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CHOICES IN INDUSTRIAL AUTOMATION

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PREFACE

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. This work has been published as the document "Trends in industrial automation", PPD.231(SPEC.), 12 October 1992.

The present document concludes the analysis by further exploring the trends identified into an examination of possible responses to these changes, at the level of government policies, enterprise strategies, and international support measures for developing countries. Financial support for the whole work was provided by the Government of Finland.

The present document was prepared by UNIDO in cooperation with Dr P. Vuorinen and Dr W. Haywood as UNIDO consultants.

The implications of these trends was examined for developing countries through analysis of the main factors at work in technology diffusion and the impact at sectoral level, together with the preparation of generic programmes of technical cooperation appropriate to different levels of intervention. This document was published as "Industrial Automation: Priorities and Programmes, PPD.269(SPEC.), 21 December 1993.

An overview of the subject, especially for decision makers at national policy level is provided in "Industrial Automation: An Introduction", PPD.270(SPEC.), 21 December 1993.

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1.1 INTRODUCTION

Although Schumpeter (1934 translation) discussed the role of technology, particularly as an explanation of Kondratiev cycles of growth, it was not until Solow (1957) published his findings on technical change in the US economy that serious study of the topic emerged.

Although Solow's suggestion that 87.5 per cent of the increase in gross output per man between 1909 and 1949 was due to technical change has subsequently been thought to be too high, the importance of technology has been accepted as a major factor behind economic growth, and has been substantiated by analysts such as Kuznets (1966).

Even the early classical, and more recent neo-classical, economists' understanding that technology was exogenous to the economic system has now been overturned, and technology has been generally accepted to be endogenous, i.e., being brought about by economic as well as social forces.[1]

One consequence of this trend has been that the so-called "dependency theory" of development amongst the less developed world has been challenged and largely overturned, for example, theories of patterns of development based on cheap labour alone have been seen to be inadequate in the case of many of the newly industrializing economies, e.g., Republic of Korea, Taiwan Province, etc.

> While hitherto less developed countries were seen as technologically dormant (by dependency theory) or as able to specialize only in unskilled labour-intensive and technology-unintensive commodities (by the neoclassical theory of comparative advantage), now these same countries (the newly industrializing countries, (NICs) tend to be seen as actively involved in the process of economic change.[2]

In the light of the above, and in the wake of a so-called "third industrial revolution" caused by the microchip and information technology, all countries from the least developed to the most developed will be affected by the rapidly accelerating pace of technological change.

However, it is not merely the changes being wrought by embodied technical change that are important but also those contained within disembodied technological change, i.e., through new forms of work organization and new forms of production, in addition to the take-up of new electronics-based technologies.

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1 Binswanger, Rutton, *et al.*, 1978.

2 Fransman, 1986.

"..., in the short-term the cutting-edge of micro-level restructuring is to be found within disembodied technological change, that is through the introduction of new forms of production and work-organization. Without these prior changes in organization, there is only a diminished possibility of successfully utilizing the new, flexible, electronics-based automation technologies." [3]

The internal structures of firms as well as their mode of operating have an important bearing on the processes of production which they coordinate. In analyzing these structures and operations a useful link may be made with the work of organization theorists. The position can be summarized by saying that in order to achieve an upgrading of production processes and products it is essential to move forward on both the technological opportunities axis and on the organizational or institutional axis. This is illustrated in Figure 1.1.

Figure 1.1 Options on the road to integration

INCREASING TECHNOLOGICAL INTEGRATION →

INCREASING ORGANIZATIONAL INTEGRATION	Current state of factories: unintegrated technology and organization	High technological integration (e.g. CIM) but unintegrated organization
▼	High organizational integration - the Japanese model	Integrated technology and organization

Source: Haywood, 1988.

Such concepts, and a growing appreciation of them, have had a major impact on both national and international decision-making:

> "The quick pace of technological change has shortened lead times between successive changes and the visible impact of these changes on the productive sector and on people's lives has induced decision-makers at national and international levels to place greater emphasis on technology-related issues and to view them in much closer conjunction with other economic policies, including trade policies. This involves efforts by the developing countries to incorporate the technological dimension into the mainstream, of economic management and policy-making, and, in so doing, to strike

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3 Kaplinsky, 1991.

a balance between short-term stabilization and adjustment objectives on the one hand, and longer-term trade and development objectives on the other." [4]

With specific reference to developing countries the distinction is also drawn between the use of what are termed to be radical or incremental technological activities. In the case of developed countries although incremental innovations are deemed to be sources of real improvements in productivity, radical innovations also provide a major impetus to growth. It has been suggested that although developing countries have made significant use of incremental innovations in the technological sense, they have not, in general, been as likely to use radical innovations:

> "Third World technological activity, accordingly, tends to be almost exclusively of the incremental kind rather than of the Schumpeterian frontier-moving type. To the extent that the latter occurs within the Third World, it is the result of technology generated abroad rather than indigenous efforts. However, it is important not to underestimate the cumulative significance of incremental technological change." [5]

It has been observed that particularly the specialized technical departments of medium- to large-sized firms in developing countries generate incremental units of technical knowledge in the areas of product design, process engineering and production planning and organization, and the domestic technological capabilities develop in this way.[6]

It is also quite likely that the disembodied innovations are diffusing through the systems of the developed ones, thus improving their competitive positions. Such changes as: improved buyer/supplier relations; the use of just-in-time approaches; statistical process control; reduced inventory levels; total quality management, etc., are all now attracting greater attention in the developed world.

One question that is therefore posed is where should developing countries focus their technological attentions; it has been suggested that it should be on the management process rather than in manufacturing applications.

> "In general, there seems to be greater immediate scope and application of microelectronics, and other devices in management, materials-handling and marketing functions, than in manufacturing proper. This is partly because the latter requires greater skills in the handling of micro-electronic technology than the former. Moreover, the applications to management are less likely to displace jobs and more likely to raise efficiency through waste reduction, faster deliveries, etc." [7]

The challenges posed by change and the totality of response have been summarized by Schumpeter (1942):

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[4] UNCTAD, 1990.

[5] Fransman, 1986.

[6] Katz, 1984.

[7] Bhalla and James, 1986.

"Competition from the new commodity, the new technology, the new source of supply, the new type of organization ... strikes not at the margins of the profits, and the outputs of existing firms, but at their very lives. This kind of competition is as much more effective than the other as a bombardment is in comparison with forcing a door and so much more important that it becomes a matter of comparative indifference whether competition in the ordinary sense functions more or less promptly."

1.2 KNOWLEDGE, SCIENCE AND TECHNOLOGY

The common belief amongst researchers, theoreticians, etc., in the developing countries too, is that knowledge, science and technology are - and are ever more certainly becoming - crucial factors in international competitive terms.

Considerable attention has been focused on the need to upgrade technological capacities in countries and companies to successfully meet this 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 adaption in many countries.

Developments towards some concept of a "factory of the future" requires a significant rethink as to 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 what has been termed a "new production paradigm." [8]

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. Yet 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[9], 60 per cent[10], and even 90 per cent[11] of the benefits of such technologies as flexible manufacturing systems (FMS) come from the radical organizational changes which accompany the introduction of such technology.

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8 Dosi, 1982.

9 Haywood and Bessant, 1985.

10 Dempsey, 1983.

11 McCracken, 1986.

As a consequence of these trends it has become increasingly obvious to many of the more thoughtful managers in companies that a systemic approach to manufacturing provides the most efficient and effective 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; and consensus as its goal - albeit - different forms of consensus in different countries, such as in Germany, Japan and Sweden.

> The acquisition of knowledge for innovation is not a once-and-for-all matter. Rather than a unidirectional, one-time occurrence of transfer of basic scientific knowledge to application, the processes of innovation and knowledge transfer are complex and interactive ones, in which a sustained two-way flow of information is critical. The ability to adopt a new technology, to evaluate a new technique, or even to pose a feasible research problem to an external research group may require substantial expertise within the firm.[12]

The term innovation is, of course, used here to contain both the concept of technological and organizational adaption. What is called for is the ability to utilize both current levels of adaptation and to relate this to previous experience; but also to use these abilities to evolve new and original concepts. It is also apparent that such knowledge is not costless, and is unevenly distributed, incomplete, implicit, imperfectly available and selective.[13] A whole series of factors must therefore be borne in mind when considering how companies or countries should view the potentialities of changes. The implications of these factors should be carefully considered by developing countries.

This leads to the acknowledgement of the importance of "tacit" knowledge:

> "A great deal of the knowledge that is important to the operation and improvement of a given process or product technology is "tacit", that is not easily embodied in a blueprint or operating manual. A closely related characteristic of technical knowledge is that much of it is highly firm specific and results from the interaction of R&D and other functions within the firm." [14]

> Rather than a page from a book of blueprints, a new technology is a complex mix of codified data and poorly defined "Know-how" (cf. Baer *et al*, 1977). A richer analysis of the economics and organization of R&D must stress the costs to the individual firm of finding and adopting new techniques.[15]

Also, concomitant with this line of reasoning is the realization of new concepts of development associated with "natural trajectories of innovation":

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12 Mowery and Rosenberg, 1989.

13 Fransman, 1986.

14 *Ibid.*

15 *Ibid.*

"One aspect of natural trajectories, whether specific to a particular technology or more general, whether 19th century or contemporary, is that underlying their traverse is a certain knowledge on the part of the technicians, engineers, scientists, involved in the relevant inventive activity. The knowledge may be quite specific, as understanding of the tactics for hybrid development of seeds, or the operating characteristics of jet engines. The knowledge may involve more art and feel than science; this certainly was so of the knowledge behind the mechanization and scale economies of trajectories during the 19th century. But in the middle to late 20th century, many scholars have been strongly tempted by the hypothesis that underlying the technologies that have experienced the most rapid advance, or built into a key component of these, is a relatively well articulated scientific knowledge." [16]

> Therefore, guidelines for development need to encompass a wide range of ideas and concepts. Knowledge, science and technology are not items for isolated consideration, and like the production technologies discussed later in the report, are systemic and closely woven fibres of the same fabric providing the impetus for successful change.

