1982 that the Fourth National Development Plan had to be replaced by a National Economic Survival Programme in 1981. The balance of payments problem became so acute by early 1982 that the Government announced that all new development projects which were due to start in 1982/83 had to be suspended.

In 1982 a structural adjustment programme (SAP) was announced. This three year programme was prepared jointly by the Ministry of Planning and Economic Affairs and a team of World Bank advisers. It aimed to stimulate the productive sectors, to curtail unproductive development schemes and government spending and to relax price controls. The World Bank's structural adjustment loan package was contingent on agreement with the IMF.[402]

An agreement with the IMF was reached only in 1986 and a policy of economic liberalization was started. A new three-year Economic Recovery Programme (ERP) was launched in the budget of June 1986. The programme was closely allied to the IMF agreement and associated with new aid arrangements agreed with the World Bank.[403]

The ERP provided for further downward adjustment of the exchange rate as well as further producer price rises, the adoption of tighter fiscal and monetary targets as well as a timetable for progressive reduction in price and distribution controls.[404] The programme aimed to achieve an average annual growth rate of GDP of 4.5 per cent. As in the past, this target was also over-ambitious. But with an improvement of GDP growth rates to +3.6per cent in 1986 and +3.9 per cent in the years 1987 to 1989, the difference between target and actual

400 Horna, 1990.

401 EIU, 1990i.

402 Carroll, 1990c.

403 Carroll, 1990c.

404 World Bank, 1989a.

growth rates has been relatively low.[405] According to other sources, the GDP growth rate even achieved 4.4 per cent in 1989 and before the Gulf crisis growth of GDP was projected of 4.5 per cent for 1990.[406]

The Fifth Five Year Development Plan, launched in 1989, aims at an annual growth rate of 6 per cent by 1992/93.[407] Infrastructure improvements - roads, schools, hospitals - and agriculture are the priority areas. The target is to decrease the major bottlenecks to the development of Tanzania. Furthermore, the Government has announced its intention to liberalize the marketing and distribution of inputs for the three major crops: cotton, coffee and cashew nuts.

Parastatal companies are another major topic. Between 1966 and 1988 the number of parastatals grew from 43 to 410. The 1988 World Bank report on parastatals concluded that 54 per cent of all the activities performed by these organizations in the industrial sector were extremely unproductive in that they even produced negative value added when imports were valued at world market prices.[408] The Government is now planning to close down those unprofitable parastatals having no chance for rehabilitation.[409] A privatization programme for the parastatal sector is also being considered.[410]

In the past, Tanzania's development policy was based on industrial development through parastatals. However, the industrial capacities created proved to be heavy users of foreign exchange due to the high import content. This policy turned out to be detrimental to the manufacturing sector itself. The MVA/capita in constant 1980 US$ has actually decreased from US$ 29.05 in 1975 to US$ 17.26 in 1989, and an estimated US$ 9.66 in 1990 and the share of manufacturing industry in GDP declined from 10.2 per cent in 1975 to 3.9 per cent in 1990 (REG database).

An overall overvalued exchange rate combined with high tariffs (on consumer goods) and import controls was considered to be helpful to the (mostly state owned) manufacturing industries to protect their domestic market, and to import cheap capital goods.

The foreign exchange allocation mechanism (executed by the Bank of Tanzania) actually favoured imports of capital goods and led to significant capacity expansions. This took place, however, often without the corresponding recurrent inputs for utilization of the capacities. This policy therefore often entailed the creation of unused excess capacities.[411]

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405 Carroll, 1990c.

406 AED, 24 December 1990.

407 Carroll, 1990c.

408 UNIDO, 1989c.

409 EIU, 1990k.

410 EIU, 1990i.

411 Valk, 1990.

With manufacturing hardly contributing to foreign exchange income and agriculture actually reducing its foreign exchange income, the foreign exchange crises had to worsen. Although the manufacturing sector (i.e. the parastatals) was advantaged in the overall foreign exchange allocation mechanism, the lower amount of total foreign exchange available put a heavy strain on the manufacturing sector also, and impeded it from growing.

Since the Economic Recovery programme in 1986, the Government has pursued a new economic policy. The Government successfully tried to break out of the vicious circle by putting the macro-economic signals right again. However, the Government is still confronted with the more difficult task of rehabilitating the industrial sector to an internationally competitive level again.[412] In this micro-economic context, the renewal and development of production technologies could play a significant role.

Although manufacturing industry has lost some of its former importance in development strategy and direct state involvement, the chances of successful development of the manufacturing sector seem to be better now than in the recent past. With the pool of foreign exchange increasing again after the rise in agricultural producer prices and the consequent increase in agricultural production, and increased domestic revenues due to the devaluations in the past years. Also the capability of industry to receive the necessary imported inputs increased and contributed to an again rising GDP in the second half of the 1980s.[413]

In terms of priorities within the industrial sector, the answer has been given by Tanzania's Basic Industry Strategy, which was first stated in the second five year plan (1969-1974). It became Tanzania's long-term industrial strategy. The main types of activities emphasized were:

(a) Activities that produce for the basic needs of the majority of the people (textiles, clothing, footwear, food processing, building materials, materials and facilities to meet the requirements of health, education and training, transportation and water supply)

(b) Activities which use domestic resources to produce intermediate and capital inputs to other activities, e.g. industries like iron and steel, industrial chemicals, metal and engineering, paper, leather, construction and electricity.[414]

Structural development in the industrial sector was planned in favour of iron and steel, and related industries such as coal, phosphates, pulp and paper.[415]

The revealed preferences of Government in terms of foreign exchange allocation are given in Table 14.3 and may be compared with the general statements of structural development.

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412 UNIDO, 1989c.

413 AED, 23 December 1990.

414 Valk, 1990.

415 EIU, 1990l.

Table 14.3 Foreign exchange allocation in the manufacturing sector, 1986/87 (per cent)

Sector	Allocation for recurrent inputs	Allocations for rehabilitation investments	Share in MVA
Food, beverages, tobacco	15.5	17.3	33.5
Textiles, clothing and leather	11.2	14.2	19.7
Chemicals and petrol	26.5	13.2	7.0
Paper and printing	3.8	4.4	3.4
Non-metallic mineral products	4.6	6.7	15.6
Metals, machinery, equipment	30.3	14.2	21.0
Others	8.1	30.0	-
Total	100.0 (US$ 148.7 million)	100.0 (US$ 67.5 million)	100.0

Source: UNIDO (1989c).

The Government has favoured in foreign exchange allocation the metal, machinery and equipment industries, as well as the chemicals and petrol industry. On the other hand, the food and beverage industry, the textile, footwear and leather industry and the non-metallic mineral products industries were allocated proportionally less foreign exchange than would have corresponded to their MVA contribution.

This structure is basically in line with the import intensities of different industries. Nevertheless, the foreign exchange allocations for investment and rehabilitation for the textile, leather and footwear industry seem to indicate, that the government did not consider the textile, footwear and leather industry to have top priority - although their share is approximately 40 per cent of total employment in manufacturing.

The 1981-86 plan shifted emphasis away from industrialization, and the 1988/89 to 1992 development plan has placed greater attention on the infrastructure and agriculture. Many of the previously proposed industrial projects were shelved, and industrial policy has been targeted on raising output in priority sectors, particularly in the agro-industrial sector.

In the Economic Recovery Programme (1986/1989) one of the objectives was to increase capacity utilization in industry through the allocation of scarce foreign exchange to priority sectors and firms. To be considered as a priority, an enterprise's activity would have to make a contribution towards at least one of the four objectives:

- increase the availability of consumers goods whose scarcity acts as a disincentive for productive activities, and has demoralizing effects on the population as a whole (soap, textiles, shoes, food and beverages are prime examples of such consumer goods);

- increase the supply of intermediate inputs and raw materials, in support of agricultural production, transportation or manufacturing of key consumer goods, as described above;

- generate export earnings;

- generate additional public sector revenue. Beer, soft drinks and cigarettes are prime examples of activities contributing to this objective.

Another priority has been given to industrial rehabilitation.[416] The industrial rehabilitation programme aimed at comprehensive repairs and replacements of equipment to restore production capacity of priority enterprises. In addition, the rehabilitation programme sought to provide recurrent input requirements, including raw materials, spare parts and components to key enterprises in order to restore their capacity utilization. Specific targets were set for some incentive good industries, industries producing intermediate inputs and raw materials, and those generating revenue for government.[417]

Exports and trade policies

Past inward looking policies have created biases against exports. Overvalued exchange rate and high tariffs strongly protected the local market; price controls for industrial production enabled firms to make profits - or at least to survive - on existing low levels of efficiency and capacity utilization rates (10 per cent-20 per cent in some cases).[418]

The parastatal sector in particular has been heavily protected, both from foreign competition through the import licensing and foreign exchange allocation practices, and from domestic competition through exclusive rights to operate in certain fields. Thus firms operated in an environment which did not provide them with any incentives to improve efficiency. The result was that export revenues decreased from over 22 per cent of GDP (1970-1973) to around 4 per cent by 1983.[419]

Changes in economic policy since the mid 1980s - several devaluations, reduction of the role of the National Price Commission, introduction of new import funding schemes - led once again to a significant increase in total exports (from 4 per cent of GDP in 1983 to 17.4 per cent of GDP by 1989). However, not only exports increased strongly, imports also rose tremendously: from 12.8 per cent of GDP in 1983 to 54.2 per cent of GDP by 1989.[420]

In 1989, total exports amounted to US$ 0.4 billion compared with imports of US$ 1.2 billion (EIU, 1990i). So, only one third of imports has been covered by exports. For the manufacturing sector, the import coverage ratio is even lower. In 1984 roughly one sixth of purchases of raw materials, spares and capital inputs were covered by manufacturing exports.[421]

The export of manufactured products has not been an important issue in Tanzanian policy for many years. Exports of manufactured products was not a major topic in the first (1964-1969) or second Five-Year Development Plan (1969-1974). During the Third Five Year

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416 UNIDO, 1989c.

417 Valk, 1990.

418 Valk, 1990.

419 UNIDO, 1989c.

420 Valk, 1990.

421 UNCTAD, 1988.

Development Plan (1975-1981), in which the Basic Industries Strategy was adopted, the primary objective of manufacturing industry was to cater for the domestic market, in accordance with import-substitution industrialization principles. In this sense, the policy pursued has also been successful. The share of consumer goods in total imports decreased from 49 per cent in 1960, to 14 per cent by 1980 and to 7 per cent by 1986, before rising again to 17 per cent in 1987 after the introduction of the economic policy changes.[422]

According to the Economic Surveys, the share of manufacturing exports declined from levels above 20 per cent in the 1970s to 13.7 per cent by 1981. Up to 1986 this share fell to 8per cent due to the lack of foreign exchange and subsequent low capacity utilization rates; however, from 1986 up to 1989 after the introduction of an export retention scheme and several devaluations, manufacturing exports recovered again quite significantly. Approximately a quarter of all exports are now of manufacturing origin, including petroleum exports.[423]

The largest export markets are the EC (with Germany 15.7 per cent, UK 8.8 per cent, Italy 5.3 per cent and the Netherlands 4.5 per cent), USA 11.6 per cent, Singapore 6.5 per cent and Japan 4.5 per cent. In terms of imports, the main trading partners have also been the EC (with UK 11.7 per cent, Italy 9.5 per cent, Germany 8.9 per cent and the Netherlands 3.9 per cent), followed by Japan 9.6 per cent, Iran 6.1 per cent, and Sweden 3.3 per cent.[424]

Generally the Government has started to liberalize foreign trade since the mid 1980s. In 1988/89 the Government decided to restructure the customs tariffs in order to improve incentives for industries, and facilitate the imports of essential commodities. In line with this the Government reduced the variety of categories used in the customs tariff from twenty to seven as follows:

- 0 per cent for basic and essential items, for example medicines, educational materials, tractors and tractor spares, agricultural hoes and fertilizers;
- 15 per cent for vital industrial and mining machinery and plants;
- 20 per cent for capital goods, such as boilers, cranes, ships etc.;
- 25 per cent for intermediate goods and spare parts;
- 40 per cent for consumer goods and general food stuffs;
- 100 per cent for luxury consumption goods.[425]

According to the Economist Intelligence Unit, customs tariffs are 30per cent for most intermediate and capital goods and 60 per cent for most consumer goods. In

[422] UNIDO, 1989c.

[423] Valk, 1990.

[424] EIU, 1990l.

[425] Economic Research Bureau of the University of Dar Es Salaam, 1988.

addition, most imports are subject to sales taxes of up to 50 per cent plus import duty.[426]

In July 1990, the government announced a further reduction in customs tariffs, by which the maximum rate of customs duties was reduced from 100 per cent to 60 per cent.[427]

Tanzania has been long known for its extensive non-tariff trade barriers - quantitative import controls and restricted foreign exchange allocations. However, with the introduction of new schemes, such as the Open General Licence scheme (OGL), Tanzania has moved away from the restrictive trade and foreign exchange regime towards a stronger market oriented system.[428]

Foreign investment

Many enterprises were nationalized after the Arusha Declarations, and foreign investment was not favoured by the Government of Tanzania for many years. Private foreign investment has been permitted in certain sectors, but only on the basis of joint ventures with a state enterprise. The foreign investors were mainly to supply technology and management.[429] In practice, the economic environment and fear of further nationalizations impeded Tanzania from becoming a favoured investment site of foreign companies. Due to the existing uncertainties, many foreign companies left Tanzania in the late 1970s. Very tight central bank control on inflows and outflows further reduced the attractiveness of Tanzania.[430]

In 1990 the Government passed the National Investment Promotion and Protection Act which aims at reviving private investment as part of the programme to liberalize the economy. A range of new investment incentives, especially for foreign investors, was introduced. Particularly encouraged are investments that boost export earnings, transfer technology or reduce imports.[431] A one stop investment promotion centre has been set up which tries to eliminate many bureaucratic hurdles.[432] The code restates the constitutional position that no property can be nationalized without compensation[433] and adds that Tanzania will join the International Centre for the Settlement of Investment Disputes (ICSID) as well as the World Bank's Multilateral Investment Guarantee Agency (MIGA).[434]

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426 EIU, 1990l.

427 ARB, 31 July 1990.

428 Valk, 1990.

429 UNIDO, 1986.

430 Africa Analysis, June 1990.

431 AED, 9 April 1990.

432 ARB, 30 April 1990.

433 Morna, 1990.

434 EIU, 1990k.

Now the policy is that foreign investors can invest on their own, or enter joint ventures with government or public enterprises. They can also enter into partnerships with other private investors, local or foreign. Among the incentives for approved investments are:

- a tax holiday on profits for up to 5 years;
- with corporation tax thereafter at 50 per cent rather than 55 per cent;
- a tax holiday on dividends and royalties for technology transfers for up to 5 years, with reduced withholding tax thereafter, (the withholding tax on dividends is reduced from 20 per cent to 10 per cent for non-residents);
- remission of import duties and sales tax on equipment and spare parts.[435]

A major problem remaining for overseas investors is the fact that the code does not spell out a clear policy on dividend remittances, because of Tanzania's balance of payment problems. However, the code does permit that up to 50 per cent of foreign exchange earned by a company could be used for overseas remittances unless those 50 per cent are used up for imports.[436]

Priority areas for foreign investment also include manufacturing. However, sectors such as iron and steel, machine-tool manufacture, chemical fertilizers and airlines are to remain in state hands. Only investors with a special concession may be allowed to enter those fields. Further, armaments, banking and insurance, transport and utilities are among the sectors where partial government or other public investment is still required. Also some smaller-scale activities, such as travel agencies and car-hire services, manufactures of office equipment and leather goods for domestic consumption, are closed to foreigners unless they intend to invest more than US$ 250,000.[437]

Tanzania is also creating a free trade zone on the shores of Lake Tanganyika, in the Kigoma region on the common border with Zaire and Burundi. The aim of the scheme is to increase regional cooperation between the three countries. Under the scheme firms from the three countries would - *inter alia* - open bonded warehouses in the area and store goods for re-export.[438]

14.3 Mauritius

Mauritius has a population of about 1.1 million and an area of 1,860 km^2. The industrial sector was very small up to the 1970s concentrating on import substitution of basic consumer products such as food, beverages, tobacco, metal products, paints and board for furniture, footwear and clothing; and sugar was by far the most important export earner.[439] The import

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[435] Africa Analysis, 22 June 1990.

[436] Norna, 1990.

[437] Norna, 1990.

[438] ARB, 31 July 1990.

[439] Carroll, 1990b.

substitution strategy launched in the early 1960s formed the basis of an early growth of Mauritius' manufacturing sector.[440]

In the mid-1970s, the decline in the price of sugar led to a dramatic turnaround in the country's terms of trade and a deterioration in the balance of payments. The difficulties were further worsened by the expansionary fiscal policy adopted to try to stabilize the demand side of the domestic economy. The result of this was a rapid increase in Mauritian debt, an increase in inflation and a deceleration of output and export growth.[441] On average GDP grew in real terms by just 2.2 per cent p.a. in the period 1975-1980 and could hardly compensate for the growth rate of population.[442]

The Export Processing Zone (EPZ) scheme was introduced in 1971, but a successful overall export-oriented development strategy was only pursued post-1978, after the programme of stabilization and structural adjustment, heavily supported by the IMF and IBRD (through structural adjustment lending). The policy included appropriate policies in the area of exchange rates (devaluation), tax rates (lowering income tax rates on companies), wage policy (wage restraint), fiscal policy (reduction in overall fiscal deficit, reduction of subsidies destined for the local market), trade policy (reduction of the overall level of protection regarding import substituting-manufacturing by eliminating quantitative import restrictions), price policy (reducing price controls). The target was to give incentives to local entrepreneurs to engage themselves more in export activities and to increase direct foreign investment for exporting purposes.[443]

The government launched a labour-intensive, export oriented strategy within the EPZs in the manufacturing industry that, together with sugar and tourism, represented the driving forces of development in Mauritius. Behind the need to increase exports was the fear of widespread unemployment caused by a rapidly growing labour force.

During the period immediately after structural adjustment started (1979-1873), the growth in real GDP reached an annual average of 5.3 per cent. Between 1983 and 1988, the GDP growth amounted to an annual rate of 6.8 per cent.

The engine of that growth was definitely the industrial sector with an annual growth of 12.2 per cent between 1983 and 1988, and especially industry in the Export Processing Zone - an annual growth of 27.8 per cent during the period. The share of the industrial sector increased from 25.9 per cent in 1980 to 33.2 per cent in 1988, which is a remarkably high percentage for a developing country.[444]

With this strong economic performance, Mauritius was able to reduce the unemployment rate from well over 20 per cent before 1983 to around 4 per cent by 1988; and double the per capita income to almost 2,000 US$ in 1988. With this Mauritius is far ahead of most of its

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440 EIU, 1990h.

441 World Bank, 1979.

442 EIU, 1990h.

443 World Bank, 1988b.

444 World Bank, 1989b.

neighbours. Simultaneously the balance of payments which had shown a deficit of almost 4 per cent of GDP in 1982 turned into a surplus of almost 4 per cent in 1987.[445]

The concentration of exports from the clothing and textiles industries, and the dependence on North American and EC markets (95 per cent of all EPZ exports) make the long-term success of the EPZ strategy fragile. This concentration of manufacturing in a few products and export markets underlines the continued vulnerability of Mauritius' economy despite its tremendous success in the 1980s.[446]

The 1988-1990 development plan, continued to pursue the same overall development strategy as its predecessors. However, a greater emphasis has now been placed on diversification of the industrial base and of upgrading the quality of export items. In this developing manufacturing technology is in a central role, while the employment creation aspect has lost some of its former importance because of the tight labour market and the overall reduction in population growth.[447]

The emphasis on diversification of industrial output arises from the concentration of EPZ exports in knitwear & garments (85 per cent of all EPZ exports in 1987).[448]

The policy guidelines for the manufacturing sector in the 1988-1990 National Development Plan were stated as follows:

> "13.16. Protectionism and Increased Competition: The garment and knitwear sectors of the textile industry are among the easiest activities for new entrants. Although the threat to Mauritius is not immediate, some of its main markets may be tempted to introduce protectionist measures in the future, and as more suppliers from other developing countries increase their output. Recent bilateral agreements, specifying limits on knitwear and garment sales, concluded with the US and Canada, following a too rapid rise in exports to these countries only serve to highlight the vulnerability of the EPZ to protectionist pressures.
>
> 13.17. To circumvent quantitative restrictions, which are usually specified in physical units, it is necessary to move "up-market" (upgrading quality) maximising the value added content and the unit value of items exported to quota markets, and to enter new markets not subject to severe quantitative restrictions.
>
> 13.18. Increased competition from other developing countries will also require the industry to develop the ability to respond rapidly and adapt to emerging market opportunities with quality products, competitive prices and reliable delivery schedules. This will, in turn, presuppose a higher degree of specialization and productivity increase through the diffusion of new technologies".[449]

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[445] Ministry of Economic Planning and Development, 1989.

[446] Ministry of Economic Planning and Development, 1988.

[447] Ministry of Economic Planning and Development, 1988.

[448] EIU, 1990h.

[449] Ministry of Economic Planning and Development, 1988.

Within the EPZ sector, however, the diversification strategy out of textiles and clothing, and into new priority areas were described in the National Development Plan as follows:

"13.31. Since textile and clothing have now become sensitive product areas, policy will be aimed at encouraging investment in non-textile sectors with emphasis on products and production processes involving more sophisticated technology. This will be reflected in the investment promotion strategy. Incentive schemes will be introduced to encourage investment in the new areas of interest. For the immediate future, the sectors that have been selected for special incentives are leather, printing, jewellery as well as "haute couture". Other areas to be considered for extension of special incentives will be electronics, light engineering, precision-engineering, plastic processing, mould and die making and toys".[450]

This diversification strategy has been rephrased in the latest programme for Human Resources Development 1990-1993 by the Ministry of Economic Planning and Development:

"The increasing concentration of the EPZ in the production and exports of textiles and wearing apparel is a cause for concern. These two activities together account for 73 per cent of the total number of firms in the EPZ, 91 per cent of the total employment in the EPZ and for 81 per cent of the total value of EPZ exports".

and:

"Production of a narrow range of manufactured goods at the lowest end of the production process and for a few markets must give way to a whole gamut of new products with higher value-added for a wider range of markets. High-tech industries in information processing, communications and possibly electronics hold considerable scope for sustaining the growth and development of Mauritius".[451]

In spite of the explicitly stated policy for diversification, no fiscal incentives have yet been offered to entrepreneurs to diversify out of textiles and garments. The government diversification policy has been restricted to the Mauritius Export Development and Investment Authority (MEDIA) which is now discouraging requests concerning new investments in wearing apparel, while steering investment into other sectors such as leather and footwear, jewellery, toys, electronics, printing and plastics.[452]

The progress of the diversification policy pursued by the government has been relatively modest. Over the three years to 1989, total employment in the clothing and textile industry rose by 17.2 per cent, its share of total EPZ employment, however, declined from 91.4 per cent in 1986 to 89.6 per cent in 1989. The industries which most notably increased their shares of total EPZ employment were the food, the leather and the jewellery industries. So, diversification is taking place in the EPZ, but rather slowly.[453]

The exceptional labour market conditions put Mauritius in a quite different situation in comparison to the other case study countries. Since the end of 1987, there has been practically

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450 Ministry of Economic Planning and Development, 1988.

451 Ministry of Economic Planning and Development, 1989.

452 World Bank, 1989b.

453 EIU, 1990h.

full employment in the country and the emphasis is moving away from quantitative to qualitative job creation, including better training, thereby enabling industries to move up-market. The National Development Plan states:

> "The country's comparative advantage is gradually shifting away from unskilled labour-intensive manufactures to relatively skill-intensive and also moderately capital-intensive industries. This likely evolution points to the need for the EPZ to attract more sophisticated and higher productivity industries to replace those which depend too much on low wages for their success".[454]

The reasoning is carried further in the Programme for Human Resources Development (1990-93):

> "It is becoming increasingly evident that to increase output per head, in a situation where unemployment has fallen near to the frictional level and where there is mounting wage pressure, requires some re-orientation in industrial strategy to de-emphasize labour-intensity. A shift towards more sophisticated techniques of production is taking place. It is important to ensure that the movement towards a more capital-intensive and skill-intensive pattern of production be accelerated".[455]

The 1990/91 budget tries to improve the quality of both labour and capital factors. In order to improve the quality of labour supply, spending on manpower training and education has been increased by 50 per cent in the budget. New courses will be run by the local university, while a series of training programmes are to be run by the planning ministry.[456] The educational issues in Mauritius are discussed further in Chapter 16.

The minister also announced additional facilities to help the EPZ. Interest on credit to the EPZ is being reduced to 13 per cent[457], while the normal lending rate amounts to 18 per cent.[458] The Development Bank of Mauritius has started a scheme for the concessional financing of machinery and equipment to modernize the textile firms.[459]

The general wage level in Mauritius is still much lower than in developed countries, but it is already relatively high in comparison to many African and Asian countries.[460] In 1989, wage increases led to a drop in the number of firms and people employed in the EPZ, especially in the textile and clothing industry. After that, the government imposed a 10 per cent pay rise limit for 1990, just compensating for the expected inflation rate.[461] The wage ceiling helped:

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454 Ministry of Economic Planning and Development, 1988.

455 Ministry of Economic Planning and Development, 1989.

456 Bheenick & Hanoomanjee, 1988; Lutchmeenaraidoo, 1990.

457 EIU, 1990f.

458 IMF, 1990b.

459 EIU, 1990g.

460 EIU, 1990h.

461 EIU, 1990f.

employment in the clothing and textile industry - which fell by 1.6 per cent in 1988/89 - rose by a little under 1 per cent in 1989/90.[462]

A ceiling on pay rises can - at best - help to stabilize the economy in the short term only. In the medium term the upgrading of skills and production facilities - as indicated in the National Development Plan and the 1990-1993 Human Resources Development Programme - is the only feasible solution for the future industrial development of Mauritius.

Exports and trade policy

In 1988, the Export Processing Zones accounted for 59 per cent of the total of Mauritian exports. Of the remaining, the share of sugar was 33 per cent, with 8 per cent for tea and other non - Export Processing Zone exports.

However, it should be noted that while the value added to manufactured products in EPZs was only 20 to 30 per cent, for sugar products it is around 80 per cent.

The breakdown of EPZ exports is presented in Table 14.4.

Table 14.4 The main exports from the Mauritian EPZ sector, 1986 - 1988 (Rupees million)

Main exports	1986	1987	1988
Textile yarn and thread	101	138	180
Clothing	4,012	5,407	6,446
Canned tuna	97	100	173
Watches and clocks	246	337	563
Optical goods	90	90	88
Precious stones	172	185	302
Toys and sporting goods	57	78	85
Jewellery	62	65	69
Other	94	167	273
Total EPZ exports	4,951	6,567	8,179
- as per cent of total Mauritian exports	52.6	55.1	59.0

Source: EIU (1990h).

As noted above, the main export markets for Mauritius are the EC and North America. Regional trade is insignificant, even though the country is a member in both PTA (Preferential Trade Area of Eastern and Southern Africa) and the IOC (Indian Ocean Commission). The latter organization comprises Madagascar, Seychelles, Comoros, Reunion and Mauritius.

The textiles and clothing sector has benefited strongly from the preferential treatment that Mauritius has received from the EC. By the Lomé Convention, Mauritius as an ACP

[462] EIU, 1990g.

country has quite free access for its exports to the EC market, a privilege which is denied to all other large textile and clothing exporters.[463]

Mauritius and the Lomé Convention

Article 168(1) of the Fourth ACP/EEC (Lome') Convention signed in December 1989 (and lasting for 10 years) states that:

> "Products originating in the ACP states shall be imported into the Community free of customs duties and charges having equivalent effect".

Further, article 169(1) declares:

> "The Community shall not apply to imports of products originating in the ACP states any quantitative restrictions or measures having equivalent effect".

The major exceptions to that rule of free access are products covered by the Common Agricultural Policy (CAP) of the EEC. However, the CAP does not apply to textiles. The Convention thus gives Mauritius a considerable advantage over non-ACP members such as Hong Kong or the Republic of Korea, since the exports of those main competitors are subject to a 17 per cent duty on entry into the EEC in addition to some quantitative restrictions.[464]

Nevertheless, two provisions have proven to be a potential hindrance to ACP exports and long-term planning and therefore also to Mauritius' garments exports, the so-called rules of origin and the safeguard clause. The safeguard clause states:

> "Should application of this chapter [Trade Cooperation] result in serious disturbances in a sector of the economy of the Community or of one or more of the member states, or jeopardize their external financial stability then the Community may take, or may authorize the member state concerned to take safeguard measures". (Fourth ACP-EEC Convention, 1990).

The target of the safeguard clause is to protect the EEC from a large or sudden increase in ACP imports of any products. The fact that the EC has - up to now - never actually invoked the safeguard clause does not imply that Mauritius is safe from protectionist actions by the EC. Under Lomé II, for example, Mauritius agreed to voluntary export restraints for fear of invoking the safeguard clause.[465] Indeed, the ACP states have been warned by one EC member state not to concentrate their textile exports in sectors which are known to be sensitive. This is in spite of the fact that the ACP countries together account for less than 1 per cent of total EEC imports of clothing and textiles.[466]

The purpose of the rules of origin is to prevent trade diversion from non-ACP countries to the EEC through ACP states. The Fourth Lomé Convention defines products as originating from an ACP state if they are produced from inputs wholly produced in ACP state(s), or if the

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463 World Bank, 1989b.

464 Fourth ACP-EEC Convention, 1990.

465 Boardman et al., 1985.

466 World Bank, 1989b.

products are produced from imported inputs which have undergone sufficient working or processing:

> "Some non-originating materials are considered to be sufficiently worked or processed when the product obtained is classified in a heading which is different from those in which all the non-originating materials used in its manufacture are classified. The expression...'heading' used ...shall mean the headings (four-digit codes) used in the Nomenclature which makes up the Harmonized Commodity Description and Coding System". (Fourth ACP-EEC Convention, 1990).

This general rule, that a reclassification is sufficient, applies only to products not explicitly mentioned in Annex II of Protocol 1. The Annex covers many garment categories (like man made staple fibres, yarn, woven fabrics, carpets, embroidery, textile fabrics, knitted or crocheted fabrics, articles of apparel and clothing accessories, footwear, etc.), for which, specific and quite complex rules are applied. For example, for some categories the import content may not exceed 40 or 50 per cent, or special materials have to be processed and so on.

A few central points from the rules of origin:

- First, all ACP states are considered as being one territory (Art. 6(1)). So imports from any other ACP country do not endanger the status of origin.

- In order to determine whether goods originate in an ACP state, it is not necessary to establish whether the electrical power, fuel, plant and equipment or machines and tools used to obtain such goods (or any other good that does not enter into the final product) originates in a third (= non-ACP, non-EEC) country (Art. 4).

- Non-originating materials may be used in the manufacture of a given product, provided their total value does not exceed 10 per cent of the ex-work price of the final product (Art. 5).[467]

The rules of origin have created some difficulties for Mauritian garment exporters. Given the scarcity of local inputs, the rules put - de facto - constraints on garment producers to buy their major inputs from either other ACP countries (relatively seldom) or directly from the EEC (more often), or else to transform the inputs sufficiently to satisfy the Lomé rules.

The knitwear industry is a good example. The rules of origin are satisfied, when both the yarn and the sweaters are manufactured in Mauritius, even though the wool is imported. Garments do not satisfy the rules of origin if they are made from imported textile fabrics, but do if they are made from imported yarn transformed into fabric in an ACP state. It is also possible to import the yarn from any other ACP state or the EEC and have the final product counted as originating in Mauritius. This has been done even though the raw materials could have been imported more cheaply from Far East producers than from European or ACP producers.[468]

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[467] Fourth ACP-EEC Convention, 1990.

[468] World Bank, 1989b.

In the case of the US market, Mauritius has mainly benefited from the existing quota system. Under this system, a foreign country can only be called to bilateral negotiations with the USA, once the country's export amounts to 1 per cent or more of total US imports in the respective category of clothing. Until this, trade is unrestricted.[469] For a long time, Mauritius could thus increase its exports whereas its Asian competitors had to enter into bilateral negotiations.

However, with the growth of Mauritius' exports to the US, the US Government has increasingly imposed quotas on Mauritian exports. By agreement year 1987/88, some 29 categories of wearing apparel had come under quotas compared with 10 categories 3 years earlier.

Trade Policy

Mauritius is pursuing a relatively liberal trade policy. The National Development Plan, e.g., states:

> "13.28 Reform of the Trade Regime: To reduce protection and encourage efficiency in the industrial sector, Government will pursue its programme of gradual reform of the tariff structure, initiated since 1986 and aimed at reducing over a period of time, the maximum tariff level of imported products. A harmonized system of customs tariff has already been introduced. Further rationalization of the structure of the tariff regime will be achieved through the merging of fiscal duties and import surcharges and reducing the number of tariff brackets".[470]

In 1987, import tariffs were reduced significantly and import controls were more or less abolished. Fiscal duty on "low priority" imports varies between 10 and over 200per cent. Preferential duties are levied on goods from the EC, the USA and Commonwealth countries.[471]

Special advantages are offered to inputs supporting the diversification strategy in the EPZ sector. For example, inputs of raw materials and machinery are free of duty if all goods are exported.[472] Also companies holding Export or Development Certificates are exempted from import duties on their imported inputs and capital goods.[473]

It is the government's stated objective to further reduce the level of protection in order to increase the efficiency of the industrial sector, however, the government is highly dependent upon international trade taxes for budget financing; about 48 per cent of total budget receipts are derived from import duties.[474] Thus, only minor steps towards further liberalization can be expected in the near future.

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469 World Bank, 1989.

470 Ministry of Economic Planning and Development, 1988.

471 EIU, 1990h.

472 UNIDO, 1989b.

473 EIU, 1990h.

474 Bank of Mauritius, 1988.

When it comes to the non-tariff trade barriers, Mauritius abolished almost all quantitative import restrictions in 1984-85.[475] One interesting side effect of this abolition was the immediate growth of Government revenues. Government receipts from import duties increased by more than 26 per cent from 1984/85 to 1985/86. On average, government income out of import duties even continued to increase despite the reduction of import tariffs by an annual average of 20 per cent between 1985/86 and 1989/90.[476]

In early 1990, the government announced further measures aimed at simplifying the import and export activities of EPZ firms. The firms now receive an import permit renewable every six months rather than needing to apply for a permit for each import order.[477]

Foreign investment

The promotion of foreign investment has been a top priority in the industrial policy of Mauritius for many years. Overall foreign direct investment increased from US$ 1.6 million in 1983 to US$ 7.4 million in 1986, and to US$ 25.6 million in 1989.[478]

With the change in emphasis from basic employment creation to diversification of the industrial base, the policy targets regarding foreign investment has also changed. Now increased technology transfer is at the top of the list.[479] As mentioned earlier, MEDIA is now discouraging requests concerning new investments in wearing apparel, while steering investments into other sectors.[480]

Companies holding Development Certificates (DCs) are exempted from import duties on their imported inputs and capital goods. Dividends paid by such companies are exempted from income tax for a period of 10 years. A nominal rate of only 15 per cent corporation tax is payable by these companies and profits can be repatriated freely.[481]

Enterprises setting up factories in the EPZ to sell their entire output outside Mauritius have since 1971 been eligible for Export Enterprise Certificates. Companies holding such certificates were granted a tax holiday on retained earnings for 10 years with a possible extension to 20 years, tax-free dividends in any 5 consecutive years and exemption of duty for imports of machinery and equipment. In addition, electricity and water have been supplied at cost.[482] There was recently a slight relaxing of the total export rule, and, for example, a small proportion of the knitwear output can now be sold in Mauritius.

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[475] World Bank, 1988b.

[476] EIU, 1990h.

[477] EIU, 1990f.

[478] IMF, 1990a.

[479] UNIDO, 1989b.

[480] World Bank, 1989a.

[481] EIU, 1990h.

[482] UNIDO, 1989b.

In 1980 the corporate tax holiday facility was extended but on a declining basis for a further 10 years. In 1981 the complementary Export Service Zones Act extended similar tax incentives to firms providing services.

In 1985, a new scheme was introduced, whereby firms established under the investment incentive scheme were given the option of:

(1) paying either corporate tax at the flat rate of 15 per cent over the whole life of the company or;
(2) instead being granted a period of tax holidays followed by a 35 per cent tax rate.

Under the new scheme (1), dividends are tax free for a period of 10 years as from production day, instead of just 5 years under (2).[483]

Other benefits offered to EPZ firms include free repatriation of profits, liberal work permits for specialist expatriate staff, and export financing at preferential rates.[484]

The main boost to foreign investment in the EPZ for textile and clothing came in the mid-1980s, after investors from Hong Kong had discovered the advantages of Mauritius. The possibilities of escaping EC tariffs and US quotas, the existence of a skilled local labour force and the approach of Hong Kong's union with China in 1997 made Mauritius an interesting investment site. Mauritius benefited from the inflow of Hong Kong capital, from the technical know-how brought in by the Hong Kong entrepreneurs, and from the ready markets which they had already cultivated.

An added attraction for entrepreneurs from Hong Kong, Singapore and other East Asian countries was the presence of an indigenous Chinese community (around 2 per cent of the total population), which facilitated the start of manufacturing activities.[485] Other major foreign investors came from India, France, South Africa, Germany, the Netherlands and Singapore. But still more than 45 per cent of the capital invested and more than half the firms are under Mauritian control (to a significant extent under Franco-Mauritian control).[486]

This influx of foreign capital, investment and technology also significantly increased the overall value added of the EPZs as well as the vertical integration of the Mauritian textile & garments sector.

14.4 Ethiopia

Ethiopia is the country with the longest history of independence in the East African region. The country has a population of almost 53 million and an area of 1,222,000 km^2 (REG Database). From 1974 to 1991 the country pursued a strictly socialist policy. Economic development during that period was characterized by high military expenditures, low agricultural

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483 Ministry of Economic Planning and Development, 1988.

484 World Bank, 1989a.

485 World Bank, 1989a.

486 EIU, 1990h.

productivity, a narrow industrial base, shortages of skilled manpower and a weak infrastructure.[487]

Ethiopia is also classified as a least developed country. It had a GNP per head of US$ 120 in 1988. It has also faced at least three catastrophic famines during a disastrous decade.

Manufacturing contributed 12.6 per cent of GDP in 1987/88. The value of industrial production by sector is presented in Table 14.5. Public enterprise account for over 90 per cent of manufacturing value added and output but are undergoing major changes, both in terms of increased autonomy and also privatization.[488]

Table 14.5 Value of industrial production in Ethiopia, 1983 - 1987 (million Birr at 1978/79 prices)

Sector	1983	1984	1985	1986	1987	Share (per cent)
Food	447	375	439	469	447	22.6
Beverages	193	207	317	327	351	17.8
Tobacco	58	62	89	108	108	5.5
Textiles & clothing	341	344	353	376	407	20.6
Leather and shoes	120	138	167	181	209	10.6
Wood	25	27	13	14	14	0.7
Cement	33	28	58	71	74	3.7
Paper & Printing	69	80	91	92	103	5.2
Chemicals	92	99	109	103	133	6.8
Metals	106	112	127	120	129	6.5
Total	1,484	1,472	1,763	1,861	1,974	100.0

Source: EIU (1990a).

Industrial expansion has been heavily emphasized in development plans. Almost half of the planned Birr 32 billion investment in the ten year plan were for 216 industrial projects, with a quarter of them improvements to existing enterprises. Import substitution was focused upon machinery and transport equipment, industrial inputs and semi-finished products. Manufactured products are for the domestic markets. The only industrial products exported to any extent are sugar, semi-processed hides, skins, leather work and oilseed products.

Growth in the manufacturing sector declined from around 6 per cent in the late 1970s to just over 3 per cent a decade later. This has occurred in spite of the high investment expenditures since the late 1970s in new manufacturing projects in the public sector.

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[487] EIU, 1990h.

[488] UNIDO, 1991b.

However, some sectors have shown a much higher growth. Output of processed food has increased annually by 4.9 per cent, but leather and footwear has been the fastest growing sub-sector with an annual growth of 11.1 per cent.[489]

Since the mid-1980s manufacturing received a considerable boost from a number of new enterprises, including the 300,000 tons per year Mugher cement factory (financed by the former German Democratic Republic), the Kombolcha textile factory with 20 million m^2 fabric capacity (financed by Italy, the former German Democratic Republic and Czechoslovakia) and the Nazareth tractor factory with an initial production of 1,000 tractors, expanded in 1985 (financed by the former USSR). Other recent major projects include Czech financed breweries at Harar and Bedele, and the edible oil works at Bahr Dar (again with finance from the former German Democratic Republic); and there are plans for a meat packing factory, more textile plants and flour mills, and for a pipe assembly plant. Italy has also provided US$ 57 million in mixed credit towards the industrial spare parts and hand tools factory at Akaki.[490]

Exports and trade policy

Ethiopia has had a substantial trade deficit for many years. From 1979-85 export earnings stagnated, with sharp falls in 1985 (20 per cent), as the drought conditions affected output and in 1987, (22 per cent), as the emphasis on famine relief caused diversion of transport facilities into food aid distribution. In 1986, however, the government was able to take some advantage of the boom in coffee prices, reaping remarkable gains on the external accounts. Coffee normally accounts for about 60 per cent of foreign exchange earnings. This rose to 72 per cent in 1985/86, when world coffee prices were high and the drought had reduced output from other agricultural sub-sectors. The principal manufactured exports in 1989 were hides and skins, textile products, sugar and molasses, pepper extracts, and finished leather and leather products. Manufactures total exports (1986/87) and 7.4 per cent of industrial production (1988).

The direction of trade has actually shown few changes since 1974. The USA was Ethiopia's main market, importing the largest share of the country's arabica coffee exports until 1985/86, when it was overtaken by West Germany. There are extensive annual fluctuations in coffee sales to other countries. The USSR provides substantial non-military imports, although Italy was the principal source of imports in 1988.

The government has kept a tight control on foreign exchange, with strict currency restrictions and sparing allocations of import licences. Import controls, part of the austerity measures to mobilize all domestic resources for drought relief, were introduced in February 1985. They included a ban on all non-essential imports, including textiles and private cars, and suspension of all new private construction.

The restrictions were relaxed a little at the end of 1985, as reserves built up. Private businessmen were allowed to raise capital on the local market. By October 1989 the government had further relaxed its controls by allowing the import of cars and permitting foreign manufacturers and importers to maintain a representative in Ethiopia. However, licensing imports remained strict.

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489 World Bank, 1990c.

490 EIU, 1990a .

Foreign investment

The government is increasing its efforts to attract foreign finance, and a new joint venture code was announced in January 1983. This offered concessions on tax, customs duties and repatriation of dividends. However, it limited foreign participation to 49 per cent and 25 years. This was revised in 1984 and further concessions were made, with exemption from duty on capital goods, corporation tax for five years and income tax for foreign staff. All restrictions on profit repatriation were removed, and the possibility of majority foreign participation was allowed.

A joint venture for a lubrication blending plant, announced in June 1988, with four Western oil companies together holding a 49 per cent share was the first result of the new regulations. Since 1985, local business people have been allowed to raise up to Birr 2 million on the local market, and import machinery valued at Birr 9 million.[491]

The government has taken steps to facilitate greater private sector participation in the industrial sector. New investment codes announced in 1989 and May 1990 have removed most of the legislative and procedural hurdles to private investment in small-scale industry. The government has also sought to attract foreign investment through a refinement of its 1983 Joint Venture Code. As of July 1989, the government dropped the requirement that it should be a majority shareholder in any joint venture and allows the partner to negotiate the duration of the agreement. In addition, an institutional framework has been established to facilitate applications by prospective foreign partners.[492]

14.5 Zimbabwe

Zimbabwe has a population of slightly under 11 million and an area of 390,580 km^2. The country achieved independence in 1980.

The AED Special Report on the economic development of Zimbabwe states:

> "The combined effects of world recession, prolonged drought and indecisive economic planning have badly hit Zimbabwe's economy in the last 10 years, the country's first decade of self-rule. The result was uneven, mainly sluggish economic growth rates, ranging from an impressive 10.7 per cent growth in real terms at independence in 1980 to 4.9 per cent last year.
>
> In 1988, it started to recover again, registering a growth rate of 6.3 per cent in real terms. On average, Zimbabwe's economy grew by a sluggish 3.2 per cent over the past decade, far below targets".[493]

The country has a rather well developed and diversified manufacturing sector, prosperous commercial farming, varied mineral resources and relatively good infrastructure. The country's economy is far more developed than those of all of its neighbours, South Africa excluded. The manufacturing base is rather strong with over 183 000 people employed in

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491 EIU, 1990a.

492 U'IDO, 1991b.

493 AED, November 1990.

it in 1988. The manufacturing industries have accounted for more than a quarter of GDP since about 1970.[494]

The most important sectors within manufacturing are food, tobacco and beverages together with textiles and clothing (Table 14.6).

One interesting point is contained in the fifth column in Table 14.6, i.e. the change in output per employee by sector. While the source does not reveal whether the figures are deflated or not, and so it is not possible to evaluate absolute change in labour productivity, the relative figures reveal that in the drink and tobacco, transport equipment and electrical products industries the output per head has grown at a rate clearly above the average. The worst performance is shown by the metal industries, while the textile and clothing industries are also below the average.

The largest firms in manufacturing have turnovers above Z$ 100 million. Many of the largest corporations are subsidiaries of UK or South African companies. The largest single company is the Delta Corporation - owned one third by the state with South African Breweries holding another third of the shares - with a turnover of Z$ 495 million. The company dominates the beer and soft drink industry but also has interests in retailing, furniture and hotels (EIU, 1990m).

Table 14.6 Net output of manufacturing industries and workers employed in Zimbabwe, 1980 and 1987

Sector	Net output (Z$ million)		Average Number of employees ('000)		Output/ employee	
	1980	1987	1980	1987	1980	1987
Food	505.3	1581.0	24.0	27.6	21,054	57,283
Drink and tobacco	160.8	871.7	12.4	12.0	12,968	72,642
Textiles	254.7	686.3	17.4	22.0	14,603	31,195
Clothing and footwear	143.3	479.1	19.1	19.1	7,503	21,484
Wood & furniture	82.2	195.9	13.8	9.8	5,957	19,990
Paper and printing	114.4	327.8	7.6	9.0	15,053	36,422
Chemicals	335.3	1371.5	11.6	17.5	28,905	78,371
Non-metallic minerals	62.0	219.4	7.1	8.1	8,732	27,086
Metal industries, of which	613.4	1380.6	44.6	41.4	13,753	33,348
- basic	281.3	491.9	15.0	15.2	18,753	32,362
- metal products	210.0	496.4	20.0	15.6	10,500	31,821
- electrical	63.9	145.4	5.3	4.2	12,057	34,619
- transport equipment	58.2	241.6	4.3	6.3	13,535	38,349
Others	30.5	36.7	3.2	1.6	9,537	22,938
Total	2301.3	7150.0	160.8	171.3	14,312	41,740

Source: United Nations, Industrial Statistics Yearbook, Vol I.

[494] EIU, 1990m.

The state-owned Zimbabwe Iron and Steel Corporation (ZISCO), is by far the largest steel mill in Southern Africa. Apart from this the state does not play a very dominant role, although it has a number of minority and a few majority shareholdings, mainly through the Industrial Development Corporation (IDC). One of the governments policy targets has been to increase state participation in the manufacturing sector. This has taken place through direct purchases into existing private sector corporations, indirectly through IDC, and by taking equity stakes in new joint ventures. One of the most important joint ventures was that with Heinz, in which the state took 49 per cent share in an investment which involved the takeover of the local Olivine Industriel (EIU, 1990m).

Manufacturing has a long tradition in Zimbabwe, with several firms already established in the early years of this century, and the steel and cotton industries were established in the state sector in the 1930s. Between 1965 and 1982 the number of industrial products manufactured in the country increased from 600 to over 6000, as manufacturing flourished under extreme protection. The protective approach has to a large extent survived in the independent Zimbabwe. The newer industries are, however, according to World Bank studies, considerably not so ineffective than might be expected (EIU, 1990m).

The basic metal and metal product industries received the bulk of investment allocation during the time of the Unilateral Declaration of Independence (1965 - 1980). Most of the recent growth has, however, come from the textiles and clothing, food, and chemical sectors. The metals sector is still producing just above the 1980 level, though showing signs of upturn in 1989 (Table 14.7).

Generally industrial output is very varied, covering almost all areas except high technology. An exceptionally high proportion of consumption, 96 per cent in 1984, is of locally produced goods (EIU, 1990m).

Table 14.7 Index of manufacturing production in Zimbabwe 1984 - 1989 (1980 = 100)

Sector	Weight[a]	1984	1985	1986	1987	1988	1989	1990
Food	135	119.4	113.6	125.6	131.2	129.7	131.3	144.1
Drink & tobacco	104	86.4	94.8	95.6	107.0	117.3	112.1	129.9
Textiles	101	124.1	175.0	169.1	196.2	202.7	211.7	216.6
Clothing & footwear	72	99.9	111.5	73.0	119.5	120.2	144.5	145.1
Wood & furniture	44	81.6	82.4	49.1	80.9	95.3	84.8	89.9
Paper & printing	61	95.0	111.7	100.8	119.2	121.4	129.6	136.6
Chemicals	125	112.2	121.8	97.6	119.3	130.8	144.4	158.8
Non-metallic minerals	37	99.0	104.7	129.9	140.6	104.7	152.2	161.2
Metals & metal products	288	89.4	100.5	93.1	95.1	100.4	107.3	111.4
Transport equipment	21	114.7	96.6	51.7	83.8	103.6	148.7	147.6
Others	12	50.9	64.2	40.8	60.3	74.1	85.9	44.7
Total	1000.2	100.7	112.2	115.4	118.1	123.9	130.9	138.1

a Based on net output values in 1980.

Reserve Bank of Zimbabwe, Quarterly Economic and statistical Review, Vol. 12, No. 2, June 1991

Source: EIU (1990m).

The transport equipment sector is relatively small but very significant, because it illustrates very graphically the industrial capabilities of Zimbabwe. The branch covers motor vehicle assembly and repair, which in fact includes the design and construction of vehicles (drivers and trucks especially) suited for conditions in the region. Railway equipment is also important; Zimbabwe has successful manufacture of rolling stock (goods, weapons and passenger coaches).[495]

Export and trade policies

Manufacturing exports have grown quite well during the late 1980s. The trade deficit of the early 1980s had been turned into a growing surplus in 1987, and the depreciation of the Zimbabwe dollar has helped in this (EIU, 1990g). The most important export products are minerals and other raw materials, (Table 14.8).

The most important target countries for Zimbabwe's exports are the UK, Germany, South Africa and the USA (Table 14.9). The share of South Africa has gone down, but is still important.

The most important countries exporting to Zimbabwe have been South Africa, still with a share over 20 per cent in 1987, the UK with a share of about 10 per cent and the USA a little less. The UK has not succeeded in recapturing the market shares held before Zimbabwe achieved independence and has lost shares both to the USA and other EC countries.

Table 14.8 Main exports from Zimbabwe, 1982 and 1990 (Z$)

Product	1982	1990
Tobacco	194,700	834,995
Ferro-alloys	77,200	379,549
Cotton lint	52,800	211,743
Nickel	45,500	246,308
Asbestos	60,900	
Iron & steel	41,200	
Textiles & clothing	13,100	
Sugar	52,300	
Meat	7,100	
Copper	21,700	
Coffee	14,700	
Tea	622,900	2,030,942
Total (incl. others)	947,600	3,614,271

Source: CSO Stats Flash

495 UNIDO, 1987.

Table 14.9 Zimbabwe's main export partners, percentage of total, 1981 and 1990

Exports to:	1981	1990	1990 Per cent
UK	6.9	394,919	10.9
FRG	8.3	426,120	11.8
South Africa	22.6	321,667	8.9
Japan	2.8	198,484	5.5
Netherlands		154,963	4.3
Others	59.4	2,163,454	59.9
Total	100.0	3,614,271	100.0

Source: CSO Stats Flash

Foreign trade in Zimbabwe is heavily regulated. Practically all imports and exports require permits. The import control system allocates foreign exchange to importers in relation to overall export earnings. There are four types of import authorizations:

- Imports of a number of raw materials and essential items not produced locally are covered by an open general import licence (OGIL), i.e. no specific licence is required.
- Imports of agricultural items and processed foods require a permit issued by the ministry of agriculture with seasonal restrictions applying.
- Imports of coffee, maize, sorghum, soya beans and wheat may only be made by the grain and coffee marketing boards or by others with their authorization, again subject to possible seasonal restrictions.
- Imports of all other goods are subjects to global import licences being issued after, for example, applications have been decided by an interdepartmental committee.[496]

Import duties are assessed on an ad valorem basis and can be up to 40 per cent. Many goods attract a 20 per cent surcharge.[497] This system is under review, and the import licensing system will, in the long run, be replaced to a large extent with a tiered tariff structure. Restrictions on some imports were lifted in October 1990 and further products will be moved on to the open list in time. For example, since October 1990 some essential products used in packaging, textiles (e.g. dyes) and cement production may now be imported freely.[498]

Simultaneously with facilitating imports, access to foreign currency has also been made easier. The strict price controls are also now undergoing a process of liberalization.

496 Africa Analysis, 22 June 1990.

497 Africa Analysis, 22 June 1990.

498 African Business, Nov. 1990.

Foreign investment

The role of foreign investment is more central in Zimbabwe than in most other East African countries. The share of foreign capital has, however, not grown to any great extent lately. To attract more investment into the country, the government has introduced new regulations facilitating foreign investment and repatriation of profits. The new regulations apply to:

> "Export oriented projects which export at least 75 per cent of their total output or in which the project has a payback period of not more than three years and is able to earn, over five years, double the foreign exchange released by the government for its requirements of imported machinery, equipment and other capital goods".[499]

According to the new regulations, a 100 per cent foreign owned and funded company may repatriate 100 per cent of its net after tax profits, if it meets the criteria of an export oriented project. A joint venture with at least 30 per cent of local participation will have the level of dividend remittability determined along the same lines. After 5 years the company will be able to remit dividends to the foreign shareholder to the extent of 100 per cent.[500]

The Zimbabwe Investnent Centre, established in 1989, reports significant interest from foreign companies in investing, especially in the mining and manufacturing sectors.

14.6 Namibia

Namibia is located in South West Africa and gained independence from South African rule only in March 1990. It is a very sparsely populated country, with just over 1.5 million people living in an area of 824,290 km^2.

The economy is heavily dependent on the mining industry for the extraction and processing of minerals for export. Mining accounts for almost 40 per cent of GDP, agriculture and fisheries 10 - 15 per cent. The share of manufacturing is low, under 5 per cent. The mineral resources are exceptionally rich: Namibia is the fourth largest exporter of non-fuel minerals in Africa and the world's fifth largest producer of uranium. Alluvial diamond deposits are among the richest in the world, and it is a primary source for gem-quality diamonds.[501]

It is Africa's fourth largest non-fuels mineral producer and leading gem-quality diamond producer, accounting for 30 per cent of world output. It has the world's larges uranium mine and some of the largest-known tin and lithium resources. It is Africa's second largest producer of lead, third largest of cadmium and fourth largest of zine and copper.[502]

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499 AED, November 1990.

500 AED, November 1990.

501 World Atlas, 1990.

502 UNIDO, 1990a.

Table 14.10 Real growth of GDP by sector in Namibia, 1985-1990

	1985	1986	1987	1988	1989	1990
Agriculture	43.0	-10.5	40.1	22.9	-19.5	41.1
Industry	-2.8	5.9	-2.0	1.3	-4.5	-6.3
Manufacturing	-3.2	1.0	1.5	1.3	4.2	5.1
Construction	0.5	-14.1	3.4	2.1	-5.8	-9.2
Commerce	1.1	2.4	3.5	4.0	3.0	1.3
Transport and communications	0.3	5.4	2.1	-0.4	10.4	5.0
Others	-5.6	5.6	-1.0	-8.5	14.9	-0.9

Source: UNIDO, REG Database

Food and other agro-related industries are the most important manufacturing sub sectors. They are also priority areas for public policy. There are not any clear development targets for industry yet; however, policy makers interviewed often mentioned the importance of import substitution. Industry is private and based on small- to medium-sized companies. The state is involved mainly in infrastructure related issues such as the production of electricity. Foreign investment has not had any major role to play, though South African investments have been - and are still to some extent - quite important. Foreign investment is governed by the Foreign Investment Act, which also established an Investment Centre.[503]

Generally the economy is still quite dependent on South Africa, though linkages to other countries are gaining more significance. Industrial exports are negligible.

The country has a relatively well developed physical infrastructure. The small population and community structure of small localities - for example, the capital city Windhoek has roughly 120,000 inhabitants, the next largest town less than 20,000. Domestic demand is very modest and cannot be expected to grow markedly. Because of long distances, transport becomes a very important issue. Water supply is a critical issue in some areas. The social infrastructures, for example, the systems for education and health care, are not well developed and need further enhancement.

Until 1990 the country was under South African rule, and both the economy and the institutional infrastructure are inherited from that period. New institutions, administrative patterns and policy guidelines are only now being developed. No long-term development policy has been formulated yet.

The importance of the mining industry is not only as a dominant export earner. It also integrates a considerable level of manufacturing type activity in the form of processing, as well as significant activity in technological adpation and skill upgrading.

[503] Republic of Namibia (1990).

14.7 Brazil

Brazil is the largest country in Latin American with an area of 8.5 million km^2; a huge country with enormous natural resources. About 30 per cent of the land area is used for agricultural purposes and approximately two thirds is covered by forests. In mineral resources, Brazil is particularly rich in iron ore, bauxite, manganese, coal, zinc and chrome.

No less than eleven cities have populations exceeding a million, of which Sao Paulo (10 million) and Rio de Janeiro (5. 6 million) are the largest. The capital city Brasilia has a population of some 1.5 million. Approximately 75 per cent of the population lives in urban localities, often in very poor slum conditions.

The total population is over 150 millions - more than all of our African case countries counted together and three times as big as the largest of them (Ethiopia with a population of roughly 50 million). This creates considerable internal market possibilities. Generally, the population and natural resources together give the country a development potential on a considerably higher level than in our African case study countries.

The possibilities for creating huge domestic markets and realizing the development potential are, however, limited by income inequality perhaps greater than in any other of the newly industrialising economies. It is evaluated, that about 60 per cent of the population is living outside the modern economy, and the real domestic market consists of about 60 million people living in the relatively affluent areas in the coastal areas, particularly Sao Paolo State and Rio. (EIU, 1990/91).

In the late 1980s, the Gross National Product (GNP) was almost US$ 340 billion - the eighth largest economy within the market economies block - giving a Per Capita Income (PCI) of about US$ 2245; at the time GNP was increasing at an annual rate of 2,9 per cent.

However, the economy is suffering from very high rates of inflation and under the burden of a huge national debt. The balance of trade in goods and services in 1987 was some US$ 4,134 million in deficit.

The literacy rate is around 78 per cent and 3.3 per cent of GNP was devoted to education. However, we were informed during the research visit, that 70 per cent of the education budget was allocated to universities and other tertiary education. The primary and secondary education sector are substantially deprived, and, as a result, about 90 per cent of children are dropping out of education at the age of 10 (EIU, 1990/91).

After 20 years of military rule the country reverted to a democratic political system in 1985. This may still be classed as a transitional state; during the field visit we obtained the impression amongst many industrialists that there was a nostalgia for the more stable and centrally-directed - though less democratic - pre-1985 institutions.

Democracy has brought greater industrial uncertainty and employment and investment were both significantly down in 1989 and 1990, as companies awaited the unfolding of economic plans of the newly (1989) installed Collor government.

Prior to this the economy had grown by 5 per cent in 1984 and 8.3 per cent and 7.5 per cent in the two following years, then going down to 3,6 in 1987 and nil in 1988.

The origins of GDP by sector shows that industry was a major element of income at 39.5per cent in 1988 but that real growth rates had declined profoundly dropping from 11.7 in 1986 to a figure of -3.2 in 1988 (Table 14.9).

Table 14.9 Real growth of GDP by sector in Brazil, 1985 - 1990 (per cent)

Sector	1985	1986	1987	1988	1989	1990
Agriculture	9.8	-8.1	14.9	-.03	3.9	1.8
Industry	8.7	11.1	0.9	-3.2	1.6	2.2
Manufacturing	8.4	11.2	1.0	-3.4	1.8	2.5
Construction	10.3	8.3	3.3	6.2	4.1	4.1
Commerce	7.8	8.1	2.6	-2.8	1.5	-.07
Transport and Communication	9.8	13.6	6.0	5.8	3.1	3.1
Others	6.2	8.9	2.6	1.6	7.4	1.4

Source: REG Database

The agricultural sector represents a significant proportion of export income for Brazil. It accounted for 65 - 70 per cent of the value of exports in the 1970s, and was still over 40per cent in 1988 and 1989. The sector has, however, been denied funds from government; as we have seen in several other countries covered by this study.

The country is the largest producer of coffee, the second largest producer of sugar (about 70 per cent of which is processed to alcohol, powering 94 per cent of Brazil cars and light vehicles), and the second largest producer of soya. The latter was claimed to be produced at lower cost than in the largest producer, the USA, but was considered somewhat uncompetitive due to the high costs of transport within Brazil, e.g.,by road/rail to Santos, from where it was shipped.

In the manufacturing sector, the mid-1980s boom was founded on expanding domestic consumption rather than export driven. There was rapid expansion in sales of both capital goods and consumer durables; with the mechanical engineering sector growing by 10.1 per cent in 1985 and 21.4 per cent in 1986 (Table 14.10).

The automobile sector grew from almost 460,000 cars in 1985 to 734,000 in 1989. However, total output of all vehicles in 1989, a little over one million, meant the industry was only then getting back to the levels of the late 1970s.

The informatics industry has grown rapidly in the 1980s, and is based on both rapid domestic growth and exports, with profits in the sector totalling US$ 5.1 billion in 1989, an increase of 15 per cent on 1988. The industry has been protected by the governments Special Informatics Secretariat (SEI), which will continue to exercise control until 1994 (EIU 1990/91).

In 1987 there were 1,675,040km of roads in use, of which only 8 per cent were paved. The railway system has become increasingly inadequate, with only 6.7 per cent electrified by 1983; in fact freight carried declined by 43 per cent between 1977 and 1983 (EIU 1990/91).

The main port handled 280 m tons of freight in 1982; though the inland water ways linking the interior to the ports are badly underutilized. The air transportation system is extensive with nearly 30 major airports in use, served by three major national airlines and numerous smaller airlines, largely restricted to domestic routes.

Table 14.10 Industrial production in Brazil, 1985 - 1989, per cent annual real growth

Sector	1985	1986	1987	1988	1989
Total manufacturing sector	8.4	11.3	1.0	-3.4	3.0
Capital goods	12.2	21.6	-1.8	-2.1	0.4
Intermediate goods	7.2	8.5	1.1	-2.1	2.6
Construction goods	9.2	11.0	0.2	-3.5	3.7
Durable goods	15.1	20.4	-5.4	0.7	2.4
Non-durables	7.9	8.8	1.6	-4.5	4.0
Major industries					
Chemicals	6.5	1.6	5.4	-3.0	-0.3
Metallurgical	7.0	11.9	0.5	-3.3	5.3
Mechanical	10.1	21.7	4.1	-8.6	4.4
Foodstuffs	0.1	0.1	7.0	-2.4	1.3
Vehicles	11.7	12.5	-10.1	9.1	-2.8

Source: EIU (1990/91).

In terms of communication networks, although there were around 11 million telephones installed by 1987 (about 1 per 13.6 members of the population) it was often difficult to contact other major cities. The international exchanges were found to be much more efficient.

Export and trade policies and foreign investment

From the early 1980s up to 1990 there has been a strong import substitution direction given to the Brazilian economy; and the national structure of manufacturing can be seen to be highly oligopolistic with 200 companies accounting for 75 per cent of exports. However, the new Collor government has tried to ease many of the barriers to imports in an attempt to make indigenous producers more price conscious and competitive, and protection now plays a minor role.

Between them the US and the EC accounted for over 54 per cent of exports and 42 per cent of imports in 1989, the first figure being slightly up in 1988 (53 per cent) and the latter slightly down (43 per cent).

Brazil's national debt has been one of the largest in the world and was some US$ 115 billion at the end of 1989, with the public sector being responsible for about 90 per cent of this.

Inward investment has been strongly encouraged for most of the post-1950 period, with the US as the prime investor (about a third of the total).

14.8 The Field Work Research

The field research consisted of a two week trip to each of the case study countries. The original target was to visit and interview the representatives of approximately 20 firms/organizations in each country. This target was not reached in any of the countries, mainly because of problems in practical arrangements.

The original criteria for choosing the target organizations (representativeness, central role in national development, interesting technological developments) could not always be met. Because of time limits, geographical proximity and easy access (no waiting times) of the target organizations became crucial criteria. Eagerness to cooperate was another central one. Practical criteria varied from one country to another - and depended in many cases on the personal contacts of the local experts - so the interviews cannot be taken as a representative sample. However, together with published information and work-in-progress reports from other research work on the same field, they add considerably to the picture of technological development in the case study countries.

The original intention was to make about one third of the visits to companies in the case study sectors, one third to firms in other industrial sectors and one third to policy and research organizations. Table 14.11 shows, that this target was reached quite well: out of a total of 105 interviews, 39 were to textiles, clothing and footwear companies, 30 to other industrial firms and 36 to private consultants, policy makers, and research and development institutes.

Table 14.11 Field interviews by country and by sector

Sector	Country							
	Zimbabwe	Namibia	Mauritius	Ethiopia	Kenya	Tanzania	Brazil	Total
Textiles	6	1	1	3	3	6	2	22
Clothing	0	4	2	1	0	1	1	9
Footwear	3	0	2	0	1	1	1	8
Electronics	1	1	1	0	1	0	2	6
Metal goods	1	1	2	1	0	1	1	7
Printing	1	1	1	1	0	0	1	5
Food & drink	1	2	1	2	0	0	1	7
Others[a]	1	3	0	1	0	0	0	5
Consultants	0	0	1	0	3	0	0	4
Policy makers	2	3	4	6	4	1	0	20
Research	1	0	1	1	4	3	2	12
Total	17	16	16	16	16	13	11	105

[a] Others include tanneries, an office equipment manufacturer and a freight company.

The interviews with representatives of industrial firms were made with the help of structured questionnaires, with questions both on the technical and economic development of the company and on the more general infrastructure and policy related issues.

Usually there were more than one person answering on behalf of the company. However, even if there were quite a number of respondents in some companies, not all questions were always answered. For example, sometimes the figures on economic performance were kept confidential, sometimes the respondents just did not know them and did not have access to the sources of information. In some cases, questions on the technological level of production processes were not answered correctly, because the respondents did not really know about the machinery. This was the case in, for example, when enquiring about microelectronically controlled machinery in textiles mills. The firms seemed to have, which was proved by visits to the production sites, often more microelectronically controlled machinery than the factory/technical managers could - or wanted to - talk about.

The interviews with policy makers and researchers were made with the help of a structured questionnaire as well. The interviews were, however, usually carried out more freely, concentrating on the topics the respondent was specialised in. Additional material was gathered from local daily newspapers and through informal interviews and discussions with both local people and people working in international organizations located in the countries.

15. The Textile Industry

The textile industry encompasses the production of yarn, fabric (primarily for use in apparel) and finished goods such as bedding, carpets and industrial textiles. It uses both natural (cotton, linen, wool) and synthetic (chemical, oil based) fibres as raw materials. Textile manufacturing is an old, established industry, and the starting point for the industrial revolution in the 18th century. For national economic development everywhere, the textiles industry - as a producer of basic necessities - has been fairly important. From the late 1970s on the share of developing countries has risen considerably in the world market showing a 5.9 times growth from 1973 to 1988 compared with a 3.2 growth in OECD countries.[504]

Textile manufacturing is a continuous process industry of reasonably standardized products, which makes it relatively capital and raw material intensive. For a long time, technological development in the sector has been mainly incremental. There has been slow evolution with no radical leaps but a stable growth in productivity. Programmable automation is not assumed to have radical impacts either. However, micro-electronics have been introduced widely into individual machines to achieve more automation, flexibility and solid quality. Computer technologies are also used for overall manufacturing control purposes, thus integrating the production process further.

15.1 Textiles in a Global Market

Of the three main case study sectors (textiles, clothing and footwear), the value of global markets in textiles is the highest. However, the value of world trade in textiles is increasing slower than that of clothing. In 1980 the value of world trade in clothing was equivalent to 73 per cent of the trade in textiles; in 1988 the corresponding figure was already over 96 per cent. World market prices of clothing have increased more than that of textiles, partly because of higher increases in manufacturing value added in clothing, and partly because of more process rationalization in textiles.

The share of developed market economies in the world trade of textiles has decreased gradually, from 70 per cent in 1980 to 58.8 per cent in 1988. This decrease was, however, only partly due to the good performance of developing countries, whose share rose from 21.9 per cent to 28 per cent. Almost as important was the growth of exports from planned economies, from 8.1 per cent to 13.2 per cent (Table 15.1)

Table 15.1 Global exports in textiles 1973 - 1988 (US$ 1000 million)

Country group	Year					
	1973	1976	1979	1982	1985	1988
OECD	17.3	22.1	35.2	34.1	35.3	54.6
Developing	4.4	6.4	10.7	11.6	13.8	26.0
World total	23.4	30.7	50.1	51.0	54.7	92.9

Source: GATT (various years).

[504] Cline, 1987.

The future development of world trade in textiles depends on many factors. Technological change, which is discussed in detail in the following section, is one of them. It is also connected to developments in the clothing industry, to changes of global market demand, and to t: ː strategies applied by large clothing enterprises.

Future development may, however, be more technologically directed in textiles than, for example, in clothing. Textile products are more uniform, the quality of products is of crucial importance - and quality is easy to measure consistently. Further integration of production - both within a textile mill and upstream in the production chain to the clothing industry - is also possible with modern automation technologies. The fact that profit margins in textiles are clearly lower than in clothing, or in manufacturing industry on average,[305] puts heavy pressure on the need to introduce best practice machinery and organization.

15.2 Technological Developments

Technological development in the textile industry has been considerable during the whole period since the end of the Second World War. The most radical innovations have taken place within raw materials. In addition to the introduction of new synthetic fibres, the production processes have also gone through major changes, both through new machinery, new production control technology and new architectural mill design. Production machinery development has, however, been primarily incremental. Textile manufacture is already a basically automatic process technology. In this kind of industry, the microelectronics revolution has not caused as deep changes as in batch production industries. Recent developments have occurred especially in overall mills control, integration of factory departments, higher and more stable product quality, and increasing flexibility of production.

For example, US figures on labour productivity growth for textiles show a long time growth over both the clothing industry and US manufacturing on average. They also indicate the significance of continuous technological development (Table 15.2).

Table 15.2 Growth of labour productivity in US: textiles, clothing and manufacturing, 1961 - 1985 (annual percentage)

	Textiles	Clothing	Manufacturing
1961 - 72	4.88	1.28	3.51
1973 - 85	3.71	2.75	2.90

Source: Cline (1987).

Unlike the clothing industry, the textile sector is dominated by large companies. This is partly because of the nature of the production process and the cost structure of production. This is true for both developed and developing countries, where the large parastatals often make up the majority of the sector.

Because of the incremental nature of technological change, developing countries have been able to follow the technological evolution at least to some extent. Investment in modern textiles technology in developing countries is often impeded more by the lack of finance than by technology related problems.

[305] Cline, 1987.

Up to the late 1950s textile manufacturers would order their machines, and upon installation would introduce some degree of change reflecting the proprietary technology of the mill. The changes would relate to machine setting, gears, shapes of cams, drafting aprons, and other devices. They were based on the company concept of what was the best engineering practice for the mill. Thus, technological development was largely contingent on the mill proprietary technology, based on learning by doing and the long time mill experience gathered.

This made it rather difficult for new entrepreneurs and countries to enter the business.[506] In the mid 1960s the basic machinery development process had changed, and machinery innovations became available primarily on a merchant basis. A major factor precipitating this shift was technological innovation stemming from many scientific disciplines in various fields, which made it more or less impossible for one firm to have the requisite skills in all of them. By then any firm could actually purchase any one of the major types of equipment. The concept of internal machine innovation now played a minimal role in the development of modern textile machinery. Thus even developing countries could have access to the same technology level as developed countries.

The main innovations in textile manufacturing between 1950 and 1990 consist of new automatic bale feeders, aerofeed systems, highdraft spinning, texturization, shuttleless looms, needlepunch machines, transfer printing, rotary screen printing and the introduction of more computer integration into manufacture. These led to the following improvements:

(a) New machinery and methods were introduced, resulting in improved material handling within the mill;

(b) New yarn spinning methods were created resulting in increased labour productivity and a reduction in the number of sequential processing steps;

(c) New types of looms with higher speed and improved fabric quality were made available;

(d) New dyeing, printing and finishing equipment was introduced to improve the surface appearance of fabrics;

(e) New methods of carpet manufacture were created, including needle punch;

(f) Automation of machinery functions, machine self-diagnostics, machine self-correction from deviations, textile design along with colouring, and the interlinking of processes were developed and commercialized.[507]

As noted in the printing industry example in Chapter 1, a similar trend of integration of what were once discrete parts of the textile process is taking place.

In spinning, technological change with significant effects on both productivity, product quality and production flexibility has occurred in all phases of production. In the following, the

[506] UNIDO, 1990b.

[507] UNIDO, 1990b.

most important developments of the key machinery for short staple spinning - for spinning cotton and cotton like synthetic materials - are described in more detail.[508]

The output of blending and feeding raw material has increased from 200 pounds of fibre per hour in 1945 to 1,320 pounds in 1987. The developments of output in various spinning processes is summarized in Table 15.3. During the same period, however, the price of one machine has gone up from US$1,369 to US$103,448, and is expected to double by the year 2000. The 151 fold increase in cost is much larger than the productivity increase, even if price adjustments are made for inflation. The increases in cost in various phases of spinning are summarized in Table 15.4. The real benefits from blending and feeding automation is, that it gives the opportunity to blend various raw materials on a large volume basis. New technology has contributed to an improved blending process.

Aerofeed pickers have replaced manual transport laps and increased productivity significantly with a relatively small investment. In the African case study factories many manually fed systems were still in use.

Table 15.3 Main technological developments in various phases of short staple-spinning and their effects on output, selected years 1945 - 1990

	Output (pound/hour)							Change (per cent)	
	1945	1955	1962	1969	1975	1987	2000	45-62	69-87
Blender	200	200	200	200	550	1320	2200	0	560
Picker	382	382	382	382	..	..	..	0	100
Cards	7	8	10	18	55	88	154	43	389
Drawings (feet/m)	100	400	800	800	273	574	874	700	-28
Lapping	150	190	500	500	484	836	99C	233	67
Combing	28	33	45	50	57	110	132	61	120
Roving									
warp[a]	1.01	1.15	1.53	1.75	2	2	2	51	14
filling[a]	0.70	0.80	1.06	1.30				52	100
Spinning									
warp[a]	0.02	0.03	0.03	0.04	0.03	0.04	0.05	58	-1
filling[a]	0.02	0.02	0.02	0.03	0.04	0.05		51	41

[a] pound/spindle/hour.
Source: UNIDO (1990b).

In cards there has been more than a twelve-fold increase in productivity between 1945 and 1987, and another significant increase is expected by the year 2000. But the prices have also increased: it is anticipated that the nominal price of cotton card will reach US$172,414 by the year 2000, while it was only US$103,448 in 1987.[509]

[508] UNIDO, 1990b.

[509] UNIDO, 1990b.

Drawing and tapping provide the means of blending the card slivers in preparation for the next process. Both types of machine have experienced significant increases in productivity and investment costs. Output per hour and investment costs are expected to increase further, through to the year 2000 (see Table 15.4)

Table 15.4 Main technological developments in various phases of short staple-spinning and their effects on costs per output unit, selected years 1945 - 1990

	Cost/unit (US$ 1000)							Change (per cent)	
	1945	1955	1962	1969	1975	1987	2000	45-62	69-87
Blender	1.4	2.1	3.9	4.5	34.5	103.4	206.9	183	2199
Picker	7.7	14.6	19.5	..	..	..	..	153	0
Cards	2.2	5.0	6.0	69.4	103.4	172.4	..	171	150
Drawings	.	.	.	3.2	17.2	51.7	103.4	0	1516
Lapping	5.0	9.6	11.5	14.0	69.0	124.1	172.4	132	787
Combing	3.8	9.9	13.3	14.5	86.2	137.9	172.4	253	851
Roving	8.5	12.2	20.2	26.4	117.2	124.1	310.3	139	370
Spinning	4.9	11.6	18.6	21.5	61.6	79.5	149.0	281	270

Source: UNIDO (1990b).

The objective of combing is to separate within the fibre mass the longer fibres from the shorter ones, thus leaving a processed mass of fibre that contains a preselected minimum length of fibre. The end result of this sequence is that the yarn made out of this material will be more uniform, stronger and finer than an equivalent yarn made on the carded system. Even though the basic combing process has not changed, productivity and investments have increased. Productivity has increased because of the input of a greater lap weight and increased machine speed.

The major changes that have taken place within the spinning department have occurred on the spinning frame itself and involve two production parameters. Through high-draft spinning, and the development of new spinning methods particularly the type exemplified by open end spinning, the O-E frame. The impact of these changes has been to reduce the required number of pre-spinning steps, such as slubbing, and to limit in most cases the need for roving, to only one step instead of several as before. This again is a reflection of trends in integration of previously discrete functions we noted in Chapter 1.

In addition, the newer frames run at much higher spindle speed, with further increases expected by the year 2000. In spinning, the number of spindles per operator has also risen considerably - from 3,000 in 1945 to 5,500 in 1969 and is expected to rise to 12,000 in 2000 (see Table 15.5).

In long-staple spinning for wool and wool-like synthetic fibres developments have been slightly slower. However, the speeds for the two key processes have increased by about 75 per cent from 1,030 to 1,800 revolutions per minute for rover and from 4,300 to 9,500 (+ 121 per cent) for spinning. These costs have increased as well: the price for a single spinning frame with 204 spindles with automatic doffing was around US$ 351,000 in 1989.

Table 15.5 Main technological developments in various phases of short staple-spinning and their affects on workload per operator, selected years 1945 - 1990

	Work load/operator							Growth (per cent)	
	1945	1955	1962	1969	1975	1987	2000	45-62	69-87
Blender	10	10	10	14	2	2	2	0	-86
Picker	6	6	6	6	..	..	..	0	100
Cards	36	64	88	55	24	16	12	144	-71
Drawings	40	32	28	38	14	6	4	-30	-84
Combing	36	64	80	80	80	80	80	122	0
Roving	240	384	480	480	310	360	500	100	-25
Spinning									
warp[a]	2	2.6	6	6.5	1.8	2.2	12	200	-76
filling[a]	3	4	5	5.5	1.8	2.2	12	67	-60

[a] 1000 spindles per operator.
Source: UNIDO (1990b).

Texturizing is a heat treatment process needed to obtain elasticity for synthetic filament fibres. There are two main technologies - the air-jet method and the false twist method - which have both developed notably in terms of speed, from approximately 250 metres of fibre per minute in 1973 to more than 1,000 metres a minute in 1989.[510] In addition to increases in productivity, the newer texturizing machines produce higher quality yarns.

In weaving, the traditional shuttle looms have gradually been replaced by shuttleless looms, which provide higher speed and improve fabric quality (see Table 15.6). Productivity, expressed in terms of loom speed in picks per minute, has increased from 185 to 900 picks per minute, and this is expected to rise to 1,000 by the year 2000.[511] A corresponding development has taken place in the width of the fabric. The new looms also permit better product quality especially through greater yarn and woven fabric flexibility.

In all, innovations in various phases of textile manufacturing, entail trade-offs between productivity, product flexibility and quality. More recently these have lessened, and the industry has obtained both higher productivity, and higher product flexibility and quality. Within yarn manufacturing, for example, ring spinning provides the greatest product flexibility, but is less productive than other yarn-forming systems. The newer spinning systems, especially rotor and air-jet spinning, are able to produce a large number of yarn counts, at good quality and high speed, suitable for most applications in knitting and weaving.

In weaving there are three major types of shuttleless looms and each features some form of product specialization. Air-jet looms are primarily used on plain fabrics, and rapier and projectile looms can weave more complicated types of fabrics, such as colour stripes and designs. They can use both cotton, wool, synthetic, and many other types of yarn.

510 UNIDO, 1990b.

511 UNIDO, 1990b.

Table 15.6 Main developments in weaving technology and their effects on performance, selected years 1945 - 1989 and projection to 2000

Processing variable	Shuttle loom			Shuttleless air-jet loom	
	X2 - type		X3 - type		
	1945	1962	1975	1989	2000
Speed, weft insertion	..	..	..	1,860	2,300
Speed, pick/min.	185	212	210	900	1,000
Cloth width, inch	39	47.5	68	130	142
Cost/unit	700	2,000	8,500	40,000	50,000
Work load					
looms/weaver	60	100	120	19	30
looms/fixer	60	100	100	..	..

Source: UNIDO (1990b).

Generally we find that important technological developments have taken place in all phases of textile manufacture. Conversely to many other industrial sectors, the prices of new production facilities have typically increased more than the straightforward machine productivity figures. This is partly caused by the characteristics of textile machinery: electronic control components - which are becoming cheaper - are gaining in importance, but the core of textiles machinery still lies in sophisticated, and expensive, high precision mechanics.

In addition to productivity gains there are, however, other superior features embodied in the new machinery. Above all they are more flexible and can maintain higher product quality. This makes investment in new production facilities quite imperative even for developing countries. In the world market, quality and reliability of delivery are all the more important features. In this sense, modern machinery is without equal in performance, and there is no real trade off between labour and capital, or between old and new machinery.

15.3 Textiles in Developing Countries

As noted in Section 15.1, the share of developing countries in total world textile trade has constantly grown. A time series of textiles exports from developed and developing market economies between 1970 and 1985 is shown in Table 15.7.

In the late 1980s however, textile exports from developed countries have actually increased more than from developing countries (Figure 15.1). This indicates that some inflection point may have been reached in the early/mid 1980s, showing a reversal in the decline commented upon by Hoffman and Rush (1988). While the exports of developing countries may still be increasing more rapidly than those of developed countries, a new technology boost may have been achieved in the latter countries - similar to that noted in Chapter 1 regarding the printing industry in the UK.