The popular perception is often of science leading technology rather than of a flexible relationship between the two, but the concept has become increasingly questionable:

"Well into the twentieth century, metallurgy was a sector in which the technology typically "got there first", "developing powerful new technologies in advance of systematic guidance by science. The technologist demanded a scientific explanation from the scientist of certain properties or performance characteristics. Such technological breakthrough as Taylor and White's development of high-speed steel (1898), and the subsequent development, in the 1920s, of sintered tungsten carbide, are classic instance of technological improvements that preceded and gave rise to scientific research. The sequence of technological knowledge preceding scientific knowledge has by no means been eliminated in the twentieth century. Much of the work of the scientists today involves systematizing and restructuring in an internally consistent way the knowledge and practical solutions and methods previously developed by the technologist." [17]

> The knowledge necessary for development is both science based and technology-based, both tacit and explicable; and the question for a developing country or firm is whether this exists in their own environment at such a level that it is capable of sustaining growth.

16 Nelson and Winter, 1977.

17 Mowery and Rosenberg, 1989.

1.3 SYSTEMIC PRODUCTION

It has been noted above that modern concepts of production in the developed countries have moved from a fragmented system to one in which all aspects of production, i.e., both technological and organizational, implicit and explicit, have become almost crucial for industrial and therefore in many ways developmental success.

Merely having the desire or motivation for change is insufficient to guarantee success. The intricate linkages between developed and developing countries' concepts of change; the sophisticated linkages between industrial sectors, etc., have to be taken into account for success. One important indicator of the way in which development is a condition of the relationship within the industrial infrastructure is expressed by Rosenberg (1979):

> Any consideration of the textile industry would be artificial which did not include the chemical, plastics, and paper industries. Consideration of the machine tool industry must now take into account the aerospace, precision casting, forging, and plastics forming industries. These industries are now complex mixtures of companies from a variety of SIC categories, some functioning as suppliers to the traditional industry, some competing with it for end-use functions and markets. "The industry" can no longer be defined as a set of companies who share certain methods of production, and product properties; it must be defined as a set of companies, interconnected as suppliers and market, committed to diverse processes and products, but overlapping in the end-use functions they fill.[18]

The interlinkages between industries are, however, just one example of changes in the relationships of companies under a systemic form of production. Individual companies operating in this way have become increasingly aware of the importance of establishing close contacts with their suppliers in order to secure the advantages of improved quality, rapid delivery and appropriate prices - though in many ways the third of these is becoming viewed as the least important factor.

Within the company itself it is also clear that machines themselves can provide only part of the answer to meeting competitive pressures - and for developing the challenge of economic growth. Increasingly the "man-machine" interface has emerged as a crucial element for success. Experience from a number of studies[19] has shown the importance that needs to be attached to organizational adaptation throughout the company, and the necessity to involve skilled and well trained personnel in the process of production.

> A factory or a firm is an organization of interacting humans and machines (a system). It is not a big piece of hardware the performance of which is constantly improved through technological change - the way production is typically viewed in production function analysis. A system for one thing can be organized more or less efficiently and we have frequently observed how new, expensive and very efficient machinery has been installed in such a system without producing any noticeable effect on the productivity performance of the entire system. On the other hand, we can report on many cases where simple reorganizations of the flows of intermediate parts between old machines and the men allocated to them have produced very large improvements in systems performance.[20]

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18 Rosenberg, 1979.

19 Haywood and Bessant, 1985; Dempsey, 1983; Voss, 1986.

20 Eliasson, 1982.

This becomes even more important if a choice between "Product" and "Process" innovation has to be taken as a guideline for development. While some countries have been able to proceed along simultaneous paths in both areas - and these have usually been the developed countries with high levels of skilled and educated labour - for some countries a choice has to be made with regard to which area should be concentrated upon. In many instances in the developing countries the choice of product or process innovation is set by the factors of production or types of output. In very few instances have developing countries been able to produce new innovative products, as have the developed countries.

Any attempt to move into areas containing higher technology value added products would have significantly affected the level of capital intensity in those countries under traditional technology influences. However, it has been suggested that the new technologies might affect the capital/labour ratio less, because they reduce the cost of capital adoption.

This is, of course, in part a function of considering organizational innovation as part of technological innovation; however, even the technology alone may be capable of limiting the rate of increase in costs.[21]

In summary of the above discussion on knowledge, science and technology, and their role in development in general, a number of guidelines or items for consideration emerge, falling into six main categories:

(1) Technological and organizational or institutional integration. Here we have noted that much of the improvement in performance in companies in the developed countries has stemmed from organizational or institutional changes preceding the technological changes, or at least alongside them. Japan has been a classic example of this.

(2) The need to take note of the importance of tacit knowledge in the successful use of new means or forms of production. Merely buying a new technology may not be sufficient to utilize it effectively if *both* implicit and explicit knowledge are insufficiently developed.

(3) The importance of the inter-dependence of industries. For example, textiles would not be adequately considered if the chemicals, plastics and paper industries were missing from an overall analysis of the industry. The filière approach reflects this consideration.

(4) Similarly, under the new relationships between companies, links between final product manufacturers and their suppliers have moved on to a much more long-term and "obligational" setting which is likely to result in reduced prices, better quality and more rapid service.

(5) Any consideration of a production system must take into account not merely the machine but also the people who have to manage and operate them. Thus the man/machine interface becomes increasingly important in full competitive terms.

(6) The distinction between "product" and "process" innovation. While the former holds considerable difficulties for developing countries, the latter may hold considerable potential. In many instances organizational or institutional innovations may provide substantial improvements for such countries, and probably at much less cost than a simple reliance on new technology.

Under point 6, on innovation, the distinction drawn has implications for the national policy responses, which will vary according to the stage of innovation attained. At an initial stage, it has

21 Mowery and Rosenberg, 1989.

been suggested that[22] the emphasis will be on product innovation in response to market needs. Measures to encourage the market and the emergence of new (including small firms) will be important, such as by supplying seed capital and institutional and services support. With maturity, the firm will emphasize innovation in the production process. Product innovations may be fewer, but a greater proportion will be technologically stimulated. Government assistance in technical information services and specialized human resource development will be important. Increased capital requirements to expand capacity will be addressed by measures such as investment tax credits and accelerated depreciation.

Table 1.1 suggests that a useful distinction can be drawn between "efficient" and "effective" production systems. The "efficient" mode might be said to conform to the old style of production under which somewhat Fordist or Tayloristic modes of operation were in use; while in the "effective" mode an *economies of scope* approach was employed rather than an *economies of scale* one.

Table 1.1 Contrasting Approaches

EFFICIENT	EFFECTIVE
Conventional layout	Cellular layout
Process Organization	Product Organization
Long runs	Short runs
Large batches	Small Batches
Max. M/c utilization	Quick changeovers
Long lead times	Short lead times
Large stocks	Stocks minimized
Make to forecast	Make to order
Complex controls	Simple controls
High indirects	Lower indirects
High cost and customer insensitive	Lower costs and responsive to customers - JIT

Source: Kaplinsky, 1991.

1.4 BARRIERS TO INNOVATION IN DEVELOPING COUNTRIES

The new technologies are quite likely to mean that old neo-classical concepts of low cost production being switched to the less developed countries are no longer valid. With the ability to switch production possibilities so rapidly and to re-design the basic product so rapidly being enhanced, it is quite likely that design, re-design and production will become much easier in a developed country context, and therefore less likely to be switched to the low wage labour cost countries.

22 Utterback, 1977.

This makes the need for innovation and, more generally, technological development all the more crucial for developing countries. But it is clear that although innovation in both the technological and organizational senses is possible in developing countries, many barriers do exist. Moreover, there is growing complexity in international markets and increasing difficulties associated with breaking out of the developing country mould.

Analysis of innovative activity in nineteen OECD countries showed a close relationship between such activity and national income. The higher the per capita income of countries the more the countries in general spend, comparatively, on research and development.[23]

The conventional approaches to breaking out from developing to developed country status will be very difficult in the future if reliance is placed merely on low cost labour as a competitive advantage. It is possible for countries possessing low cost labour to make this break, ***but only if they adopt strategic policies which do not rely solely on that factor.***

Even where developed and developing countries have adopted identical technologies, in the former incremental improvements have raised levels of efficiency in subsequent years, in the latter case many of these countries have actually reduced levels of productivity in subsequent years. In part this is a consequence of an inadequate concentration on the infrastructural framework which supports the use of new technologies.[24]

Such infrastructural failures include:

- Inadequate levels of formal education;
- Low emphasis on training for vocational skills;
- Poorly maintained or non-existent logistical systems, e.g., transport, communications;
- A low emphasis on management skills;
- Poorly developed buyer/supplier relationships;
- Restrictive technology and trade policies;
- Lack of financial resources,
  etc.

UNCTAD have also noted that technology itself has contributed to the changing pattern in international markets.

> "Important in this context *[the development of new types of manufacturing]* are certain emerging characteristics of developing-country exports and the current international economic environment. Coping with the debt problem necessitates an increase in net export earning. But the demand for primary goods is stagnant, the terms of trade are adverse and there is a continuous outflow of resources. The trends are likely to remain much the same owing to factors such as (i) the increasing substitution of primary material by synthetics as a result of technological advances, (ii) the orientation of technological advances towards materials and energy saving (iii) the

[23] Horn, 1977.

[24] UNIDO, 1992.

increasing rate of automation and labour-substituting characteristics of modern technology, and (iv) slow world growth and the rising protectionism in developed countries. In short, technology has in itself strongly contributed to altering the characteristics and rules of the game in the international market". [25]

It is nevertheless true that some developing countries, or enterprises in these countries, have succeeded in breaking through to a more developed state. For instance, experience in the Republic of Korea suggests that technological mastery of plant operation may be enough initially, and mastery of plant and product design may come later.[26]

Applications of, perhaps, less than frontier technologies, might well be advocated alongside organizational adaption, particularly in the process rather than the product areas; and a strong central government role in a narrow range of industries, together with liberalized trade policies might prove the most advantageous course of action in developing countries.

Trade policy is critical in this regard, and poses several dilemmas. On the one hand, too much competition has been seen as a danger, since this would discourage industries at a rudimentary stage from innovation in either products or processes, if for no other reason that surpluses for the associated investments would be reduced. Too few foreign goods on the market, however, will not only reduce the impetus and perceived need to innovate but will also, through the absence of technology diffusion effects, restrict the technical options and horizons for innovation.[27] Moreover, the climate of world trade has changed considerably since the 1950s and 1960s when the successful patterns of manufactured export-led industrial growth were laid down by Japan and the Republic of Korea, among others. Protectionism is now a far more sensitive issue, and the world trading system is characterized by commitment to open trade accompanied by restrictions to counter restrictions.

1.5 THE HUMAN RESOURCE BASE

Clearly the possession of high levels of skill and education affect the efficiency with which new technologies can be utilized.

> Acquiring the relevant skills for technological development is 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 in addition to the basic education requirements.

In a UNESCO study, the share of students in vocational secondary education in percentage terms were very low, for example, in four African countries (see Table 1.2).

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25 UNCTAD, 1990.

26 Fransman, 1986.

27 Fransman, 1986 and Kaplinsky, 1991.

Table 1.2 Share of Students in Vocational Secondary Education (per cent)

	Mauritius	Kenya	Tanzania	Zimbabwe
1975	1.6	2.3	0.0	1.9
1980	0.3	2.0	0.0	1.0
1984	1.1	1.8	0.0	0.1
1985	1.2	1.7	0.0	0.1
1986	1.4	1.3	0.0	0.0
1987	1.2	1.0	0.0	1.9

Source: UNESCO, 1989.

What is perhaps more alarming than the fact that these percentages are so low, is that in most countries it has declined post-1975. Kenya with one of the most extensive educational systems in Africa has seen vocational training decline from 2.3 per cent to 1.0 per cent of the secondary education sector in vocational terms.

The main problem of the education system in the Sub Saharan African countries may not be the overall volume of education or even the size of secondary education, from the point of view of industrial development. Secondary education is almost completely of a general "arts and sciences" nature and the share of vocationally oriented education has not reached three 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.[28]

The same three main problem fields which exist in secondary education are also relevant at 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 the economy.

Similarly, the relationships between higher education and industrial research - and by implication national development - has been suggested to have been a significant factor in the United

[28] UNIDO, 1992.

States.[29] These linkages and their importance for the creation, diffusion and utilization of new technologies has been an important criteria in developments in the industrialized countries - and have become increasingly recognized as major contributory factors in the growth of NIC.

Whether these opportunities exist at the same level as a result of the microchip and the information technology has been questioned:

> "It is not inconceivable that the industrial nations of the west are on the threshold of a "technological revolution": But if so - and that remains to be seen - the revolution will not depend on electronics alone. If it occurs it will only be observed in retrospect because of the time it requires to materialize and it will depend on a new organization of production that combines knowledge with new materials, new designs and manufacturing methods and perhaps electronics. But it will not arrive faster than the complementary growth of human capital takes place, and the nature of that human capital is still well beyond a generalized understanding and a theoretical representation." [30]

This was written in 1981, when the implications of the new technologies were only just emerging, but time and numerous researchers have tended to substantiate the view. For example, the UNCTAD report (1990) comments that production possibilities were enhanced, not as much by increases in the volume of labour being used, but by the changes in the skill and knowledge base of individuals.

> Investments in training and education at least matched that in high-tech methods. As such, they suggest that human resources are an important asset and that this accumulation and possession of appropriate skills is essential in matching with physical technological assets. This has accelerated the pace of technological innovation and imposed new requirements and directions of skill development - and as a consequence on socio-economic development.

Clearly recent high technology research and development (R&D) in most industrialized countries has prompted both fundamental and incremental innovations which have offered new opportunities for companies - both the suppliers and users of such equipment. Those technologies, such as flexible automation, computers, and robotics, require somewhat different levels and types of skill in the people using them, than did their more traditional equipment predecessors.

The skills now needed in some respects will mirror the flexibility of the systems themselves. Traditionally metalworking, chemical products, electrical and electronic equipment have been sources of such flexibility.[31] But the new technologies call for a wide range of skills, combinations of traditionally distinct "technical" and "managerial" skills.

One example provided by Kaplinsky (1984) with regard to a new grade of "manufacturing craftsman" saw training required to carry out the roles of:

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29 Mowery and Rosenberg, 1989.

30 Eliasson, 1982.

31 Pavitt and Soete, 1982.

"... machine monitoring and operation; parts gauging; work scheduling; machine setting (including setting CNC controls, but not parts programming); machine changeover; preventive maintenance; quality control (including statistical process control techniques); tool maintenance; and problem diagnosis. In the old system all of these different tasks would have been performed by different grades of the workforce."

What then emerges as a powerful weapon in industrial competition is the existence of in-firm expertise. This is not merely in terms of levels of skills at shopfloor or managerial level, but of the existence of the ability to search for, internalize, and successfully utilize such knowledge in the interests of the firm. Such abilities include the skills of identifying the relevant research results from elsewhere and to apply them in the enterprise: without these abilities, a firm cannot benefit from research programmes ostensibly directed towards their requirements.[32] Nor, more generally, can firms take advantage of technological progress in other sectors, whether domestic or foreign.

The experience of developed countries

The importance of the development of a broad range of knowledge, scientific and technological abilities in order to achieve - and to maintain - leading edge manufacturing capabilities has been noted earlier. It is important to stress also that these are needed in combination, and in particular, there is an important complementarity of skills and ability to successfully emulate best practice techniques from outside national borders:

"Great Britain's experience demonstrates the insufficiency of high-quality science when it is not associated with complementary managerial and engineering skills or institutions. On the other hand, the experience of Japan has forcefully demonstrated the remarkable possibilities for economic growth based on the systematic transfer and exploitation of foreign technologies." [33]

Part of the reason for this successful transfer lies within the cultural and institutional framework of individual countries. High levels of investment via national developmental strategies, allied to a flexible though structured socio-economic system may have provided part of the reason for Japan's success:

"It may well be that part of the reason for Japan's successful "catch up" and, in some cases, "take over" lies in the technical change generated by rapid diffusion which was itself facilitated by appropriate socio-political relations and fuelled by high rates of investment." [34]

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[32] Mowery and Rosenberg, 1989.

[33] *ibid.*

[34] Fransman, 1986.

2. AUTOMATION IN BUSINESS STRATEGY

The previous chapter looked at automation especially from the point of view of national policy considerations. In this chapter, automation is inspected from the individual enterprise's point of view.

Before considering investment on automation, the company has to have an articulate business strategy, a clear view on to what direction it wants to change its operations. All production technology investments should then be evaluated in respect to the targets and to the existing resources of the firm. Automation is only one tool for company development. From this angle, it is not the technological side that comes up first. Introducing new manufacturing technologies should neither be a target as such nor should it be considered independent of organizational changes.

2.1 BUSINESS ENVIRONMENT AND FLEXIBILITY

The introduction of new manufacturing technologies is always based on business considerations, such as raising productivity and efficiency or increasing production volumes. The diffusion of **conventional automation** was mainly based on the aims of reducing production costs - especially labour costs - and increasing the technical reliability of the production process. In the case of **programmable, flexible** automation these objectives still remain, but the need to automate is essentially based on other consideration.

The need for flexible automation and increasing integration of production processes is caused by the changing economic environment, by new features in demand and by new production possibilities. New trends are apparent in at least three spheres: in the markets, in technological development and in international relations.

In the **end product markets**, there are growing uncertainties caused by rapidly changing demand structures. In developed countries, the demand changes are caused by a general increase in wealth, by tastes that are diversifying and fashions that are changing. In most consumer products, the markets are both rapidly changing and highly segmented. As a consequence, even the markets for intermediate goods and subassemblies become more segmented and more complex, and they change more rapidly.

In the **technological** field, the microelectronics revolution has opened completely new trajectories for both product and process development. Rapid technological changes also mean growing complexity and interdependency between various technologies, uncertainty and a need to choose between parallel technological development lines. Thus the requirements for technological knowledge are significantly higher than before. Even very large enterprises have fewer possibilities of mastering the whole range of relevant technological knowledge.

In **international relations**, the growing openness in international economic relations is increasing competition between countries and country groups, and increasing uncertainty with respect to markets.

To summarize, the rapid rate of changes and growing uncertainties in the economic environment are pushing towards new business and production strategies at the firm level. There is, above all, a need to increase the overall flexibility of firm activities. It is in this context that modern automation is utilized.

Segmented end product markets Rapid technological change Growing international openness	⟶	Growing uncertainty and need to change business strategy towards more flexibility

Flexibility is a key theme in both modern business philosophies and in the practical implementation of automation and other integrated production technologies. It means an ability to change rapidly the production parameters of an enterprise, and be prepared for a continuous change.

The issue of flexibility can be approached from many angles. There are, for example, time-related and quality/quantity-related aspects in automation. By combining these two features, we get six distinct dimensions of flexibility (Table 2.1).

Table 2.1 Dimensions of flexibility

Dimensions of flexibility	Static	Dynamic	
	Operational	Tactical	Strategic
Qualitative	Number of product variations (a)	Minor product and process changes (c)	Major product and process changes (e)
Quantitative	Variations in batch sizes (b)	Flexibility of capacity (d)	Variability of the firm size (f)

Source: Ollus *et al.*, 1990.

The six dimensions are described below. When aiming towards more flexibility, firms may emphasize them individually. An enterprise may, for example, be focusing just on short-term operational flexibility and pay much less attention to long-term strategic flexibility.

By increasing **operational** flexibility (**variability**, a-b), the firm strives, at a given moment, towards responding to the demand needs of various customer groups, both in quality and quantity. The need of variability - to produce many modifications of a one basic product - is mainly based on market segmentation. For the firm, the target is to get a better firm identity (trade mark products), to serve customers better (customized products) and to achieve large enough market size. To a growing extent, large markets are not achieved by increasing production volumes, but by increasing product variety:

> A mass producer firm manufactures one commodity for thousands of customers

> A flexible firm has to manufactures various products to reach the same number of customers

The **qualitative variability** (a) means obtaining economies of scale through economies of scope: decreasing the average unit costs by increasing the number of product variations. This is possible if the firm can use the same fixed resources for the manufacture of various products.