The textile industry has, as a rule, been important in the initial stages of industrialization of developing countries. Nevertheless, the importance of the sector usually diminishes with further development. Still in 1973 textiles accounted for almost one third of all developing country exports, but by 1986 this had decreased to about 10 per cent (Figure 15.2).

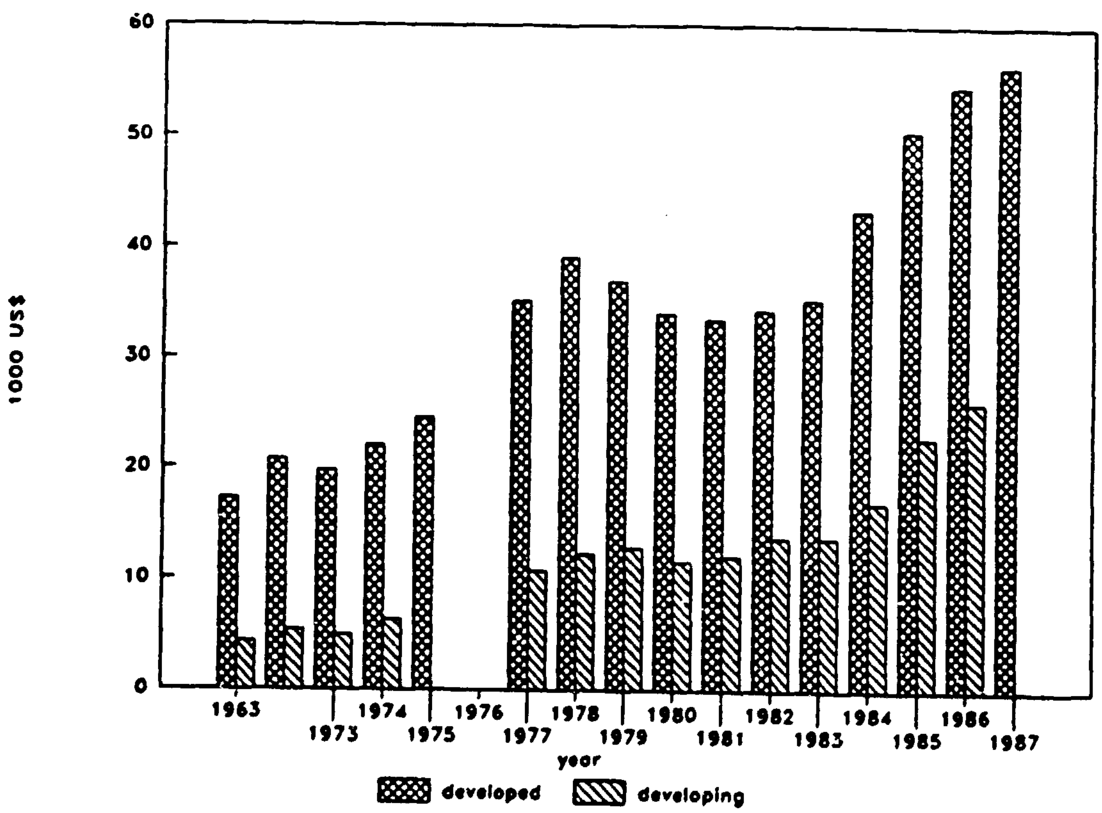
Textile exports from developing countries have mainly come from a few NICs. The picture is, however, changing and the core of production is moving from the East Asian NICs to the second tier of the ASEAN four and some other lower wage Asian countries.

Table 15.7 Textile exports from developed and developing market economies 1970 - 1985

Year	World trade	Exports of developed market economies		Exports of developing market economies	
	US$ billion	US$ billion	per cent of world trade	US$ billion	per cent of world trade
1970	6.44	4.09	62	1.36	21
1973	12.59	6.92	55	3.82	31
1974	14.97	8.05	53	4.77	32
1975	16.73	9.00	54	5.40	32
1976	20.62	10.08	50	7.87	38.5
1977	23.50	11.80	50	8.70	37
1978	28.33	14.44	51	10.42	37.5
1979	34.37	17.83	52	12.35	35.5
1980	40.21	20.60	50	14.67	36.5
1981	41.10	19.10	46	16.86	41
1982	40.02	18.09	45	16.85	42
1983	40.37	17.79	44	17.39	43
1984	45.87	18.70	41	21.90	48
1985	49.42	19.49	39	24.92	50.5

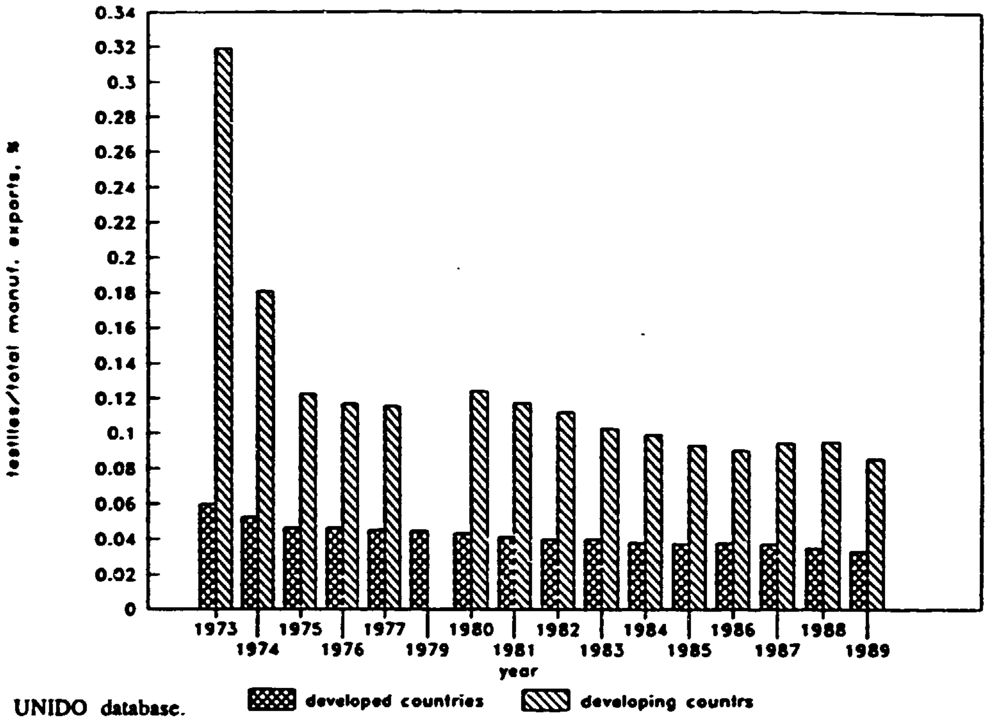
Source: UNIDO (1990b).

Figure 15.1 Textile exports from developing and developed countries 1963 - 1987



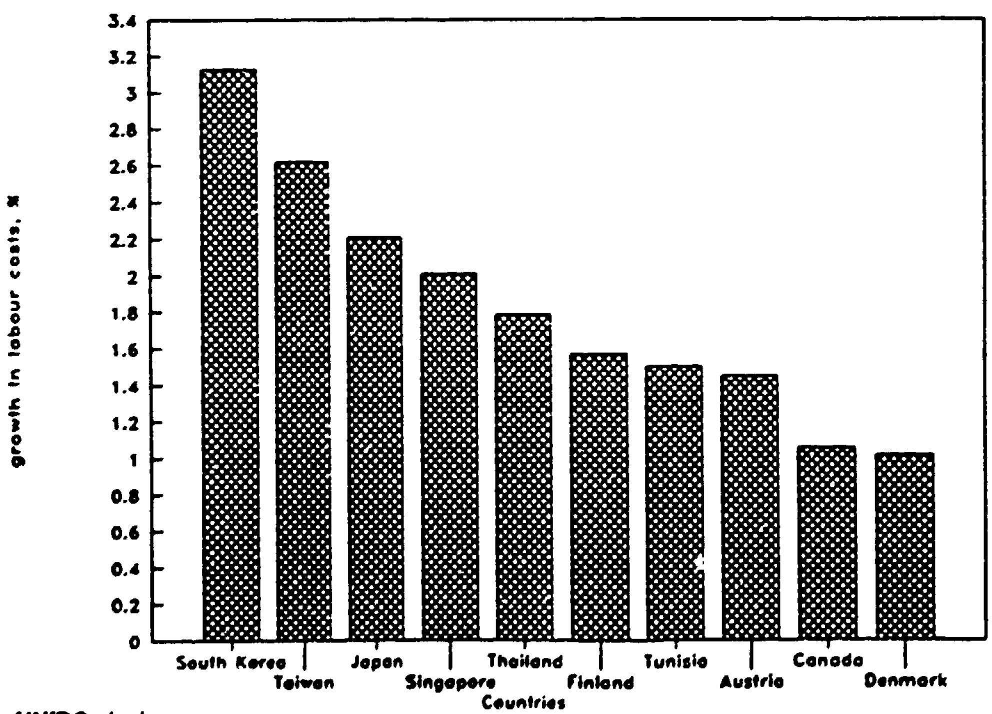
This is partly due to the increase in wages in the NICs. During the 1980s, the Republic of Korea and Taiwan Province topped the list - and Singapore was fourth - of highest relative growth of labour costs (Figure 15.3).

Figure 15.2 Textiles share of total manufacturing exports, developing and developed countries, 1973 - 1989.



Source: UNIDO database.

Figure 15.3 Growth in textiles labour costs 1980 - 1990, 10 top countries



Source: UNIDO database.

Source: UNIDO database.

There is still a clear relative advantage in labour costs in the developing countries. For example, in Thailand, Malaysia, Philippines and India labour costs are at a level of less than 10 per cent of the US labour costs, while Swedish and Swiss labour costs are almost double the US figures (Table 15.8).

Table 15.8 Labour cost by country in textiles industry, 1980 - 1990

Ratio 1990	Country	1990	rank	1989	rank	1980	rank	Change 1980-1990 %
192	Switzerland	19.23	1	14.58	2	9.65	5	99.3
187	Sweden	18.70	2	14.60	1	10.43	4	79.3
183	Denmark	18.35	3	14.00	3	9.00	7	101.2
178	Belgium	17.85	4	13.42	7	11.82	1	51.0
178	Holland	17.84	5	14.06	4	11.68	2	52.7
164	West Germany	16.46	6	13.17	8	10.65	3	54.6
163	Norway	16.37	7	13.62	6	9.62	6	70.2
161	Italy	16.13	8	13.03	9	9.12	8	76.9
157	Austria	15.70	9	12.45	10	6.42	10	144.5
144	Finland	14.44	10	11.79	12	5.62	14	156.9
139	Japan	13.96	11	13.98	5	4.35	17	220.9
128	Canada	12.83	12	11.79	11	6.25	12	105.3
127	France	12.74	13	9.82	13	8.57	9	48.7
103	Australia	10.34	14	9.33	15	..	..	..
102	UK	10.20	15	8.18	16	5.75	13	77.4
100	USA	10.02	16	9.71	14	6.37	11	57.3
91	Ireland	9.15	17	6.94	17	5.13	16	78.4
83	East Germany	8.28	18	..	..	..	..	..
77	Spain	7.69	19	5.65	18	4.90	17	56.9
71	Israel	7.09	20	..	..	..	..	..
58	Greece	5.85	21	4.32	19	4.03	18	45.2
46	Taiwan	4.56	22	3.56	20	1.26	26	261.9
32	South Korea	3.22	23	2.87	21	0.78	33	312.8
30	Hong Kong	3.05	24	2.44	22	1.91	21	59.7
28	Singapore	2.83	25	..	..	0.94	31	201.1
28	Tunisia	2.82	26	2.37	23	1.13	27	149.6
27	Portugal	2.75	27	2.03	25	1.68	24	63.7
22	Mexico	2.21	28	2.11	24	3.10	20	-28.7
20	Brazil	1.97	29	1.78	27	1.57	25	25.5
19	Uruguay	1.86	30	1.78	26	1.76	22	5.7
18	Turkey	1.82	31	1.27	30	0.95	30	91.6
17	Colombia	1.71	32	1.71	28	1.76	23	-2.8
16	South Africa	1.57	33	0.69	37	..	..	..
14	Argentina	1.42	34	1.42	29	3.33	19	-57.4
14	Venezuela	1.39	35	1.26	31	5.63	15	-75.3
13	Morocco	1.28	36	1.10	33	0.85	32	50.6
12	Hungary	1.24	37	..	..	..	..	..
12	Peru	1.23	38	1.13	32	1.11	28	10.8
9	Syria	0.94	39	0.86	34	0.96	29	-2.1
9	Thailand	0.92	40	0.68	38	0.33	39	178.8

continued

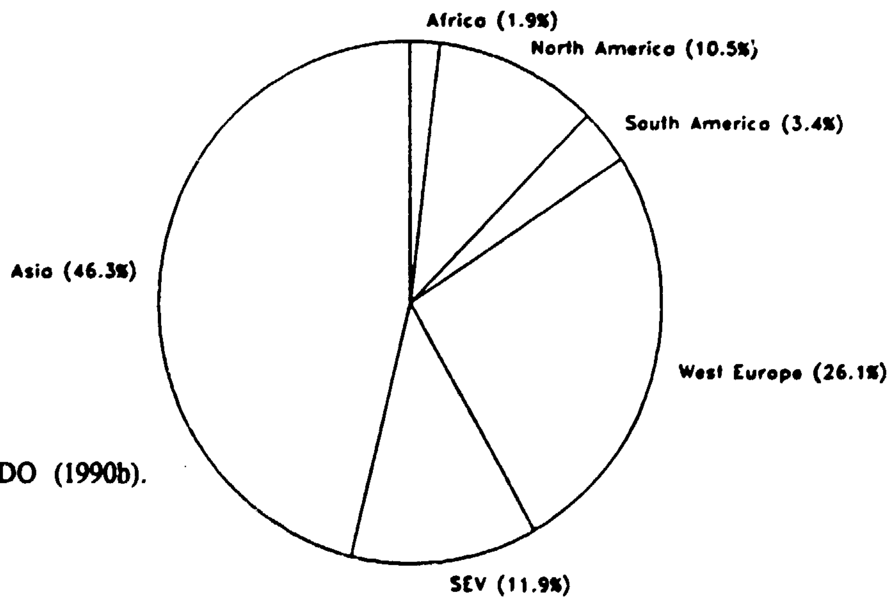
Ratio 1990	Country	1990	rank	1989	rank	1980	rank	Change 1980-1990 %
9	Ethiopia	0.87	41	0.78	36	..	..	..
9	Malaysia	0.86	42	0.82	35	..	..	..
7	India	0.72	43	0.65	39	0.60	35	20.0
7	Philippines	0.67	44	0.64	40	0.43	36	55.8
6	Kenya	0.63	45	0.54	41	..	..	..
5	Egypt	0.45	46	0.45	42	0.39	37	15.4
4	Pakistan	0.39	47	0.37	44	0.34	38	14.7
4	China	0.37	48	0.40	43	..	..	..
3	Tanzania	0.32	49	..	..	..	..	..
3	Nigeria	0.30	50	0.26	46	..	..	..
2	Indonesia	0.25	51	0.23	47	0.63	34	-60.3
2	Sri Lanka	0.24	52	0.26	45	0.16	40	50.0

Ratio: USA 1990 = 100
Rank: 1 = highest, 52 = lowest
Source: Textile Horizons (March 1991).

The implications of labour costs are, however, not self evident. For example, in the late 1980s Italy has been the most successful OECD country both in textiles production and exports in spite of the high - 60 per cent above the US level and rising - level of labour costs. Other things seem to have grown in relative importance. Among these are technological and organizational factors providing more flexibility and ensuring fast and reliable delivery of products with stable and high quality. The relative importance of flexible linkages within the production chain and contacts to the markets, which to a growing extent are divided into many segments with diverging demand patterns has increased.

Textile industries in a numbei ıf developing countries have closed the technological gap with developed countries quite rapidly. This is shown by investment figures in new machinery: In 1988, Asian countries invested US$ 7 billion in textile machinery, over 46 per cent of world investment; and almost twice as much as West European countries (Figure 15.4). This investment pattern suggests, that many developing countries in Asia are putting considerable emphasis on the modernization of their textile industry, which in turn will increase pressure on African countries.

Figure 15.4 Expenditure in textile machinery by region in 1988



Source: UNIDO (1990b).

World total investment in spinning machinery was US$2.8 billion, in weaving machinery US$2.5 billion and in spare parts, supplies and other equipment about US$9.4 billion. A greater proportion of the investment was in spinning rather than weaving equipment (Table 15.9). This shows, that the world textiles industry is emphasizing the modernization of yarn making capacity more than fabric making.

Table 15.9 Share of investment in spinning as a share of total investment in textile machinery by region in 1988

Region	Share of spinning in total textile machinery investments (per cent)
Africa	62.7
North America	60.6
South America	58.2
Asia	48.7
West Europe	57.1
CMEA	49.6
World total	52.8

Source: UNIDO (1990b).

The highest share of investment in spinning machinery (as a share of total investment in textile equipment) is in Africa. Experience in the six African case countries confirms that this is a crucial area: for example in Tanzania, one of the basic problems for the whole textiles and clothing sector was the low quality of yarn. The modernization of spinning is without doubt a vital starting point for technological renewal.

Table 15.10 Investment in spinning machinery in 1988 by region and machine type

Region	Type of machinery			Value of investment (US$ 1000)
	short staple (per cent)	long staple (per cent)	O-E rotors (per cent)	
Africa	62.8	15.4	21.9	92,430
North America	24.4	6.2	69.5	316,020
South America	50.4	20.7	28.9	138,844
Asia	48.1	33.4	18.5	1,379,362
West Europe	27.2	50.0	22.8	745,784
CMEA	6.0	54.2	41.5	146,199
World total	38.4	34.5	27.4	2,818,638

Source: UNIDO (1990b).

The breakdown of spinning investment into different types of machinery, however, shows that African investments are biased towards short staple spinning; over 60 per cent in comparison to world expenditures of under 40 per cent on this type of spinning frame. This suggests that Africa is placing too much emphasis on this type of equipment. Even though there are many types of technological improvements in the short-staple spinning, new investment should be directed more toward the O-E rotor frame, which offers much higher productivity, an equivalent quality of output, and more flexibility of raw material use and product types.[512]

Table 15.11 Investment in weaving equipment in 1988 by region and machine type

Region	Loom type		Value of investment (US$ 1000)
	shuttleless (per cent)	shuttle (per cent)	
Africa	88.4	11.6	5,5016
North America	98.4	1.6	205,461
South America	91.2	8.8	99,668
Asia	74.2	25.8	1,454,724
West Europe	99.9	0.1	560,390
CMEA	99.9	0.1	148,406
World total	84.4	15.7	2,523,215

Source: UNIDO (1990b).

African figures for investment in weaving equipment are quite low: roughly a 2 per cent share of total world investments (Table 15.11). The more modern - faster and more flexible - shuttleless looms are, however, clearly emphasized. The vast majority of all investment comes from Asia, with an emphasis on more old fashioned shuttle looms. This may be because of the enormous domestic need for textiles. Therefore the need for very large production figures is more urgent than the need for flexibility or especially high export quality.

Table 15.12 Investments in spinning and weaving machinery in relation to other textile equipment (spare parts, other machinery and equipment) by region in 1988

Region	Spinning and weaving machinery (per cent)	Spare parts and other equipment (per cent)
Africa	51.8	48.2
North America	32.6	67.4
South America	46.5	53.5
Asia	40.3	59.7
West Europe	33.1	66.9
CMEA	16.3	83.7
World total	35.2	64.8

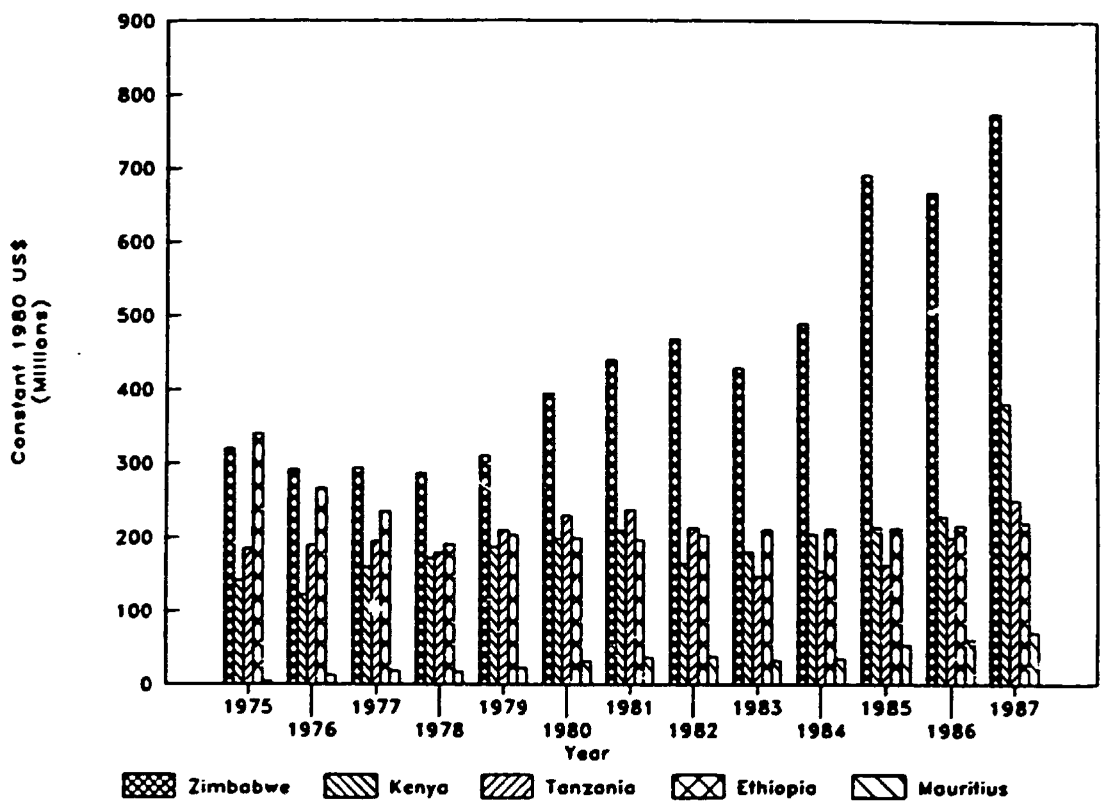
Source: UNIDO (1990b).

[512] UNIDO, 1990b.

15.4 The Textile Industry in the Case Study Countries

The textile industry is important in all the African case study countries, but the textiles share of total manufacturing output varies from under 5 per cent in Kenya to almost 25 per cent in Tanzania. Zimbabwe is the most important producer with a net output of US$96 million in 1988, followed by Kenya with growing production volumes since the mid 1980s. Ethiopian production has remained at a quite constant level since the late 1970s, through to the escalating civil war a decade later. Tanzanian production has fluctuated, while Mauritius, with rather modest total volumes in comparison to the other larger countries, has expanded production volumes quite extensively since the late 1970s (Figure 15.5).

Figure 15.5 Gross output of textiles industries in the five African case countries 1975 - 1987, constant 1980 US$



Source: UNIDO database.

The textiles industry is important in all the countries also in terms of manufacturing value added. The textiles share of total industrial MVA varies between 7 per cent (Mauritius) and 22 per cent (Zimbabwe). The ratio of MVA to gross output has been clearly highest in Zimbabwe, and lowest in Tanzania. Thus, of the case countries, it is Zimbabwe where the textiles industry has generated both relatively and absolutely most additional earnings. The ratio of MVA to gross output has been declining in most countries, and it has been declining especially rapidly in Tanzania (Table 15.13).

Table 15.13 The ratio of MVA to gross output in the textile industry in five African case countries, between 1975 - 1987 (per cent)

Year	Zimbabwe	Kenya	Tanzania	Ethiopia	Mauritius
1975	31.1	25.1	26.1	40.1	36.0
1976	33.4	27.8	31.9	36.1	38.6
1977	32.7	27.8	31.4	33.8	19.8
1978	34.6	27.8	63.8	43.5	31.9
1979	35.4	27.9	54.0	35.6	32.9
1980	37.1	27.8	41.2	53.0	28.5
1981	43.2	27.8	30.2	46.0	30.4
1982	73.4	27.8	22.0	43.3	27.0
1983	88.9	28.2	27.2	37.8	25.7
1984	86.6	27.8	21.8	34.1	26.8
1985	68.1	27.8	15.4	33.0	24.7
1986	78.3	31.1	10.2	31.5	26.9
1987	74.9	19.5	7.6	30.1	29.3

Source: UNIDO database.

As an employer the sector is even more important. The overall employment level has been growing in most countries up to the late 1980s, with the exception of Tanzania where the numbers employed in textiles has fallen slightly since the early 1980s (Table 15.14).

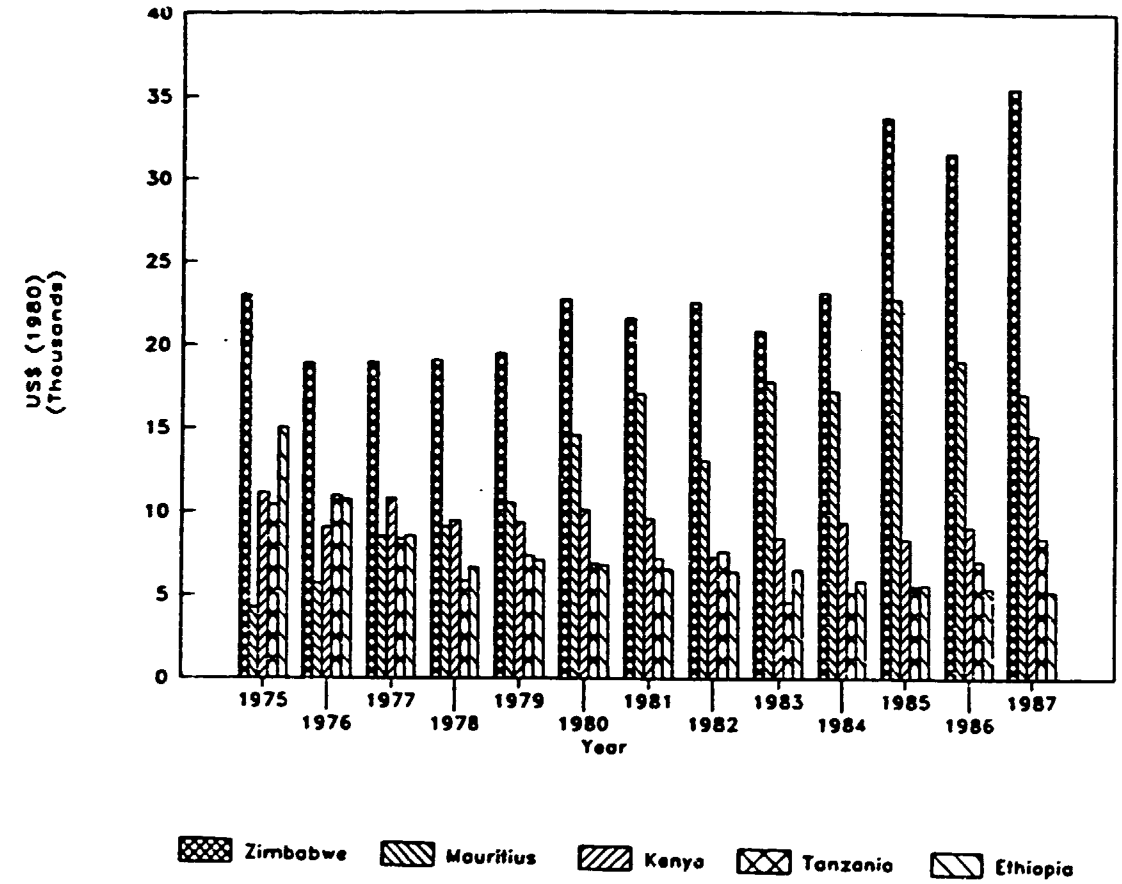
Table 15.14 Employment in textile industry (321) in African case countries, 1975 - 1987

Year	Zimbabwe	Kenya	Tanzania	Ethiopia	Mauritius
1975	13,929	12,716	17,846	22,599	992
1976	15,413	13,644	17,349	24,843	2,208
1977	15,509	14,816	23,295	27,554	2,190
1978	15,023	18,217	30,713	28,645	1,947
1979	15,964	20,080	28,579	28,510	2,117
1980	17,373	19,660	33,359	29,305	2,154
1981	20,417	21,853	33,197	30,012	2,156
1982	20,789	22,728	28,160	31,604	2,882
1983	20,607	21,513	32,335	32,206	1,848
1984	21,200	21,891	30,114	36,389	2,064
1985	20,500	25,817	29,387	38,208	2,396
1986	21,156	25,350	28,497	40,118	3,258
1987	21,833	26,160	29,722	42,123	4,146

Source: UNIDO database.

The productivity of labour - measured as MVA per employee - in the sector varied in the late 1980s between US$7,723 (1987) in Zimbabwe and US$1,998 in Ethiopia. The productivity figures have clearly fluctuated in Mauritius, grown slightly in Kenya and Tanzania and been on a steady low level in Ethiopia (Figure 15.6)

Figure 15.6 Gross output per employee in the textile industry, 5 African case countries, 1975 - 1987, constant 1980 US$

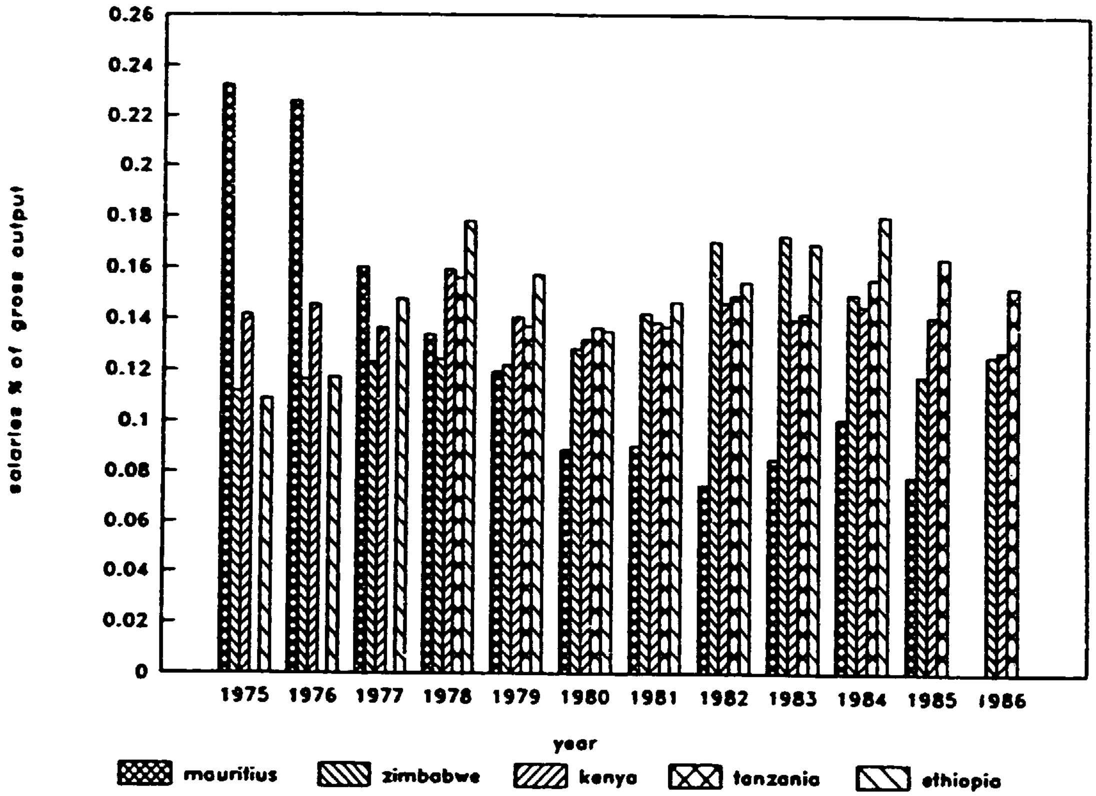


Source: UNIDO database.

The figures by gross output per employee in value terms might only tell us something about increasing wage levels. Figure 15.7, however, shows that this is not so. Generally the share of salaries of gross output has fluctuated in all the countries within a margin of 2 - 4 SAC per cent. Mauritius was the exception, where the share has declined from about 23 per cent in 1975 to about 8 per cent in 1985. However, in Mauritius the textiles sector has modernized rapidly and fewer people are involved in production with increased output.

Most countries - with the exception of Mauritius - have not been very successful in exporting textile products. Production is mainly for the iocal market and for the needs of domestic clothing manufacturing. The export figures have actually declined in most countries.

Figure 15.7 The share of salaries of the value of gross output in textile industry in 5 African countries, 1975 - 1986



Source: UNIDO database.

The importance of the textiles sector, however, exceeds these statistics. On the one hand, the sector provides the main raw materials for the clothing industry. Thus product quality and quantity is crucial for the development of the clothing industry. On the other hand the industry is, in all the countries, mainly based on cotton, which makes it an important customer for domestic cotton farming - except in Mauritius, which relies entirely on imports for its natural fibres. In all, the textiles industry has strong backward and forward linkages, building up productive networks with other manufacturing industries such as ginneries, filament extruders, mechanical engineering and furniture manufacturing.

Textile industries in all the case countries are traditionally based on cotton - and to a much less extent on wool - but a long-term shift towards using more synthetic fibres has occurred since the 1970s. In Kenya especially, most mills, even those that had exclusively woven cotton fabrics, now increasingly produce cotton/synthetic blended fabrics. The shift has been stimulated partly because of a decrease in local cotton growing, and partly because of insufficient import licences granted by the government, the Cotton Lint and Seed Marketing Board.

The national profiles of textile industries differ considerably between the case countries, both in performance, technological level and firm structure. Zimbabwe and Kenya have been the countries longest involved and the most successful in the industry; while Mauritius has shown a very rapid development during the last decade. The Tanzanian textile industry has been declining quite seriously over a longer time span, and the Namibian textiles industry is still rather modest.

In all countries, an important share of the textiles industry consists of integrated mills. In some cases the companies have even combined textiles with clothing within the same factory. The role of large firms is important in all countries as well, and parastatal ones are central in Tanzania and Ethiopia, and to some extent in Kenya as well. In Mauritius the sector is dominated by smaller, often foreign financed private firms.

In Kenya most textile firms are either owned by large finance and development institutions, such as Industrial Development Bank and ICDC, or by private Kenyans. The share of foreign capital is not high, even though the non-Governmental sector is mostly owned by Asian-Kenyans with quite often equity shares held by overseas Asians. The role of Indians is central even in parastatals. Even if the top management is manned by Africans, technical managers are often expatriate Indians, or in some cases Europeans. The private firms have also employed many textile technicians from India for engineering expertise (UNIDO, 1990b).

The Kenyan textile industry is diverse, robust and fairly mature. The industry has been highly protected. In 1986 its effective rate of protection for polyester yarn and diverse fabrics ranged between 72 and 93 per cent. The capacity utilization rate has been rather high in the African context, usually over 80 per cent. In 1986 there were 14 fully integrated factories from fibre blowing through fabric finishing. However, during the 1980s, the Kenyan textile industry has declined in terms of exports. Between 1980 and 1987 the export figures fell from US$6.1 to US$3.3 million. This has been blamed on the inefficiency of local companies.[513]

Kenya has easy access to the EC market for textiles and garments. This has attracted Asian investors prevented from expanding in their own countries by import quotas under the Multifibre Agreement - a similar development to that in Mauritius. They often manufacture garments in Kenya using fabrics from their own countries. If local factories were able to sell fabrics and yarn to these new factories, the possibilities for the Kenyan textile industry would improve substantially.[514] The prospects of attracting more foreign investors to the country, however, depends largely on the policy problems discussed earlier in Chapter 12.

The technological level of Kenyan textile firms is quite diverse. According to the World Bank, both in spinning and weaving:

> "Kenyan firms display superior technological mastery, with levels creditably near world best-practice levels". (World Bank, 1987).

This statement could well be true, as far as the most advanced private firms are concerned. The practical situation is - at least when it comes to the majority of parastatal companies - not as good. Here technologies are not very modern and the factories are not run at optimal levels. Technical and managerial problems of the Kenyan industry are discussed later in the chapter.

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[513] Coughlin, 1986.

[514] UNIDO, 1990b.

In Zimbabwe, the basic situation of the textiles industry resembles very much the Kenyan situation. However, the role of foreign capital is slightly more important in the Zimbabwean textiles sector in so far as the level of technology is concerned. Technical and managerial problems, on the other hand, play a less significant role. The problems are mostly with respect to the availability of inputs, and of spare parts not produced in Zimbabwe. The most notable textile mills are either parastatals or parts of multinational groups. There are some important private, domestic industrial groups in the sector. Technologically Zimbabwean textile mills seem to be more modern and automated than companies in some other case countries. There have been many important rehabilitation and investment projects in the country during the late 1980s, continuing into the 1990s.

The supply of cotton has been quite abundant in the country. During the 1980s, an average 60 per cent of the crop was exported, which implied the possibility of further growth of domestic cotton based industry. The situation has, however, deteriorated. In the late 1980s cotton crops have declined. This has been partly caused by weather conditions and diseases, but the main reason is a decrease in the area planted. Lack of rain has been another cause. As in Kenya, the price guaranteed by the central body responsible for buying and selling cotton, the Cotton Marketing Board, has been too low and farmers have moved to more profitable crops. The area planted in 1989/90 was not much more than half of the record planted area in 1984/85 (EIU, 1990b).

In Tanzania the textiles industry is given a high priority in governmental plans and economic recovery programs, and is seen both as an important basic industry, and as a sector with strong development potential. It is an essential sector from the point of view of the whole industrial sector; since textiles and clothing together comprise 22.8 per cent of establishments in manufacturing industry, 34.2 per cent of employment, 22.7 per cent of gross output; and 24.5 per cent of capital formation.[515]

Generating all the basic economic benefits are largely attached to the roles expected from the sector. According to the planning documents, the textiles sector should promote:

- clothing the people;
- saving and generating foreign currency;
- generating employment;
- providing a source of investible surplus;
- promotion of the economy through wide linkages;
- generating income.

The sector mainly consists of rather basic manufacturing - spinning and weaving - with a rather low share of high value added articles, such as made up textiles - even though the share of knitting is increasing.[516] There has been very little export success, and exporting is mainly restricted to goods that are not the main textile products: knitted fabrics, and semi-processed products such as yarn and grey cloth. The share of exports has, however risen slowly since the mid 1980s, with the private sector exporting a higher share of its products than the public sector.

The sector is split into two quite different segments: the private sector consists mainly of rather small companies that account for the majority of employment, while the

[515] Valk, 1990.

[516] Valk, 1990.

governmentally owned sector consists of very large companies with the majority share of installed capacity.

Technologically the sector is very diverse and often very old. The machinery used originates from various countries, and even the new installations show a great variety of suppliers. The supplying companies are often chosen by aid donor countries and not by the firm where the new equipment will be installed.

In Ethiopia, the technological and economic level of textile mills also varies substantially. Many factories are old, run inefficiently and at a low rate of capacity utilization. Machinery is often outdated, or broken, and out of order because of a lack of spare parts. The civil war has further exacerbated the situation. However, Ethiopia also has the most automated, sophisticated and modern textile mills of all the case countries: the Awassa Textile Mill.

The Awassa Textile Mill (located in Awassa 100 kilometres from Addis Ababa) started full-scale production in 1989, 12 years after introduction of the original concept and three years after the approval of the project. The Italian built factory can produce 11.1 million m^2 of woven 100 per cent cotton articles, and perform dyeing, printing and other finishing tasks for 25 million m^2 of cotton/polyester articles produced elsewhere per annum.[517] The factory employs approximately 1,200 people. If it had conventional technology it is estimated that it would need three times as many workers.

The factory is very highly automated - the factory manager estimated a 90 per cent level of automation - and all technologies are up to date. There is a spinning department with 24,288 spindles and a weaving department with 124 shuttleless rapier looms. In addition to automatic production machinery starting from automatic placers, there is, for example, automatic inspection for the evenness of yarn; a PC based production planning and control system; PCs for managerial automation and NCMTs for maintenance and repair in the workshop. The finishing department will be, according to present plans, automated within two years.

Awassa is a good case of the benefits of automation as well. The most important effects were, according to the factory manager, an increase in the machine utilization rate, better and more even product quality, generally better productivity, increased company turnover and shorter lead times. The automation also improved overall production control and resulted in a greater speed of output. All inputs are being used more effectively and there are more product options. Working conditions have also improved markedly.

Training the workforce has been important in establishing the new factory. For example, 90 secondary graduates were trained for 6 months for maintenance tasks; 302 machine operators were trained for a 3 month period. 43 technical and production personnel were trained in Italy. Additional operators and other personnel will be continuously trained. 200,000 birhams was spent on training.

What is significant is that the factory managers also report a very high level of both labour productivity and motivation. The main problems faced are connected with unreliable supply and delivery of raw materials not with the use of modern technology.

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[517] Awassa, 1989.

Obtaining spare parts is a problem as well, and the company has to hold a one year advance stock of spares. Because of this, the production manager could not envisage any more modern interfirm relations, and any JIT organization would not work.

Like that of other Ethiopian companies, the economic organization of the company is very rigid being owned by the National Textile Corporation which takes care of, for example, sales of products; the factory does not have independent outside business relations.

The factory is, in the Ethiopian context, used also as a demonstration centre for new textiles technology. Its experiences are spread to others through training. For example, workers of the new Arbaminch mill under construction are trained at the Awassa facilities.

15.5 Textiles Problems in the Case Study Countries

The situation in textile industries and firms, of course, varied considerably in the countries visited, however, some common features exist. In the following discussion, the main problems are discussed under six headings:

- infrastructure;
- training and education;
- financial and trade policy;
- raw materials, intermediates and spare parts;
- firm organization;
- specific technology problems.

(a) Infrastructure

Many problems go back to basic infrastructural shortcomings in the countries. We have dealt with many of these aspects already in Chapter 13. From the firms' point of view, defects in the physical infrastructures - water supply, roads and railroads for physical transport - are inconvenient, but not critical. The most vital physical infrastructure problems were defects in electricity supply and inadequate telecommunications networks. These may become major barriers to future technological development. In Tanzania especially, cuts in electricity supply were among the main reasons for low capacity utilization.

Generally weak infrastructure means that the acting firms have to supply the basic needs for themselves. They have to overcome the physical infrastructure defects, for example, by locating the plant in a region with above average connections or creating special arrangements in transport. Taking care of these concerns involve costs, and thus reduces the competitiveness of the firm.

If we think about more modern production relationships such as JIT (Just in time production), the physical transportation barriers may become critical for establishing efficient cooperative company networks which we have seen are becoming increasingly important in the OECD countries. In the case countries transportation problems have supported the establishment of integrated mills with fewer outside transport needs. Generally, from the point of view of textile firms in the case countries, physical infrastructure has not posed major problems. The only severe problems have occurred in electricity supply, and partly with national telecommunication facilities.

(b) Training and education

More important than the physical infrastructure concerns are education and training aspects, the supply of human skills and capabilities. The education and training systems in the respective countries are not normally capable of supplying companies with sufficient vocationally skilled workers or with capable managers. In this respect, Mauritius seems to be a major exception with, as noted earlier, high levels of literacy and participation rates at all levels of education. In Zimbabwe there is a very high level of unemployed labour with post-secondary education but no vocational specialization.

In addition to the problems in the system for basic education, there are only very limited resources for supplementary training of the workforce. Additional training of the workforce becomes all the more important in developing technologies, and in developed countries this kind of vocational adult education is expanding rapidly. There are lots of examples of various arrangements and organizational forms for adult education and training that could be applied to a much wider extent than presently, even in the context of developing areas such as our African case countries.

For surmounting training problems the large successful textiles companies in the case countries, as a rule, had very extensive training arrangements for the whole workforce, ranging from basic vocational training for newcomers to arrangements for further education in institutes abroad. Short-term training was often arranged in cooperation with equipment suppliers.

Taking care of training at the firm level is costly and from the firms' point of view often less beneficial. In many cases, it has been said that large firms practically serve as suppliers of skilled workers for the whole sector. After training in a large company, workers are skilled and in high demand in the small firms that cannot afford to train themselves, but may be able to pay higher wages. This was especially evident in the textile industry, where, in most countries visited, the large firms are actually the sole trainers.

Lacking managerial skills seem to be critical in many companies. As one report states on the Kenyan textile companies:

> "Many firms, especially parastatals, have very weak upper management and miss easy, immediate opportunities to reduce costs or increase production and sales. Most managers - public or private - do not understand and use the concept of marginal costs, and, hence, forego the chance to use compartmentalized pricing to capture new domestic or export markets". (UNIDO, 1990b).

This view was confirmed by visits to many companies, and not only in Kenya but all case countries. Managerial capabilities are limited, and not only at the highest levels. The middle management in some countries was blamed, both by people interviewed in the textile firms, and by consultants and researchers, for being quite incapable of organizing, delegating and managing the actual production process. Mauritius, is perhaps an exception. Management problems - as discussed already in more detail in Chapter 12 - are partly due to the curricula within the education system, partly to company cultures.

(c) Trade and financial policies

Trade policies pose various problems. Most of them are related to importing and exporting. Customs regulations and taxes to be paid on imported spare parts, intermediates and raw materials are a problem and an extra cost as such, but the bureaucratic procedures are usually more obstructive for business activities. The tedious import practices mean that the inputs needed often have to be ordered months before the actual need and foreign exchange is wasted by accumulating stocks of spare parts.

This puts additional pressure on the company planning departments which are not always very capable of long time planning. Many cases were mentioned where the needed inputs were ordered too late - for example spare parts after the machine had broken - and caused longer down-time of individual machines or whole departments. The operation of a whole factory could be interrupted, with delayed deliveries of critical imported raw materials.

Allocation of foreign currency is another problem in many countries. This came up as vital in Tanzanian parastatal companies, that had very limited possibilities of obtaining foreign currency, even for purchasing the necessary inputs. Obtaining currency for needs of minor urgency - such as subscribing to technological journals or visiting international exhibitions on process technology development - were usually out of the question. Similar problems were present even in countries like Kenya. Obtaining foreign currency was especially difficult for small firms who were not involved in the export trade.

Generally, financing operations was a major problem in all the case countries except Mauritius. Most companies suffered from a continuous shortage of working capital, and there was as a rule less capital available for machinery/equipment investments than the firms would have liked to invest. This was most evident in the textile industry, where the investment costs are highest of the three sectors studied.

Financial markets are not fully developed in all case countries, though in Mauritius a considerable liberalization of financial institutions was accruing and credit with major financial institutions, e.g. the World Bank was high. Kenya and Zimbabwe and Mauritius have their own equity markets. Domestic interest rates are generally high in most African countries and the possibilities of obtaining loans on better rates are limited. Foreign loans are little better but difficult to acquire by highly indebted countries.

One way of obtaining more capital to finance operations would be by establishing joint ventures with foreign companies. This is generally favoured in the case countries policies, but joint ventures were not very common in the textile industry - with the exception of Indian equity share holding in many companies established by Asian Africans. The particular benefit attained from joint ventures is access to foreign production networks and other linkages abroad. These were widely used at least by the Kenyan companies with Indian connections, and in Mauritius; in both cases the linkages were utilized for obtaining information on market and technology developments, and for training the workforce.

Problems in repatriating profits have been a general hindrance to foreign investment in most case countries. However, repatriation has gradually been facilitated. Foreign investment is encouraged by various arrangements simplifying importing for export production and by tax free production zones. In Kenya, the so called "Manufacturing Under Bond" for facilitating imports for export production has not attracted many producers so far.

In contrast, the Mauritius Export Processing Zone has been a success in attracting foreign investors - also in the textiles industry - and has thus brought foreign capital into the country. The Zone is acting as an example for other countries, and Kenya is planning to establish a corresponding tax free processing zone within a year or two.

Wage policy poses additional problems. The wages are not too high - the highest share of wages of gross output in the late 1980s (in Tanzania) was about 15 per cent. The labour costs of the Tanzanian textile industry were only about 3 per cent of the US labour costs in 1989, or less than 7 per cent of the Taiwanese costs. The corresponding figures for Kenya were 6 per cent (USA) and 13 per cent (Taiwan); and 9 per cent (USA) and 20 per cent (Taiwan) for Ethiopia.

Wages in general are very low, and so is productivity and this has been discussed in more detail in Chapter 12. The consequence of below subsistence level salaries in the textile industry are similar to other sectors, neither shop floor workers nor managers are motivated to work. They need all extra energy to think about supplementary means of earning a livelihood. Also there are no functioning incentive schemes for workers to increase output.

(d) Raw materials, intermediates and spare parts

Basic raw materials are not very problematic for textile industries in most case countries. The industries are primarily based on cotton, and domestic cotton production covers the main needs. For example, Tanzanian cotton, which is of especially high quality, is exported to other countries, despite Tanzania having an extensive domestic textile industry.

The situation is more problematic in Kenya. Domestic cotton production has fallen despite strong growth of the textile industry. Kenyan cotton is also of lower quality, with shorter fibres than, for example Tanzanian cotton. The main reasons for falling production has been the declining price paid to the farmers, and long delays in paying farmers; in addition to the low yields, which further depress the profitability of cotton growing for farmers. These reasons have caused many farmers to stop growing cotton and move to more profitable crops.

The main reason for this is, again, in the realm of public policy of cotton pricing and the bureaucratic procedures in actuating the transactions. The cotton is brought from farmers and sold to firms by a public monopoly, the Cotton Lint and Seed Marketing Board, The monopoly sets the prices, and pays them to the farmers with over a years' delay. Despite shortages, the CLSMB has only recently imported cotton and then only to a very limited extent:

> "In response to complaints from textile manufacturers, the government began in early 1989 to require manufacturers to submit a joint request for imports through the Textile Manufacturers Association. Still, the requests are delayed both by the association, the CLSMB which must give a letter of no-objection, and the import-licensing and foreign-exchange authorities. The result: factories still do not get enough cotton".[518]

The availability of other raw materials and intermediates, such as synthetic materials, dyes and other chemicals is in most countries limited by access to foreign exchange.

This is true in respect of spare parts as well. Textile machinery is completely of foreign origin. Spare parts have to be imported, and firms face the same import regulations again. Attempts to overcome the problem by domestic and in-house spare parts manufacturing have been made, but domestic engineering firms are not usually capable of manufacturing spare parts for textile machinery.

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[518] UNIDO, 1990b.

In Mauritius, there is no domestic cotton production. This means that the basic raw material has to be imported, which of course, adds to the overall costs of the industry. This has not, however, affected the success of the Mauritian textiles and clothing industry in any respect.

(e) Firm organization

The parastatal companies in the case countries are usually owned by developing and financing organizations, or specific holding companies. For example, in Tanzania the Tanzanian Textiles Corporation (TEXCO) owns 14 major companies together employing more than 25,000 people. The organization is problematic, while all important decision making including financial needs are in the final instance made in the holding company. There is a very similar system with the National Textiles Corporation (NTC) at the core in Ethiopia.

The holding company is actually exercising detailed control of the companies. On the other hand, the actual support given to them appears to be very limited. Interviews with TEXCO owned companies revealed that the holding company could not, for example, give the firms the most elementary aid or supervision in matters related to acquiring new machinery. The firms, with no contacts to suppliers and without financial possibilities to visit foreign exhibitions - not granted by the holding company - had to make the actual investment decisions themselves. The holding company only granted finance for the investment.

This kind of umbrella organization for individual firms could be useful and finance saving, but only if their main purpose is to aid the companies in practical matters like training the workforce, obtaining and spreading information on technological development, and establishing facilities for cooperative use (such as CAD systems for textile printing design).

When it comes to the internal organization of companies, the main problems were often located in the repair and maintenance department. The successful companies could act as demonstration examples in this respect: In textile mills which did not have any notable problems with maintenance and capacity utilization, maintenance was a focal area. They had systematic preventive maintenance programs, maintenance and repair decentralized by department, centralized workshops for manufacturing minor spare parts, and a centralized maintenance group for the infrastructural engineering issues (steam and power supply, etc). The most vulnerable parts in machinery were changed regularly according to a preplanned program, and spare parts were ordered in time to keep a sufficient stock of these.

In some cases, maintenance was one of the few functions within the company that was computerized. For example, in a Tanzanian textile mill information on every machine was on computer and all the spare parts were listed in the computer, so that up-to-date data on the status of each machine was accessible at all times.

At the other end of the scale companies were found with no preventive maintenance and no stock of spare parts. The result was that the capacity utilization rate of these companies was extremely low - between 10 per cent and 20 per cent even stated officially - while the best companies reached rates of over 90 per cent; in some departments practically 100 per cent.

Another critical function in a textile mill is quality control. Both the quality of the yarn and that of the fabric has to be checked in relation to many parameters (such as strength, elasticity, colour, fabric structure), and laboratory equipment is needed for most of these inspections. Quality has to be checked regularly because all changes in raw materials and within the process may affect the quality. In order to avoid producing stocks of defective products, a swift feedback from quality inspection is required.

Not all the textile companies visited, however, had their own laboratories. For example, in Tanzania many parastatal companies had to send samples of their products to the Tanzanian Bureau of Standards for inspection. The firms got results back after a few weeks. If the quality was inferior, the firm might have produced inferior products for weeks without knowing it.

An opposite case was found in Kenya, the quality was inspected continuously with in-department laboratories providing immediate feedback. In this case, the amount of defective production was diminished to a minimum. For this, up-to-date laboratory facilities are essential.

(f) Technology

The technological level in companies was very diverse, from factories with machinery of 1940s or 1950s vintages installed in the 1960s with only minor investments during the following quarter of a century, to very modern and automatic up-to-date machinery. The inconsistencies often relate to individual factories, which may have significant imbalances between departments.

In every country almost all firms expressed an eagerness to acquire new machinery. How 'appropriate' or 'high technology' machinery they were hoping for was usually related to the technology in use. Companies with very labour intensive and old technology were quite nervous about more radical leaps. The main reason for not wanting the most up-to-date machinery was the need to retrain the workforce and the fear that maintenance service would not be capable of repairing the more automated machinery. Also governmental regulations often tend to discourage automating. For example in Tanzania, the official labour market policies that are making it practically impossible to dismiss workers are a rather effective additional reason not to proceed too rapidly in automating.

It was interesting, however, that even the most old fashioned factory visited in Tanzania, expressed the wish to modernize some of their smaller departments with the most up to date technology.

Second-hand technology was usually not favoured. In some countries, such as Kenya and Zimbabwe, there is an official policy against importing second-hand technologies/equipment. Most firm representatives interviewed were also against buying second-hand technology, not so much of fears that the technology would be obsolete, but because of the risks involved. But in some cases attractive opportunities are lost because of this general policy.

There is no established market for second-hand machinery, so the prices are quite random. The actual condition of used machinery is difficult to evaluate, and the relocation of machinery from the previous site to a new one may cause both unforeseen practical problems and additional costs. The warranties are usually worse than with new machinery, and the supply of spare parts, maintenance, and training support is generally worse than with new machinery brought from an established supplier.

The more advanced and more complex the technology in question is, the more risks are involved in acquiring second-hand machinery. Buying second-hand usually only comes into play when a company is buying machinery it is already familiar with. It is also favourable if the machinery is supplied by a company already familiar to the buyer, and preferably in a long time cooperative relationship. This would ensure support with eventual problems. There were textile firms, for example in Zimbabwe, that favoured investment in second-hand technologies in situations like this.

One technology related problem was the immense variety of machinery types in companies. The diversity makes maintenance and having domestic stocks of spare parts much more difficult. A difficult issue is that foreign donors tend to favour their own suppliers, which further increases the variation in machinery. This is a problem both at company and national level.

Transferring textiles technology seemed to be, as a rule, rather uncomplicated in comparison to other more rapidly changing technologies. In most cases, it is only a question of incremental developments, where the basic operations remain fundamentally unchanged, even though the individual machinery may be much more advanced. Often it is only a question of growing degrees of automation, more capacity, more reliability, and more stable quality in products.

In the case companies visited, the renewals were usually made in small stages, one department at a time. And at least in the most developed companies, the investments were accompanied with simultaneous training of the workforce.

15.6 The Textiles Industry: A Brief Summary

In the long run, global textiles production has gradually shifted from developed to a few developing countries. The trend is not as clear any more as it was during the 1960s/1970s. There are technological and market related issues that emphasize the proximity to consumer markets and/or end users. The segmentation of demand structures and the rapidly fluctuating fashions in the developed countries' garments market also accentuate the need of flexibility within textiles production.

Technology has a part to play in this development. Developments in textile technologies have mainly been incremental. However, gains from the developments in terms of quality, productivity, speed, reliability and flexibility of production have been considerable. This is a fact that developing countries are obliged to face, if trying to compete in the textiles field. There are few alternatives to technological development when international performance standards are set by possibilities offered by up-to-date technologies. For example, many quality standards are very difficult to reach without modern automated machinery and corresponding laboratory facilities.

Textiles are among the most important industrial branches in all the African case countries. However, the countries have not done so well in the industry during the 1980s. The countries have been especially unsuccessful in exporting. The role of African countries has been marginal in the global textiles trade.

In this respect, Mauritius is a clear exception. There, however, the emphasis of the industry is on clothing (knitwear) manufacture and the basic textiles sector is actually quite small. The case of Mauritius will be discussed in more detail in Chapter 16.

Technologically the majority of the textiles firms in the case countries are backward and not operated at the best practice level. But contrary, examples can be found in every case country. There are firms with the most up-to-date, highly automated production technologies showing outstanding performance in every business field. These examples demonstrate that it is quite possible to reach the top level in textiles manufacturing in the African countries.

The few cases of excellence also reveal that difficulties in modernizing industrial technologies and business practices are complicated. The obstacles the exemplary firms have faced in their modernization process also expose the fact that there are problems and defects at all spheres and levels of the political, economic and social systems in the countries that hamper techno-economic renewal. The problems are partly caused by international developments and historical settings, but a notable share also results from internal policies and practices.

Most of the difficulties textiles companies are facing are common to all industrial activity in the countries. Some features are sector specific. From the point of view of technological renewal of the textiles industries, the most important targets for policy renewal at governmental, sectoral and firm level are:

(a) At the governmental policy level the strict and complicated import regulations are among the things seriously hindering the renewal of production technologies. Financial and monetary policies complicate the situation further. It is usually very difficult to obtain loans at reasonable interest rates, not to mention venture capital. This, of course, is partly due to the countries' high level of indebtedness. In most case countries firms are also facing serious difficulties in obtaining foreign exchange for their investment. This even applies to companies earning foreign exchange through exports.

Many infrastructural policies are inadequate from the point of view of modernizing textiles industries. For example educational and training policies do not support the industry, while there is practically no vocational education for the industry in any of the countries.

(b) At the sectoral level firms especially need information on technological (and market) developments, support for technology choice and cooperation in learning the new technologies. Only the largest companies, usually with foreign owners, partners, or other substantial linkages abroad, are free of this need. The sectoral research institutions and sectoral organizations (holding companies, industrial associations etc.) in the countries do not seem to be capable of supplying this kind of support.

(c) At the company level technological renewal has often been, in the long run, quite haphazard. Typical textiles factories in the case countries are amazing collections of machinery originating from several decades and countless suppliers. New investments are primarily carried out when foreign currency for the purpose is granted, not according to a long-term investment plan.

Renewals and rehabilitations financed and organized by foreign donors are more planned and long-term oriented. Often, however, the local basic conditions are not taken enough into account, and the fruits of renewal are lost within a few years after the completion of the project.

Elementary considerations in renewing textiles factories in the case countries are:

- building up within the factory the physical and human infrastructures that are missing from the countries generally;

- starting restructuring from overall production control and general factory lay-out and working through all departments in the factory;

- in a textiles factory it is usually reasonable to renew one department at a time under the criteria above, but with the integrity of the whole factory in mind. The integrity aspect is especially important in a fundamentally continuous process flow type of technology such as textiles;

- the basic functions and structures in the factory organization should be taken into account long before the actual technological renewal. These include for example repair and maintenance, quality control, supply and delivery of raw materials, management information systems, business and financial administration, the supply of a trained workforce and/or training of the workforce, and, finally but not least important, the organization of work with the new machinery;

- continuity, long-term development targets and using the transferred foreign technology as a learning basis and a basis for future development are key themes in the company level technological renewal.

16. The Clothing Industry

In developed countries, the clothing industry has long been characterized as a declining industry with significant reductions in employment, diminishing or slow growth of output and poor export performance. From a global point of view the production of clothes has gradually been moving to developing countries.

In the 1960s the clothing industry accounted for about 8 per cent of total manufacturing employment in the OECD area, in the late 1980s the corresponding figure was 3 - 4 per cent. This is usually explained by increased productivity and the low wage costs of new producers in developing countries. Since the production process is very labour intensive, labour costs are seen to be a decisive factor in determining international comparative advantages.

There are, however, some industrial countries (Italy, France), where the clothing industry has shown relatively strong growth until recent years. This illustrates that labour costs alone do not determine the international competitiveness of the clothing sector. There are in addition a number of demand side factors related to product differentiation, rapidly changing consumer tastes, fluctuations in fashion, etc. that can bring about a specific competitive edge.

The demand side factor together with the possibilities posed by micro-electronic technologies and automation of production processes have been seen from the developed countries point of view as an opportunity to change the course of global development in clothing. These developments could, by improving productivity and production flexibility, compensate for the huge differences in wage costs. New production concepts and organizational innovations are factors further promoting the creation of new competitive advantages for developed countries, especially in the fashion markets.

The clothing industry is by no means regarded as a technologically progressive one. Research and development costs in the industry are among the lowest within the whole manufacturing sector. However, some clothing firms - such as the Italian Benetton company - have actually been raised as paradigmatic examples of the new, flexible production mode. On the other hand, a lot of artisanal clothing production based on very traditional production methods and task divisions, still exists. On the whole this means that the global clothing industry is actually more diversified than before, and there are also more differentiated markets.[519]

16.1 Clothing in a Global Market

During the 1970s the pattern of international trade in clothing changed dramatically. The share of world exports held by developed market economies fell from more than 60 per cent in 1970 to under 40 per cent by the mid-1980s (table 16.1). This was to a large extent due to rapidly increasing exports from developing countries and - to a lesser extent - from centrally planned economies. At the same time, as the advanced market economies lost their export market share, the output volumes and employment in the clothing sector decreased considerably. When looking at the industrialized countries as a whole, the clothing sector has gone through an extensive restructuring process.

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[519] Kasvio, 1991.

Table 16.1 World clothing exports 1970 - 1985 by country groups

Year	World trade	Exports of developed market economies		Exports of developing market economies	
	US$ billion	US$ billion	per cent of world trade	US$ billion	per cent of world trade
1970	6.44	4.09	62	1.36	21
1973	12.59	6.92	55	3.82	31
1974	14.97	8.05	53	4.77	32
1975	16.73	9.00	54	5.40	32
1976	20.62	10.08	50	7.87	38.5
1977	23.50	11.80	50	8.70	37
1978	28.33	14.44	51	10.42	37.5
1979	34.37	17.83	52	12.35	35.5
1980	40.21	20.60	50	14.67	35.5
1981	41.10	19.10	46	16.86	41
1982	40.02	18.09	45	16.85	42
1983	40.37	17.79	44	17.39	43
1984	45.87	18.70	41	21.90	48
1985	49.42	19.49	39	24.92	50.5

Source: Vuori & Ylä-Anttila (1988).

However, GATT statistics up to 1988, with a slightly different country classification, show that the growth of developing countries relative share has actually stagnated (Table 16.2). In 1985 the developing countries share of world clothing exports was 45.5 per cent (US$ 22.0 million out of the world 48.4 million), and 3 years later 45.4 per cent. During that period, only the East European countries increased their share in clothing exports.

Table 16.2 Clothing exports 1973 -1988, country groups (US$ billion)

Country group	Year					
	1973	1976	1979	1982	1985	1988
OECD	7.0	10.1	17.7	18.1	20.6	36.4
Developing	3.8	8.1	13.6	17.4	22.0	40.6
World total	12.6	20.6	35.4	41.1	48.4	89.5

Source: GATT, various years.

During the late 1980s clothing production has actually recovered in many developed countries, e.g. in the EC-area the output volume rose by some 10 per cent, though it is still clearly lower than in the early 1970s. It is however, too early to conclude whether there is a turning point in the trend. There are some transitory factors which have had a bearing on the improved performance of European clothing industries:

(1) The considerable appreciation of the US dollar against the European currencies until early 1985 weakened the competitiveness of many South East Asian

countries which had largely fixed their currencies to the dollar. The same mechanism in fact acted the other way round in the early 1970s.

(2) There was an investment peak in European textile and clothing industries around 1983-84 which strengthened their competitive position. Furthermore, the Multi Fibre Agreement (MFA) was renewed and extended in 1983 so that it was more restrictive regarding the imports of the most sensitive products to West European countries.

At the same time as the industrial countries saw a continuous decline in their clothing production, employment and exports, the developing countries expanded their production as an important element of their industrialization strategies. The share of world clothing trade held by developing market economies increased from 21 per cent in 1970 to more than 50 per cent in the mid 1980s. This is explained not only by low wage costs but also by the nature of clothing technology. So far the technology has been easy to transfer from one country to another and the adoption of even the newest technological applications has been fairly rapid. The situation may, however, change with more integrated and complex production technologies.

If we take a look at production figures, it is worth noting that the major share - over 70 per cent - of global clothing production is still held by the developed countries. Thus exports are of greater importance for developing countries than for industrialized countries, which have so far been able to keep a substantial part of their home markets through protectionism and product specialization.

Table 16.3 Breakdown of clothing production and world population (centrally planned economies excluded)

Year	Developed countries share of (per cent)		Developing countries share of (per cent)	
	Clothing production	Population	Clothing production	Population
1953	92	32	8	68
1970	80	27	20	73
1985	71	21	29	79

Source: Vuori & Ylä-Anttila (1988).

Clothing firms and policy makers in industrial countries have responded to the growing import penetration by the developing countries with two basic reactions: with growing demands for increased protectionism; and with efforts to improve productivity by means of innovations and micro-electronics based technologies. The applications of new technology have been seen as an opportunity for developed countries to revitalize clothing manufacture. This has led to a growth in R&D activities in many developed countries.

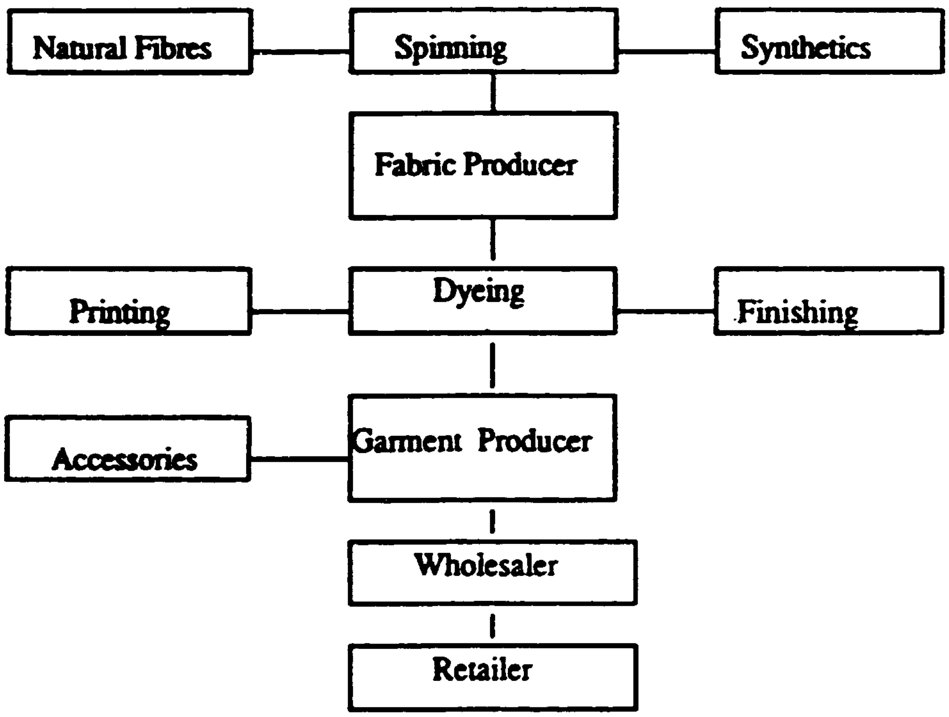
This suggests that the diffusion of new process technologies will play an important role in the clothing industry in the near future. If this results in clearly diminishing the comparative advantages of low cost labour, the position of the less developed countries especially may worsen since micro-electronics-based systemic technologies are much more difficult to transfer and adapt to the existing production structures than conventional technologies.

16.2 Technological Developments

In the past, technological change in the clothing industry has been slow. In sewing, which is the vital stage in the production process, techniques have not basically changed since the sewing machine was introduced over a hundred years ago. The production process is still highly labour intensive. The basic reason for this is the nature of production, where two-dimensional, soft or limp materials are subjected to a series of individual handling and assembly processes, to become a product that fits a three dimensional human body. The production process is complex with hundreds of operations, even in the case of rather simple products.

The manufacture of clothing is tightly connected to the textiles industry and its sales network (Figure 16.1). The textiles industry supplies the basic raw materials (fabric, or yarn to knitwear manufacturers), and the ready made products are then distributed through the sales network.

Figure 16.1 The textiles and clothing production chain



Source: Whitaker, Haywood & Rush (1989).

Some processes upstream of the clothes manufacturing industry or some particular clothes have been adapted to more capital intensive methods, but the process as a whole remains largely disjointed. However, though mainly incremental, changes in technologies have already changed the nature of the production process. But this is not a question of technology alone; the changes in the structure of the industry and the global market are at least as important. Together these evolutions - not to speak of the more radical technological innovations are expected to change global advantages, and thus the competitive possibilities of developing countries as well.

The main phases of clothing manufacture are:

(1) the pre-production stages (design, pattern making, grading, nesting, marking and cutting);
(2) the actual production process (sewing, assembly of the product);
(3) and the finishing operations (inspection, pressing and packaging).

There are technological development in all of the phases, the most important, however, in pre-production, as we noted in the printing industry. However, the changes have been quite incremental, and the basic innovations all go back to the 1970s (Table 16.4). The technologies are discussed in more detail in the following chapters. The description is mainly based on Hoffman and Rush (1988), Rush and Soete (1984) and Kasvio (1991).

Table 16.4 Major technological innovation in the World clothing industry in the 1970s

Technology	Description	Diffusion
Computers	Computers are used by management for sales analysis and forecasting, process inventory and workflow management	Widespread use of computers expected. More software will become available for the product engineer, cut planning and production schedule creation. Will be linked to real time applications
Computer Aided Interactive Graphics	In the production process computer aided design equipment is applied to grading and marking operations resulting in increased fabric utilization	The use of computers in pattern grading and marker making will continue to grow rapidly. Use of systems is likely to spread to small- and medium-size firms.
Numerically Controlled Cutting Devices	Numerical control equipment directs devices through their operations with improved product quality and higher cutting speed (linked to CAD)	Will continue to diffuse within mainly larger firms which are prepared to centralize cutting facilities.
Laser Cutting	Computer Aided laser cutting systems cuts single ply fabric at high speeds with high accuracy, reducing material losses	Used to a very limited degree in cutting men's suits and interlinings. High capital costs and technical difficulties limiting cutting depth will restrict use until development of continuous spreading and cutting from roll.
Pre-programmed dedicated sewing machines, pre-programmed convertible units, operator programmable sewing machines	Automatically sew various components such as collars, cuffs and pockets. High productivity gains but limited to sub-assembly operations	Diffusion limited primarily to large firms with long runs and stable fashions. Operator programmable units for more general purpose will increase flexibility and diffuse even to medium-sized firms.

Source: Rush & Soete (1984).

(a) Design

The design of clothes can be a very human capital intensive process, and the greater the fashion content in a given design the more complex and varied are the factors involved. At the one end of the scale, there is the designing of standard clothing items, where the fashion content is close to zero; the designing share in this case amounts to no more than a technical description of standardized inputs. At the other end of the scale is "*haute couture*", where creative and highly individual designing activities can account for a considerable share of the final sales price. It is in this field that the use of CAD systems has greatly increased the productivity of individual designers. Designing with a light pen on a screen in full colour poses fewer limitations than designing on a piece of paper with the use of coloured drawing utensils. This system provides a wide range of structuring and patterning options, thus considerably shortening the trial and error process (during which creative mistakes may be made) before completion of the design. This simplifies the setting up of a fashion collection for the usual reason because quick additions can easily be made by modifications carried out in the computer system on those fashion items which are proving to be more popular.

The system has even greater potential, since the on-screen, full-colour patterned cloth can be off-printed in the pre-selected width to ensure that the visual conception corresponds with the fabric itself, which is two-dimensional. Similarly, the colour and material input demands can be sent off on-line to the respective producers of these intermediary inputs so that they can examine the technical feasibility as well as price, production and delivery specifications of the input demands. Hence, almost the entire time-consuming and human capital-intensive range of activities located in front of the pre-assembly process can be enormously simplified and accelerated through CAD.

A limitation of CAD is, that it does not offer the possibility of immediate simulated on-screen three dimensional presentation of material movements. The reason for this is the nature of clothing: its fit depends on the kind of material used, its thickness, the pattern employed and fashion demands. For instance, while even PC-based CAD systems can easily portray a snug-fitting cotton t-shirt on a computer-formed individual, they cannot portray a long flowing dress, incorporating different types of materials, patterns and cut. There are too many individual parameters involved in the latter case. The problem is not however, crucial, since skilled designers know how the materials will behave. Of course, this means that designers must still have the basic material knowledge and CAD systems do not necessarily decrease the skills needed, they just increase the productivity and add new possibilities to variety in products.

One vital contribution of CAD interfaced with telecommunication networks is the possibility of separating human-capital intensive activities from the location where the purely labour-intensive production activities can take place, without sacrificing necessary information linkages. It is easy to link, for example, design studios in Europe with manufacturing operations in the Far East. Given that the labour intensive core of the clothing manufacturing process has so far remained largely unaffected by the introduction of micro-electronics, a micro-electronic revolution could accelerate the migration of clothing industries to low labour cost areas. Assuming other factors to be equal, this migration would involve moves from one country to another, or more likely, one continent to another, as the cost of telecommunications world-wide satellite is only marginally more expensive than that within continents. As noted earlier, one example of this was the Mattel company transmitting data on clothing design to Indonesia for manufacture at isolated sites. However, there are also problems associated with production at sites which are geographically isolated, e.g., time scales for delivery, fashion changes, etc.

However, in addition to transportation costs, which have always been a factor preventing the move to low-cost production locations, whether within a country or abroad, access to qualitatively acceptable inputs may also act as a brake on moves to other continents. There are those who believe that the long standing links between the textile and clothing industries are vital to ensure that the demands of quality-minded customers for up-market products can be met. Nevertheless, this argument may be less valid for the wide range of medium-priced products, where textile producers in developing countries are approaching the standards of industrialized countries.

Finally, as noted in Chapter 3, CAD systems are becoming more powerful, and prices are coming down. There are several systems on the market which include plotting for a price under US$ 40,000, and software for CAD systems even sell for under US$ 4,000. This means that they are quite within reach of smaller companies as well as for firms in developing countries.

(b) Pattern making

Pattern making involves transforming a finished design for a three-dimensional piece of clothing into two-dimensional cloth segments which, when reproduced, can be assembled to produce any number of copies of the original one-off pattern. Two basic functions must be fulfilled. First, the pattern structure must not detract from the original design. Second, the pattern structure must be such that it can be adapted to the time and cost constraints of the production process. Highly paid, skilled personnel are employed to ensure that both these functions are fulfilled, and so far they have only been partially assisted by computers.

Dividing a clothing product into a number of parts, which after assembly fit into the overall design, requires knowledge about the many properties of cloth and the way it can be combined with the same or other types of cloth to fit a human body. The structure of the material, the type of patterns printed on it, and the other design specifications (e.g. type of pockets, number of fasteners) all represent demands that still are often best fulfilled by skilled workers. However, CAD systems can be used efficiently for breaking down a piece of clothing into manageable components more effectively. This is quite easy with somewhat standardized products, but there are still difficulties associated with tasks where optical and sensory attributes must be taken into consideration.

Once a pattern has been created for a specific piece of clothing the downstream production specifications have to be met. This involves defining each production step needed to assemble the individual parts into the final product and estimating the ensuing production costs. Because the lead-time for new fashions is quite short, there are time constraints which exclude the introduction of major capital equipment for restructuring purposes. Since the technical capabilities of specific equipment are well known and both the sequence and demands of certain steps are either dictated by nature of the product or have evolved out of past experience this task, given a computer-based production planning system, can be reduced to making estimates whenever there are gaps.

The output of all these calculations is a set of figures on the material, labour and capital costs of production, plus the time frame needed to produce a given amount of output. Similarly, this set of figures is used to draw up the production schedules and map out material flows from the incoming fabric to the outgoing packaged final product. The more standardized the individual steps are, the greater the impact of technology in this area can be expected to be. The small size of the firms has so far limited the spread of computer assistance in production structuring. Given the similarity of production processes in clothing factories, there is obviously room for inter-firm production planning services, as practiced in the US, if an overall attempt is being made to improve the competitiveness of the national industry.

(c) Grading, nesting and marking

CAD systems ensure a very high level of automation in most stages of pattern making. Similarly they are used for calculating the necessary allowance for salvages, seams, hems etc. Grading, whereby different-sized patterns are produced from an initial-size pattern to correspond to the entire range of standard sizes, is a similar procedure. Therefore CAD systems permit virtually instantaneous grading for any market specific size specifications. The once tedious and time-consuming process of grading each new piece is now reduced to a computer software package, including standard grading factors which can be adjusted accordingly to individual firm or fashion parameters.

The pre-assembly lay-out process is the final step before the actual fabric is put together. At this point the graded patterns are arranged, nested, in such a manner on a master pattern sheet (marker) that they cover as much of the fabric as possible. Whereas conventionally each and every piece of a pattern had to be hand placed, nested and marked on a pattern sheet, CAD systems allow the structuring of an entire marker up to for example 144 inches wide and 99 metres long. Nesting will be accomplished - in an interactive process - in over 30 per cent less time than before, with an average 5 per cent reduction in material losses and up to a 9 per cent saving in one case noted.[520] To make optimum use of the system, the nesting pattern is often run on an automatic mode overnight with the interactive adjustment occurring during normal working hours.

Since material costs account for a major share of the final product price (40 - 60 per cent) and fabric wastage has little re-usable value, this aspect is quite important in improving competitiveness. Computer systems not only assist the operation in moving around the individual pattern pieces, nesting them and creating multiples of given nesting structures across the width or length of the marker, they also provide tolerance checks on the distance to be maintained between individual pieces and the cutting system specifications. Such checks ensure that costly mistakes are not made in trying to squeeze as many pattern segments as possible out of the fabric by nesting them closer than cutting tolerances allow.

Labour costs for phases of grading, nestling and marking are only a small fraction of total labour costs, and reducing labour inputs has not actually been a major criterion for acquiring CAD/CAM systems. High levels of absenteeism, labour turnover, and the increasing difficulties involved in attracting qualified and experienced graders and markers were frequently mentioned as important factors in the decision to introduce the technology.[521] The main benefits are in material savings and increased flexibility, as noted earlier.

The benefits are, however, not easy to achieve. The introduction and efficient use of a CAD system requires users to affect fairly sweeping changes in the organization of production and its mode of operation. New routines and new tasks are required. The established design and pre-assembly activities need to be changed entirely.

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[520] Hoffman and Rush (1988).

[521] Rush and Hoffman (1986).

(d) Cutting

With the cutting process, the actual fabric enters the pre-assembly stage in the clothing production process. It is delivered on rolls of discrete widths of between 36 and 88 inches. The fabric is then unrolled, inspected for flaws, cut into specified lengths as dictated by the marker, precisely laid out and stacked in what is called a lay. The number of fabric layers in the lay is mainly dictated by the type of cutting equipment and type of the fabric. The marker off-printed by the CAD/CAM is placed on top of a lay for a given production run, or rather the marker information in the system is interfaced directly with the cutting system.

Until the 1950s, the cutting process, the most highly skilled activity in the manufacture of garments, had been subject to virtually no technical change. Manually operated shears were replaced by electric shears and the hand-held electrically powered reciprocating knife only in the 1960s and early 1970s. During the mid-to-late 1970s, the pace of innovation in cutting technology began to increase dramatically. Innovations included hot wires, plasma streams, water jets and laser beams. These techniques have enjoyed some limited commercial acceptance but they have all been effectively superseded in the market place by NC-controlled systems. These rely on a mechanical knife to cut the fabric.

The most sophisticated system was developed by Gerber, which is also a major supplier of CAD systems. The Gerber computerized system receives digitized marker data on pattern pieces and shapes and placement from computer tapes prepared by the CAD system. A high speed reciprocating knife is directed by computer through material held flat by means of a vacuum system. The blade cuts through the fabric into a series of plastic bristles upon which the material rests. All cutting movements are possible without removing the blade from the fabric, although the blade is lifted for self-sharpening and to begin new cut lines. This technology has become the dominant automated system on the market today.

Already Gerber cutter models from the late 1970s could cut cloth at a rate of 200 inches a minute to a height of 288 plies, thus it is possible to cut 600 men's suits, 200 dozen shirts, 450 dozen bras or 2400 pairs of trousers in a hour. This has meant a radical decrease of labour needs in the cutting room with, from the early 1980s, labour costs reductions of 50 - 60 per cent being documented.[522] The price of such systems is also reducing, and new one-ply or low-ply cutters are available for prices as low as US$ 75,000. Since 1989 prices have dropped significantly, since newcomers have entered the market, and Gerber's own prices have declined by about one third in the two years up to 1991.

(e) Sewing

The core production process in clothing manufacture, sewing, has developed only slowly technologically. By the 1960s, the control of industrial sewing machines was based on an often complicated mixture of electro-mechanical systems, hydraulics, pneumatics and fluidics. The systems were overwhelmingly mechanical in nature and with many moving parts. Towards the end of the decade, suppliers began to replace some elements of these systems with simple solid-state devices and hard-wired circuitry although no attempt was made to extend the use of electronics to the full range of the machines produced.