With **dynamic flexibility** (c-f) a firm aims at responding - rapidly and with as low costs as possible - to the qualitative and quantitative changes in the market. This can be achieved by many means. Generally a flexible firm tries to convert its resources to a more transferable and variable form. It tries to avoid irreversible investments and aims at keeping them in a more liquid form. Thus a flexible firm needs:

General purpose personnel (flexible skills)	General purpose equipment (flexible, programmable machinery)

Quantitative tactical flexibility (d), the flexibility of production capacity deals with the limits of economic use of the production system. The smaller the lowest economic production volume (in relation to the maximum volume of the system), the more flexible is the system. If the capacity is inflexible, the average production costs rise very rapidly when the production volumes deviate up or down from the planned level.

Qualitative tactical flexibility (c) is the firm's ability to introduce new product models (responding to technological possibilities or fashion changes) rapidly and with low development costs.

The essential difference between tactical and **strategic flexibility** (e-f) is in the predictability of changes. Short term changes can usually be estimated or forecast with a certain risk, but long-term changes include genuine uncertainty.[35] Thus strategic flexibility means the firm's ability to change its behavioural patterns and structures according to unexpected long term technology and market changes.

One basic feature in all dimensions of flexibility described above is that in most cases they contradict the short term efficiency targets. Thus it is never a question of maximizing, but reaching the optimal level of flexibility.

2.2 HOW TO REACH FLEXIBILITY?

To increase flexibility, the firm can use many means. Among them are new production technologies, programmable automation and other techniques of computer integration in the manufacturing process. Technology, however, is not the only method to reach flexibility, not even the most important. 'Flexibilization' has its starting points in the overall **firm strategy, organization and manufacturing strategy**. The target is to reach a more flexible overall conception and behavioural model of the firm. It is a strategy preparing the firm for continuous change and a generally more unpredictable and uncertain future

> "CIM is not only technology, it is not a selection of machinery or systems, not even a far away target - 'Factory of the Future' - but a business management strategy to develop company competitiveness on short and long term." [36]

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[35] Carlsson, 1989.

[36] Andersin, 1989.

In this approach, the first task is to specify what strategic targets are expected to be met through the proposed increased flexibility. The next question is to ask what problems can be solved with organizational renewals without any heavier investments in new technologies. The third step is to define the overall development path towards the desired new manufacturing mode or firm behavioural pattern. It is only on this stage, that technological issues really become important and the sequencing of new manufacturing technology investments enters the picture. In doing this, the organization, competence and skill related issues are as important as the straight forward questions of choosing and implementing the actual technologies.

This approach is supported by many case studies that show that starting from the potential of technology and just adapting flexible technologies does not lead to the desired targets:

> "Some degree of organizational adaptation is also required - and evidence increasingly suggests that the more extensive the technological change, the more fundamental the organizational change required to exploit it." [37]

and:

> "CIM projects should not be dominated by technology. The successful projects are based on positive attitudes by company management, appropriate firm culture and skilled, highly motivated personnel. It is also important to create a CIM-strategy and an overall plan in the beginning. The planning of CIM has to be integrated into the normal strategic and long term planning of the company in such a way, that CIM strategy supports the business idea, the basic strategy and other sub-strategies of the company." [38]

A high emphasis is put on management decision-making and on commitment of the whole organization. In the present technological situation this is even more important, while at least in theory, almost everyone has access to new production technologies. The benefits of technology - e.g. the level of flexibility reached - depend much on the answers to questions like:

- why was it acquired?	" appropriateness "
- when was it bought?	" timing, too late/early "
- how was it adopted, and introduced?	" management imposition employee involvement etc. "
- what non-technological changes took place at the same time?	" organization, skills management, etc. "

Flexibility and optimal use of new organization technologies is an outcome of a complicated process, where many issues should be taken into account. This implies that as a minimum there should be an appropriate, integrative corporate strategy linking technology to the overall strategic approach of the company. Key points of action in relation to technology decision-making include at least the following issues: [39]

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37 Bessant and Ettlie, 1990.

38 Liukko *et al.*, 1989.

39 Preece, 1991.

Articulate new technology objectives and strategy at an early point in the adoption process and establish mechanisms to ensure that they are translated into practice. Compare outcomes with objectives, and analyze the reasons for any differences found. Disseminate throughout the organization (which is much broader than just the plant in a divisionalized company) the information derived from above. Recognize the complexity of much new technology introduction and its demands on staff time and knowledge - and remember that it is just one element of an organizational change process. Recognize - and act on - on the one hand, the distinction between new technology adoption and introduction and, on the other hand, the opportunities the former provides and the constraints it sets for the latter. Therefore, be prepared to put time and effort into the adoption phase - anticipating enhanced and more timely benefits from introduction/'operationalization' as a result.

A recent Japanese survey of companies introducing automation concluded, that factory automation has to be - first of all - systematically integrated into the strategy of the enterprise.[40] This involves clarifying the reason for introducing the factory automation system in the first place; then establishing an effective implementation strategy. The needs of a factory automation system in the plant must be analyzed and evaluated cautiously and thoroughly, in order to clarify all the problems to be solved.

It is essential to establish a plan for the careful introduction of the new systems. It is also important, not only to have strategic discussions throughout the entire corporation, but to review issues that have important influence on the extent to which factory automation can contribute to the expansion of production capacity and how automation can be integrated with the improvements of labour productivity and control level (Table 2.2).

Table 2.2 Issues affecting the needs to introduce automation systems

1. Expansion of production capacity
- Speedy and accurate work - Switching work patterns, rapid change of product and accuracy - Expanding, fineness, complication and higher-precision of the production system - Product performance improvement, stabilization of quality
2. Improvement of labour productivity
- Decreased dependency on conventionally skilled labour - Improvement in working environment and quality - Improvement of working efficiency and stability of employee - Improvement of working safety
3. Improvement of control level
- Improvement of adaptability of production in line with changing needs of the market - Increased speed of the feedback function of control - Reduction of unfinished products/work in progress - Elimination of all losses such as raw material, service and labour

Source: Takanaka, 1991.

[40] Takanaka, 1991.

The next stage is to build up a systematic plan of the process of implementing automation. Automation is not a question of the production process only. The whole manufacturing process is involved: production technology and organization, product variety and designs, personnel management, overall planning and control of production.

In this stage, the plans should also be discussed and redesigned with all the people concerned. The automation system plan should not be handled in secret. It is necessary to examine the implications of the system throughout the factory by using the talents of all employees. It is essential that the automation introduction area and its systems are build systematically and reliably.

In doing this, the role of personnel involved is crucial. We will return to the importance of employee motivation, involvement and training later in section 2.6. It is crucial to start both discussions with personnel and training early enough. In an automation introduction plan, at least the points listed on Table 2.3 should be checked.

Table 2.3 Checking points in automation system introduction plan

1. Overall planning
- clearly visualize the automation system introduction before starting work - The system design of the overall factory should be well defined - the situation of surrounding companies who support automation system introduction in the plant needs to be considered
2. Product design
- Integrate the system design with product development - The system shall be based on a long range view of the product to be manufactured - Review how the product design is to fit into the automation system
3. Production
- Standardize parts and establish appropriate groups - RE-examine the whole process in order to ensure CAD/CAM consistency - Rearrange processes where necessary - Develop a special exclusive process and machines within the company - Establish an effective controlling and operating system
4. Personnel management
- Always train personnel for controlling and operating - Establish a plan for effective utilization of excessive manpower

Source: Takanaka, 1991.

Product design is critical for a successful application of flexible automation. The more comprehensive the change is, the more likely it is that the existing product designs are not the most economic to manufacture with the new system. Parts should be standardized in the beginning of the implementation; the product and process technology design should proceed simultaneously.

The firm should establish a procedure to plan the development of automated production system design. In the plan, the points of fundamental design should be systematically arranged to unify as far as possible the products or parts prior to the introduction of an automation system. According to Takanaka (1991), the areas to be standardized and redesigned in products include at least:

Making products and parts in *series*
Making products and parts in *modules* and in *units*
Making *standardized* and *commonized* products and parts as far as possible
Making *simplified* products and parts
Making products and parts with *multifunctions*

Introducing automation technologies is naturally not a solution for all production problems and renewal needs. It has both advantages and disadvantages. For a firm, it is important to estimate and analyze - before the investment decision - the expected advantages and disadvantages, so that action can be taken to reduce the disadvantages. The most common advantages include at least:

Increase in actual production *capacity*
Reduction in production *lead time*
Reduction of *unfinished products* in production line
Reduction in *duplicated investment* on production equipment

The disadvantages may often be difficult to see beforehand. In spite of the general notion of flexibility, many automation technologies in fact limit the scope of production flexibility. They make a certain area of production more flexible, but often even more difficult to reach outside this area economically. In addition to this, there are many problems and drawbacks included in the introduction and early operation phase of more comprehensive automation systems, for example FMS. These problems are usually temporary, but it may take years before the system is running as it was expected in the plans.

The disadvantages most often present include at least:

Limiting the field of *product development*
Greater costs when production *line stops*
High production equipment *investment costs*
Increase on *high level maintenance* technology required

Extra problems are caused by management accounting issues. When factory automation systems are introduced, too much attention is often paid to the technical side only, and insufficient attention is given to the control system and personnel side. If the control system does not adjust to the technical automation system, it will result in the effect of the introduction of the automation system not being measurable. The training and personnel problems will be discussed further in section 2.6.

Some problematic points related to control system and management accounting issues are listed in the following:

What about gaps between the reduced life cycle of the equipment and legal amortization periods?
Increased investment in software and its accounting treatment
How to quantify advantages and disadvantages?
Increased importance of payback period method of assessment
Change of indirect cost distribution standards from direct working time to equipment operating time
Increased difficulty of defining costs by product because of the much greater element of indirect cost
Increased importance of cost control in planning rather than operations
Increased requirement for simplified management accounting

2.3 FLEXIBLE SPECIALIZATION AS A BUSINESS STRATEGY

Automation was discussed above in the general context of business strategy. There are many business targets that can be reached by using automation technologies and many strategic options that can take advantage of automation. However, very often widespread applications of programmable automation are associated with a business strategy called **flexible specialization**. New automation offers the best technical possibilities for realizing the strategy, and the advantages of the technologies are often best exploited through the strategy. Flexible specialization is often seen as the key element in the new 'post Fordist' manufacturing strategy challenging traditional manufacturing thinking based on Taylorist and/or Fordist ideas on business, manufacturing organization and relations between machinery and human skills.