These efforts represented the first foray by those firms into the electronic age and were typical of the approach adopted by equipment companies in the other sectors trying to learn to

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[522] Hoffman and Rush (1988).

use the new solid state technology. The changeover to electronics, both within the companies and across the industry proceeded very slowly and unevenly. First attempts with numerical control technology were made in the early 1970s, and by the mid 1970s three basic types of machine control applications emerged.[523]

The first category are machines in which dedicated microprocessors and NC control units are used to control the operation of specialized work stations carrying out small parts assembly, or repetitive sewing. Operators usually do no more than load the work pieces, initiate the sequence and unload completed parts. Programming is usually performed away from the machine. Typical applications involve run stitching for small parts, collar and cuff assembly, shirt front and sleeve assembly, belt loop attachment and pocket welting.

The second type of micro-electronics application relates to pre-programmable convertible machines. These are modified conventional sewing machines that are convertible to different sewing tasks by the use of pre-programmable data input devices. The operators tasks are similar to dedicated machines. Programming may be done on a separated digitized unit, or on one that is attached to the sewing machine and has a direct input. No translation of the design into a machine-readable form is required. The range of design changes that these machines can accommodate may be quite large, and both decorative and functional stitching can be performed in a sequential fashion.

The third, most advanced, type is the operator-programmable sewing machine. The software in this type makes it highly flexible and adaptive to real operating conditions. The degree of integration between hardware and software is much higher in this type of machine, and the control units carry out a much wider range of functions than the control units used on other automated machines. The machines are easy to program; after setting the machine controls in a teach/learn position the operator first carries out the required operation by manually guiding the work piece under the needle head and programs the various machine functions required to perform the operation. The operator's instructions are converted by the machine into an optimum sewing programme that can be repeated perfectly on every work piece. After the programming is completed, the machine takes over all or most of the operator's functions except for guiding the material. These systems are mainly suitable for a range of small parts assembly activities such as top stitching collars and cuffs, and pocket setting.

Technical change in sewing machine technology has been primarily incremental and concentrated on three features:

- increased speed of operation;
- the development of work aids to facilitate materials handling;
- the mechanization of small parts assembly via the introduction of dedicated machines.

Micro-electronics is used for incremental innovation in a way typical for most industries beginning to exploit the technology. It enables an industry previously based on mechanical engineering to introduce an unfamiliar technology at relatively low risk and begin to learn about its potential relative to the particular problems of their industry. In this respect, the clothing industry is very similar to others. The biggest difference is that the application of microelectronics to assembly technology has proceeded more slowly than in other industries.

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[523] Hoffman and Rush (1988).

Even however, incremental evolutions have considerable effects on labour productivity. Cases from the early 1980s of impacts of various types of machinery on labour productivity are given in table 16.5.

Table 16.5 The impacts of microelectronically controlled sewing machinery on labour productivity

Kind of machine and operation	Type of product	(a)	(b)
1. Dedicated machines			
Attach belt loops	Men's & ladies' jeans	50	n.a.
Attach belt loops	Men's jeans	60	n.a.
Collar & band stitch	Men's shirts	36	41
Collar & band stitch	Boys' shirts	48	51
Button holes	Men's suits	75	57
Small parts run stitch	Ladies' blouses	59	38
Embroidery	Ladies' blouses	74	75
2. Programmable convertible machines			
Pocket setting	Jeans	54	65
Cuff top stitch	Ladies' blouses	50	65
Hip pocket stitch	Children's jeans	72	70
Decorative tabs	Sports shirts	56	57
Shirt fronts	Men's shirts	59	57
3. Programmable conventional machines			
Collar stitch	Men's shirts	40	n.a.
Cuff stitch	Children's shirts	18	n.a.
Hip pocket set	Ladies' jeans	46	n.a.
Shirt pocket set	Men's shirt	22	n.a.
Pattern sewing	Athletic shoes	140	n.a.

(a) Increase in Labour productivity: Reduction in Standard Allowed minutes per operation (per cent).
(b) Reduction in total labour costs (per cent).

Source: Hoffman & Rush (1988).

The same authors also report on reduced training times (Table 16.6) when micro-electronically controlled sewing machines are used. With otherwise as up-to-date but not micro-electronically controlled machinery there were notably less savings in training time, as a rule under 10 per cent.[524]

[524] Hoffman and Rush (1988).

Table 16.6 ***Reduction in training costs of times due to the use of microelectronic equipment in sewing***

Activity	Reduction in training time or cost
Collar and band attach	60 per cent reduction in training time
Hip pocket set	40 per cent reduction in training time
Collar stitch	30 per cent reduction in training time
Small parts run stitch	From 12-15 weeks to 3-4 weeks
Small parts run stitch	50-70 per cent reduction on training time depending on task
Attach decorative tabs	Training time reduced by 90 per cent by employing operators who are unskilled instead of skilled.
Button hole and button attach	30 per cent reduction in training time
Right hand shirt fronts	20 per cent reduction in training time
Collar and band attach	Reduction in training costs of 93 per cent
Jeans pocket set	Reduction in training costs of 70 per cent
Design embroidery	Reduction in training costs of 90 per cent

Source: Hoffman & Rush (1986).

Innovations to be expected in the future may include sewing robots and further sophistication of NC controlled sewing machines, and more automation in conveyor systems. In addition to the technical innovations, many organizational innovations are expected within sewing. Some of these are discussed in detail in section 16.3. A growth in multi-shift production is expected, in particular because of accelerating machinery prices.

(f) Finishing

Downstream in the clothing production process, technological innovations have been limited to pressing, and, to some extent, repairing rejects from the inspection process. Inspection, pressing and packaging - the finishing process - is all the more important the higher the value of the final product. It is the key interface between the reputation of a company and the production process. Money saved at this stage leading to lower-quality output will be fed back to the company via decreasing demand and lower prices. Obviously at this point in the process a compromise has to be made between thoroughness and speed. However, if the production process is functioning correctly, the number of rejects will be small and the production line output will not end in a bottleneck. An indication of an increase in rejects means that certain parts of the process are not tracking. Then the primary task is to pick up the reason for this in the process itself.

Pressing units have been devised which are highly automated and ensure a high-quality finish. Although these machines are expensive, they are proving their worth not only by speeding up the process but also by being able to rectify certain types of garment defects, and they are spreading rapidly in developed countries.

(g) The spread of new technologies in developed countries

Even in developed countries, new automation technologies have only spread to a wider use in the clothing industry during the late 1980s. This is true especially for the actual production technologies; the pre-assembly stages, financial, managerial and administrative functions had been computerized earlier.

This is partly due to the firm structure in the sector. For example, in Germany (West), almost half of clothing companies employed 50 or less people, and only 10 per cent of companies had more than 500 employees. The spread of production automation has, so far, been slower in small firms that are usually also operating in more labour intensive, design based segments of the industry with higher needs of production flexibility. With further technological development the situation may change.

The spread of the main new technologies in Germany (West) are presented in table 16.7. It is noticeable that by the year 1987 a few firms had actually introduced automatic sewing technologies; only 6 per cent had introduced flexible sewing units, 8 per cent sequential automation, and 14 per cent full cycle automation. The rates of diffusion by 1990 were expected to be much higher; 38 per cent, 20 per cent and 39 per cent respectively. Even more interesting is that 25 to 40 percent of the firms proclaimed that they do not need any automatic sewing.

Table 16.7 The implementation of new technologies in the clothing industry in Germany (former Federal Republic in 1987 (per cent)

Technology	Implemented by 1987	Will be implemented by 1990	Not needed
Automation of production			
Full cycle automation	14	39	32
Sequential automation	8	20	40
Flexible sewing units	6	38	25
Automatic cutting	14	48	26
Automatic transport	3	21	50
Computerization of Production			
CAD	12	31	31
Pattern making/grading	23	33	26
Automatic storing	25	27	27
Managing of orders	50	24	10
Production planning	36	39	12
Production management	26	43	17
Payroll work	40	31	13
Information for management and on production process	22	35	17
Other innovations			
Ergonomic design of workplace	27	35	21
Pick-ups, stackers, robots, automatic handling	19	18	32
Other new technologies, e.g.: gluing, welding, moulding, 3-dimensional sewing	4	30	42

Source: Gebbert (1990).

The source does not give any considerations to the background factors and possible reasons for this. It is most likely, that firms with no automation needs are small and producing very small batches. In this segment the relative benefits of automatic assembly technologies are still less evident than in more mass market oriented sectors. With further development of flexible sewing automation, however, the situation may change. The firms with no apparent automation need may, on the other hand, also be the ones that have been in the process of relocating production to low wage countries.

Sewing automation was, however, put quite high on the list of expected key areas of technological development in the German clothing industry. Only production planning and management got a higher response rate.

Table 16.8 Expected key areas for application of new technologies in the next three years by West German clothing firms in 1987 (per cent)

Area of technology	per cent of firms
Production planning and management	54.4
Cutting	50.0
Sewing	50.0
Designing	47.5
Cutpattern-making	45.6
Managing of Orders	40.4
Dispatching	37.0
Pressing	23.7
Administrating	23.7
Storing of completed garments	22.0
Quality control of fabrics	20.2
Storing of fabrics	16.0
Transporting	14.9
Finishing	14.0
Preparing	13.2

Source: Gebbert (1990).

16.3 Work Organization and Training

The technical innovations described above do not, as such, have significant effects on the modes of manpower use, or on the content of individual tasks in clothing firms. The greatest changes so far have been in the initial stages of the manufacturing process. There the introduction of computerized planning has to some extent obscured the traditional division of labour between designer and master-tailor. In the cutting process, automation has relegated the once highly regarded and well-paid profession of cutter to the level of an operator.[525]

In the assembly of clothing automatic sewing devices have in some instances reduced the work of the production seamstress to feeding ready-cut sections into a machine and removing

[525] Fischer and Minssen (1985).

the finished article at the other end. Automatic conveyor systems, again, may have reduced the degree of cooperation among workers as articles are passed from one stage to the next in the process. In basic outline the work of, for example, the seamstress on the production line remains more or less unchanged, a relatively short-span, fast-pace task carried out by relatively unskilled and low-paid labour, compared in the developed countries mainly of women.[526]

Since the 1970s the efforts to evolve new modes of work organization have been intensified throughout the developed world. In the initial stages the main motive was to secure the availability of manpower. The object was to re-model work tasks in the industry in order to constitute more meaningful entities and to reduce health risks common in monotonous production line work. This was the point of departure, among other things, for the so-called humanization programme for work in West Germany. In the German programme, the most extensive individual development project concerned the clothing industry.[527]

In the clothing sector humanization meant mainly adopting arrangements already familiar in other sectors, like rotation of tasks, extension of assignments, self-regulating work groups and so on. During the 1980s, however, the emphasis in development efforts shifted, and now companies have concentrated their efforts on reorganizing working life into more general flexibility strategies caused by changes in the market. The traditional modes of work organization have proved to be too cumbersome, for instance, production line workers accustomed to performing one particular stage may be relatively reluctant to adapt themselves to constantly changing tasks.[528]

Table 16.6 listed some clear cut savings in training time and costs related to sewing automation. Generally the effects of technological and organizational changes on training needs are not that simple. New forms of work organization and task division especially, imply new training needs. For example, German firms highlighted many areas as important for training in the 1987 survey (Table 16.9).

Table 16.9 Relative importance of industrial training subjects in the German clothing industry in 1987

Important subjects for industrial training	For white collar workers (per cent)	For blue collar workers (per cent)
Wide basic education	41	39
Training for job performance	-	41
Training for increased flexibility	-	74
Training in machinery know how	39	40
Training in-house circulation of goods	14	9
Training in production planning systems	39	8
Training in electronic data processing	68	11
Training in information and communication techniques	43	4
Training in quality performance	32	53

Source: Gebbert (1990).

[526] Kasvio (1988).

[527] Aktionsprogramm, 1980, ref. Kasvio (1988).

[528] Kasvio (1988).

The need for training for flexibility and quality performance are clearly the most important issues mentioned for production workers. For white collar workers the most important needs are more directly computer oriented. Training in data processing and information and communications techniques are marked as the most important needs.

From the developing countries point of view the new training needs make applications of modern production technologies rather more complicated. While skill requirements with new machinery might generally be lower than with old, they are definitely different. Familiarity with computerized technologies becomes a basic qualification.

This is an evident barrier to the diffusion of new technologies in developing countries. Computer literacy and familiarity with new technologies are not generated by the education systems or by the everyday living environment. In developed countries, people become accustomed to the use of computers in childhood; computerized technologies become items of the everyday culture and natural working tools.

In developing countries this may have to be taught more formally. And often not before it is related to the actual work. The postponed familiarization with new technologies not only hampers the thorough learning of the new basic qualifications, it also restricts the more innovative ways of organizing the use of new technologies which should be based on an exhaustive proficiency of the new machinery and other devices.

There are no general solutions applicable to the needs of the clothing industry as yet. One relatively extensive strategy is dividing the assembly sections into smaller units in which each worker takes responsibility for two or more phases of the work and where the make-up process is thus clearly curtailed. This model is not suitable for all types of companies. In some cases the use of small work groups has been abandoned after the experimental stage, and different firms have been obliged to seek solutions appropriate to their own particular circumstances.[529]

Since the mid 1980s the pattern of organizational development activity has assumed a greater diversity. Technological changes have furnished enterprises with a variety of alternatives. In addition to the adoption of small group manufacture, the installation of computer-aided conveyor systems offers new possibilities for automation with the computer ensuring a balanced work load on various work stations and dispensing orders as their respective urgency requires. There are also increasing efforts to apply JIT (Just In time) approaches to the needs of the clothing industry. This means, for example, attempting to reduce intermediate stocks to a minimum, changing from batch production to the manufacture of individual articles, and shifting quality-promoting activities covering the entire production organization to individual workers.[530]

16.4 Firm Organization

In clothing industries in developed countries, innovations in firm organization are often much more important than technological innovations. The most characteristic feature in these changes is the creation of firm networks, tightly interconnected groups of firms involved in common business. In this concept, the old division of labour between commercial firms,

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[529] Kasvio (1988).

[530] Halinen (1986).

manufacturing firms and artisanal production is often split and new combinations of functions are created. The key themes are common design, decentralized but coordinated production, continuous and rapid feedback from market changes leading within the flexible production organization to rapid changes in the variety of products.

The core of the network - the coordinating centre - may be a commercial firm marketing products under its own trade mark, but using both outside designers and producers. It may be a company focused on design, producing everything outside and marketing the products through independent retail networks. It may also be a manufacturing firm using various outside designers and retailers.

The Italian Benetton is the text book example of the new organizational mode. It has also served as an example to many clothing companies in developed countries. Companies like this have been central in the resurgence of the OECD clothing industries.

Benetton is basically a family firm, originally designing and manufacturing knitwear at home, and selling them to outside retailers. Thus the background is in an organizational form preceding the industrial manufacture of cloths. With growth the crucial inventions in the firm were organizational, combining the ancient forms of cloth making to the factory system and the newest technologies within a network organization.

Typical for the Benetton production mode is that the firm itself is concentrated on designing the products, acquiring materials and on the most capital intensive phases of the manufacturing, such as knitting, dyeing and printing. Sewing is performed in many subcontractor firms. In the mid 1980s Benetton had about 300 subcontractors employing about 15,000 people, while the Benetton company directly employed less than 2000 persons. The subcontractor network is rather stable, with an annual change of only about 5-6 per cent. The basic criteria for subcontractors are quality and reliability in delivery.[531]

The retailing system is an original Benetton invention. It is a special form of informally regulated franchising system. Retailers that sell Benetton's products do not pay royalties, but are rigidly controlled. They cannot sell other makes of clothing, and even the locations of the shops are decided by Benetton. The shop design is also common:

> "The typical Benetton shop is standardized. This allows for a centrally determined 'optimized' lay-out for the display of goods and the selling system. In a Benetton shop it is the colours, the window display and the open shelves that strike you most, as they are designed to do by the now famous architects Afra and Tobia Scarpa. The organizational and labour costs are much lower than in other typical clothing shops. Another advantage, also in terms of space, is the absence of warehousing, indeed all the items are displayed on the sets of shelves. The absence of warehousing is linked to the use of information technology and to the flexibility of the whole productive cycle. Benetton's commercial strategy is to stay ahead of competitors in costs, and thus in prices; both in Italy and abroad Benetton imposes the price of each item on the retailers".[532]

The development of Benetton to what it is currently did not take place overnight. The company was established in 1957 and the first factory started in 1965. The path to success was

[531] Kasvio (1991).

[532] Belussi (1990).

paved with continuous innovations in products, processes and above all, organization.[533] The development of the company has been divided into four phases:

In the first phase (1965 - 1970) the dominant features were:

(a) the introduction of incremental in-house innovations in machinery through minor but effective changes in ordinary second-hand machines bought in the market.

(b) the building up of the Benetton's particular retailing system, which acted as a major resource for the general growth of the firm.

(c) special attention towards a product differentiation strategy with the introduction of light colours in casual and sports fashion.

Thus, in this phase the development was based on tacit knowledge on the production process and on the ability to link innovations to a systemic view, interlinking design, production and distribution.

In the second phase (1970 - 1977) the firms growth did not involve any major innovations. During that period, the firm developed its operations through learning by doing, using, and failing.

In the third phase (1977 -1982) the new feature was the introduction of process innovations aimed at a higher level of automation in the most capital intensive production processes (cutting, knitting and dyeing). This phase was characterized by the acquisition of new technology, supplied externally by machine producers.

In the fourth phase (1982 -) typical features are a wider use of new information technologies: the building up of an information network connecting productive and commercial activities, applying CAD and new automated warehouses. In the information system, the shops are the "antennae" of the firm. They are in weekly contact with the head office, reporting takings and detailed sales. In the headquarters information is used for three basic functions:

(a) collecting orders from shops;
(b) storing detailed orders by shops for use in long-term planning, and
(c) financial accounting.

Benetton is not - has never even tried to be - a producer of actual fashion articles. It is more oriented to the mass market of youthful, leisure time clothing (Kasvio, 1991). The firm has succeeded in conquering the market with the above described combination of product, process and organizational innovations. To these should be added very aggressive (in some cases controversial) marketing and advertising.

16.5 Clothing in Developing Countries

The developments of clothing exports was discussed earlier in Chapter 16.1. The relative importance of clothing exports for developing countries has, however, declined. The share of clothing exports of all manufacturing exports has decreased since the late 1970s (Table 16.10). Conversely, clothing's share of developed country exports has slightly but steadily increased since

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533 Belussi (1990).

1982. This may, again, be an indication of a change in the trend, caused by changes in market patterns and developments in production technologies.

Table 16.10 The share of clothing exports of total exports in main country groups

Country Group	Year (per cent)					
	1973	1976	1979	1982	1985	1988
OECD	2.4	2.1	2.3	2.1	2.2	2.3
Developing	15.8	14.7	15.7	15.4	14.5	13.4
World total	3.6	3.5	3.7	3.9	4.1	4.4

Source: GATT, various years.

The earlier general remarks on the importance of textiles production (Chapter 15) largely apply to the clothing industry as well. It has been a very important sector for initial industrialization of developing countries. The growth of the sector has been partly facilitated by the relatively simple production technology, that has been reasonably easy to transfer and adapt to the traditional, pre-existing cloth making. Still the vast majority of clothing firms in Africa are very small, largely handicraft producers.

As a labour intensive sector, the clothing industry has also been a relatively easy sector for basic import substitution policies. If markets are protected from foreign competition, a rather stable demand for domestic cloth production is ensured. This has been the usual pattern in most African countries.

The jump to export promotion is more difficult, and has in fact, succeeded in only a few developing countries. Table 16.11 shows, that the vast majority of low wage country imports to the OECD area comes from Asia, and from only a few countries at that. Imports to the European OECD countries are notably imports from the (Southern) European peripheries and Eastern Europe, in addition to a few Asian NICs. (Though the latter are the major suppliers.)

The African export performance to OECD countries is especially low, though the figures have grown from a 1970 level of almost nil, to a 1987 figure close to the Latin American level. The number of countries responsible for the growth are nevertheless quite limited. The most important OECD importer of African clothing has been France, and the most important source countries are apparently Mauritius (alone responsible for about 15 per cent of African clothing exports) and other countries in Francophone Africa (Table 16.12).

Table 16.11 Clothing imports to USA, Japan and OECD from various areas in 1970, 1980 and 1987

Year	Exports to					
	USA		Japan		Europe	
Imports from	million US$	(per cent)	million US$	(per cent)	million US$	(per cent)
1970						
European periphery	8	1.2	0	0.0	90	12.6
East Europe	9	1.3	10	15.9	188	26.4
Africa	0	0.0	0	0.0	5	0.7
Latin America	54	7.8	0	0.0	2	0.3
Asia	616	89.5	52	82.5	434	60.9
Low wage total[1]	688	54.2	63	69.2	713	21.6
Total imports	1,269		91		3,294	
1980						
European periphery	26	0.4	1	0.1	1,728	16.2
East Europe	92	1.5	3	0.3	1,651	15.5
Africa	13	0.2	0	0.0	668	6.3
Latin America	639	10.3	2	0.2	203	1.9
Asia	5,452	87.6	1,098	99.5	6,160	57.9
Low wage total[1]	6,223	89.6	1,104	71.8	10,647	42.4
Total imports	6,943		1,537		25,133	
1987						
European periphery	426	2.2	2	0.1	5,354	25.0
East Europe	272	1.4	0	0.0	2,677	12.5
Africa	184	0.9	0	0.0	1,752	8.2
Latin America	1,934	9.8	3	0.1	208	1.0
Asia	16,865	85.6	3,929	99.8	11,134	52.1
Low wage total[1]	19,700	89.1	3,937	84.2	21,384	49.8
Total imports	22,116		4,674		42,902	

[1] The share of low wage areas of total imports. The shares of individual areas are counted from the low wage area total.
Source: Wortmann (1990).

Table 16.12 Clothing imports to some European OECD countries from Africa 1970, 1980 and 1987

Country	Value of clothing imports from Africa (million US$)		
	1970	1980	1987
UK	0	5	76
Germany	1	208	481
France	4	236	854
The rest of OECD Europe	183	219	341
OECD Europe total	188	668	1752

Source: Wortmann (1990).

16.6 Clothing in the Case Study Countries

Clothing is a reasonably important sector in most African countries. The countries were, however, producing garments mainly for domestic consumption, and the sector is not as important as textiles, neither in terms of production nor employment. African countries have not become an important source area for international clothing companies, and very few African companies have, as mentioned above, had success in exporting.

In this respect, Mauritius is an exception (and Zimbabwe to a lesser extent). Mauritius is the only Sub-Saharan African country with important clothing exports. The evolution of exports from Mauritius are presented in Table 16.13.

Table 16.13 Clothing exports from Mauritius 1985 - 1989

Year	Clothing exports			Clothing share of total exports (per cent)
	million rupees	million US$	growth rate (per cent)	
1985	2548	170		38.4
1986	4051	270	+59	44.7
1987	5587	372	+39	48.6
1988	6559	437	+17	48.7
1989	7148	477	+9	47.5

Source: Mauritius Annual Digest of Statistics (1989).

It can be seen however, that despite healthy growth rates these have steadily declined (calculated on value), though in 1989 the value of exports was almost three times greater than in 1985.

The Mauritian clothing industry is in an entirely different size group than the other case countries. It employs more than the Kenyan, Tanzanian, Zimbabwean and Ethiopian clothing industries put together (Table 16.14). It is also of a very different type; while the clothing industry in most African countries is dominated by manufactures of sewn clothes, the industry in Mauritius is producing mainly knitwear.

Table 16.14 Employment in clothing industry (322) 1975 - 1987, African case study countries

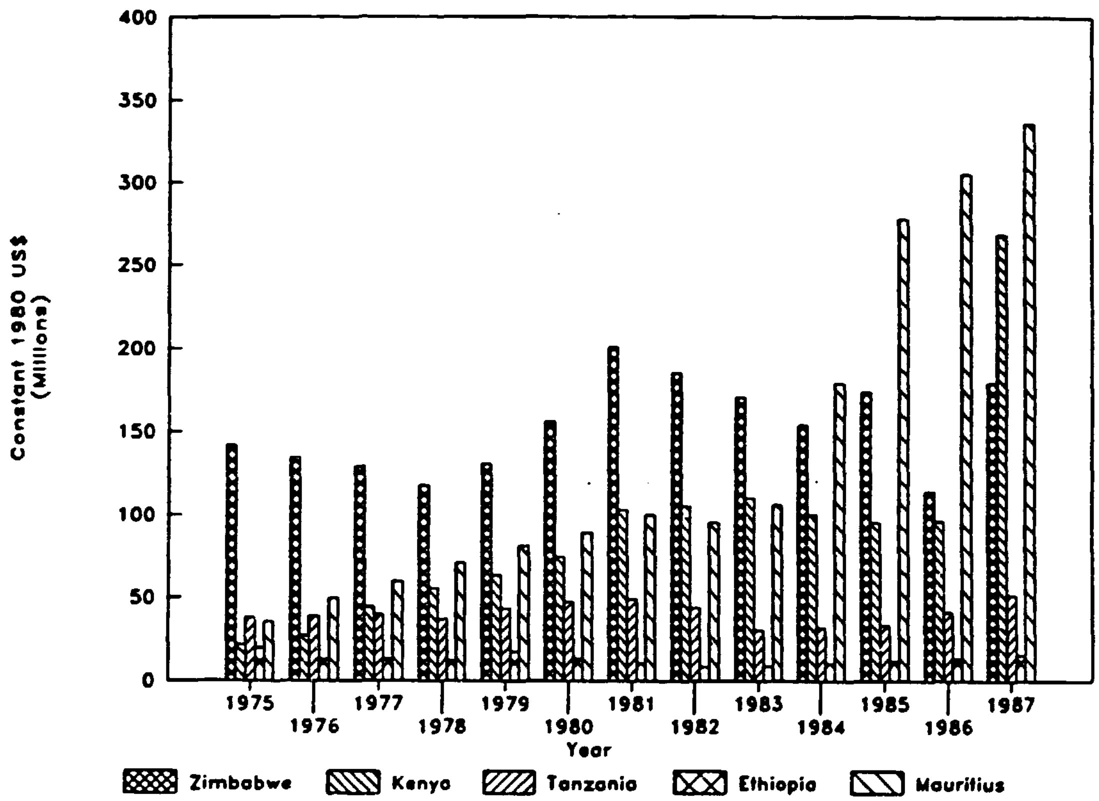
Year	Zimbabwe	Kenya	Tanzania	Ethiopia	Mauritius
1975	14,587	4,284	4,080	1,216	7,574
1976	14,023	4,785	3,966	1,201	11,484
1977	12,406	4,911	3,536	1,243	13,757
1978	11,765	5,011	4,914	1,313	14,280
1979	13,061	5,308	4,694	2,107	15,144
1980	14,624	5,320	4,358	2,148	16,298
1981	16,127	6,686	4,116	2,293	18,718
1982	16,530	6,652	4,134	2,459	19,395
1983	14,783	6,813	3,890	2,587	21,324
1984	14,800	7,007	3,907	3,139	29,186
1985	15,300	7,682	3,225	3,390	48,044
1986	15,377	8,050	4,936	3,661	61,552
1987	15,454	8,250	5,019	3,953	74,526

Source: UNIDO database.

The clothing sector is an important employer in Zimbabwe and Kenya as well as in Mauritius. In Tanzania and Ethiopia the sector is quite modest, especially in comparison to the textiles industries, and in Namibia it is even smaller.

A time series on the clothing gross output reveals the rapid growth of Mauritian industry since 1984 (Figure 16.2). The growth of Kenyan production has also been significant in the late 1980s, while figures for Zimbabwe show fluctuations.

Figure 16.2 Gross output of the clothing industry in the 5 African case countries 1975 - 1987, constant 1980 US$.



Source: UNIDO database.

A typical feature for the case countries is, that the clothing industry is clearly less important than textiles, both in terms of output and employment. Here again, Mauritius is an exception: textiles production is very modest in relation to clothing which employs a major share of the whole labour force of the island.

The ratio of MVA to gross output has been highest in Ethiopia, where the industry is however quite small. The ratio is very low in Ta⁻⁻ania (Table 16.15).

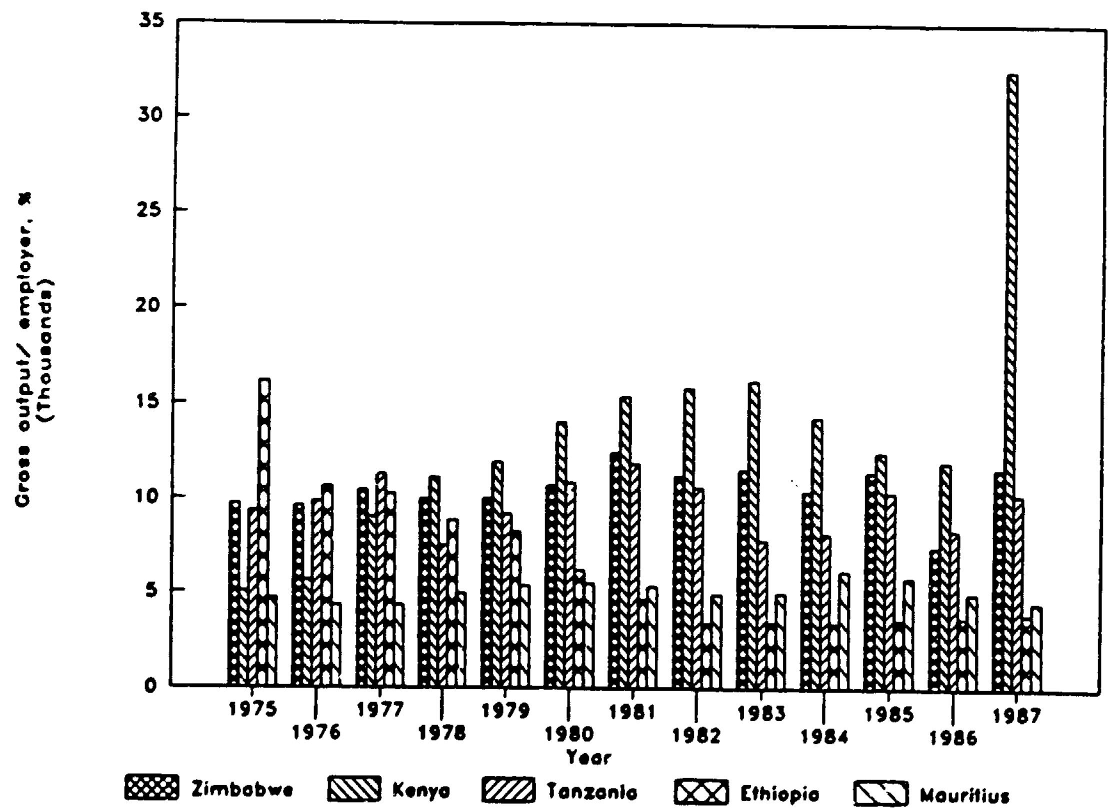
The productivity of labour - measured as gross output per employee - in the sector has varied between around US$ 5,000 in Mauritius and Ethiopia and a rough US$ 10,000 in Zimbabwe. In all countries, productivity figures seem to have been rather stable (Figure 16.3).

Table 16.15 The ratio of MVA to gross output in clothing industry in four African case countries, between 1975 - 1987 (per cent)

Year	Zimbabwe	Tanzania	Ethiopia	Mauritius
1975	52.0	14.2	18.3	38.3
1976	46.0	70.5	21.3	33.2
1977	40.2	66.3	29.0	34.2
1978	41.2	55.0	25.1	31.5
1979	39.3	26.2	19.1	34.8
1980	44.8	21.1	25.6	31.3
1981	35.0	16.2	51.1	33.6
1982	30.2	14.4	60.3	32.8
1983	36.1	19.4	87.7	34.4
1984	45.4	13.7	72.1	32.8
1985	41.8	7.2	69.3	34.3
1986	66.6	4.5	66.7	35.2
1987	44.2	3.3	64.2	36.2

Source: Unido database.

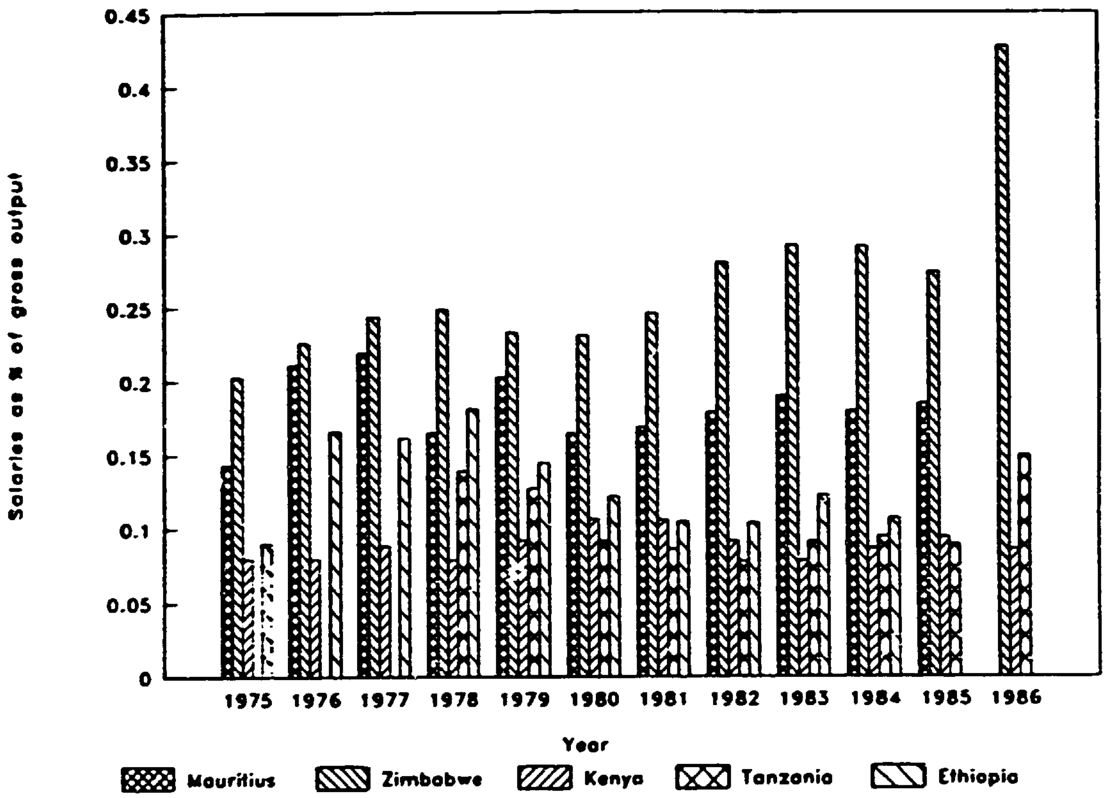
Figure 16.3 Gross output per employee in clothing industry, 5 African case countries, 1975 - 1987, constant 1980 US$.



Source: UNIDO database.

The share of wages of gross output has also remained quite stable. The share of salaries is, and has been, clearly highest in Zimbabwe, 30 per cent to 150 per cent above the other countries (Figure 16.4). Mauritius comes next, while the ratio has been quite low in the other countries. In comparison to the textiles industry, the share of salaries is roughly on the same level as in the textiles industry. This is astonishing, when the clothing industry is generally considered to be more labour intensive.

Figure 16.4 The share of salaries of the value of gross output in clothing industry in 5 African countries, 1975 - 1986.



Source: UNIDO database.

The differences in wages between developed and developing countries are extreme. In 1988 the level of average hourly wages costs including social costs in the clothing industry were almost 16 ECUs in Norway, above 13 in Switzerland and above 10 in Denmark, Italy and the Federal Republic of Germany, while the figure in the European periphery, in Greece, was below 3 ECUs.[534] The African wage costs are far, far below this. But, as shown above with the Italian case, it is not only the wage costs that count.

In all the case countries, the clothing industry is dominated by rather small companies. The few large complexes integrating textiles and clothing within one company are exceptions to this. An important share of production is still very traditional, manual production of an artisanal nature. Uniforms, other official and basic clothing take a rather important share of the

[534] Kasvio (1991).

production in all the case countries (except Mauritius, again). A factory, which would be the largest clothing factory in the country was being set up in Namibia for the production of uniforms at the time of the field research.

The sector is most advanced in Mauritius. It is also very important for the economy of the country. The Mauritian industry is completely export oriented, and the dominating products are knitwear. Firms are rather small, and many are owned by foreigners, mainly Asian entrepreneurs; and are located in the Export Processing Zone. Multinational or other larger international companies do not play a major role in the Mauritian clothing industry.

The industry has been one of the basic sectors of industrial development in the country. Recently the Government of Mauritius has actually been trying to discourage rather than encourage new clothing entrepreneurs from establishing in the EPZ. There is a conscious effort by the government to shift industrial development to other sectors. When it comes to developing the clothing industry, the government has ambitions of introducing more productive and labour saving technologies in the industry, since the supply of labour is becoming scarce; and it wishes the industry to move further up-market into haute-couture.

Kenya and Zimbabwe are two other countries with a longer tradition in the clothing industry, and who have also had some success in exports. The exports are usually based on foreign design and orders, and the role of domestic design is rather modest.[535] In Ethiopia and Tanzania the clothing industry is quite modest, with very few exports and with quite traditional product lines. The Namibian industry is small and still in the initial phase of development. There are only two or three qualified designers in the country.

16.7 Clothing Problems in the Case Study Countries

In all the countries the basic problems in the clothing industry were very similar to those faced by the textiles industry. The different structural, technological and organizational nature of garment manufacturing, however, changes the emphasis of these problems. Also the overall situation in clothing industries and firms varied notably in the countries visited.

In many cases, the textiles industry produced the basic problems for the clothing industry. In Tanzania, the yarn and textiles produced by local manufacturers were often of inferior quality. The same problem was occasionally met in Kenya, but primarily because of the low, short-fibre quality of domestically grown cotton. In Mauritius the modest size of the domestic textiles industry has been a problem for a long time, however, this is changing with the rapidly growing local textiles industry.

Infrastructure

Problems with infrastructure issues were quite similar to the textiles industries. Interruptions in energy supply were however, less critical for clothing factories. This is true, even to a larger extent, regarding the water supply. Transport and telecommunication problems exist, in much the same way as in textiles with poorly maintained roads and vehicles, considerable distances to be covered; and poor national telecommunications links – often worse than their international links.

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[535] African Business, January 1991.

Training and education

There are very few vocational training possibilities for the clothing industries supplied from outside the companies, though the situation is less problematic than in the textiles industry. Most tasks especially in cloth assembly are rather simple, and the training needed is modest. The training is mainly arranged by firms themselves as on-the-job training in the small ones, and as more organized courses in the larger companies.

With further technological developments in the sector the inadequate qualifications of the workforce are likely to be more problematic. This is also true in relation to more demanding organizational structures. The shortages of skills may hinder the production if high quality products or the introduction of more flexible production organizations with broader task definitions. Insufficient skills for quality products were especially mentioned as a barrier for the industry's development in Kenya.

Financial and trade policy

The financial and trade problems mentioned by the textiles industries were valid for the clothing industry as well, though here trade barriers came up as more problematic. For example, a small Tanzanian clothing factory lost its promising start up in the US market because of US trade barriers. The loss was not final, but the company had to create contacts with new partners, and change the product line thus losing a full year of exports. In Namibia, competition from South African producers is mentioned as the greatest problem.

On the other hand, imported used clothing is a major competitor to the domestic apparel industry. In this respect, the Kenyan example reveals that even a total ban on importing used clothes has not helped since they will be smuggled in. Second-hand European and American clothes have, in fact, caused quite considerable troubles for the domestic clothing industries in countries in Sub-Saharan Africa.

Raw materials, intermediate goods and spare parts

Problems with raw materials, intermediates and spare parts are again quite similar to the textiles industry. Because of the nature of the machinery in the industry, spare part problems are, however, not that crucial. Machines are rather simple, and often easier to repair.

Less intermediate goods are also used, and the raw material troubles go back to the problems within the textiles industries. The quality and delivery of textiles was often problematic, and in fact a key issue considering the further development of clothing industries in the countries.

Firm organization

The clothing firms have less problems with the big parastatal holding company organizations than the textiles firms. Most firms are small and independent. A large share of the firms are very traditional and producing mainly manual, artisanal products. However, the Italian example above shows that it is quite possible to combine basically artisanal, traditional apparel manufacture and factory production under a common network concept of business and renew it with the help of state of the art technologies.

If we think about the possibilities of these new, more flexible and network type of firm organizations, firms in our case countries seem to be quite far from that. The problems go back to the infrastructural issues and to the rather traditional ways of business administration in the companies. The management skills - as in textiles - are not very sophisticated, and the development of the Italian type of systemic network is above all conditioned by managerial skills and insight.

Technology

Problems with technology were less than in the textiles industry. The technologies in use were mainly quite traditional, but there were also more sophisticated special purpose sewing machines, etc. used in the firms. Mauritian knitting production was quite developed technologically. In general in these countries, the wide variety of machinery - both in terms of age and supplier - posed difficulties in relation to operator and maintenance skills.

Knowledge of technological development and new machinery availability was not, generally, very good. This implies, as in the case of textiles, the need for a more centralized system supporting diffusion of information on technological development in the industry.