Among the core ideas of flexible specialization are - briefly - the following:

(1) **Specialization** is a basic condition for flexibility. A company has to decrease both horizontal diversification and vertical integration. For a large company this often means a tight commitment to the traditionally strongest business area; for a smaller firm it means the need to define a very clear main business area and target all operations into this field.

(2) The basic difference between **flexible and conventional (rigid) specialization** is, that the company does not specialize into manufacturing a standard product or a part of one. There is also a simultaneous effort to develop the products so, that they become clearly differentiated trade marks competing above all with quality. This further means that quality thinking has to spread throughout the company. The **Total Quality Management** ideology is a good example of this.

(3) Within the chosen area of specialization the company will operate very flexibly. Product variety will be increased within the decreased product area. This often implies an effort to develop customized products, where the provision of a **total service package** (selling design, installation, training and maintenance as a part of the physical product) becomes an important dimension of competition.

(4) When the company is manufacturing customized products on customer orders, timing and exactness of delivery become very important. The company may focus on competing with very short delivery times - with **quick service products** - or it may build its competitive strategy on the long term **quick response principle**, on the ability to adapt rapidly to market changes. The clothing industry gives a good example of this:

> "The whole operative model of the industry is slowly changing to the quick response principle, and products are now manufactured directly to various customers in the sequence of orders with short delivery times, while in the earlier model the whole supply for the next season was manufactured beforehand in long series to store." [41]

(5) An essential feature of the flexible specialization strategy is that the risks of too narrow specialization are diminished with tight cooperative relations with other companies and customers. Linkages to subcontractors are arranged through **network relations** and the product variety is extended with products supplied by partner companies. Firms are also cooperating in other business fields like research and development. Through networking linkages the company can maintain the strategic flexibility even in situations when the area of specialization is facing dramatic changes.

(6) The strategy of flexible specialization also very often leads - especially in smaller countries - to **internationalization**. Because of the relative narrow scope of product area domestic markets are usually not large enough. The importance of exports grows rapidly, which also means the need to establish an international marketing network and later perhaps start up production abroad, nearer to the main markets.

The strategy can be summarized:

A flexibly specialized firm - tightly linked to cooperative networks - tries to produce clearly profiled quick delivery trade mark products with a wide range of customized varieties within a narrowly defined product area to an international market.

The point of views of a large corporation and a small manufacturing firms to flexible specialization are, of course, quite different. The basic approach is usually from the large company's angle. For a **larger company**, the main question is to dissolve the rigid hierarchies and to be better prepared for operations in a market environment with growing uncertainties and a need to create new market areas.

For a small firm it is more a question of narrowing the production area and gaining economies of scale through economies of scope made possible through flexible specialization. There are two basic approaches to flexibility for a **small firm**. Either it has a clear product family that is so well standardized and modulated, that the firm can afford to invest in effective production technology and in creating the necessary productive and marketing networks. The other strategy is based on subcontracting: the firm is not selling a product, but effective and flexible production capacity. The range of production can consist of a wide variety of products, if they have enough manufacturing similarity.

The differences of small and large firms could be summarized as follows:

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[41] Kasvio, 1988.

For large firms, change to flexibility is in the first instance marked driven: changes on the market compel more flexibility in the previously rigid production process.

For small and medium sized firms technology push, the possibilities of reaching economies of scale through economies of scope, are more central. For them introduction of flexible automation may even mean decreased flexibility, but increased competitiveness in a field previously dominated by large firms.

2.4 MANAGEMENT, ORGANIZATIONAL CHANGE AND AUTOMATION

Flexibility is the result of multiple changes within a company. It is a combination of technological and organizational changes. Thus manufacturing management with a clear manufacturing strategy is of extreme importance. **Manufacturing strategy** could be described as the efforts of the company to use and develop its manufacturing capabilities to enable it to pursue its competitive strategy over the long term.[42] The organizational and technological aspects of the change are combined by the firm's technology and manufacturing management.

In the present situation with growing uncertainties both in the market and in technological development, manufacturing strategy aiming towards flexibility and sustainable change is becoming one of the major business themes. In this, management qualifications and management styles become significant.[43] These are some of the characteristics of managers that are good at creating sustainable change in their organization:

They have an extensive understanding of the *environment* surrounding the business;

They are capable of consciously knowing what *approach* to take to making change happen in their own organization;

They are *temperamentally* suited to the particular change needs;

They understand some of the *complexities of the organization* they lead;

They are able to understand and direct the use of an appropriate *range of 'levers'* to bring about change.

The levers of management are different in various types of changes the company has to face. One classification of levers typical in basic change situations is presented in the setting below. In this context, the peculiarity of flexibility and flexible automation is, that they are applicable tools in practically all change situations. Actually, the need of flexibility is one of the basic causes for most changes. However, in different change situations the approach to flexibility and the weight of technology varies.

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42 Hayes and Wheelwright, 1984.

43 Young, 1991.

Table 2.4 Types of business change situations and key management issues

1. Crisis	4. Transformation
• Selling parts of the business • Removing and replacing people quickly • Restructuring the organization to centralize control, clarify accountability and remove overheads • Designing systems to measure key short term performance factors • Communicating simple, powerful messages about Targets and Consequences • Visible personal leadership • Rewards tailored to short term results	• Developing extensive networks of 'Change Agents' • Extensive use of wide range of communication media • Visible backing of the 'transformation' themes and actions by key people • Incentives and competitions • Designing systems specifically tailored to monitor qualitative performance, e.g. Customer Satisfaction • Extensive and intensive training and indoctrination involving a mass of people
2. Fine tuning	**3. Building**
• Introduction of involvement techniques, Quality circles etc. • Training for performance improvement and skill upgrading • Systems designed to give detailed feedback on improvements • Rewards and incentives for contribution towards improvements and ideas or suggestions • Detailed organization and work methods analysis	• Longer term planning and strategic systems and processes focusing on investment • Extensive development and training • Recruitment, appointment/selection, career development and promotion • Longer term incentive plans focusing on improvement, market share and growth • Tailoring of Personnel practices aimed at retention of key people

Source: Young 1991.

In a crisis situation (1) extensive new automation investments are usually not the first actions taken. However, organizational changes related to rationalization and automation are important even in this situation, and to overcome the basic causes of the crisis, comprehensive technological renewals and strategy aiming at flexibility may be needed. In **fine tuning** (2) stage organizational issues are of the highest importance.

In **transformation** (3) and **building** (4) flexible automation investments may be central, and especially in these situations the automation strategies should be carefully integrated in the total strategy and development targets of the firm.

When introducing computer integrated technologies with the aim of increasing flexibility, adopting a very narrow technical perspective on manufacturing management can be disastrous. For example, it is very important to design the different interfaces of the manufacturing process:

> "Technical approaches to CIM treat all organizational interfaces as equivalent, because there is simply no technical reason to modify a standard for networking and communication in a firm. However, in reality, the interface between purchasing and manufacturing is not only unique, it is poised to experience a significant amount of change in the next decade. Another interface in deep trouble is the MIS

(Management Information System) - manufacturing interface. These interfaces must be managed for their uniqueness and propensity to change."[44]

There are several focal organizational characteristics which change when integrated manufacturing technologies are deployed in an organization. The changes can occur uncoordinatedly and by chance, or by purpose through systematic **organizational design**. This, in turn, impacts an array or organizational outcomes, such as productivity.[45]

From the manufacturing point of view, organizational design has two important aspects:

• **the interfaces between the manufacturing process and other functions of the company;**   • **the manufacturing internal interface between the technical aspects of the process and work force.**

The first set of interfaces includes the issues mentioned above - manufacturing and purchasing, manufacturing and management information systems - as well as the interfaces from manufacturing to sales, marketing and other departments within the enterprise. The issues of organizational design of the firm totality will be discussed further in chapter 2.5.

The other dimension is work organization design. Traditionally, engineering design has not given much notion to work organization. The technical planning of the production system has occurred both **independent of** and **before** the planning of work organization. Thus the worker has usually entered a technically complete production system. From the engineering point of view, the machine system has been the subject of the manufacturing process, man only a supplement to it - often seen either as a possible source of disturbances or as an object to be protected from the technical hazards.[46]

This division is expressed clearly in the Taylorist doctrine of scientific management: planning takes place before production, and is outside the production process both organizationally and as activity. Within production it is the responsibility of supervision to take care of the practical organization, the worker only has to fill the holes in the system of machinery. After technical planning of production, the manpower planning of a factory often has the sole target of minimizing the labour force.[47]

This has been the fundamental approach also in respect of complex automation technologies. The basic target has been to create a fully automatic factory, without any or only with a minimum of human intervention. The basic ideology of engineering design has been the belief in perfectly functioning technology. Accordingly, it has widely relied on comprehensive pre-planning, prediction of disturbances and minimization of the role of manufacturing workers.

With actual experience, this approach, has, however, lost its appeal. With growing **technological complexity**, the number of unforeseeable situations and problems increases. The systems simply cannot be planned in advance. With growing **flexibility** the need for user

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44 Bessant and Ettlie, 1990.

45 *Ibid.*

46 See e.g. Schumann *et al.*, 1982.

47 See e.g. Doeringer and Piore, 1971.

interventions becomes even more important, and there are even fewer possibilities of planning all human tasks beforehand.

From this point of view, the basics of engineering planning philosophy are being rethought. The flexible use of complex technological systems seems to require a completely new approach to the man - machine interface within the production process. The unforeseen situations require more active intervention by the user. There is also more need for cooperation between different tasks in the process, caused mainly by the integration, dependability and complexity within the machine system.

An example of organizational change: the car industry

Car manufacture is a good example of organizational change. The industry has been the text book example of "taylorized" work. Car assembly especially has been characterized by a high division of labour and narrow tasks with low skill demands.