16.8 The Clothing Industry: A Brief Summary

Technological developments in the clothing industry have not been very rapid. The automation of the main function, assembly of clothing mainly by sewing, has proven to be very difficult. The role of manual labour is still crucial. In global trade, however, the long time trend seems to be breaking down. The share of OECD countries in production and exports is no longer diminishing at the rate it used to. This change has been caused by a combination of technological, managerial and organizational innovation, linked to changes in market demand, which together are outweighing the relative advantage of cheap labour.

Some of the developing countries, that started as cheap labour producers, are moving along with the new development trajectory, e.g.,Hong Kong.[536] Simple mass production, still based on cost advantages, is moving away from them to countries with even lower labour costs.

The African countries have never been important in the global clothing trade. In the case countries, the clothing industry is generally not as important as the textiles industry and the development of the industry has been rather modest.

Mauritius is an exception among the case countries. There the clothing industry has clearly been more important than textiles - even though the main product, knitwear, is in many respects nearer to the textiles industry than other types of clothing manufacture.

The Mauritian clothing industry is a clearcut success story of the late 1980s. The case of Mauritius is, however, hardly generalizable to the average African conditions. The country's success has been due to many circumstances, which are unlikely to be reproduced in the other case study countries.

The islands development path shows the virtues of a rather liberal policy, and a government more concerned with economic development than political control of the population. Mauritius has often been compared to the East Asian NICs, but a basic difference remains: the

[536] Kasvio (1991).

development on the island has not in any sense been strictly technology driven. It has been based quite directly on the existing comparative advantages, cheap iabour, a rather fortunate relationship with the United Kingdom and France, and its attractiveness to outside, in many instances Asian sources. Nevertheless, in the long run the focus may change. Already there is a keen interest in advanced automation, and government has put a lot of emphasis on educational development, which has been a cornerstone in the NICs long-term policy.

Export Processing Zones are the core of the Mauritian success story. This kind of tax free production area has already been shown to be successful in other East Asian countries, the People's Republic of China included. They could quite well be worth trying in the context of the African mainland. Kenya is already introducing one export processing zone, after a less successful attempt with another system reducing the tax burden of and facilitating the customs procedures for firms manufacturing for exports only.

However, it should be noted that since the EPZs have been successful in attracting companies and finance into Mauritius, full employment has resulted in a much higher per capita income and labour costs are becoming something of a problem.

Mauritius now intends to try to attract industries other than textiles, clothing and footwear companies into the EPZs to raise value added; and also to expand into the services markets - perhaps through the provision of software translation services.

Mauritians, in general, speak several languages including English, French and Creole, or/and Indian language (Bhojpuri, Hindi, Tamil, Urdu) or a Chinese language. This offers them a further skill in international operations.

Generally, the basic problems hindering the development of the clothing industry in the case countries are quite similar to the problems faced by the textiles industry. Technological developments are, however, not as crucial as in textiles. The production processes are rather simple, and not very expensive, making it easier to modernize by replacing existing machinery with more sophisticated ones.

The main problems are not technological, but economic, managerial and skill related. The possibilities of expanding clothing manufacture and exports are conditioned by the renewal of business strategies and increasing the quality of products. The most important technologies in this are perhaps not the most automatic sewing machines, but CAD facilities - and, after that, probably (in larger firms especially) more automation in cutting and other pre-assembly phases of production.

The introduction of CAD would above all serve the development of own designs, which are very modest in all the case countries - except Mauritius, again. The need for a CAD capability was also mentioned most often by the firms visited.

17. The Footwear Industry

Global production of footwear grew by 4.1 per cent between 1983 and 1987 reaching about 9.7 billion pairs, and is estimated to increase to 11 billion pairs by the year 2000. 51 per cent of this production is manufactured in Asia, 18 per cent in East Europe and 12.5 per cent in West Europe, 9 per cent in South America and 6.5 per cent in Central and North America.[537]

Developing countries, which accounted for about half of the world's footwear output in 1983, increased their share to 61.4 per cent in 1987. China, Taiwan Province, Brazil, the Republic of Korea, India, Mexico, Thailand, Indonesia, Portugal and Columbia were among the countries that increased their production of footwear during that period. In contrast, output fell significantly in the USA, Italy, Spain, Japan, and France; the UK and West Germany showed smaller reductions.[538]

The value of world footwear exports were about US$ 20 billion. The largest exporter was Italy, which together with Taiwan Province, the Republic of Korea and Brazil accounted for almost 65 per cent of total world footwear exports in 1987. The shares of the three non-European countries mentioned above has risen rapidly.

From 1978 to 1987 several other developing countries, most notably China, Thailand and Indonesia, showed high export growth rates from low initial bases. A shift of high volume, low-cost footwear manufacturing from Korea to Thailand and Indonesia has made these two countries important new sources of footwear from Asia. They have also gained from the Generalized System of Preferences (GSP) with the EC, which are not available to Taiwan Province, the Republic of Korea, Hong Kong and Singapore.

African countries have not been important producers or exporters of footwear. Production is mainly for the domestic or regional markets, and the sector has declined in recent years.

17.1 Technological Developments

Technological development has been relatively slow, evolutionary and incremental in the footwear sector. There have been few significant technological breakthroughs and their diffusion appears to take a long time. The machinery is quite standardized and even very old machines are still in productive use. The vast majority of machinery is of a rather simple mechanical type; and usually the automation level is modest and relates to standalone machines and functions of the production process only. Very little microelectronically controlled machinery is in manufacturing use at this time, though technological innovations have occurred, for example in cutting, closing and in bottom stock preparation.

The estimated value of global production of shoemaking machinery is US$ 80.1 million, of which Italy is thought to account for around 60 per cent. The other major shoemaking machinery countries are Germany and the UK. It is estimated that shoemaking companies

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537 Hadjimichael, 1990.

538 Hadjimichael, 1990.

spend annually about 2 per cent of their turnover on new shoemaking equipment.[539] The main sources of various types of shoemaking technologies are presented in Table 17.1.

Table 17.1 ***The main sources of footwear technology***

Country	Type of technology
Italy	All types of tanning and shoe machinery. Drums. Semi-automatic lasting and bottoming track.
Germany	All types of tanning and shoe machinery. Drums. Tunnel driers. Sewing machines. The Levacast process. Spraying machines. Chemicals and dyestuffs. Effluent treatment.
US	Computer controlled sewing machines. Shoemaking, particularly lasting machinery. Chemicals and dyestuffs. Hide processors. CAD/CAM systems.
Switzerland	Computer controlled tannery systems. Stretching and vacuum dyeing machines. Dyestuffs.
UK	Computer linked hide evaluation systems. Shoe tracking. Computerized stitching performance evaluation systems. Shoe pattern and leather evaluation. Dedicated work handlers. Computer applications to shoe making. Tanning and shoe making machinery. Chemicals and dyestuffs. Leather measurement machinery.
France	Through-feed electronic measurement machines. Semi-automatic lasting and bottoming tracks.
Czechoslovakia	Vibration stakers. Shoe machinery.
Spain	Tanning machinery. Hide processors.
Finland	Auto-toggling machines. Drying systems.

Source: ILO (1985b).

Globally there is a continuous move of shoemaking towards the lowest labour cost countries and areas with adequate infrastructures for production and international trade in shoes. Thus, the Republic of Korea and Taiwan Province are moving towards higher value production and new shoemaking plants are rapidly being opened up in China, Indonesia and Thailand. This means an expanding market for footwear technology and a generally growing and buoyant demand for new shoemaking machinery. The higher cost countries tend to invest in the most sophisticated equipment, but with the need to respond quickly to the challenge, producers in East Europe and Asia are considering the purchase of such equipment as well. This trend applies equally to CAD, which can translate new shoe designs into production in a matter of hours.

Investment in new machinery has generally been hampered by the nature of the raw materials, small batch production, the absence of standardization of products, the prevalence of

[539] UNIDO, 1990b.

small artisan and medium-sized companies with an insufficient capital base and low investment capacity, overcapacity, shrinking markets in industrialized countries, trade barriers, and the relatively low number of machine-tool suppliers for whom the industry constitutes a comparatively small market that does not warrant much outlay on research and development.[540]

The sector is one of the least research and development intensive of all manufacturing industries. It has little contact with and draws little inspiration from research centres, universities and management development institutes. It has also been observed that the skilled manpower necessary to operate, programme and maintain complex automated machinery is seldom available in this sector.[541]

Table 17.2 The main process developments in shoe manufacturing

Main cost area	Large companies	Medium-sized companies
Pre-production engineering (better materials utilization)	CAD CAM: lasts, moulds, cutting, computerized pattern grading	Micro-computerized pattern assessment, pattern grading and shoe casting. Guidelines and training developments.
Closing	Automatic machines. Pick and place handling. Real time recording from factory floor. Microcomputer work scheduling and transportation	Automatic machines. Efficiently set closing machines. Micro-computer work scheduling and transportation.
Overheads	Computerized management information. Process control and monitoring development	Micro-computer based management information and control. Process control and monitoring developments.
Developments 1990-1995	Robotics FMS (automatic sole attachment)	

Source: ILO (1985b).

The main fields of computer use are still in CAD and management systems. The main developments in process technologies occurred during the 1980s and are summarized in Table 17.2 and discussed in more detail in the following sections.

The following description of the process of footwear manufacturing, and technological change within it is based mainly on ILO (1985a, b and c), Hadjimichael (1990) and UNIDO (1990b).

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540 UNIDO, 1985b.

541 ILO, 1985b.

(a) Design

Design involves determining the shape of the last, the appearance of the upper, the type of the sole, the height and shape of the heel, the material of the upper, and in essence, the construction of the shoe. CAD facilitates the process of design. In the initial design operation, the last is numerically defined by "digitizing" its surface. This is turned into a two-dimensional surface, which is displayed on the computer screen. A footwear designer can create a new design pattern on the two-dimensional surface which can easily be modified on the screen. The two-dimensional image can also be converted into a three-dimensional view that can be studied from any angle. Finally the designer can also experiment with colour by using digitized colour books to superimpose coloured patterns on the original design.

The next stage in design is grading. This involves production of patterns for all the different sizes and widths in which the particular style of footwear will be manufactured. Whereas manual grading by specialists could require several weeks, with CAD patterns can be produced within hours and with a greater accuracy. Data on the new shoe's specifications are stored in the computer. This data can be used for costing and production patterns. The computer can also develop programmes for laser or water jet-cutting - thus achieving material savings of about 3 per cent - automatic or computer-controlied stitching, workflow and management schedules.

(b) Management systems

Computer based management systems for footwear include, in addition to standard accounting and administrative programmes, leather measurement systems, computer programmes for calculating costs of production - using data bases for piecework prices - components and materials stock control systems, production scheduling, and finished stock control systems.

Such systems have been developed commercially for large companies; and the Shoe and Allied Trades Research Association (SATRA) in the UK has produced scaled-down systems for personal computers that can be used even by very small companies. One example of such a programme is a diagnostic system that compares the performance of one operator with another and evaluates the relative efficiency of each operator's machine use. Another system is the SATRASUM, a material-management system for footwear uppers that can assess material utilization to predict the costs of making uppers. SATRATRACK is a microcomputer-controlled work handling system that was first used in the stitching room of a shoe factory in Northampton, UK. The adoption of this system resulted in an increase in productivity and a large reduction in work-in-progress.[542]

(c) Cutting

There are several types of cutting machines for cutting patterns: automatic lasers, water and knife cutters and computer-controlled cutting presses. Cutting machines can interface with computerized grading, and in this way patterns stored in the computer can be recalled and sent to the cutting machines. As an alternative, enterprises known as service bureaux can be set up to perform cutting and pattern grading for manufacturers who either cannot afford or prefer not to assume the cost of such capital outlays.

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[542] Manning, 1985.

(d) Closing

The closing - stitching together of the parts - of the shoe uppers is the most labour intensive phase in shoe manufacturing and the most resistant to technical change due to the three-dimensional shape of the shoe. The work content ranges from skiving, folding, cementing, hole punching, eyeletting, pattern sewing and printing, to assembling the pieces and stitching them together. Significant technical changes include the development of faster and automated or computerized transfer between workstations, improvement in non-automated machines, development of edge-folding machines, computerized stitchers and computer-based training systems for workers.

Stitching machine speeds have increased as a result of technical advances in the steel for needles, oil feed systems, motor operation, needle positioning, under-bed trimmers and back tracking. The main new advances are in microcomputer controlled profile stitching.

Operations include major functional stitching, such as vamping (attachment of the vamp or front part of the shoe's upper to the quarter or back part), as well as fancy design stitching. These machines stitch automatically and rapidly with plug-in modules that contain stitching patterns. The modules, technically identical to erasable-programmable-read-only-memory (EPROM) cards, can be programmed directly on the machine. An operator loads the work pieces, punches a button, and the EPROM card carries out an operation automatically for a whole range of footwear sizes.

Computer stitching in vamping reduces unit labour requirements and improves the quality of the product through greater accuracy and consistency. In contrast, older conventional processes of vamping are very labour intensive. It is estimated that computer stitching used for long production runs results in a productivity increase of at least 25 per cent. However, the machines are not efficient for short production runs because of the costs involved.

In certain plants, a mechanic with a high school education plus some additional mathematics can qualify for a programming position after 2 to 3 months of instruction. Maintenance of the machines requires only a modest knowledge of electronics. Some machines contain built-in systems that self-diagnose most operational problems. Microcomputers may also be used as an aid for training sewing machine operators. They can record and analyze the operator's precise movements and be a guide to improved operations.

Interactive teaching/learning was highlighted by TC^2, the American Apparel Technology Center. Such training for sewing machine mechanics can cover a wide range of categories:

- feed timing;
- pressure foot alignment;
- hook shaft position;
- check spring position and tension;
- tension assembly;
- snubber position, etc.

In order to obtain the maximum efficiency from such technology operators need to able to: programme the machines and use control panels; be aware of oiling, cleaning, threading situations, etc. Interactive videos are claimed to be able to improve learning to such an extent that it takes 60 per cent less training then comparable classroom instruction.

"People retain about 25 per cent of what they hear, 45 per cent of what they see and hear, and 70 per cent of what they see, hear and do".[543]

Initially closing technology was used for decorative stitching, primarily by manufacturers of Western-style boots. Now computer-based machines for functional and fancy stitching are used by firms of all sizes. In fact, computerized control of functional stitching has begun to be used by a broad base of manufacturing. Increased use is expected in the next 5 to 10 years as new machines are developed with improved accuracy and stitch quality.

Fibre optics are being developed that will observe individual stitch lengths and adjust the next stitches automatically. This would enable the upper to be produced without variation, a problem that currently hinders the introduction of automation.

(e) Bottom sole preparation

Bottom sole preparation is usually subcontracted to specialty firms that can achieve major economies of scale since soles are relatively standardized and not subject to fashion changes. Soles, known as moulded unit bottoms, are purchased by shoe manufacturers and glued to the uppers, thereby eliminating labour that would be required in the shoe factory. About one-quarter of the shoes made in the US contain such unit bottoms. However, if the volume of production is large enough, shoe manufacturers will still cut soles in-house.

(f) Making

New technology has had the greatest impact on the making process. Making occurs when the uppers are pulled over the last and attached to the insoles and the sole and heel are attached. The latest technological developments have been in the roughing and the lasting processes.

The roughing process consists of scouring the margin area of the fitted shoe upper with a rough brush, usually wire, to provide a good base to which glue can adhere. The traditional and still most common method is manual. This relies on the operator's good hand-eye coordination. Another method is to shape the shoe on a metal template. The upper is then roughed with a wire brush that follows the outline of the template.

The latest technology involves the use of numerically controlled upper roughing machines. The shoe bottom properties are digitized, which involves securing some 20 points corresponding to the outline of the shoe's bottom. The NC machine automatically makes the calculations to direct a wire brush in the roughing of right and left shoes in all shoe sizes.

The NC machine is an improvement over both the manual method and the automatic machine that uses templates. One advantage is in its ability to operate on a wider range of shoe types. Another is the greater speed in shifting from one shoe style to another. Better quality of roughing can also improve the process of sole attachment. Unit labour requirements are slightly lower for NC roughing machines - shoes can be damaged in the manual process if an operator holds a shoe incorrectly when applying the rotating brush. Also the operator can work on other jobs after the machine is set in motion. An operator with limited job experience can quickly learn to use the NC machine. Although the maintenance of the NC machine is not

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[543] Training and Development Journal (December 1983).

simple, a digital readout screen indicates the site of operational problems. The number of upper roughing machines is expected to rise in the next few years.

Forepart pulling and lasting machines with microcomputer control assure precise lasting for the process of stretching the upper over the last and gluing it to an insole. In addition to determining sizes and position automatically, with these machines it is possible to adjust rapidly to various shoe style adjustments, which greatly improves the efficiency of the lasting operation. For example, when shifting from one shoe last to another, downtime is reduced because the many machine changes are accomplished by the computer programme. Unit labour and skill requirements are greatly reduced as well.

Programming for these machines can be mastered after about one week of instruction. Maintenance technicians can also be trained in a matter of weeks. This microcomputer-controlled machine is relatively expensive but is likely to be considered cost effective by large and medium-sized firms that expect to remain competitive with imports from low labour cost countries.

Gluing a sole to the upper part of a shoe is still labour intensive, but automatic adjustments on some sole-laying presses substantially improves the uniformity of production. An operator, after receiving uppers and soles with glue already applied, uses heat to reactivate the glue and then spots the soles to the uppers temporarily. In the newer sole-laying presses,the operator uses a self-adjusting pad box that automatically determines the contour of a shoe's bottom and a toe-and-heel rest that automatically adjusts for heel height. This ensures that the lasted shoe is held in an accurate position.

After the loading and initial adjustment, the operator starts up a high-pressure cycle to secure the permanent attachment of the sole to the shoe bottom. While unit labour requirements are not reduced significantly by this machine, less operator skill is required and the quality of output is improved. On a traditional machine, that is without the automatic adjustment, an operator may break the last when high pressure is applied, or may fail to achieve precise adhesion of the shoe's parts.

An injection moulding machine automatically moulds a shoe bottom from thermoplastic polyurethane and fuses it to the upper part of the shoe. It is considerably less labour intensive than the major alternative processes of cutting, stitching, or gluing. Also training costs associated with injection moulding are relatively low. Only modest skills are required to operate the machines. Two operators with little mechanical experience can operate a machine with 12 or 18 stations to load or unload. They periodically examine units of production so as to minimize the number of defective parts that may occur because of an occasional error in the process. The optional feature of automatic loading further eliminates labour requirements. It is expected, that computerized moulding machines will diffuse for use in large and medium-size shoe manufacturing firms.

(g) Finishing and raw materials

Finishing involves examining the shoes, correcting minor faults, and spraying colour if necessary. Little technical change has taken place in this area.

In the type of raw materials used in the construction of footwear there have been countless technological improvements. These include new materials for the uppers, new insole or lining fabrics, new threads, adhesives and glues. Manufacturers of athletic footwear, for example, are constantly searching for materials beyond the standard materials. Some of the industry believe that material used in current space exploration could make athletic shoes lighter and more breathable.

17.2 Technological Change and Training Needs

Technological developments, though rather slow and not revolutionary, are however, changing the skill needs in the industry. Some operations are being de-skilled, particularly in departments dealing with patterns, cutting and stitching, while increased skills are required especially in departments concerned with management information, management control and pre-production planning.

As a result of an increased demand for better quality materials and products, more detailed technical specifications are required and used. In many industrialized countries, shoes are sold by large retail enterprises who wish to sell high quality products to a more discriminating public.

Fashion is becoming an increasingly important factor in styling and manufacture of a greater number of products, and is no longer merely conditioned by seasonal changes. Longer production runs are becoming less common and enterprises and workers have to be more flexible, adaptable and versatile. Changes in colours and textures and changes in the work content of products are having a particularly marked effect on cutting and sewing departments.

The existing level of technology, the effects of market demands, fashion and economic and social policies are major influences on the demand for manpower. In developing countries a major area for training is that of small artisans, who are often found in rural areas and have little or no education. They also have limited or no access to machinery and equipment. Direct assistance and access to equipment and provision of management skills in purchasing, marketing and finance are the features of common facility centres established in some countries, such as India.

An ILO summary of manpower surveys reveals, that in nearly all countries the training of technicians and supervisors is considered a major priority.[544] All the changes mentioned above require new and better skills in functional management, such as the organization and control of workers, human relations, quality control, marketing, and financial planning and cost control. However, there is still a priority need to train sewing-machinists, a traditionally difficult sector. Because of the slow introduction of new technology in this area, this training need is likely to remain or increase.

The quality of the training staff, which includes instructors and trainers who have direct contact with trainees, is a major factor in successful vocational training. These people require abilities in both theoretical and practical skills associated with technology and must also be able to pass on their skills and knowledge to trainees by practical demonstrations and clear explanation. In many developing countries, instructors and trainers require sound initial and further training not only in technology of the industry, but also in instructional techniques and teaching methods. Even in industrialized countries, trainers need updating since much of their knowledge does not cover computerization and automation. In such circumstances, an interchange of information and visits to training and research institutes and enterprises at home and abroad form an essential part of the training programmes for these staff.

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[544] ILO, 1985c.

17.3 Organizational Innovations

In the global footwear market and production, there are changes taking place that are somewhat similar to the developments within the clothing industry. Markets are more segmented than before, and there are specific fashion related, youthful mass markets that are characteristic to the clothing industry too. This is especially true regarding the market for leisure and athletic footwear. The companies manufacturing sport shoes are typical examples of the new, globally spread production networks within the footwear industry. Within these networks, developing countries, Sub-Saharan Africa included, have a special place, particularly, if they can tie themselves to a major name, such as Reebok, Adidas, etc, though this calls for the ability to produce high quality on a consistent basis.

The expansion of the footwear industry in developing countries is primarily based on low labour costs. Average wages in the footwear industry are among the lowest in manufacturing industry. Nevertheless, in the developed countries, labour accounts for a significant percentage of total cost, compared with developing countries, and the costs of maintaining work-in-progress and inventories are higher in the latter countries. Given such a breakdown, a traditional footwear factory in a developed country may find it difficult to compete on production costs with low-wage newly industrialized and less developed countries for the time being.

Although low cost countries will continue to have a comparative advantage in production for some time, they will need to consider the use of modern, more automatic production and information technologies. The reasons are basically the same as in the textiles and clothing industries: modern machinery can secure better and more even quality, productivity is higher and control over the whole production process becomes more efficient.

Thus, technological innovation represents both a threat and an opportunity for developing country suppliers. The threat comes from the possibility that in the long run, when computer integrated manufacturing becoming a reality, mass producers in industrial countries could gain a competitive advantage over current developing country producers. Also, to the extent that the new production technologies give producers in industrial countries an edge in quality and in timely delivery, developing countries could be at risk of losing market shares in developed countries, particularly in the high-value segments.

Adopting the latest micro-electronic technologies, however, is not the most important way developing country firms can maintain or increase their competitiveness. The success of footwear companies in all countries depends mostly on adjusting production organization and increasing responsiveness to market changes. Such organizational changes will be critical for smaller firms, particularly because automated methods are not usually conducive to small-scale production and frequent changes in design.

Production reorganization should mainly aim at reducing work-in-process through:

- improving access to raw materials,
- improving quality control,
- improving inventory control and production scheduling,
- providing training for both management and staff.

Footwear manufacturers in many developing countries rely on low-quality, local raw materials, which relegates these firms to the low end of the export market if they are capable of exporting at all. Unavailability of raw materials is often connected with high duties or restrictions on imported inputs - for both direct and indirect exporters - and inadequate development of local industries linked to footwear. Liberalizing the importation of inputs for export production will be critical for developing countries, if they are to compete internationally, in the way the NIC exporters have succeeded. Lowering duties on imported materials would also force domestic suppliers to improve the quality of their products. Further, leather footwear manufacturers need to establish stable and effective supply networks.

In view of strong international competition in footwear markets, especially in the low-value segments, developing country firms need to invest in training for their management and operators. Design, production and marketing skills embodied in their workers would also allow these firms to produce better quality footwear.

17.4 The Footwear Industry in Developing Countries

As mentioned at the beginning of the chapter, the Republic of Korea, Taiwan and Brazil together with Italy account for about two thirds of the total world footwear exports. As Table 17.3 shows, the growth of exports from both Taiwan and Korea has been growing steadily since the late 1960s. In both countries, it is clearly a question of production for export. The share of production exported in 1984 was 90 per cent for Taiwan and 70 per cent for Korea. (Levy, 1990).

Table 17.3 Footwear exports from Korea and Taiwan 1969-1986 (US$ million)

Year	Korea			Taiwan		
	Export	Firms	Export/ firm	Export	Firms	Export/ firm
1969	10	-	-	10	75	0.1
1970	18	-	-	40	105	0.5
1971	50	9	5.6	69	178	0.4
1972	62	9	6.9	105	243	0.4
1973	109	11	9.9	186	284	0.7
1974	182	13	14.0	190	288	0.7
1975	200	16	12.5	258	305	0.8
1976	417	18	23.2	542	335	1.6
1977	515	19	27.1	652	503	1.3
1978	726	19	38.2	771	547	1.4
1979	765	20	38.2	945	563	1.7
1980	904	25	36.1	1411	582	2.4
1981	1049	34	30.9	1444	708	2.0
1982	1182	41	28.8	1463	760	1.9
1983	1270	50	25.4	1886	884	2.1
1984	1398	58	24.1	2270	1057	2.1
1985	1571	68	23.1	2301	1140	2.0
1986	2109	83	25.4	-	-	-

Source: Levy (1990).

It is interesting that in both the Republic of Korea and Taiwan Province, export oriented footwear production was originated by a Japanese company. In both cases, the same company

(Mitsubishi) located production aimed for the US market on the countries in question. In Korea the initial products manufactured were rubber footwear, in Taiwan Province plastic sandals. In both cases, production then diversified to other sectors, most notably to athletic footwear. The diversification was much broader in Taiwan Province, where the share of athletic footwear in 1985 was 27.5 per cent, and 75.3 per cent in the Republic of Korea.[545]

The development patterns in the two countries have been quite different. In Taiwan Province, production was based on a network of small firms with many subcontracting relations, while Korean production was concentrated on a few large factories. The Korean production mode is, however, changing towards a more network type of organization, since the average value of exports per firm has been declining since the late 1970s (Table 17.3).

The differences are interesting, because they reveal some background factors of the respective countries' development conditions and policies. Taiwan Province had, to start with, better education levels, more experience in commercial activities, more developed domestic markets and a policy preferring small scale activities.[546]

The Republic of Korea, as mentioned already in Chapter 11, has been a much more centrally governed and a more hierarchical society. The economy has been organized in large vertically integrated companies. With all the features present in Taiwan Province missing, it was easier to organize the rapidly growing footwear production within the large conglomerates with less division of labour and less economic transactions between independent agents.

However, with continuing growth of production and with both learning by doing and institutional development in the country, less hierarchical business relations based on subcontracting and network linkages have developed.[547] Even policies have changed in a direction less favourable to the very large companies.[548]

One of the lessons from comparing the two NICs is that there are different institutional conditions that can lead to growth and industrial development. In the case of footwear, the trends for development in both countries, however, point towards the development models familiar from the developed countries and discussed in the chapter on the clothing industry. There is a change towards less hierarchical relations, stronger subcontracting linkages and more flexible organizations that are able to react more rapidly to market changes.

17.5 The Footwear Industry in the Case Study Countries

Internationally the African case study countries are not important as footwear manufacturers. Even in domestic terms, the footwear sector is not an important employer in any of the countries.

Employment figures have fluctuated during the period 1975 - 87, but over the whole period, employment has grown in all countries: between 10 and 20 per cent in Zimbabwe and

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[545] Levy, 1990.

[546] Levy, 1990.

[547] Levy, 1990.

[548] Westphal (1990).

Kenya, roughly a third in Tanzania and over 50 per cent in both Ethiopia and Mauritius (Table 17.4). In the two latter countries this means an average yearly employment growth of about 5 per cent, However, in the case of Mauritius this was from a very low base, and the sector still only employed 660 people in 1987.

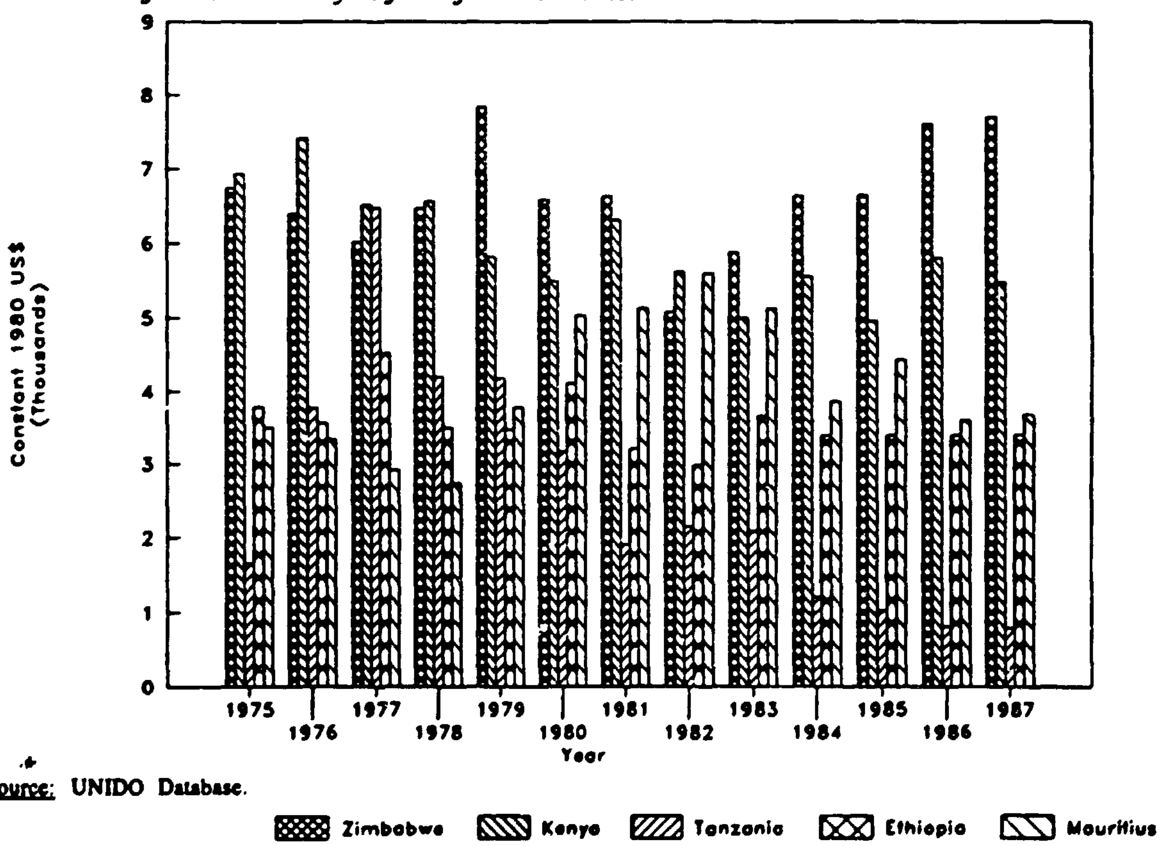
Table 17.4 Employment in footwear in five African countries, 1975 -1987

Year	Zimbabwe	Kenya	Tanzania	Ethiopia	Mauritius
1975	4,134	1,672	2,803	1,688	430
1977	3,959	1,781	2,357	1,730	491
1979	3,819	2,123	3,194	2,148	450
1981	5,124	2,160	3,328	2,471	442
1983	5,081	2,289	3,533	2,504	512
1985	5,200	1,988	3,712	2,550	507
1987	4,692	1,980	3,760	2,701	660

Source: UNIDO database.

This growth in employment does not necessarily indicate economic success. The manufacturing value added per employee has actually declined in all countries other than Mauritius and Zimbabwe (Figure 17.1). Even in Mauritius the ratio shows a declining tendency since the early 1980s. In Tanzania the level of the MVA/employee ratio is low, and the decline has been dramatic. In Kenya and Ethiopia the decline has been slower and more stable.

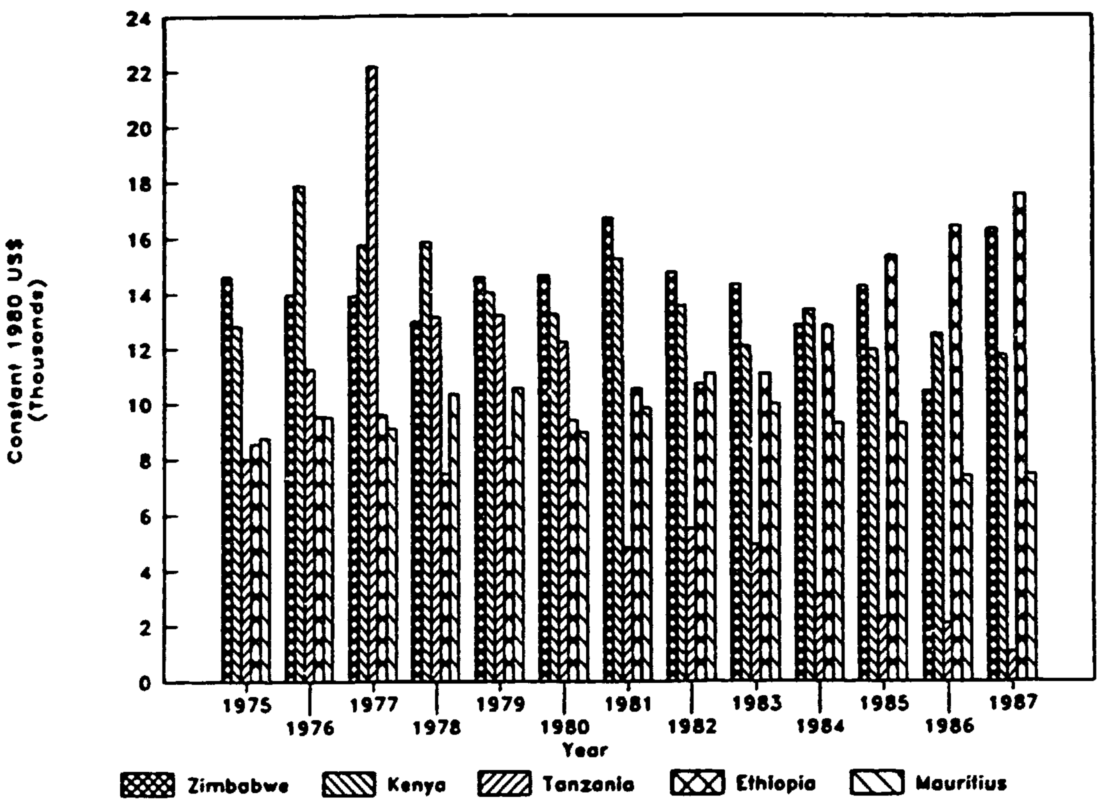
Figure 17.1 Manufacturing value added (MVA) in constant 1980 US$ per employee in the footwear industry in five African countries



Source: UNIDO Database.

The productivity of labour - measured as gross output per employee - in the sector has been very low and declining in Tanzania (Figure 17.2). Figures for Zimbabwe have fluctuated, but show an increasing tendency during the late 1980s. The Ethiopian figures show an even more explicit growth ever since the late 1970s. Kenyan figures are fluctuating, but on a rather high level, higher than Mauritius.

Figure 17.2 Gross output per employee in the footwear industry, 5 African case study countries, 1975 - 1987, constant 1980 US$.

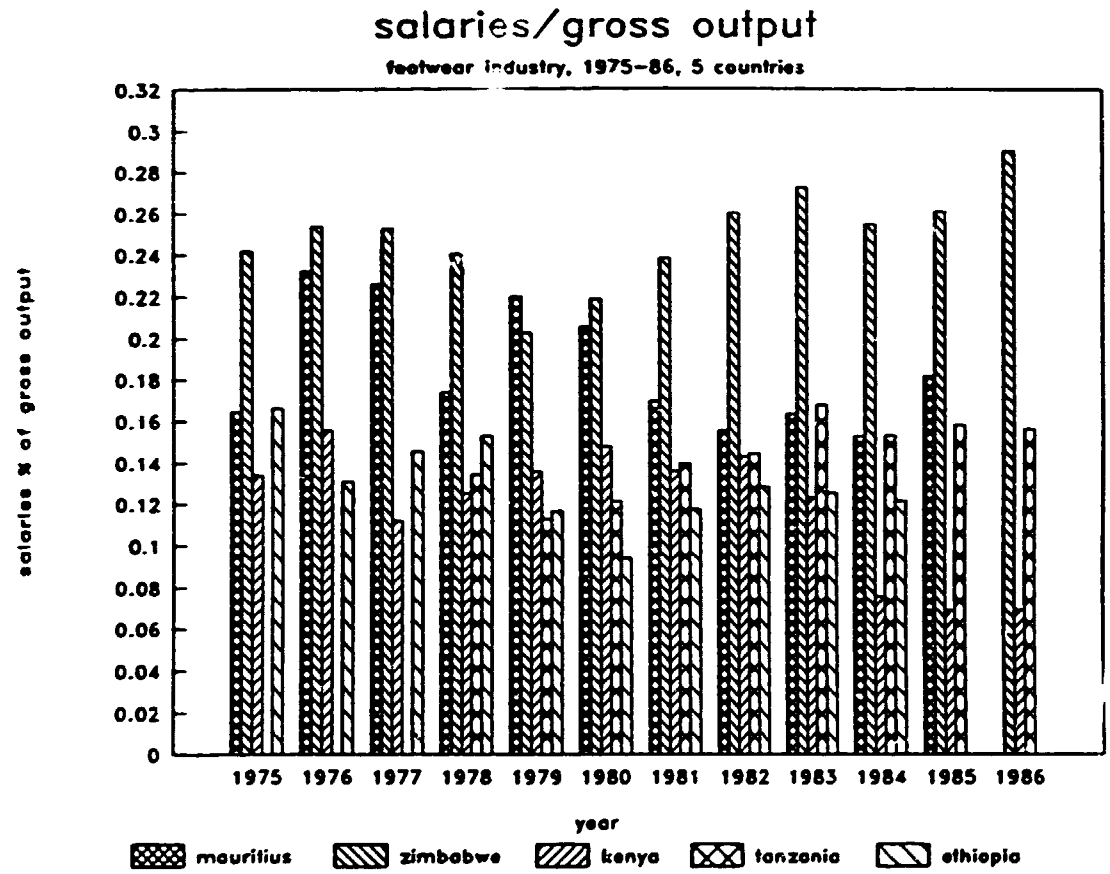


Source: UNIDO Database.

In footwear, the share of salaries in gross output has been on a clearly higher level in Zimbabwe than in the other countries. This is actually caused by a high wage level. In the local firms visited in Zimbabwe the wages were described as being exceptionally higher in the footwear industry than in the textiles and clothing industries. Even there, relative to developed countries, the labour cost level is still extremely low. In Zimbabwe the share has also risen considerably during the period 1975 - 1986. Just the opposite has happened in Ethiopia and Kenya. The Kenyan share of salaries is very low.

Generally, the level of activity in the footwear industry was rather low in all countries, and there are only a few important companies remaining in the sector. In Kenya, although there were over 30 shoe manufacturers in the country, one major company dominates the industry, and the sector was facing considerable problems.[549] The situation was quite similar, but perhaps even worse, in Tanzania with one large parastatal company and a few smaller private ones. The sector is dominated by one large company in Zimbabwe as well. The Mauritian footwear industry was modest and consisted of a few small companies and one larger company employing about 250 people. Namibia has one small company producing hand made desert boots, and one other boot-making company.

Figure 17.3 Salaries as a share of gross output in the footwear industry in five African countries



Source: UNIDO Database.

The sector in the area is dominated by one company, the Canadian headquartered multinational Bata Shoe Company. Bata has factories in Kenya, Zimbabwe and Mauritius. The Bata companies are all the largest and most important in the respective countries. The Bata market share, for example in Zimbabwe is, according to the general manager, about 80 per cent. In Kenya, Bata employs over 2,000 people and has a production capacity of 9.5 million pairs per year, while the next largest, Tigers Shoes has barely 100 employees and a capacity of 240,000 per year.[550] The company also had a factory in Tanzania, which was later nationalized and is now operating as a parastatal firm.

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549 African Business, April 1990.

550 African Business, April 1990.

Very little footwear is exported from any of the countries. Even the Mauritian industry is producing for the domestic market only. The only exceptions are the Bata companies in Kenya and Zimbabwe, who are producing athletic footwear (Adidas) for developed country markets. The Kenyan Bata is exporting approximately half a million pairs annually.[551]

Technologically the factories were mostly traditional. Small firms visited did not have any automated machinery, and machines were in some cases bought second-hand. The factories owned by multinationals had more up-to-date, in some cases numerically controlled machinery, for example in lasting, engineering moulds and occasionally in sticking and sewing. Computers were also used for administrative purposes and stock control. CAD was not yet used by any of the companies visited, but most of the larger companies had either planned or hoped to be able to acquire a CAD system in the near future. In Zimbabwe, smaller companies were investigating the possibilities of using a CAD system located in the Leather Institute in Bulawayo through terminals.

All companies visited had high expectations of automation. They believed, that more automated machinery would help them especially in raising the quality of products, and save in the use of all inputs, plus general gains in productivity. All companies were interested in buying more up-to-date machinery. CAD especially was mentioned by almost every company visited, even in cases where the firm in question did not - yet at least - design the products they manufactured.

17.6 Footwear Problems in the Case Study Countries

The general problems in the footwear sector were very similar to the textiles and clothing industries: troubles of varying degrees with the basic infrastructures (energy, communications, telecommunications); a limited supply of skilled manpower for operating and maintaining equipment, and management tasks; difficulties with import regulations for inputs and spare parts; and obtaining foreign exchange. All these were discussed at length in Chapters 15 and 16, and apply equally to the footwear industry.

The companies visited did not mention any specific technology related problems. Except, of course, the generally outdated machine stocks and substantial need of better equipment. So far technological changes have been slow, and no major problems have occurred. Some companies, however, feared skill related problems with the introduction of modern machinery.

There were also some problems specific to the footwear industry, with the supply of raw materials being one of them. For example, in Zimbabwe, there was a shortage of leather, because of increased exports of leather by tanneries. The small size of the footwear and related industries also caused problems. It was not possible to use subcontractors, and companies often had to invest in machinery with very little use. For example, a small footwear manufacturer in Zimbabwe had to invest in a plastic injection machine in order to make 150 pairs a day. The capacity of the machine allows production figures over 12 times higher.

Similar problems were faced by the companies visited in relation to many other business functions as well. The thin local firm structure allows little subcontracting and forces the companies towards a higher level of integration and endogenization of supportive functions. It was very common for larger footwear firms in the area to have, for example, tanneries integrated into the factory.

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[551] African Business, April 1990.

Factories were often manufacturing shoes from a wide range of raw materials: leather, canvas, plastic and rubber may all have been used in the same factory. This significantly complicates both the planning of the factory lay-out and logistics, and control over the everyday production process.

Generally the footwear sector seems to be facing problems in the case study countries. They have not been able to increase exports, and domestic markets are not expanding notably. Further, in domestic markets, imported shoes - for the mass market from Asia and from Italy to the quality market - are often superior competitors. A Kenyan manufacturer even argued that if the domestic market was completely opened to imports, all local manufacturers would be wiped out from the industry, mainly because of poor productivity and low quality. The notion from a Zimbabwe company, that they can't really compete with the Asian countries with the technology and cost structures they have now, supports this pessimistic view.

Problems of entering export markets were faced, for example, by a large Tanzanian shoe company. The company tried to enter the field of higher quality shoes, but the attempt failed because of a lack of skills and unsuitable machinery. Now, so argued the factory manager, they have trained the labour force, but the company is badly in debt and there is no possibility of obtaining foreign exchange for the investment. Especially so when the capacity utilization rate of the factory is barely 10 per cent. Generally the productivity levels in the firms are low, production machinery outdated and the production organization rather rigid and hierarchical.

17.7 The Footwear Industry: A Brief Summary

Production technologies in the footwear industry have developed quite slowly. The incremental innovations are, however, quite important from the productivity, quality and materials use points of views. Important developments have also taken place within firm organizations and firm strategies, and on the organization of the markets.

A few developing countries - the Republic of Korea, Taiwan Province and Brazil - have increased and developed their production rapidly and are now, along with Italy, the most important footwear exporters in the world. This development is not so much based on superior technology as on company organization and superior network performance. The Taiwanese and Korean examples show that development towards becoming an important exporter is a long process of institutional, technological and economic build up. In this process cheap labour is not the most decisive factor. Domestic capability development and external linkages to buyers are among the crucial conditions for development.

The African countries have so far not been able to cope with these developments. Footwear industries in the case countries are minor with insignificant exports only. The examples from the firms manufacturing athletic shoes in Kenya and Zimbabwe, however, show that it is not at all impossible to manufacture high quality products in these countries. The hand-made desert shoes in Namibia seem also to have found a niche.

Nevertheless, many important preconditions are missing. To create them, the infrastructure developments suggested in previous chapters are quite necessary. In addition to this, firms in the sector need support in acquiring new production technologies and changing the organization of production.

The need to subcontract supportive functions is also quite central. It is very unproductive to have to perform in-house all phases of the manufacturing process. Some functions are only needed in the making of a minor share of products only. If these tasks cannot be subcontracted, the company has to invest in machinery that will be constantly underutilized.

Problems related to subcontracting and other inter-firm linkages were, of course, present also in the other sectors studied. They are often, however, more important in the footwear sector, where the production process comprises many very different technical phases with dissimilar machinery. The Korean and Taiwanese examples also show that expansion on the world market depends to a large extent on the ability to build up local agglomerations with rich interfirm linkages.

18. Other Sectors

As noted in Chapter 14, electronics, mechanical engineering - especially machinery and machine tools - textiles and garments, as well as transport vehicles are often taken as key sectors in developing countries' economic progression. Some basic process industries - such as the chemical and petrochemical sectors and perhaps pulp and paper - could be added to these. However, the latter have not been dealt with in the present study which has in general, been concentrated upon the automation of batch production technologies.

Textiles and clothing are usually - in addition to the food and drink processing industries - the sectors employing the majority of the industrial labour force in developing countries. These sectors have been studied in detail in Chapters 15 and 16.

The electronics industries provide the key resources for industrial automation. But they have also been one of the main fields for multinational corporations global sourcing operations, and thus been very important as a springboard for the NICs take off to rapid economic growth.

The engineering industry, especially machine tools and machinery are basic industrial sectors through which new technologies are often introduced to manufacturing. In addition to supplying other industries with capital goods, they also build up the skill basis for running (and maintaining) many other industries.

Thirdly, vehicle manufacturing is a sector that can be used for testing whether the industrial structure is capable of a more complex form of manufacturing, which involves several backward and forward linkages to sub-contractors. Vehicles are composite and complex products that entail both mature, basic manufacturing techniques and the most sophisticated new technologies. Vehicle production is also the sector where new, flexible manufacturing technologies so far have gained the most widespread use in developed countries.

These three sectors have not been very important in the past in most of the African case study countries, and therefore the discussion in sections 18.1 - 18.3 is focused on the situation in NICs and developing countries more generally. Data from Brazil is widely discussed in the context of these sections.

The African case countries possibilities for developing these industries is also related to the more general developments. In section 18.4, a few other industrial sectors that have been important in the case countries in the past and which were covered by the field work are also briefly discussed.

18.1 Electronics

The electronics complex is the heart of the new technological system. It is also on the way to becoming the single most important sector in the world economy. It has been predicted that the electronics industry and its products will be the most important carrier of technological change in many developing countries in the short to medium term. Its importance is based on many factors.

> "First, electronic consumer products are already affecting consumer patterns even in the poorest countries. Microcomputers offer enormous scope for immediate applications which could yield substantial social benefit.

Second, this sector - because of the pervasive character of micro-electronics - will increasingly come to play a role in economic development akin to that attributed to the capital goods sector.

Third, electronics related skills will have wide applicability throughout the economy first to adapt imported process and product technologies to local conditions, and eventually to develop indigenous technologies. They are, for example, necessary for a successful implementation of industrial automation techniques. So, the greatest opportunities for developing countries to enter new markets seem to be in electronics products".[552]

The role played by developing countries as exporters of electronics products has already been prominent. The annual growth rate of developing countries' exports in seven categories of electronics products exceeds the growth rate of world exports by more than two - three times. Hong Kong, Singapore and the Republic of Korea are exceptionally strong in virtually every product category. Taiwan Province, Malaysia, the Philippines, Mexico and Brazil form the next most important group.

The African countries have, however, been almost completely excluded from developments so far. Even production for domestic markets is very modest, with the countries performances varying considerably in different electronics product groups. Electronics is also one of the fields where the possible opening of trade with post-apartheid South Africa may well shatter the existing status quo. The country has far better resources and possibilities for more advanced electronics production than most countries in Sub-Saharan Africa.

Semiconductors

Semiconductors are at the core of new electronics. The growth of global semiconductor production has been rapid - between 20 and 35 per cent annually - up to the late 1980s, since when the growth figures have been much more modest (Table 18.1).

Table 18.1 World production of semiconductors, 1986-1991 (US$ million)

Item	1986	1987	1988	1989	1990	1991
Discrete semiconductors	7,190	8,085	10,420	10,620	10,725	11,260
Integrated circuits	27,570	33,815	46,290	47,850	45,800	50,600
Total	34,760	41,900	56,710	58,470	56,525	61,860
Growth from previous year	20.4%	20.5%	35.3%	3.1%	-3.3%	9.4%

Source: UNIDO (1990b).

Initially semiconductor assembly was the main field of multinationals operations particularly in South East Asian NICS and Latin American countries, especially Mexico. Developments up to the end of the 1970s are summarized in Table 18.2, with most of the investments being made by US firms.

[552] Hoffman, 1986.

Table 18.2 ***The development of offshore investment in various Third World locations by major Japanese, United States and Western European semiconductor firms, 1971 - 1979 (number of production sites)***

Country group	1971	1974	1976	1979
The 4 Asian NICS	19	27	32	36
Other Asian	0-2	14-17	18-19	25
Mexico	0	0	12	13
Other Latin American	0-2	3	8	13
Mediterranean Area	0	0	4-5	5

Other Asian: Malaysia, Philippines, Thailand, Indonesia.
Other Latin American: Barbados, Brazil, El Salvador, Puerto Rico.
Source: Ernst (1985).

Offshore assembly largely began in 1962, and direct foreign investment in new IC production facilities in developing countries has actually slowed down considerably since the mid-1970s. For newly developing countries, the traditional way of entering export markets via final stage assembly under multinational control appears to be closing. Multinationals have created regional production, testing and distribution centres, especially in the Republic of Korea, Singapore, Taiwan Province, Brazil and Mexico; and opportunities for other countries seem to be contracting.

The development of US offshore semiconductor production by region by the early 1980s is shown in Table 18.3. The focus has been primarily in Asia, but a locational shift from the 4 NICs and towards other Asian countries is apparent since the late 1970s.

Table 18.3 ***Market shares of the principal exporters of semiconductor devices brought into the United States under tariff items 806.30 and 807.00, 1969 - 1983 (per cent)***

Region/Country	1969	1973	1976	1980	1983
Mexico	22	19	11	5	5
Other Latin American	1	0	4	2	5
Europe	14	7	2	..	..
Asia, total	61	72	82	88	85
- Japan	2	..	..	..	..
- The 4 NICs	59	65	55	39	30
- Other Asian	0	7	27	49	55
Total value of 806/807 imports (US$ million)	127	413	879	2,506	3,383

Definition of regions:
Other Latin American: El Salvador, Haiti, Barbados, Antilles, Brazil.
Other Asian: Malaysia, Philippines, Thailand, Indonesia.
Source: Flamm (1985).

In the semiconductor industry, the barriers to entry may now be too high for new entrants, since start up investment costs are already very high. Chip manufacturers must stay near the forefront of product technology or else rapidly lose their market share. Therefore, the required level of R&D may also be beyond the capabilities of most developing countries, since a large number of well trained and highly specialized scientists, technicians and electronics engineers are required. Even developed countries, such as the UK, France, and Italy have no - or very little - semiconductor production.

The trend toward rapidly moving technological frontiers, a regional concentration of MNC investment and expanding national capabilities within the NICs are evident in the semiconductor industry, and almost exactly parallel developments in the machine tool and clothing industries.[553] Smaller developing countries, especially in Africa, are in danger of being permanently excluded from gaining access to the most rapidly growing parts of electronics markets.

From a policy perspective this makes the development of national component design capability essential, since the key to exploiting the technology's application flexibility will rest on having the ability to design circuits. In many countries even production for domestic markets may not be feasible.

The present conditions governing entry into the integrated circuit market differ significantly from those of consumer electronics, software and computers. For these sectors have common characteristics:[554]

- Because of the rapid diffusion of micro-electronics within the electronics complex, a very wide variety of product niches are emerging with characteristics which could allow much greater participation of developing country firms;
- The successful exploitation of these product niches depends much more on product design capabilities than on process technology;
- In spite of the MNCs major role, small units enjoy distinct advantages in responding to or anticipating specific and/or changing market demands in many product categories;
- For a number of products, efficient scales of production are quite low - domestic market opportunities can be much more easily exploited to nurture the development of small firms without forcing them to move to export markets too directly.

The main question for the future is whether or not the trends of technical change that are dominant in the semiconductor industry will expand to other segments of the electronics complex. Or is there emerging, also within the semiconductor area, a sphere of "appropriate technology" suitable for developing countries to produce circuits to be used in their own products?

553 Hoffman, 1986.

554 Hoffman, 1986.

Data on development during the 1980s shows a concentration of production on fewer premises. Proximity to markets seems to be a more important criteria for location than the traditional relative advantage of cheap labour. For example, in the mid 1980s there were very few Japanese overseas production sites of electronic components outside the few neighbouring East Asian Countries and main market areas in Europe and North America (Table 18.4).

The "cutting edge" of the electronics industry is therefore the domain of a handful of large enterprises, predominantly in the USA and Japan. The world market shares (for all components) of these two countries were 45 per cent and 34 per cent, respectively, in 1989. In general, Japanese firms dominate the DRAM market, while United States firms dominate the microprocessor market. Firms from the Republic of Korea have however made considerable gains and are now estimated to have 15 per cent of the world DRAM market.[555]

Table 18.4 Overseas electronic component and device production facilities of Japanese corporations, 1986

Country or area	Number of Facilities
North America	33
USA	31
Canada	2
Western Europe	21
Germany	7
UK	6
Spain	2
Ireland	2
Belgium	2
France	1
Italy	1
Others	183
Taiwan	62
Korea	42
Singapore	30
Malaysia	14
Brazil	13
Hong Kong	7
Mexico	7
China	3
Thailand	2
Philippines	2
Indonesia	1
Total	237

Source: Electronic Industries Association of Japan, 1988, ref. UNIDO (1990b).

[555] UNIDO, 1992.

Consumer Electronics

As in semiconductors, multinational corporations involvement in offshore assembly for export was a crucial element in the initial expansion of the consumer electronics industry in Asia. (The multinationals sourcing strategies have already been discussed in some detail in Chapter 11). Developing countries have mainly been successful exporters in low technology products whose manufacture entails only limited local linkages. A number of countries have, however, succeeded in developing a strong local industry in certain mature products where design has standardized and process changes are of an incremental nature. Even in Thailand where most components are imported, there were seven large TV & radio assemblers already in the early 1980s.[556]

The emergence of Asian countries as the dominant world source of consumer electronics products was the principal feature of the industry during the 1970s and the 1980s. This persuaded many others to attempt to follow the same path, however, where the intended objective is an export market in more sophisticated products, a whole new set of difficulties has arisen. This suggests that some form of mutually beneficial cooperation with the MNCs will be necessary. When international competitiveness is increasingly determined by factors other than low wages, considerable barriers to entry for new entrants are likely to exist. Even in the successful producer countries employment has not grown as fast as production and exports.

In South East Asia dependence on Japanese MNCs either for product design know how or for components is strong. Japanese firms are quite reluctant to provide product and process technology, preferring to reserve production of these products for their domestic facilities where they can quickly exploit scale economies to achieve market dominance. This can cause problems:

> "In the past Japanese producers directed their attention to Asian countries as a place for overseas production but there is now a move to divert investment to developed countries in North America and Europe. No substantial expansion beyond the current fairly active situation is expected".[557]

Other sources point out that Japan has not been active in setting up assembly plants in the neighbouring South East Asian NICs. It is mainly the small- and medium-sized Japanese companies, who only have one or two foreign plants, that have set up assembly plants, for example, in Korea. These plants are also mainly producing for the domestic markets in the host country.

Technologically, consumer electronic products contain a high share of advanced micro-electronics, both in basically old (radio, TV) and new (cellular phones, cd players, digital cassette recorders) products. The development of new product models is rapid and a high share of development costs is needed. This in addition to the intense international competition and pressures to cut production costs has actually cut small manufacturers out of the field. New domestic manufacturers in developing countries have very limited possibilities to enter consumer electronics production, even for import substitution. This is accentuated by the fact, that for example the European manufacture of TV sets and other consumer electronics has concentrated

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556 Hoffman, 1986.

557 Hoffman, 1986.

very rapidly, and there are only three or four important producers left on the market by the early 1990s.

Production processes are being rapidly automated. In many phases of the process the role of manual labour is still central, but diminishing because of automatic assembly based on robotics, new types of integrated circuits and more automatic test facilities. These are all aspects reducing the comparative advantages of cheap labour. For example in most African countries, the existing consumer electronics production - usually in plants owned by multinationals - is mainly assembling rather simple, mature, even obsolete products with low prices for the local and regional market. The relative advantages are based on cheap, manual production facilities and low transport costs because of proximity to the market.

The prospects for the growing demand of consumer electronics are, however, high, even in the less developed countries. While proximity to market is important - both because of low delivery costs and access to information in changing demand structures - more consumer electronics production is likely to be established in the countries.

In the African case this means, that some additional multinational assembly and production is liable to be established in the continent. The location of sites will depend on the ability of the country's infrastructure to support the activities with sub contractors, skilled labour, reliable communication networks and a good geographical location in relation to the regional market.

Computers

The computer industry is still largely dominated by US and Japanese firms. Rapidly growing small firms have emerged with the introduction of microcomputers and high growth rates have led many established firms from other parts of the electronics complex to enter the market. This has led to intense competition in an already fierce and crowded market.

Personal computers are, however, extremely important for industrial development in developing countries. They are multi-purpose basic tools for modern technological systems. Also manufacturing technologies can be widely developed with the help of personal computers, for example, the use of PC-based CAD systems in the clothing industry. They will involve the increasing domestic and commercial use of 'stand alone units', which can integrate systems via local area networks and these can further merge via the tying of domestic terminals to subscription based interactive information systems.

The production of computers, peripherals and related components for export has grown quite rapidly in some developing countries. The sourcing strategies of foreign firms and export activities of local firms mean that NICs have already become important forces in the world computer market.

However, there may be new threat on the horizon. This is based on the decreasing importance of labour costs and growing role of logistics and proximity to market. The purchase of the largest computer manufacturer in the Nordic countries, the Finnish Nokia Data, by the Japanese owned, British headquartered computer company ICL is a good example of this. Earlier the company used to acquire PCs mainly from the Taiwanese ACER, but is now emphasizing the importance of producing the goods in proximity to the market. As Mr. Peter Bonfield, the executive director of ICL, commented on the high labour costs in Finland and Sweden, where most of Nokia Data production is located:

"Logistics are more important than labour costs. When labour costs in manufacturing the hardware are only between 3 and 5 per cent, they do not count. The East Asian countries relative advantage in labour costs is easy to compensate, for example, by intensifying component purchases. When volumes supplied grow, it is easy to negotiate on 3 - 5 per cent extra reductions on prices".[558]

Some countries have also safeguarded their computer manufacture by imposing protective policies for the domestic industry. For example Brazil and Mexico have used a "market reserve" strategy with some success. But problems have occurred, too; domestic PCs are often produced with very high costs. This means that in the long run the industry becomes a burden to the economy. In addition to this, they are seldom of a quality comparable to international norms, e.g. Japanese, US or European PCs.

However, even in very large developing countries like Brazil, it is also an extremely hard task to shift domestic start-up firms toward a self-sustaining growth path. In doing this, there should be a significant increase in domestic supply of components and local innovation. Such efforts are obstructed - in addition to skill related problems - for example, by the aggressive responses from foreign firms barred from what they see as extremely lucrative markets.

In Africa, the manufacture of computers has been quite modest so far, though in the Sub-Saharan region, at least in Cameroon, Côte d'Ivoire, Kenya, Nigeria and Zimbabwe some assembly plants do exist. Cote d'Ivoire assembles PCs in conjunction with a Taiwanese company; and a Cameroon company started PC assembly in 1988, and now assembles IBM clones with 80386 processors.

In Kenya, in spite of very high import duties - 120 per cent on an average PC and 35 per cent on components and spare parts - computer sales have developed rapidly. In 1989 5,000 PCs were sold in Kenya, most of which were industry standard 286 machines. About a half of these came from Taiwan. The industry estimates a sectoral growth of nearly 40 per cent annually.[559]

There are also various firms assembling computers in Kenya. Kenya Microcomputers Ltd. is assembling IBM clones called Neptune; and the Micropower company is importing kits and assembling them for the local market and for export.[560]

In Zimbabwe, Transafrica Computer Services is manufacturing computers and LAN stations; CF Tulley Associates and Plessey Zimbabwe are involved in a joint venture to assemble clones, with the aim of producing 600 units a year.[561] In all, African production volumes seem to be rather low which does not imply high economic efficiency.

Generally, as with consumer electronics and developing countries, the same largely applies to the future of personal computer manufacture as well. The basic products, although developing new models rapidly, are by now rather mature. The prospects for growth in demand

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558 Tekniikka & Talous, 20.6.1991.

559 AED, 9 April 1990.

560 UNIDO, 1991.

561 UNIDO, 1991.

are high, however, because of the need to use computers in a wide variety of industrial and business activities.

This makes growth in assembly of computers expedient also in African countries, even if the computers assembled would not always be at the absolute edge of technological development. With the growth of the regional market, it also becomes more lucrative for multinational companies to locate production there. The location of production within the continent will, again, depend on the infrastructure, inputs and logistical framework the country can furnish the possible manufacturers with.

Signs of multinationals growing interest are already to be seen. For example, Nigeria may become an important producer for computer related equipment if the US investment project in UPS manufacture in Lagos begins.[562]

Computer software

Software may be even more important than the manufacture of computer hardware, at least in regard to export prospects. Software costs are rising in the developed countries and demand is increasing enormously. Throughout the developed countries there is a growing shortage of trained software personnel. For developing countries themselves software development is essential for without a software capability there can be no real indigenous electronics or mechatronics production capacity in the country, nor can the country go very far in adapting available systems to its specific needs.

Many developing countries face a considerable local need for computing systems, and systems that are available are often not suitable for local needs. One illustrative example of overcoming the problem is as follows: in Argentina a few skilled ex-employees of IBM, NCR and Burroughs set up their own firm to supply highly "location specific" sets of software packages to the banking community. Later they moved into designing and assembling both peripherals and microcomputer systems for a wider domestic market.[563]

The development of applications capability may be one of the best and most cost-effective ways through which even smaller and poorer developing countries can begin to build up a capacity in electronics and other modern technologies. This capability is crucial in introducing all kinds of advanced industrial automation techniques into the manufacturing processes. In particular the software capability will in fact determine a country's ability to develop an independent capacity in electronics and other modern technologies.

The prospects for developing countries exporting software and computer services to the developed countries have been assessed as good, because:[564]

- A large demand for products and services is outstripping the supply capacity of the industry in the advanced countries.

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[562] UNIDO, 1991.

[563] Hoffman, 1986.

[564] Hoffman, 1986.

- The highly fragmented markets for products means that there are many market niches where small firms can gain entry provided they have a reliable product.

- The skill barriers to entry are not very high, if the basic education in the field is taken care of.

- Capital costs are low as well.

In developing countries unit costs of software development can be 3 - 10 times below that of developed countries. But, there are countervailing trends as well:

- A variety of programming tools are being developed and this will lead to substantial cost reductions in developed countries.

- Developing countries software exports are almost all tied to the operations of multinational corporations which subcontract only relatively simple processing tasks to their offshore locations. There are though also possible benefits from this entry route, such as subcontracting may provide a springboard - as with hardware - which NIC firms can use to launch their independent capacity.

- A distance problem is present, but can be overcome with telecommunications or subsidiaries in the main markets. This is already happening, e.g. in Silicon Valley.

- Copyright problems are becoming very central in the industry. Computer software is easy to copy and spread illegally.

A World Bank study on the opportunities of software production for newly industrializing economies (NIEs) concludes:

> "For NIE firms seeking to penetrate the international software market, the experience gained in the processes carried out in the software cycle, the tangible products that are produced, and the settings in which software is used and maintained will become increasingly important. Without some engineering 'discipline' during the system development process that ensures a consistent, practical approach to system development on projects, management will probably not be able to effectively control the development effort and to accurately assess progress. But this experience is not gained overnight. It is not unusual, for example, for firms to have to wait at least three years before broad organizational trends are available from software metrics. This is why a long-term management commitment to understanding and managing software development more effectively will be required of NIE firms".[565]

In addition to the topics mentioned above, a good supply of thoroughly computer literate and well educated labour is a basic condition for internationally important software production. This indicates, that African countries are not likely to be in the front line, when multinationals are seeking new sourcing locations for software. A UNIDO report on computers in African states:

> "In Africa the skilled labour force needed for a successful software industry is not available, apart from the absence of other necessary factors. There is however a common feeling,

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[565] Schware, 1989.

that if African countries are to make a start in the informatics fields, they should do so first in software, because the capital equipment costs are lower than in other industries and because there may be domestic market opportunities for software to meet African conditions".[566]

So far software production in Sub-Saharan Africa (South Africa excluded) mainly consist of importing software packages and tailoring them to local conditions. Even the market need is focusing on applications of standard spreadsheet and database packages. This, in turn, opens up markets for small computer service firms supporting the use of standards software. The UNIDO report continues:

"The opportunities in African as in other countries may derive from applying the package to special business situations, providing a mixture of design, development and advisory services".[567]

Computer services are already an important growth area in many African countries. For example in Botswana, there are at least ten major companies offering consultancy, supply, repair, assembly and training. In Côte d'Ivoire there are about 20 computer service companies, and competition is keen. The largest of them, Cieria, has an annual turnover of 600 million francs CFA. In Zimbabwe, business applications for PCs are done by the Micropac company in Harare. The company also has a support network for the programmes in Zambia and Malawi.[568]

In all, some remarkable growth in software is certainly to be expected in African countries. As a labour intensive industry with low capital needs it offers in the long run, rather good prospects for countries with a large labour force. A growth in domestic software production is also inevitable for the future development of the countries.

18.2 Machine Tools

In many developing countries and especially in the NICs the capital goods sector has been a central target area for governmental policy and support measures. Production of capital goods, in particular machine tools, is often regarded as the backbone of a nation's industrial structure. This seems to have been a fact for many developing countries' successes in gaining notable industrial strength.[569] Machine tool consumption is also often used as a measure of industrialization. Some developing countries have achieved remarkable results in machine and machine tools manufacture.

The sector is also of great importance for the development and diffusion of modern automation technologies in developing countries. In particular, when a country is targeting, for example, the production of advanced electronics or metal products, it obviously needs an up-to-date machine tools industry. The sector not only supplies the economy with the needed machinery but also with the skills necessary in the installation and maintenance of imported

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[566] UNIDO, 1991.

[567] UNIDO, 1991.

[568] UNIDO, 1991.

[569] Chudnovsky, 1986.

machinery. An up-to-date machine tool industry is also needed for the adoption of more complex imported flexible automation systems.

However, it is not always sensible to try to produce domestically all the capital equipment necessary. The make or import decision is quite important when thinking about national strategies of industrial development. It may often be a more successful strategy to import most of its modern technology, and have its own production only to such an extent, that adoption, maintenance and incremental development of imported equipment succeeds with little extra effort. From the capability development point of view some domestic industry is, however, quite indispensable.

On the other hand, the sector itself is an important user of flexible automation technologies. In many developing countries the same multi-sector corporations - with a core in the engineering industry - are often responsible for most production of, and use of, flexible automation. They are, as a consequence, both learning by doing, and diffusing the building blocks of technological development which we discussed at length in the earlier chapters. Again we reiterate that even when discussing such discrete items of technology as NCMTs, CAD etc., these are as applicable in clothing, textiles and footwear as they are in the metal working industries.

The USA dominated the world machine tool industry for over a century. Even in 1967 it accounted for 34 per cent of world production and 31 per cent of world consumption. The situation has changed drastically since, and in the late 1980s the US share of production was only 6.4 per cent and 11 per cent of consumption.[570] The single most important feature behind this change has been the swift rise to dominance of the Japanese. The main reasons for this have been:[571]

- Major domestic users of machine tools such as the automobile industry undertook an intensive innovative effort to develop these tools for their own use.

- Producers set out to capture scale economies in machine tool production based on the extensive use of automation technologies and via product standardization so that unit costs were considerably reduced.

- The Japanese identified particular market niches at the lower end of the cost/complexity scale and designed superior products to fill these niches.

- The producers established an extensive world wide network for marketing and after sale service which served to cultivate demand among users normally ignored by other firms. Now the Japanese network covers over 130 overseas locations.

- Japanese machine tool producers established close design links with suppliers of CNC units and due to the scale of their production were able to reap substantial unit savings in purchasing the machine controllers by buying in bulk - achieving unit reductions of 35 per cent.

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570 UNIDO, 1990b.

571 Hoffman, 1986.

The last point is the most important - the CNC unit accounts for about 25 per cent of total costs, so this gave an important boost to their price competitiveness compared with conventional producers who manufacture machine tools in small batches.

The production of machine tools is heavily concentrated in the industrialized countries with around 70 per cent of world production (Table 18.5). The shares of country groups have remained almost unchanged in the late 1980s. The production of machine tools within the group of developing countries alone is considerably dominated by the share of the four East Asian NICs; this has constantly risen, from an approximate 44 per cent in 1985 to over 59 per cent in 1988. If this is added to the figures of the other developing countries explicitly mentioned, the production of machine tools in less developed countries is seen to be near zero. This applies especially to Africa; the only African country mentioned on the list of 34 most important machine tool manufacturers being South Africa.

Table 18.5 World machine tool production 1985 - 1988. Five leading developed countries and major developing country producers (US$ million)

Country/area	1985	1986	1987	1988
Japan	5,316.7	6,872.2	6,419.4	8,643.3
FR Germany	3,168.6	5,185.4	6,402.6	8,633.3
USSR	3,035.8	3,672.0	3,976.3	4,500.0
Italy	1,115.5	1,623.3	2,235.2	1,803.6
USA	2,727.8	2,747.9	2,585.0	2,440.0
China	341.2	363.7	632.5	731.6
Brazil	265.0	370.0	575.5	448.9
India	245.1	269.8	277.7	272.0
Mexico	18.0	16.5	21.4	18.0
Taiwan Province	278.2	366.6	577.8	695.2
Republic of Korea	175.0	333.5	530.9	597.1
Singapore	37.0	34.4	35.0	37.0
Hong Kong	1.5	1.3	1.4	1.5
NICs together	491.7	735.8	1,145.1	1,330.8
Developed countries	15,393.2	20,774.5	22,765.6	26,625.9
Developing countries	1,112.7	1,522.1	2,184.5	2,242.8
Planned economies*	5,464.9	6,594.0	8,131.4	9,178.7
World total	21,970.8	28,890.6	33,081.5	38,047.4
Percentage Shares				
Developed countries	70.1	71.9	68.8	70.0
Developing countries	5.1	5.3	6.6	5.9
Planned economies*	24.9	22.8	24.6	24.1
NICs/Developing countries	44.2	48.3	52.4	59.3

* Planned economies: including China. Not all countries are listed, e.g., South Africa.

Source: UNIDO (1990b).

When it comes to the consumption of machine tools, the situation is not much different. The same five countries top the list, and the same developing countries show good performances. In the case of consumption, the share of developed countries has actually increased during the 1980s. And again the group of developing countries is dominated by the four East Asian NICs that account for almost 60 per cent of total developing country machine tool consumption. The machine tool consumption figures reflect, even more than data on production, the level of general industrial development. The African performance is again completely absent. The only country on the continent mentioned among the 36 most important machine tool users is South Africa, and even it falls clearly behind countries such as Hungary, Denmark and Finland.

With regard to numerically controlled machine tools, the use of NC and CNC tools in the developing countries has grown rapidly, but mainly in the NICs. In the Republic of Korea the share of CNC lathes in total lathe investment grew from 2.4 per cent in 1977/78 to 34 per cent in 1981/82; and in Taiwan Province the respective shares were 7 per cent in 1977/78 and 20 per cent in 1981/82 (Table 18.6). On the other hand, the overall diffusion of NC machines in developing countries is still very modest. In Argentina, for example, NC tools accounted for only 6-9 per cent of capital good imported between 1978 - 1982 and NC lathes accounted for 38 per cent of all imported lathes.

Table 18.6 World machine tool consumption. The top five countries and the most important developing countries (US$ million)

Country/area	1980	1987	1988
USSR	3,751.0	5,303.2	5,990.0
Japan	5,232.7	3,649.1	5,686.8
USA	5,325.9	3,967.2	3,850.0
FR Germany	2,545.0	4,001.4	3,843.7
Italy	1,260.1	1,753.0	2,181.5
China	532.0	1,033.5	1,151.6
Brazil	418.9	601.5	453.0
India	216.2	389.6	383.0
Mexico	327.9	247.4	255.5
Taiwan Province	191.9	412.7	589.9
Republic of Korea	452.8	979.5	1,109.1
Singapore	101.9	95.0	97.0
Hong Kong	..	70.4	75.0
NICs together	746.6	1,557.6	1,871.0
Developed countries	16,341.7	19,089.1	22,295.3
Developing countries	1,827.3	3,041.2	3,187.7
Planned economies	6,802.5	8,764.7	9,751.0
World total	24,971.5	30,895.0	35,234.0
Percentage Shares			
Developed countries	89.3	61.8	5.3
Developing countries	7.3	9.8	9.0
Planned economies	27.2	28.4	27.7
NICs/Developing countries	40.9	51.2	58.7

* Planned economies: including China. Not all countries are listed, eg. South Africa

Source: UNIDO (1990a).

Table 18.7 *Stock of NCMTs in some countries, thousand units*

Country	1980	1981	1982	1983	1985	1987	1988	1989	1990*
USA				103			222		240
USSR	21				65				110
Japan		23				85			100
Italy	11				55				100
FR Germany	25				65				100
UK			26		45	69			80
France	10		20		35				60
Korea					2.7	5.0		7.5	
Taiwan					1.2	2.8		6.3	
Brazil		1.0			2.0	4.2		5.8	
Singapore		0.1			0.7			1.8	
Mexico								1.3	
Argentina		0.4			0.5			0.8	
Colombia						0.1			
India						1.2			

Source: UNIDO (1990a).

Brazil is an interesting case of the growth of NCMT production. NC production was started in 1975 by the leading national producer of machine tools. After that, subsidiaries of German companies also started production, whereby they adapted NC control units to conventional machinery. Table 18.8 shows the development of NCMT production, imports and stocks from 1979 to 1989. Domestic production has been supported by heavy import restrictions.

Table 18.8 *NCMT production, imports and stock in Brazil, 1979 - 1989 (units)*

Year	Production	Imports	Total	Stock	Import coefficient
1979	110	274	384	384	71.4%
1980	172	306	478	86[illegible]	64.0%
1981	69	55	124	986	44.4%
1982	120	30	150	1136	20.0%
1983	150	30	180	1316	16.7%
1984	153	53	206	1522	25.7%
1985	413	60	473	1995	12.7%
1986	833	180	1013	3008	17.8%
1987	1018	150	1168	4176	12.8%
1988	742	n.a.	n.a.	4918	n.a.
1989	1052	n.a.	n.a.	5970	n.a.

Source: Tauile & Erber (1991).

After quality problems during the 1970s and early 1980s, now local users consider the quality of domestically produced NCMTs as satisfactory and are satisfied with the technical assistance received:[572]

"Such factors coupled to the mastery of design skills, and the reduction in prices indicate that a strong learning process is under way in the Brazilian CNC industry. Given the short life of the policy and the pervasiveness of high price differentials to imports, which includes products that are not under the market reserve policy, to indict the latter on the basis of CNC costs is hazardous".

Of the case study countries, the only machine tool production is in Tanzania, at the Kilimanjaro Machine Tools factory. It is dependent on imported casting. Any important manufacture of NCMTs does not seem to be likely in the near future in Sub-Saharan Africa. This is because notable production of NCMTs is rarely possible without established manufacture of conventional machine tools. Production of modern machine tools is, typically, based on sophisticated automated and flexible production processes that demand highly skilled labour, advanced user-producer relations, and relatively developed market structures. In addition to reliable high precision mechanics, NCMT production requires qualified knowledge and mastery of electronics.

18.3 Motor vehicles

Vehicle production has so far been the foremost sector in using flexible manufacturing technologies. A large share of world FMS are installed in car factories or factories manufacturing car parts, noted earlier, and although their share in world FMS installations will decline, they will remain heavy users of the technology. They may also present the best material for comparing the nationally and culturally specific approaches to the idea of flexible manufacturing. For example, American, European and Japanese car manufacturers have rather different work organizations; they have also adopted flexible manufacturing technologies with differing expectations and based on different types of investment calculations.

Even the targets of flexibility differ, as was illustrated in Chapter 5. Also the relationships of production organization and production technology in implementing flexibility are not at all the same in, for example, the USA, Japan and in diverse European countries. Where the Japanese most often begin with rethinking the organization and implementing technology within a new organizational structure, it is often the other way around in the UK and US: first - to install new machinery, second - to educate the workforce, third - to introduce changes in the production organization when the system runs into difficulties.

Historically the car industry has also been a very important sector from the point of view of industrialization. The leading industrialized country governments probably now view vehicle production with four main motives (apart from the original one of making profits):[573]

- to create employment on a large scale;
- to establish industrial complexes which could stimulate the growth of many ancillary industries, especially in heavy industry and metal working;

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572 Teuile and Erber.

573 O'Brien, 1990.

- to introduce product, process and managerial technologies that could diffuse to the rest of the economy;

- to mobilize private sector industrial investment into supplying the vehicle industry and providing after sales and distribution services for it. (O'Brien, 1990).

These have also been the goals in developing countries when trying to establish car industries as well - in addition to the straightforward import substitution and more prestige related intentions. The success, however, depends on the sophistication of production and the ability of the country's industry to provide components for car manufacture. If all components are imported, even the import substitution benefits remain modest.

There is a quite notable production of vehicles - of both trucks and cars - in many developing countries. Developments started in the 1950s, when the largest Latin American countries began car manufacturing and assembly. Since the 1960s, direct foreign investments have grown while multinational companies became more interested in locating assembly in developing countries. US companies have concentrated especially on Brazil and Mexico.

Since the early 1980s developing country car manufacture has increased particularly in the Asian countries. Table 18.9 shows that the Asian developing countries share of world motor vehicle production has more than quadrupled in seven years, from 0.6 to 2.8 per cent. The table also shows, that the African share of car manufacture has been minimal, and has been decreasing.

Table 18.9 Developing country involvement in world motor vehicle production 1970 - 1987 (per cent)

Year	World Total	Latin America	Developing Asia	Africa
1970	100	2.2	0.4	0.10
1976	100	3.6	0.3	0.06
1980	100	3.8	0.6	0.05
1987	100	3.2	2.8	..

Source: O'Brien (1990).

A closer look at the countries in car manufacture confirms that several countries have important production scales. Two producers come above all others for volume: Brazil and the Republic of Korea. The overall vehicle production is clearly highest in Brazil, but the Republic of Korea is ahead of others in passenger car production with 77 per cent of total output (nearly 1 million) being personal cars. The growth has also been most rapid in Korea increasing nearly sevenfold in 7 years.

The share of local content in production also reveals the degree of sophistication of the industry. In this respect, only three countries have reached a level of production which involves a local content of 90 per cent (Argentina and Brazil) or over (the Republic of Korea, 95 per cent). In the next group we have Mexico, India, Taiwan and Thailand with a local content between 50 and 65 per cent. In Kenya the low share (15 - 25 per cent) means that up to 1990 the country was most likely producing only the simplest components, and almost solely assembling the vehicles. The local content figures are, however, partly misleading because the national definitions vary.[574]

The number of car models manufactured is also revealing concerning the size and sophistication of the industry. The number of different passenger car models in many countries is very high, while production volumes for each model remain very low. For example, in Indonesia there were 162,630 vehicles manufactured in 1986, with 20.8 per cent of the output being passenger cars. With 110 different models produced this implies that the average annual production of each model is less than 400 units. A daily production of roughly one car per model is hardly likely to be efficient or productive even for the most advanced flexible production organizations and technologies, which Indonesia does not have.

With respect to the African car industry:

> "The production levels and the sophistication of manufacture in those African countries where some activity takes place are both far lower than in Latin America or Asia. The biggest producer in Africa is Nigeria yet its output is extremely small when compared with either the aggregate of all developing countries or with the size of the country's own population. Egypt is a minor manufacturer despite the long-standing nature of the country's involvement in the sector. As of now, production levels are far below that necessary to satisfy the requirements of scale economy and there seems to be but little chance that matters will improve in the future. It is therefore quite clear, that Africa is many years away from challenging the position of Latin American or Asian nations and, in fact, the gap is widening rather than narrowing".[575]

For example, the Kenyan car industry is producing very small volumes. It is also worth noting, that the share of personal cars is very low. In 1988, there were less than 2000 personal cars manufactured in Kenya, which is all too low a figure for efficient production. In general it is uncompetitive in character.[576]

> "The contribution to the national income (value added) is actually negative. Industry spokesmen have blamed the problem on a commercial policy which favours imported vehicles and it is indeed true that the rates of duty on imported commercial vehicles have been set deliberately low in order to keep costs down for transport users, but the fundamental problem is that in spite of massive protection on the finished product, assembly of passenger cars in Kenya is so inefficient that imports cost less than domestically assembled vehicles. In any rationalization of Kenya's industrial sector that takes place under the shift to an export led strategy, the passenger car assembly industry will be one of the most vulnerable".

The industry has faced major problems already. For example, in 1989 the Mombasa based Associated Vehicle assemblers closed its Peugeot assembly line because of a shortage of import licenses and foreign exchange. As a result, production from the factory - the country's largest - was expected to drop by 20 per cent.

[574] O'Brien, 1990.