Since the 1970s, however, the assembly work has gained new features. The picture of narrowly specialized mass production worker has faded: vertical and horizontal division of labour has been reduced, better skills and more comprehensive thinking are demanded from workers.[48] The changes have been interpreted as signs of a new, more integrated mode of labour force usage. This mode is characterized by demand of both high vocational and social skills. The requirements for new type of social skills - communicative abilities, cooperativeness and personal development - rise from the more cooperative and flexible way of operating with continuous pressures towards changing ways of working.

Vocational competencies are increased within the car industry by enriching the task contents of jobs, by redesigning work operations and joining them in new combinations as new jobs, by dismantling old hierarchies and distributing decision making power downwards within the organization. The target may be the building up of new working teams by demolishing old professional boundaries or increasing the flexibility of already existing work groups. These activities are supported by systematic in-house training geared towards developing worker skills to more integrated vocational entities. The social qualifications are also developed through e.g. group formation and group dynamic training. Simultaneously, skills have gained more significance as recruiting criteria.

Changes within the German automotive industry may be summarized as follows:

> Within the industry, there is a clear paradigmatic shift in use of labour power and in work design. A new type of car worker is being born, who has had long training and has 'obtained the basic information on the operational problems of modern production machinery and can with these skills give an important input to the optimal operation of the new production system'.[49]

The differences from the former, poorly trained mass production workers - who in the German case were often foreign 'Gastarbeiters', are significant.

The changes have a wide scope: whole production systems are involved. And they are taking place not only within individual systems and firms: it is actually a comprehensive change concerning the totality of the production branch. The productions system, products, production technology and

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[48] See e.g. Benz-Overhage *et al.*, 1982, and Kern and Schumann, 1984.

[49] Kern and Schumann, 1984.

use of labour are linked to each other and require changes in each other. Product development or process development alone and as such cannot be taken as the clear starting point. And in respect of work organizations, the individual firms have alternatives and possibilities to choose.[50]

The car industry is also one of the most advanced sectors with respect to using flexible automation technologies. A very important share of FMS, for instance, are in the sector. As an industry it also illustrates well the interdependence of various functions: product, process, market strategy and external linkages. The car industry example will be used again later to illustrate firm external relations.

2.5 WORK ORGANIZATION AND SKILLS IN FLEXIBLE MANUFACTURING SYSTEMS (FMS)

Flexible manufacturing systems are the most advanced and complex technologies of flexible automation. FMS also illustrate the variety of work tasks and the possibilities of planning the division of tasks within work organization. In table 2.5, the human tasks needed to make and to keep FMS running after implementation are divided into three main categories.

Table 2.5 Operating tasks in FMS

Planning and development tasks
- methods planning (transforming blueprints into sequence of working methods, speeds, feeds etc.)
- programming (transforming methods plans into NC programs)
- materials planning (quality requirements, availability)
- tools management (management and development of tool system)
- production planning (batches, scheduling, route planning, work queue planning)
Setting-up tasks
- presetting tools plus transporting and fixing them (if not automated)
- testing (step-by-step testing, correcting and optimization of NC or robot programs in a trial run)
Manufacturing tasks
- loading and unloading parts on and from pallets
- starting and stopping the automated operations
- monitoring of automated operations
- quality control (checking of parts)
- tool changing
- maintenance (cleaning, chips removal, adding cutting oil etc.)
- disturbance handling (diagnosis, repair, calling help if needed)

Source: Toikka *et al.*, 1990.

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[50] Kern and Schumann, 1984.

Empirical studies on work organization with FMS discovered a great diversity of ways in which FMS could be organized. It is interesting that the variation could not be explained by technical differences:

"Different work organizations, recruitment and training policies are compatible with FMS which are technically similar." [51]

It is possible to create two opposite poles of this empirical diversity, two models of organizing FMS work: **'traditional'** - work organization based principally on taylorist division of labour - and **'alternative'**, a more skill based organization type.[52] The main features of the two models are outlined in Table 2.6.

Table 2.6 'Traditional' and 'alternative' FMS organization

'Traditional' organization	
-	hierarchical job and skill structure within FMS
-	traditional division of FMS internal and FMS external functions (programming, maintenance and quality control)
-	on-the-job training based on 'creaming off' recruitment (selecting the best from old production)
'Alternative' organization	
-	homogenous job structure and team work at a high skill level
-	greater deal of programming, maintenance and quality control as FMS internal functions
-	extensive off-the-job training enabling wider recruitment

Source: Köhler and Schultz-Wild, 1985.

An empirical German survey using the organizational dichotomy found out, that a narrow majority (56 per cent, n= 93) of FMS and FMC studied in 1985 were designed along the lines of traditional work organization, based on high degree of division of labour.[53] In these, the main jobs and tasks may be defined as follows: [54]

Foreman/ shift leader:	Main domain planning and developing (responsibility for proper functioning of the system, production planning), in addition manufacturing tasks (e.g. management of minor disturbances;
Setter:	Main domain setting-up (presetting and setting of tools, testing and optimization of NC programmes); in addition manufacturing task (e.g. management of minor disturbances, tool changing).
Machinist:	Main domain 'middle range' manufacturing tasks (e.g. monitoring of automated operations, checking of parts, tool changing); in addition loading and unloading work pieces.
Paletizer:	Main domain simplest manufacturing tasks (loading and unloading of work pieces); in addition e.g. monitoring.

51 Köhler and Schultz-Wild, 1985.

52 *Ibid.*

53 Fix-Sterz *et al.*, 1990.

54 Toikka *et al.*, 1990.

In alternative FMS organizations, there was just one job classification: the system operator. The system operators were usually responsible for proper functioning of the system, testing and optimizing of NC programmes, maintenance of tools systems, loading and unloading of workpieces, monitoring of automated operations and maintenance (chip removal). Typical additional tasks were management of minor disturbances and quality control (measurement during machining). However, the most demanding tasks like programming, production planning, major maintenance and repair were much less frequently assigned to the system operators. They were usually carried out by upstream or downstream areas, and the system operator was - if involved at all - only working as an extra helper to a specialist from a department outside the system.[55]

The results, which are in line with surveys from other countries,[56] imply that different work organizations, traditional as well as skill based are compatible with FMS, even with technically similar systems. They do not, however, imply that technology has no relationship with organization and skills.

The two organizational prototypes are based on opposite philosophies of engineering design and production organization that were already discussed in chapter 2.4. They are not specific to FMS only, but to the organization of flexible automation technologies more generally as well. The differences between the two approaches on various dimension are outlined in Table 2.7.

Many argue that the 'present' trends - or the 'alternative' ways of organization - are becoming more common.[57] The reasons for this are, as demonstrated above through the case of FMS, not technologically determined. The trend is more an outcome of the actual experiences gained from the operational practice of modern technologies. FMS can again serve as an example.

The dichotomies of 'traditional' and 'alternative' FMS organization and 'past' or 'present' trends in organizational design have also been generalized to all modern automation. The two essentially opposite approaches to manufacturing development are called 'technocentric' and 'human-centred' approach.

The purest form of technocentric approach has been attributed to the United States, from where it has been distributed to other countries. The approach constitutes:

> "... an attempt to gradually reduce human intervention in the production process to a minimum and to design systems flexible enough to react rapidly to changing market demand for high-quality products. Workers and technicians on the shop-floor are typically seen as unpredictable, troublesome and unreliable elements capable of disturbing the production and information flow, which is best controlled centrally through computers. The 'unmanned factory' is the ultimate goal. Only a residual role is assigned to workers, whose skills are supposed to be gradually incorporated into and progressively embodied in the machines." [58]

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55 Fix-Sterz *et al.*, 1990.

56 See e.g. Hörte and Lindberg, 1990.

57 Bessant and Ettlie, 1990; Brödner, 1990; Toikka *et al.*, 1990; Hörte and Lindberg, 1990.

58 Ebel, 1990.

Table 2.7 Overview of generic trends in organizational design to support CIM

Area	Past	Present
Skills	Single functions Long skills life-cycle Skill life = employee life Fixed relationship to task and equipment Stable skill-technology relationship One man, one skill demarcation Training model: Apprentice - craftsman	Multi functions Short skills life-cycle Skill life < employee life Emphasis on flexibility and problem solving Varying skills/technology relationships Cross-trading, multi-skilling Training model: continuous education Need for system understanding Elimination of skilled/unskilled divide
Work Organization	High division of labour One man, one job Pre-determined tasks and allocation Function/line based Specialization and task fragmentation Elimination of discretion Payment by results Supervisor as controller	Increasing integration of tasks Teamworking and role sharing Semi-autonomous working groups Cellular manufacture Flexible teams, multiple roles and skilling Increasing local discretion Alternative payment systems - e.g. for skills, for team output, for quality etc. Supervisor seen as resource
Functional Integration	Specialization Differentiation Coordination through formal mechanisms and procedures Demarcation and tight role specification Boundary limited	Generalists/multi-functionality Integration Coordination through new roles, structures and informal mechanisms Loose role specification Team working Boundary crossing
Hierarchical Integration	Control via formal rules and procedures Bureaucratic and mechanistic Emphasis on standards Traditional tall and pyramidal structures	Informal and self-organizing within broad framework Opportunities for simultaneous centralization and decentralization via networking Flatter structures
Interorganizational relationships	Arms-length and transaction based Short-term criteria Tight boundaries Tradition of confrontation (with supplies) and lack of investment (with customers)	Close and cooperative Long-term relationship-based Blurred boundaries 'Partnership' model
Organizational culture	Mechanistic Emphasis on local rather than global goals and their optimization Non-participative Single loop learning	Organic and flexible - the 'learning organization' Shared goals and participative approach Double loop learning

<u>Source:</u> Bessant and Ettlie, 1990.

The Japanese, German and Scandinavian approaches to flexible automation are based on different rationales. Especially in the Japanese model, companies introducing advanced, flexible automation can rely on a highly qualified, versatile and loyal workforce. Gradual improvements in production and quality, fully involving the staff, are the norm. There are many advantages to this approach:

> "Integrated manufacturing systems are very vulnerable to disruption. Running them efficiently and, so far as possible, round the clock presupposes harmonious industrial relations, since work stoppages, go-slows or other types of resistance stemming from

demotivating working conditions can cause major losses. The success of CIM, therefore, presupposes mutual understanding and co-operation between management and the workforce and its representatives. While the introduction of even well-designed CIM systems is bound to cause tensions, it also offers new opportunities for enhancing dialogue and breaking down barriers between the social partners - a change not to be missed."[5b]

Thus the central role of personnel - and the difficulties of 'unmanned factories - are based on the complexity of technology. The profitability of flexible automation technologies is based on a high rate of utilization. This again, includes both the daily operation with a minimum of disturbances and the fluent execution of changes within the production process.