[575] O'Brien, 1990.

[576] EIU, 1986b.

In spite of all these problems, Kenya is planning to start production of locally designed cars, and even for exports:

> "Kenya also plans to start its own car industry following the successful production of three vehicles with local technology by the University of Nairobi. A company is to be formed with Mitsubishi owning 5 per cent of shares and providing international marketing outlets. Production is for 3,000 cars initially. Land for a manufacturing and assembly plant has been set aside at Athi River.
>
> The 4 cylinder, 1300cc vehicles were produced at a cost of Ksh 160,000 ($7,000) in close collaboration with the local railway industry after President Moi challenged the University to come up with an economically viable car for Kenya.
>
> Other production details have not been made available but University Vice Chancellor Professor Phillip Mbithi insisted that only Kenyan components were used".[577]

Bearing in mind the share of local content in Kenyan car assembly and the overall problems in the country's vehicle industry, the plan does not - especially not with the target of using local components only - sound very realistic.

18.4 Other Sectors: A Brief Summary

The sectors reviewed in this chapter are the ones usually seen as most important - and typical - for developing countries aiming for more ambitious development: electronics, machine tools and vehicles. The East Asian NICs and some larger Latin American countries have given an important place to these sectors in their economic development.

The African case countries have not yet made much progress in these fields, neither in terms of exporting, or in terms of technological development. To the extent that such industries exist, they remain as suppliers for the domestic market.

The reasons for this seem to accumulate from a series of interrelated factors: a short industrial history, thin local and regional markets, weak infrastructure - especially in terms of skills and capabilities - to support the industries, and public policies too hesitant and indecisive without clear long-term development targets. All this in addition to the problems of continuously facing insufficient financing.

There are however possibilities to improve the situation in all of the sectors. The possibilities seem perhaps most promising in electronics, which in the present situation may also be the most important sector, and especially in software development.

While the growth of domestic demand is likely to increase both in consumer electronics and computers, local assembly/manufacture in Africa also becomes more lucrative for multinationals. This is supported by the multinationals production strategies increasingly focusing on globally segmented but locally integrated production networks, where manufacturing is located in proximity to the market.

Especially in electronics, the domestic industry is largely dependent on foreign firms - at least on a licensing basis - while the basic product development is all too expensive and difficult in these product areas. However, as noted in Chapter 6, there are problems associated

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[577] African Business, May 1990.

with licensing agreements with developed countries. The supplier survey revealed only one country where firms were willing to license high technology products at all extensively - Germany.

In future development, the role of infrastructure and supply of local subcontractors becomes decisive. In policy terms this means that the African countries have a lot of work to do to develop basic social and economic infrastructures, if they intend to entice more foreign capital into sectors of modern industrial development.

Capability development is the key theme in creating the basis for growth in both electronics and other modern manufacturing industries. Creating capabilities for modern, technologically sophisticated manufacture, in turn, is not an easy task. It requires both formal education and training, and especially extensive learning by doing. The possibilities for learning by doing are, again, limited as far as the local industrial structures are very thin, outdated and/or not oriented towards technological development.

In this respect, however, most of the case countries are progressing, both in terms of facilitating the operations of foreign capital and in developing the local capabilities. The latter task is more difficult, and takes more time.

19. Conclusions and Policy Options

In a sense, all countries are developing. The questions posed by industrial automation are where on the scale of development a country appears and how long the infrastructure and the countries industries have been active in a development sense.

The United Kingdom and the Netherlands were two of the earliest countries to exploit manufactures as a basis for wealth creation and both have been surpassed by an increasing number of countries, e.g.,the USA, Japan, Germany, etc.

All three of the latter countries achieved their success - over a very long period of time - by building powerful infrastructures with highly developed educational, social and logistical underpinning. All developing countries should be aware of the degree of effort and time that lay behind this trend towards world competitive success.

This report has tried to highlight both the developed countries efforts in encouraging the upgrading of production processes, and to draw out some of the implications of this for developing countries - including an assessment of the existing situation in the case study countries.

This final chapter attempts to pull together the underlying themes which are felt to be worthy of consideration by industrialists, researchers, educationalists and policy makers in developing countries, and in particular, in the case study African countries.

Five broad themes are covered:

(1) The technological/organizational/structural interface and the integrative trends from a "machinofacture" to a "systemic" form of industrial organization.

(2) The findings on the implications of four manufacturing technologies, CAD, Robotics, NCMT & FMS.

(3) Developed country policies to support modernization and competitiveness.

(4) Some policy options for consideration within developing countries, and also by development agencies wishing.

(5) Some concluding considerations on the present technological level, future development possibilities and needs of automation in the three sectors - the textiles, clothing and footwear industries - studied in the African case study countries.

19.1 Industrial Adaptation

The earlier chapters of this report showed that the advent of the computer, and information technology in general, has created a radical transformation of production possibilities which has provided the opportunity to integrate manufacturing processes in a way no earlier technologies have offered.

The ability to link the whole process of a company's activities from design, through materials processing, manufacture, packaging and transfer, has increased dramatically. But it is still not much further advanced than its infancy. Its potential in manufacturing currently appears unlimited.

Early warnings about automation were too alarmist and the proposers were clearly unaware of the time, cost, and learning aspects of its diffusion. In fact, contrary to these early expectations, the computer and its allied developments (particularly in consumer durables manufacture) have created employment and wealth. The United Kingdom gives one example:

> "Between 1983 and 1985 the total decrease in jobs has been much greater than that expected by industry - three times the level in the previous two years. The higher level of decrease may be explained in part by the effects of increasing adoption of more advanced systems, in which case further spread of their use may lead to further rises in the rate of decrease in jobs... The new jobs becoming available are often of different kinds and in different places from the old ones and are therefore not necessarily within the reach of those displaced from the old ones.
>
> These considerations do not imply that the risk of worse unemployment problems means that the pace of adoption of new technology should be encouraged to slacken off. On the contrary, the potential benefits of increased productivity are real and need to be exploited if we are to maintain and improve our international competitiveness. Falling behind in this would only lose more jobs to other countries which adopt the new technology more effectively".[578]

This is the crux of the problem for in an increasingly accessible world no country can remain indifferent to change or competition. This is why technologies discussed in this report are as important to the developing world as to the developed.

As observed in Chapter 1, there have been two pressures for change in companies, internal and external. However, both have at their root an attempt to increase responsiveness to changing customer needs, and to increase ability to cope with demands for short lead-times, high quality, increased customization and competitive prices.

Only by an evolution towards a simplified structural set-up, e.g.,reduced functional and hierarchical barriers; allied to organizational adaptation, e.g., just-in-time production, total quality control, design for manufacture, closer supplier links; and with the use of new technologies, e.g., CAD, Robotics, FMS, can modern industry compete internationally (see Figure 1.3).

The "systemic" nature of information technology based on the microchip is permeating through all aspects and functions of companies (see Figures 1.4 and 1.5). Chapter 8 examined the design and redesign trends which are part of this newly integrated system and it was emphasized that without creating a vigorous design function developing countries may be increasingly consigned to the role of providing low value added goods or agricultural/raw materials supplies. This is because in traditional product cycle theories it was assumed that only very minor changes in product design would take place in the mature phase of a product, and in this context this was the point at which relocation to low cost countries would occur. Now there is a danger that the product will go through rapid and constant change facilitated by flexible production processes and CAD options.

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[578] Northcott et al., 1986.

From a design viewpoint this implies a need to design products that are easy to alter without significant process changes; while the flexibility of the production process has to be - and is being - extended.

As a result of this integrative trend industries are being transformed from "sunset to "sunrise" industries. The pre-press function of the printing industry was given as an example (see Chapter 1, Figure 1.6 and Table 1.1).

Chapter 9 extended this discussion of organizational and manpower issues somewhat and suggested that some combination of technological and organizational adaptation was essential to current manufacturing efficiency (see Figure 9.1).

This contains profound implications for national education, skills, and training institutions. Only with a highly educated, skilled and managerially enlightened environment can these two trends be brought together.

Automation as a whole will lead to a gradual transformation of employment structures; and there will be consequent changes in skill requirements both in existing jobs and industries, but in particular in the new jobs and industries being created. This calls for considerable analysis and planning in developing countries, and perhaps the development of not merely a skilled workforce, but a multiskilled one.

The importance of these issues was noted at various points in this report, but particularly in Chapter 9, where the "knowledge" base of new production techniques was discussed, together with the "organo-centric" rather than "techno-centric" nature of these.

It is this knowledge base which provides the "virtuous circle" of success which has been observed in Germany and Sweden and more recently in Japan and the Republic of Korea.

Such an integrated and total concept of industrial adaptation requires:

- the development of coordinated skills;
- design and redesign for manufacture;
- a joint technological/organizational approach to change;
- closely coordinated buyer/supplier relations, and the adoption of JIT; and
- allocating to the computer what it is good at, and leaving the innovative, creative, and flexible actions to the human being.

19.2 Technology

The focus on some of the new technologies which has been used in this report may, at first sight, be thought to be not too relevant, e.g., Robotics or Flexible Manufacturing Systems. However, if developments in manufacturing processes in the developed world are progressing in these directions they bear significant implications for developing countries, i.e., can the latter catch up or even maintain their positions if technological developments are changing comparative advantages, and the international division of labour?

Similarly, our emphasis in explicit discussion has focused upon mechanical engineering, when perhaps it might be considered less important to developing countries than textiles, clothing, footwear, food processing, raw materials or agricultural produce. However, implicit within our arguments is that these are technologies of much broader application, and we have sought to highlight this throughout the report, for example, in section 5.5 and in particular Table 5.7.

Raw materials, agriculture and basic low value-added products are a traditional form of development and advantage - and that these can, and do, provide stepping stones for further development. However, these are enough. At some point countries must transcend these modes of development and manufacture products with high quality characteristics, perhaps aimed at niche markets, but certainly based upon long-term, well thought-out policies of development.

It is for this reason that we offered for consideration four relatively new but significant automation technologies. As noted earlier, which have an integrative or systemic impact which transcends each of them on their own. The sum of the four technologies is far greater than each part.

Robotics

In the context of developed country use, this is still relatively unsophisticated, expensive and lowly utilized. How much more difficult for developing countries must this be then? Since this is a technology which is largely labour replacing, it is probably the least relevant of the four technologies from a developing country perspective.

Besides being expensive, robotics requires considerable computational power, sensors are not highly developed yet, there are few interface standards, off-line languages cannot exploit CAD databases, and positional accuracy can be somewhat off.

Again, the technology has been applied in fairly specific industrial sectors, e.g., motor vehicles, mechanical engineering and, in general, in fairly large companies, neither of which is a particular strength in developing countries in Africa except for a small number of exceptions.

CAD

Of all of the technologies covered in this report, this is probably the most relevant option for African countries for a variety of reasons.

In Chapter 3 it was observed that the cost of both hardware and software had reduced relatively - and in the case of the latter it was now possible to buy packages for application in textiles, clothing and footwear that were extremely cheap, e.g., section 3.2 noted complete systems available for under $15,000.

However, by application in the basic development industries, textiles, clothing, footwear, etc., the learning-by-doing, demonstration effects, and diffusion impacts would spread across industrial sectors, and the engineering, construction and many other industries would benefit - if they have not already made a start with the technology themselves.

Some of the benefits of the technology include:

- savings in material costs - up to 9 per cent;
- increased productivity - up to 20 to 1;
- replacing scarce labour skills;
- maintains competitive position vis-à-vis developed countries;
- increases user countries design/redesign capability.

NCMT

As with CAD, and in close association with it, NCMT has now become a rational investment decision for even low-to-medium wage countries, (see Tables 14.6, 14.17a and 14.17b). In a direct comparison with traditional machine tools, NCMT has become a logical choice, even in relatively low wage countries such as Argentina.

Examples of productivity increases achieved by NCMT compared with conventional machine tools indicate that the former is - on average - around 3 to 4 times more productive; instances of improvements up to 15 to 1 have been suggested (see Section 4.5).

The rationale for NCMT is based not merely on economic considerations, however, for it also affords the opportunity to change from what is essentially one-off or small batch production into a more flow-line process, thus improving machine utilization; and also enhances quality and the repeatability of this.

Interestingly the main user branches in developed countries also indicates that their applicability in developing countries could be considerable.

- miscellaneous machinery, e.g.,job-shops;
- metalworking machinery;
- general industrial machinery, e.g.,pumps, compressors, etc.

All of these might offer opportunities for fairly small-scale production to be engaged upon. Also as noted in Japan, sales of NCMT to small firms (< 300 employees) had risen by a factor of almost 21 between 1970 and 1981.

The technology has now reached the mature stage of its life cycle and this has resulted in:

- reduced costs
- increased productivity
- greater knowledge
- simpler equipment, etc.

As noted for CAD, NCMT is imperative for industrial development; and that in conjunction with CAD it forms the basis for a significant improvement in performance. This is as true for the clothing and footwear industries as it would be for the mechanical engineering sector. The result - given the appropriate infrastructures and a skilled labour face - would be higher quality products, produced more rapidly, at lower cost, and using local design capabilities.

Hopefully it would also lead to a broader industrial structure in an expanding range of industries.

FMS/FMC

Of the four technologies covered in the text FMS/FMC is the most complex, and is the most systemic since it can incorporate NCMT and robotics, and in part be driven by CAD. It is the nearest stage to full CIM, though FMS/FMC ranges from simple cells costing less than $500,000 to fully integrated systems driven by sophisticated host computers, and costing tens of millions of dollars.

The rationale for the technology is a logical extension of many of the requirements noted above in the NCMT section, e.g., to improve production flexibility, reduce lead-times, etc. In addition it offers system operations during an unmanned third shift, reduces physical machining areas (4 machines in an FMS normally replace about 16 conventional machines), and can be totally integrated with pre-machining functions, e.g., materials and tools planning, etc.

The benefits of FMS/FMC have been shown to include:

- labour savings of 30 per cent or more;
- material savings of 13 per cent to 15 per cent;
- inventory and work-in-progress reductions of 50 per cent+;
- lead time reductions averaging 40 per cent;
- increased machine utilization of 30 per cent or more, etc.

Problems associated with the technology may include the sheer cost of the more sophisticated systems, the need for multiskilled personnel to operate and maintain it, an increase in the number of programmers and systems engineers needed, etc.

However, indications are that as the technology is slowly maturing and greater knowledge is accumulating, systems are becoming simplified, and less costly (see Section 5.5).

Also that the range of applicable industries is expanding as seen in Table 5.7, where systems are now installed in the UK in leather goods, clothing, plastics, forging, footwear, glass products, food and drink processing, furniture, and office machinery; as well as in the original heavy users, e.g., aerospace, motor vehicles, mining equipment, etc.

Chapter 5 also noted the extent to which the effective use of FMS/FMC was often dependent on a radical shift in the way production was organized and the structures that were in place to facilitate this. It is feasible that in appropriate sized companies in Africa, a limited approach to the use of FMC, in particular, might prove the best approach both in terms of economic costs and benefits - and that significant benefits - in a learning and demonstration sense might be forthcoming.

19.3 Developed Country Technology Policy

In order to be able to identify technology policy in the developed countries, seven countries were examined in some detail: the USA, Japan, Germany, France, the UK, Sweden and Denmark.

Clearly there were considerable similarities in approach but with some interesting variations on a theme depending on which country was being studied. However, in this final chapter we, in general, use just 4 of these countries in order to focus in on somewhat different approaches. The detailed analysis of all 7 countries is contained in Chapter 10.

Sweden

Sweden placed a very high emphasis upon channelling support for new technologies - and innovation in general - into the higher education system, and a series of cooperative institutes. In this way they sought to provide strong links between education and industry, and the cooperative research institutes.

Although the Swedish government avoided a centralized system and support was administered by individual ministries, the state attitude was that at base its most important function was to fund basic research - but more importantly, to provide the training for both research workers and the general public at large.

The main agency for providing government support was the National Board for Science and Technology (STU). The importance of this agency in terms of automation projects can be seen in Table 10.17, and the extent of the responsibility for robotic, CAD/CAM and flexible automation developments since the early 1970s.

Policy covers a broad spectrum of support starting with the development of skills, research subsidies, consultancy services for small- and medium-sized enterprises, marketing and work organization, and the development of human capital.

This approach holds some possibilities for African countries but important parts of the whole would be missing. For example, while developing links between academia and industry is highly desirable, it is doubtful if sufficient higher education or research institutes involved with *technology* development exist in most of these countries.

Similarly, it is doubtful if sufficient funding exists to put a strong emphasis on basic research and to provide the necessary training for workers and up-grade education and skills overall. At this stage therefore, the latter appears to be the most essential of the two.

From the Swedish approach, therefore, the development of education and skills, the provision of consultancy services for small- to medium-sized enterprises, and help with marketing and work organization changes, appear to be the most appealing approaches for African countries - and probably at somewhat lower costs than some of the other approaches, e.g., funding of basic research.

Germany

There are considerable similarities in aspects of policies for supporting technology development in the United Kingdom, France and Germany. Policies adopted by one of these three countries very often become a model for the other two.

In general approaches towards developing automation technologies based on micro-electronics and information technology in all three countries began in the early or mid 1970s; and largely focused on data processing in the early stages (see Tables 10.8, 10.19 and 10.6), but also quickly took on board robotics, CAD/CAM, etc.

However, in all three countries attention rapidly switched from support for innovation to support for applications and diffusion in products, but more particularly in processes. For example, in Germany 60 per cent of support programmes were oriented towards applications by 1983.

The German programmes present industry with an outline of the framework for trends, and companies are expected to develop concrete and coherent approaches to utilization. Enlightened self-interest in German companies often means therefore, that government "pump-priming" of industry brings forward a response in which the multiplier effect of government funding is quite considerable. For example, the Mikroelektronik II programme which provided DM 450 million of state money brought forward DM 1 billion of industrial investment.[579]

The effect of government funding in France is perhaps a little less certain since it has been claimed that some of these funds are actually used to offset losses suffered by state owned enterprises.[580] Similarly, in the United Kingdom the impression given is that government funds are often a substitute for companies funds and that voluntarism is not strongly pursued. However, the additionality criteria from the UK's FMS support scheme was quite high with 52 per cent of companies claiming accelerated adoption, and 32 per cent claiming the adoption of an "up-graded" or more innovative system.[581]

The advantages of German support schemes has been that they have generally been:

- administered simply, usually through existing professional organisations, e.g., industrial engineers;
- have a very simple application and approval system;
- concentrate on specific industries, and/or on small- to medium-sized enterprises;
- undergo constant evaluation procedures.

A further advantage has been that support has been directed to exactly those areas in which Germany has been industrially strong in the past, e.g.,machine tools, precision equipment, etc., and in the specialist small/medium-sized firms. Concentration has therefore been focused upon established strengths, and on its established highly skilled workforce, working in collaboration with technical institutes and other research bodies.

The UK on the other hand, has found that a considerable amount of its support for industry has fed indirectly into its main strengths which have been aerospace and the defence sector.

The UK's approach has also been fourfold, aiming to:

- increase industrial awareness of micro-electronics;
- provide assistance with training;
- support consultancy services;
- provide project development support to firms.

Taking the Micro-electronics Applications Programme (over US$ 100 million between 1978 and 1985 - see Table 10.20), this was probably the most widely known programme amongst UK industrialists and its success was derived from a number of factors quite similar to the German instances:

- consultancy for small/medium-sized enterprises;
- little government choice in which technologies to support;
- wide ranging - both products and processes;
- of a long-run nature (7 years);

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[579] Roobeek, 1990.

[580] Rhodes, 1985.

[581] Rush, Hoffman and Bessant, 1990.

- continual assessment of the participants.

A number of options for African countries emerge from this overview of the three main European industrial countries, though, as with Sweden, several of these would not be effective in a current African situation.

It is clear that in all these countries the focus has been placed upon applications of new technologies and not on their basic research or development, this would appear to provide a basic model for developing countries.

The German model provides companies with an outline for development - as did the UK MAP and FMS support programmes within which individual firms need to respond, no government action can force a response. In Germany employers and employees tend to respond quickly and positively to this kind of stimulus. Will African countries with, up to recently, their rather centrally directed economies find as good a voluntarist response, and do they have the managerial and workshop skills to do so? Perhaps what will be required is a quite rapid change in national policies towards new technology, the greater liberalizing of individual production units, and a greatly expanded educational - both formal and vocational - sector.

Both the German and UK programmes have been founded on: simplicity of application; constant evaluation by specialists; simple administration; small/medium-sized firm emphasis; and provision of consultancy services.

The sums of money provided have been substantial but not prohibitively high, and elements of this approach do recommend themselves for consideration by policy makers in Africa; particularly if those countries can apply them to areas of industry in which they have an existing strength.

United States

The United States support for technology policy is somewhat atypical of all the other countries covered in this volume - it is also perhaps of least interest to developing countries, including African ones.

Central government support has been focused upon general policies and not on applications or diffusion of micro-electronics - as we saw was the case in Europe. Instead it seeks to increase R&D or promote the transfer of R&D developed in the Federal sector - largely through the aerospace or defence industries - into the commercial sector.

The main focus of this policy is on tax credits to companies carrying out R&D; the addition of overhead charges (up to 4 per cent) to cover the costs of R&D; support for national organisations involved in technological developments; etc.

While the total sums provided by the Federal government in the US have exceeded those in almost all other countries, it is estimated that around $ 4,000 million annually is spent on indirect support for computer science and technology.[582] It is difficult to see where any of this could provide a model for African countries, since they do not possess the national defence organisations or research institutes on the scale of NASA, or have the level of advanced technological developments which benefit from the US Federal government aid.

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582 Roobeek, 1990.

Japan

Japan has one of the longest standing and most comprehensive technology policy programmes in the developed world. With the establishment of MITI in the late 1940s, technology became a central focus of development, largely as a consequence of the employment of engineers as senior members of the organization (see section 12.6).

In fact Japanese support for industry was evident some years before that found in Europe or America, in 1966 with development of a super high-performance computer programme (see Table 10.13b).

These programmes were facilitated by the close links forged between government and the large Japanese corporations (the Keiratsu); and a major function of most programmes has been their long-term nature.

Implementation of automation in Japan has been summarized as follows:

> "The Japanese are the pioneers par excellence of flexible automation. This is not due to superior robot or related technology, but to faster implementation of the new production techniques backed up by new organizational methods".[583]

This highlights the importance of the dual approach to production, i.e., the combining of technological and organizational change.

The Japanese have concentrated on four general types of policy objective:

- to modernize industry which has failed to adopt best practice techniques
- to correct imbalances in business practices
- to encourage development and growth in small- to medium-sized enterprises
- to assist companies facing financial/investment barriers.

The support provided in order to perform these tasks is intended:

(1) To develop the manpower and skills infrastructure. In this they have developed extensive training programmes and these have been largely administered by the Japan Small Business Corporation (founded in 1980). The demand for such training is very heavy.

(2) The creation of special support programmes aimed at diffusing new technologies, e.g., robots, FMS.

(3) The establishment of collaborative networks for research in high-tech areas.

A Developed Country Overview

Overall almost all of these countries have provided substantial funds to support a variety of technology policies. Quite a number focus in upon national strengths which are not apparent in many developing countries, - and perhaps least of all in many African countries. However, the policies pursued do hold some options for the case study countries.

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[583] Roobeek, 1990.

Among the policy options that could be considered are:

(a) Support for the provision of information and advisory services regarding specific technologies. Of these, it was noted in earlier chapters (2-6) that in both economic and technical terms CAD and NCMT are technologies appropriate for diffusion.

(b) Support for consultancy services and feasibility studies regarding appropriate technologies.

(c) Support for the purchase of, at a minimum demonstration site where those technologies can be seen in action, and people can gain hands-on experience. If possible, providing that funds become available, either internally or through funding agencies, for their diffusion through the appropriate industrial sectors should also be catered for. Application support was strong in almost all of the developed countries covered.

(d) To provide, as far as possible, a long-term programme of support in order to eliminate uncertainty on the part of industrialists, though not so long that they create dependence on the part of companies.

(e) To encourage inter-firm collaboration both in an engineering sense and in a modern buyer/supplier sense. In addition to this to help create stronger links between educational and technology research institutes, and the bodies they are intended to serve, i.e., manufacturing industry.

(f) Help in organizational adaptation. In many companies visited in the case study countries, management expertise was weak and based on traditional structures. The whole system of managerial control and organizational structures needs to be modernized by less hierarchical or functional activities; and by the adoption of JIT, TQC, etc.

(g) A considerably greater concentration on education, skills and training *at all levels*. There is clear evidence from the experiences of the developed countries, that this has proven to be the starting point for a "virtuous circle of success" in a development context.

A combination of some of the above non-technological factors can often provide many of the benefits attributed to the use of new technology, e.g.,shorter lead-times; improved quality; reduced costs; better machine utilization; etc. It may also provide the economic advantages and performance that can be the bedrock for investment in best practice equipment.

19.4 Developing Countries Policy

The basic industrial policy approach in many African countries has had import substitution as a main target. There has also been an expectation of competitive comparative advantage based on cheap labour. In this setting, it is assumed that import substitution - in contrast to export promotion - is a less demanding target, a strategy, in which a country can rely on a less sophisticated industrial base, providing some basic conditions are guaranteed, e.g., heavy protection of domestic industries from foreign competition by import regulations and tariffs, have usually been the most popular supportive policy options.

Export promotion strategy has been seen as the next step in this development. It is assumed that export promotion requires a more developed and productive industry to be competitive on the global market. In the African context, this next step is often something of a mirage since domestic industries lagging behind international standards in performance are safeguarded behind protective barriers. In most cases, where export promotion has been adopted as a target the strategy has usually been based on the same competitive advantage as import substitution, cheap labour.

One of the conclusions from global approaches is that all industrial strategies - if the target is to continue industrial activity in the long run - have to be based on the idea of continuous development. This development has to be in terms of productivity, effectiveness, efficiency and quality. Prolonged protective barriers are in fact not a blessing to the economy, but a burden. This has already been noticed in many African countries - for example in Kenya and Tanzania - where several large parastatal companies are under scrutiny, e.g., to be rehabilitated or abolished.

Economists have named the contemporary era of technological change (the main developments of which, especially in terms of production technologies, are described in Chapters 1-7) the microelectronics revolution.[584] This technological revolution is changing the basic lines of technological and economic evolution on a scale comparable to the industrial revolution.

Many developing countries have hardly been touched by this industrial revolution. Industries, especially in Africa, were originally established as latecomer appendices to the developed countries industries, mainly processing foodstuffs for the European market or providing raw materials.. More generally, the developing countries were often manufacturing quite simple goods to satisfy the demand of the lower echelons of the developed countries market. In most Sub-Saharan African countries, industry is highly vulnerable. After some promising developments in the 1970s, many industries have in fact regressed.

For example, manufacturing exports have declined in fixed price terms in the majority of Sub-Saharan African countries, Botswana and Mauritius being the only real exceptions. The main reason behind this is the poor international competitiveness of the countries. The cost level has continuously risen during the past 20 - 30 years because of rising levels of protection, overvalued exchange rates and quantitative restrictions placed on - both competitive and complementary - imports.

Thus, there is a pressing need for comprehensive industrial development policies. Experiences from countries with above average success in manufacturing in the Sub-Saharan region at least point to some guidelines for policy options:

- price factors are not the only, not even the major issues behind success: management, design and engineering skills often play a more critical role in explaining differences in performance. Even more generally, the development of manufacturing depends critically upon the presence and promotion of adequate skills;

- sustained manufactured exporting do not succeed by looking only at short-run cost advantages;

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[584] Dosi et al., 1987.

- questions related to management and machinery-choice are of critical importance in creating vital industries;

- sheltered, but not too protected, regional markets can assist in creating efficient manufacturing units. Thus a very liberal regime is not a sufficient condition for efficient manufacturing production;

- the role of product quality has increased, and is to a growing extent ranked above price factors in market competition.

In the present situation the African countries cannot afford to be left out of technological development. In the contemporary global economy, with industries being restructured along the new lines of technological and organizational best practice, there is not much space for industries trying to grow along traditional lines. The new trajectories of development are based on the possibilities embodied in micro-electronics, new modes of firm organization and new features in market demand.

However, the Sub-Saharan countries industrial development policies are still mainly based on very traditional lines of argument. The role of technological development is discussed only superficially, and actual policy is more concerned with issues of short-term employment and not with sustainable long-term development (see Chapter 12).

A general conclusion from the discussion above is: a rigid import regulation policy is more harmful than beneficial to the industry, even if import substitution should be the prevailing strategy. Thus a reduction in import tariffs and an elimination of quantitative restrictions should be considered.

In addition to this, there is a very pressing need to increase productivity. For this, more complex policy measures are required. These might include the following: new machinery that is more up-to-date and appropriate than the present stock of machinery, better management capabilities and techniques, expanded research and technological capabilities, innovative ways to increase labour productivity through organizational revival, systematic attempts to enter new non-domestic markets with higher quality products packaged more attractively, attempts to reduce comparative transport disadvantages and the provision or extension of export credit guarantees and facilities to minimize foreign exchange risks.

In this context, a policy promoting the expansion of manufactured exports and an import substitution policy should be linked with each other, but in the context of policies which give priority to raising the level of efficiency of existing manufacturing firms. Sensitivity to market signals - a basic issue in export promotion - is required, but there is also a need for more interventionist policies to strengthen the expansion of manufacturing industry and support the creation of inter-linkages with the other sub-sectors of the economy.

When increasing productivity and efficiency are taken as the main targets of industrial development, technology policy becomes a core issue of industrial policy.

Technology Policy

In a developing country context, only a few of the most successful newly industrialized economies - the East Asian NICs and a few Latin American countries - have formulated long range programmes to support technological development.

In developing countries, technology policy has quite different objectives from those in the developed countries. The role of technology transfer is crucial, and the main policy targets are to manage the technology transfer process efficiently and to assimilate the technologies imported into the existing structures in a way that could contribute to a sustainable, dynamic technological and economic development. In this, the main policy areas are:

(1) management of the international technology transfer process;

(2) execution and management of technical change;

(3) acquisition and accumulation of technological and managerial capability.

The management of international technology transfer process involves a number of closely related processes, from the international search for possible technologies to the actual implementation of the new technological system.

Over time, the accumulation of incremental technical change improves the overall performance of the originally transferred production system: in terms of steady improvements to labour and machine productivity, energy and material usage; reduction of downtime and wastage rates.

The experience from developed countries reveals that the more complicated the production technologies installed are, the more minor modifications, alterations and adjustments in the technology as well as experience in operation is needed, before the best practice level is reached. In the case of FMS this often takes years after the installation. Thus, in technology transfer the recipient organization has to be capable of developing further the acquired technology. In this, local capability development is a crucial condition for continuous and accumulating technological change. There was little indication that the ability to do this existed in most companies visited. In fact, quite often the reverse occurred - systems became less efficient.[585]

In the context of an individual country, the technology policy objectives, management of technology transfer or technical change and accumulation capabilities - have to be adapted to the local conditions. This has been done rather poorly in most of the case countries - and in Sub-Saharan Africa generally. Both the interviews with industrialist and policy makers, as well as African researchers reveal that in technology policy documents, the factual technological needs and problems in the economy have not been monitored at all, or on a very superficial level only. And the linkage between technology and development is poorly understood.

As was described in Chapter 12, technology policy in many developing countries lacks detailed analysis of requirements, of the role of technology, of how it is to be mastered. Nor is the impact on manufacturing performance appreciated. Policy statements tend to be very general, and this institutional structure is inappropriate, with a bias towards scientific resolutions, while the needs of companies are very precise and practical ones. The need is for a more systemic technology policy, one in which the role of technology in the manufacturing sector as a whole is properly understood, and one in which specific measures are directed towards enhancing that role.

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[585] Bell, 1984.

In creating technology driven approaches to economic development, the Japanese experience is instructive. The Japanese innovation and technology policy highlights the key features of a systemic approach to technological development: long-term targeted development based on capability building, learning by doing and motivated commitment by all the actors involved, from workers in the simplest shop tasks to top management. It requires a coordinated policy on both governmental and enterprise level, but the firms are always the final decision making and responsible parties. At the governmental policy level, it also means the replacement of development based on self-evident ("natural") 'comparative advantages' with more demanding long-term development targets based on comparative advantages created by capability building.

The Republic of Korean case is a concrete example of a local adjustment to the Japanese model in a developing country context. In the 1960s accelerated Korean export production was mainly based on conventional comparative advantages (cheap labour, supply of raw materials). But the later, most spectacular successes in shipbuilding, steel, and manufacture of steel are mostly comparative advantages created by governmental decisions and policies - largely following the Japanese model, but with more direct governmental administration - not by free market forces.

A key factor in the development model was, as in Japan, the creation and development of new, dynamic advantages, defined as targets by governmental policy and induced by various policy options, measures and even more straightforward administrative directives. In this, a long-term development of capabilities and learning from imported foreign technology have been crucial factors. An important background factor enabling the development path has been the national educational and training system.

In more concrete terms, a few options on technology policy can be taken up from our experiences in the case countries.

- There is a need to reorganize a variety of public technology policy institutions. They should be dealing with tasks more relevant to the local economic and technological development and this should be done in more intense cooperation with individual firms and other economic actors. This implies more cooperation between universities, research institutes and firms.

- There is a specific need to spread information on the use and possibilities of new technologies. This could be done through, for example, establishing specific 'information technology centres' with differing targets, e.g.,CAD centres. There are many possible alternative forms in which this kind of centre could be organized, but it is important that they are in close contact and cooperation with educational and training institutes as well as with firms. This kind of information technology centre has proved to be rather successful in developed countries.

- Companies need direct aid in getting information on production technology developments and making technology acquisition decisions. This could be arranged for example through sectoral research institutes, branch organizations or parastatal holding companies employing personnel specialized in information gathering, and creating contacts to sources of technological information abroad. The specialists should carry out contract tasks to individual firms, to help them both in creating contacts to technology suppliers and in technology contract issues.

- Quite similar aid is needed by firms in technology assimilation and adoption matters. In this case, however, the need is for highly specialized knowledge on production technologies and for long-term support, which starts before the actual implementation of new technologies and continues until the new systems has been totally incorporated into the everyday activities of the firm. This kind of aid may, in many African cases, be only available through foreign donors.

- Even more general awareness programmes on the effects and possibilities of technological development are needed. They should be associated with an open and wide social discussion on the themes of technological development.

- Companies also need more direct financial aid in technology acquisition. This means facilitating the regulation on foreign currency in production technology matters. New production technologies are, however, means to make the economy more effective and productive and thus creating new possibilities for economic growth and increased exports. The need to make customs procedures less complicated and less bureaucratic is as important.

- For capability building it is important that local firms be deeply involved in every technology transfer case, even when foreign donors are completely responsible for the process. Technologies imported should be 'appropriate' in at least three senses: they should fit the existing production processes in the recipient organization, they should raise the technological level of the organization and serve as a basis for capability building, learning and further technological development, and, third, they should support the macro level national development targets. The last topic may often include, for example, the target of diminishing the variety of machine types and makes in the country.

Education and training

Capability building as a basic condition for dynamic and sustaining technological development is crucial. In this, the role of the educational system is critical. As noted earlier, in countries such as Japan or the Republic of Korea there has been a long-term emphasis on developing wide and up-to-date skill bases.

In most African countries education has been expanded considerably during the years of independence, but the systems as a rule are not up to the requirements of modern industry. There are too few institutions for vocational education, the vocational content in the curricula is generally too low, and the facilities for teaching technology are not adequate. Higher education, though often quite extensive, is focused in general on 'arts and sciences' subjects not giving entirely satisfactory qualifications for graduates aiming towards industrial management or research positions. It also tends to still be driven by norms set by previous colonial powers, e.g., Great Britain, France, etc.

Thus there is a need to:

- Considerably expand the system for vocational education in the most important fields of the economy.

- To up date the technical facilities for teaching, especially for teaching computer related subjects. The general level of computer literacy - even familiarity with computers - is all too low to meet the needs of the modern economy; and trainers are often poorly qualified.

- To narrow the gap between industry and educational institutions. This could be done for example by introducing elements of the Central European dual education system to vocational education. In this case students would alternate between school and factory; practical training would be given in the factory and theoretical teaching explaining the things learned by doing in the school.

- University students involved in management and technology studies should spend more time in industrial firms during their study - as should, in general, all students. They should also be given the opportunity to learn at first hand about leading edge developments from training abroad wherever possible.

- Intra-firm training is actually possible only for large firms. Thus there should be more publicly aided systems for training the personnel of small firms. This could be done by either opening the training institutes of large firms to other companies, or by establishing cooperative training centres financed by various companies with public aid. This kind of training centre could operate, for example, in the context of and using the facilities of the technology demonstration centres proposed in the previous chapter. This kind of model - based on cooperation between public authorities, local companies and technology suppliers - has proved to be rather successful, for example, in Sweden.

19.5 The Case Study Sectors

The three sectors studied, textiles, clothing and footwear are all quite important in the six African case study countries. They are also industries where the micro-electronics based automation has not yet caused any major changes. However, signs of changes in the global market environment, current technological developments and new enterprise strategies in the developed countries are evident.

The textiles industry is, both in terms of employment and output, the most important of the industries in all case countries except Mauritius.

Production processes in the textiles industry are characterized by mainly incremental but continuous technological changes. The introduction of microelectronics into the control operations of textile machinery has significantly increased both productivity, effectiveness, reliability and flexibility in the industry.

The basic nature of the industry has not, however, changed much. It is a capital intensive industry with a prolonged development trend towards further automation. The relative importance of labour costs is diminishing, while the price of modern production equipment is rising rapidly - conversely to many other industrial sectors - as noted in Chapter 15. A real trade off between labour and capital in the industry exists only in auxiliary functions, such as in the preparatory and finishing phases of manufacturing.

The textiles industry is, out of the three sectors studied, the most technology driven. The basic products are quite standardized and not changing dramatically. The role of manufacturing performance is highly important, thus there is less room for technological indifference for the international standards of product quality and company performance are set by the output set by best practice equipment. Consequently, if a developing country firm intends to reach international competitiveness, it does not have many alternatives. Continuous development of production technology and further automation is a necessity, in order to reach better product quality and overall performance rates.

The actual situation of the textile industries in the case study countries was quite diverse. Some factories had the majority of machinery dating from 20 to 30 years ago, and other factories had the most up-to-date equipment.

Many firms faced problems because of low capacity utilization rates, and the quality of products was not up to international standards. It was, however, significant that firms showing first class performance are found in virtually every country. These are firms that had both up-to-date - and continuously developing - production technology, high quality products and quite well functioning organizations.

From the point of view of future technological development and automation of the textiles industries in the African case study countries, these successful firms could well be used as examples of excellence for the other companies.

The clothing industries were far less important in the case study countries than textiles, both in terms of output and employment. In this respect Mauritius was an exception because it had a very large clothing industry, mainly producing knitwear from imported raw materials for developed country markets.

The clothing industry is less production technology driven than textiles. Product design and market considerations are more important. It is also a much more segmented industry with very differentiated products - in terms of materials, designs and production requirements - for a variety of markets.

Considerable technological developments have occurred in the industry, but the developments mainly concern the design and pre-production stages of production. Automation of the main manufacturing function, assembly of the cloth by sewing, has only developed partially and slowly.

The clothing industries in the case study countries, with the exception of Mauritius, seemed to be facing more problems than textiles. The difficulties of the industries were not primarily technological. In some countries, the problems were partly caused by the textiles sector producing yarn and cloth of uneven quality and with unreliable deliveries. Further, competition of foreign garments has affected demand on domestic markets. Exports have succeeded to a very limited extent only.

The difficulties in exports are related to low quality, but even more essentially to design factors, firm strategies and international connections. In the global clothing trade, tight interlinkages between manufacturing firms, designers and retailing firms are crucial. The new global networks of clothing were discussed in Chapter 16 through the Italian examples.

In this development, new information technologies play a decisive role. The firm networks are held together with common databases and frequent telecommunication, through which e.g. the CAD-made designs are communicated throughout the producing units.

In addition to CAD, automated pattern making, grading. marking and cutting are the most widely spread automation technologies in the clothing industry. Their main benefits are savings in raw materials, and increased productivity. These technologies were not used much in the case study country firms on the African continent visited. Bearing in mind the international developments, the global tightening of competition and relatively decreasing role of labour costs, it is very necessary for them to introduce these technologies in the near future.

The footwear sector is, of the three industries studied the least automated and the most labour intensive. Paradoxically it was also the sector facing the most serious problems. Only a few firms in the case study countries were operating profitably, and they were mostly plants of multinational corporations. There were problems with supply of raw materials, quality of products, uncompetitiveness in relation to imported shoes and overall productivity of manufacturing.

Global developments in footwear are quite similar to developments in clothing. Rapidly reacting firm networks are gaining in importance in relation to large shoe plants. This has actually also been noted by some of the African companies, e.g. the Kenyan Bata Shoe company is using small companies as subcontractors to manufacture smaller series.

Generally the main problems faced by companies in all of the three industrial sectors were, however, more policy and infrastructure related. These issues have already been summarized earlier. The companies had problems especially with import duties and regulations, restricted finances - availability of foreign currency above all - telecommunications and labour skills, particularly managerial skills on all levels of supervision and administration.

From the study of the three sectors it seems that there is actually an inverse relationship between labour intensity and company performance. The more automated the firm was, the fewer performance problems it had. This, of course, is assuming that the basic infrastructure and business functions of the firm were well managed.

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