These issues are especially important in the case of FMS. With growing technological complexity and more frequent production changes it becomes all the more difficult to maintain the high level of capacity utilization. Undisturbed design and planning of systems has proved to be very difficult, if not impossible. In this respect, the role of work organization and worker skills becomes critical.

Growing complexity and more frequent production changes	Growing difficulties in planning an undisturbed operation beforehand	Growing dependency on users' skills and intervention

A Finnish study of disturbances in the implementation and use of FMS revealed the central role of system users activity. Table 2.8 summarizes findings: the occurrence of operational hazards that induced user development activities during the 15 month long period of (the final) implementation and normal operational use. Disturbance is here defined as a situation which exceeds the normal disturbance handling that only restores the *status quo* of the system.

Table 2.8 Disturbances in FMS by cause during the implementation and normal operation of the system

Cause of disturbance	Implementation (per cent, n=110)	Operation (per cent, n=35)
Design failure	34	43
Component failure	31	26
User Error	20	20
External Factor	7	-
Undefined	8	11
Total	100	100

Source: Kuivanen *et al.*, 1988.

One outcome was that the need for active user involvement was already considerable during the implementation phase. The largest category, 34 per cent of all disturbances, was directly caused by incomplete design and could be recovered only through user development intervention. A typical example of such a failure was:

[5b] Ebel, 1990.

"... ill securing of a workpiece in the lathe when the piece would fasten slanted in the jaws becoming out of tolerances. The users corrected this by devising a mechanical restrainer which prevented slanted fastening." [59]

It is reasonable to expect that the number of disturbances would decrease after the implementation phase, when teething troubles of the system were healed. This was the case. However, the share of disturbances caused by system design failures was then even higher, almost half of the total number of defaults. It is also notable that the share of disturbances with an unknown cause was so high. This can be interpreted as a sign of the characteristic uncertainties of complex automation technologies.

The need for active user participation in all phases of implementation and design of flexible manufacturing technologies has been emphasized. In using FMS and other complex manufacturing technologies for flexible production, high and continuously expanding user skills are, in the long run, a necessary condition for success. The technical systems are really never 'ready': if business strategy is based on flexibility and adaptation to a changing environment, the manufacturing technologies and the corresponding organizations are also in a continuous process of change and development.[60] The Finnish experience suggests that users of the system may acquire a high degree of expertise in dealing with it on a day-to-day basis: this in turn should be reflected in organizational and training measures undertaken from the top.

2.6 SKILLS FOR FLEXIBLE PRODUCTION

FMS is a specific case, the most developed and complex example of flexible automation technologies. The specific nature of FMS as a completely new type of socio-economic system has been emphasized.[61] It is a system that also requires both comprehensive, systemic successively developing user skills and entirely new ways of organizational thinking in using the skills. The qualification needs are a combination of very specific process related, basically tacit skills and highly theoretical general knowledge and abilities with respect to the operation and design of the complex machinery.

Studies on FMS work point out the need of continuous training for FMS users. In addition to good basic vocational education, the organization should support continuous upgrading of skills by both formal further training and learning by doing. A Swedish project with this kind of learning organization approach concludes:

"An employee should never be regarded as fully trained - that is the ideal. But as the work progresses, it is important to absorb new impulses, experiment and try kicking off again in order to arouse the enthusiasm and motivation of everyone involved." [62]

The approach is not limited to FMS work only. For example, in the Swedish context the learning organization concept is applied to a variety of renewal processes, where different types of technologies for flexible automation are introduced. A study on introducing flexible specialization strategy and implementing NC machine tools in Danish small and medium sized companies tells a

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59 Toikka *et al.*, 1990.

60 *Ibid.*

61 Toikka *et al.*, 1990; Brödner, 1990.

62 Arbetsmiljöfonden, 1988.

similar story on skill needs and organizational development. Problems in reorganizing production, initiating new technology, changing wage system or other development issue can be avoided if two conditions are met:

> "... first, those firms which had least difficulty in changing direction also have a higher percentage of skilled workers, and it is a fair guess that there exists a craft ethic concerning responsibility and efficiency in production that provides the individual worker with a certain degree of autonomy as well as the ability to cooperate across the lines of traditionally defined areas.
>
> Second, this 'concealed' organization of craftsman-like production must be respected when new systems of supervision and management are instituted. This is difficult to achieve without giving the employees participatory influence because the organization is, as mentioned, a concealed organization within the organization." [63]

The same study also showed that in these cases production workers generally seem to be eager to improve working organization or to make work more expedient, to introduce new technology, e.g. obtain better equipment, and to meet new challenges.

In order to make new technology efficient and profitable, it is essential not only to make good use of old vocational skills, but also to add new ones. The old skills are needed in order to understand the process and materials - something which becomes increasingly important as the process of change intensifies. But it is also necessary to learn new skills, such as how to program the equipment.

When production becomes automated on a large scale, as in the process industry for example, the process operators need to understand not only the process and how it is controlled but also how the computer controls the controls.

> "It would have been possible just to train one person on the new milling machine, but the company wanted to have a broad base of skills in the company. Everyone must know what he should do and what he shouldn't do. Then we don't need a production planner or operation list to tell us what has to be done. While production is in process, each individual is involved in the entire process, and they talk with each other about what should be done. Responsibility for the quality of the result rests on the operators themselves, and they can accept this if they have the right skills." [64]

What are then the skills needed in flexible production? As noted above, the type of skills of course depends on the manpower strategy used by the firm. However, many sociologists and qualification researchers are inclined to corroborate the hypothesis that a new production mode with less division of labour and with higher skill demands is about to arise.[65]

Within manufacturing industries, a contradiction between a traditional and this modern production mode is becoming acute. In many up to date firms, the idea of skill-based production with a target of more flexible manufacturing technologies and organizations is displacing the traditional taylorized production organizations.

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[63] Kristensen, 1990.

[64] Arbetsmiljöfonden, 1988.

[65] Kern and Schumann, 1984.

This contradiction is not leading to a polarization in the skills of labour force in the traditional sense. At least not in the skills of the young labour force: the polarization line goes within different segments of labour market, and partly between the age and educational groups. The older employees within more traditional industries and old fashioned firms are the losers; youngsters with high education - and active to a growing extent within the modern segments of economy - are the winners.

However, the main efforts of qualification research have traditionally been concentrated on the changes within different productive skills. These studies based on task and trait analyses cannot find the changes taking place in the relative importance of different types of skills, that gain in importance with growing flexibility of production processes and more frequent changes in business environments. These types of qualifications are revealed by more thorough studies, that

(a) analyze on the one hand individual's qualifications in relation to the whole activity system, and

(b) on the other hand investigate work changes in the context of comprehensive organizational and structural changes.

The results of recent studies stress the role of **innovative and normative qualifications** (Figure 2.1). Within the normative qualifications, especially **motivational and cultural skills** seem to gain in importance, traditional wage labourer qualifications such as adaptability/submissiveness seem to lose in weight.

Figure 2.1 Schematic presentation of skill types

PRODUCTIVE QUALIFICATIONS

- skills necessary in coping with the concrete productive tasks

NORMATIVE QUALIFICATIONS

ADAPTABILITY (submissiveness)	*MOTIVATION*	*CULTURAL QUALIFICATIONS*
• traditional characteristics of wage labourers: obedience etc.	• personal commitment to work	• match with the firm and production culture

INNOVATIVE QUALIFICATIONS

- the ability to develop the labour process, the individuals ability to consider the actual work situations, tasks and process organizations as parts of larger interdependent systems.

Source: Vuorinen, 1991.

Flexible companies do not have much use for traditional, submissive and obedient workers with a superficial, indifferent and formal relation to the substance of their work; workers who just do what they are asked to do and work mainly for the wage. This kind of traditional wage labourer attitude and motivation to work is not enough for modern manufacturing firms. This means, that many qualifications traditionally typical for entrepreneurs and independent professionals are to a growing extend demanded also from shop floor workers. It can be concluded, that modern manufacturing firms with advanced flexible technologies are looking for employees that are:

- **deeply committed to their work**
- **culturally suitable to the employing firm and their customers**
- **capable to continuous flexible reorganization of their own workplace**
- **motivated and capable of being continuously trained in new tasks**

This does not mean that direct productive qualifications - to know what to do in order to reach a certain, preset result - would be less important. For example, in metal manufacturing machining jobs both **new and traditional productive skills** are needed. Traditional machining skills are required, even though they are usually not actively needed daily, at least in three contexts:

(a) the operator has to master the basics of manual machining in order to know how the objects to be machined behave during machining, to know what kind of machining is possible to various materials and what is not;

(b) traditional skills are also needed in unusual/crisis situations where the machinery has to be operated manually;

(c) when production requirements override the flexibility of the system: all components and parts can not be manufactured with modern technologies (e.g. singular objects with parameters very different to other components), but they require manual machining with older equipment.

An addition to the traditional, manual skills, new qualifications specific to numerically controlled equipment are required. Some of these - e.g. programming - can be allocated to specific, external personnel. However, experience from flexible production has shown, that both programming and manufacturing results are usually better, if the programmer is also a user of the system.

In all, this implies that in most cases the skill needs in flexible production using advanced automation are as a rule more complex and more demanding than in traditional, manual manufacturing. In principle, it is possible to apply more traditional divisions of labour where tasks with new skill needs are separated from basic operative tasks. Many organizational solutions are possible, as discussed above. However, when production is undertaken with teams consisting of extensively trained, qualified workers with good motivation and high commitment to work, the results are usually better - in terms of e.g. undisturbed machine utilization and better quality of products - than when using a workforce with more hierarchical division of skills and tasks.

In conclusion, it seems that wider diffusion of advanced, flexible manufacturing is linked to a new model of organizational thinking based on a highly skilled workforce. In this approach at least the following issues are typical:

(1) For higher employee motivation, it must be realized that the enterprise is also a human collectivity, a life framework for the personnel, which must allow them to realize and develop themselves continuously in their work.

(2) This orientation integrates a new conception of authority which leads the managers to consider themselves more as responsible than as superiors, it imposes a continues dialogue within the company; it also imposes the acceptation of the trade unions partnership in the enterprise.

(3) On work organization level, the principle of 'small is beautiful' is valid. Rigid hierarchical structures are replaced by 'operational teams' linked to a decentralized approach allowing a wide autonomy for functional and operational flexibility.

Organizational renewal based on wide use of human skills requires, of course, good training and education. This involves all levels of educations: the national systems for basic, vocational, higher and further/adult education as well as firm, sector and technology specific training for new technologies. These issues are discussed in chapter 4.

2.7 EXTERNAL FLEXIBILITY: NETWORKS AND STRATEGIC ALLIANCES

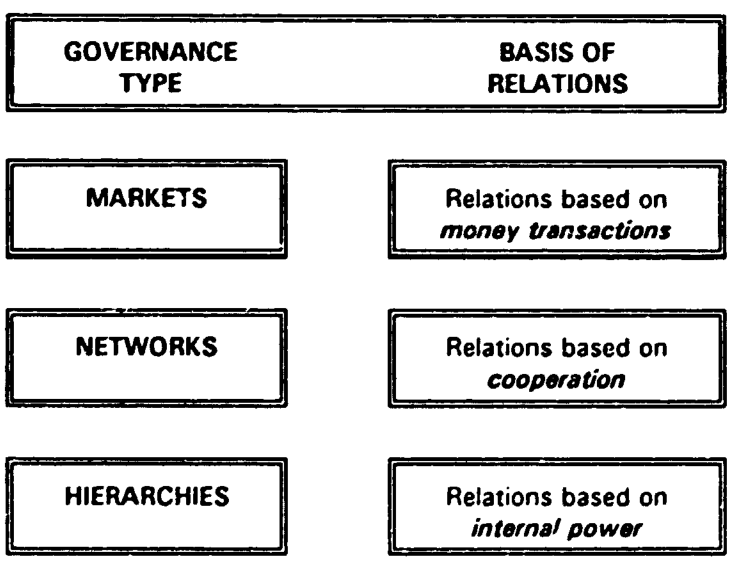
Shop floor level changes, such as implementation of new work organizations and introduction of advanced automation, are only the other part in business strategy of flexible specialization. The other part consist of changes in firm and business organization. The flexible production model involves a relatively apparent trend towards more decentralized and informal governance structures. This includes both changes in the enterprize internal organization renewals and new linkages to outside organizations.

The main trend in governance structures is twofold:

(a) Splitting up structures based on rigid internal hierarchies and strict control from upper levels towards more autonomous and independent units;

(b) Moving from anonymous market relations based on money transaction towards more cooperative, long time development relations based to a growing extent on confidence and mutual dependency.

Figure 2.2 Markets, networks and hierarchies



In large concerns this has meant a radical decentralization of power and breaking up the existing organizational hierarchies. Diverse business areas have been reorganized by establishing independent companies often with only common ownership under the same 'umbrella' - and the very general strategic management - remaining from the previous giant enterprise. Simultaneously factories and other functional units have gained more independence on strategic target formulation, decision making and practical operations.

After reorganization, relationships between different concern divisions, units and other parts of the concern are governed on a more equal, cooperative way based on substantial factors and common long term development targets, not on orders and control of central concern management. The independent units have, of course, also full freedom to develop their external relations to other firms and organizations outside the concern. They are responsible to the central enterprise management only in terms of very general business results.

The main aims of these changes are:

(a) To gain more flexibility on the enterprise level in order to reallocate resources rapidly from one area to another;

(b) To create a cooperative organization of small independent units that are all able to react rapidly to market and technology changes;

(c) To motivate management and personnel in the units to more innovative and committed activity.

Such networks of independent units working in long time cooperation are not created only within companies. Even more important are networks between firms and concerns. Networks are an outcome of a trend, where firms - instead of horizontal diversification or vertical integration - concentrate on their core business where their key skills are. Supportive functions and even parts of the main activities are to a growing extent ousted from the firm and acquired through various contracts and other arrangements from outside sources. Through these contracts enterprises create **a network of strategic alliances** with other companies.

What then is acquired from within the company (hierarchy), through strategic alliances (networks), or bought from outside sources (market), depends on the type of assets involved. The core activities involving skills of high asset specificity are governed internally within the organization. Activities involving complementary skills of medium asset specificity are governed through alliances, various types of long term cooperative contracts. All other assets of low specificity are obtained in the market.

Strategic alliances are created to all directions from the enterprise:

(1) **Backwards** in the production chain: to a growing extent, intermediates are obtained through long term subcontracting, where the partners are linked to each other by e.g. continuous technological development in both products and processes.

(2) **Forwards** in the production chain: finishing, marketing and other functions following the core activities are subcontracted in the same way as obtaining intermediates. Technological links are involved here as well.

(3) **To supportive and complementary functions**: many supportive services are acquired through alliance creating contracts. This is especially typical for research and development functions but also for more common business services involving assets of medium specificity. This kind of horizontal strategic alliances - e.g. in using same trade marks in marketing - are

also created to companies, whose product variety can be used to complement the firms product range.

(4) To **competitors**: strategic alliances between competitors are - with the growing complexity of technology and markets - becoming more and more common. The most typical are alliances on basic research, but marketing alliances (e.g. as market cooperation limited to some regions) between competitors are not unusual either.

By splitting up the rigid, integrated hierarchical concern model and replacing it with a business organization based on strategic alliances, the enterprise gains more overall flexibility and new abilities to both get information from all its interfaces and to react more rapidly to the changes. On the one hand, individual - independent or autonomous - parts within the network can react faster to changes than - hierarchically commanded - parts of a rigid concern. On the other hand, it is easier to change partners and create new linkages within the network than within a closed concern structure. Basically, in the recent economic and technological situation, networks simply often are the most economic - an intermediate - solution to the 'make or buy' question.

From the small firms' point of view, business structures based on networking relations mean that creating linkages is very important. For small firms, linkages and creating networking relations are even more important than for large concerns. Even a technologically competent small firm alone is powerless without the necessary connections and linkages to all outside interfaces. This is especially true for companies in technologically developed sectors, where small firm resources and internal skills are inadequate even for many vital activities.

The network characteristics, conditions and various types of network linkages are not discussed further in this context. However, an enterprise thinking about extensive investments in automation based on flexible specialization strategy also has to rethink its external relations.

> In an open world, flexibility only within the company is not enough.

2.8 CONCLUSION

In this chapter automation was considered from the individual firms point of view. For a firm, automation is not a target, but a tool to reach some business targets and realize the strategy of the firm.

> Automation strategy should not start from technology but from business strategy. The main questions are:
>
> What are the targets the firm wants to reach?
> Which of these can be reached by organizational changes?
> What could be the role of automation technology?
> What are the costs and benefits of technology introduction?
> What other changes are necessary to reap to most out of technology?

The basic difference between rigid, traditional automation and modern, flexible automation is definitely on this level: the main target is not - as in case of traditional automation - to save labour costs, but to gain more flexibility both in production and in other activities of the firm.

The need for flexibility rises from changes in the business environment: changes in the market as well as in the realms of technology and global economy. Many companies in developed countries are answering to the changes by introducing advanced automation as a part of flexible specialization strategy. The strategy involves not only new hard technologies, but also new organizational thinking and new ways of using labour and skills. There is a trend towards decentralized organizational models, which, more than in the era of mass production, rely on the skills of employees.

In a firm, the new organization is based on flat hierarchies and small, relatively independent and autonomous units. On the shop floor level, work is often organized as production cells consisting of teams with highly skilled employees, each with broadly defined tasks. Autonomy concerning decisions on the way and sequencing of the production process is mostly delegated to the team.

On the level of the whole company, flexible specialization involves the creation of independent units and divisions. These can be either completely independent, or connected to each other only by the strategic management of the concern.

In interfirm relations, flexible specialization involves a shift from market governed relations to more long standing, cooperative relations, based on mutual contracts. In this sense, relations between concern members and other cooperative partners do not differ much.

The basic situation for **developing country firms** is not very different. Production technology development has to be seen as a part of business strategy. The differences concern more the environmental conditions, the types of targets to be reached, and the possibilities to accomplish the change. In this respect, the pressures towards flexiblization and specialization are perhaps not as urgent as in developed countries.

For example, the (market and technology) environment is - partly - different, less segmented, and not changing so rapidly, especially with respect to activities within developing countries. But the more open and technologically advanced the market in which the firms are operating, the more similar are the pressures towards flexibility, specialization and use of advanced automation technologies.

The way of introducing the renewal may also be different. For example, the skill based strategy is often not possible in developing countries. On the long run, however, raising skill levels becomes quite obvious. This is to be seen e.g. in the East Asian NICs, where advancing skills and upgrading education is one of the key areas for policy development.

3. NATIONAL FRAMEWORKS FOR DEVELOPMENT

3.1 MARKET STRUCTURES

The importance of organizational and structural adaptation (which has been called "institutional change") has been highlighted by a number of theorists in recent years and a so-called "institutional determinism" has been part of this discussion.

In fact, some have maintained that institutional rather than technical change is the dynamic source of economic development.

A key element of this type of organizational change is that involving the way in which people are used in both product and process innovation, and the concept of flexible specialization has received considerable attention in the last ten years or so.

> "Flexible specialization also involves a rapid process of product and process *innovation*, and for this to proceed it is essential that the workforce participate actively in product and process development. Not only are two-way flows of information essential, but so too is a sense of direct involvement in production." [66]

This is analogous to the discussion earlier, where it has been stressed that the main benefits of automation at the factory level derived from changes in the way the work was carried out, the re-organization of production, rather than the specific benefits brought by the machines themselves.

> "Just as the supply curve for technical change shifts to the right as a result of advances in scientific and technological knowledge, so the supply curve for institutional change shifts to the right as a result of advances in knowledge in the social sciences and related professions such as business, planning, law, and social service. Moreover, advances in knowledge in the social sciences and related professions reduce the cost of institutional change just as advances in knowledge in the natural sciences and engineering reduce the cost of technical change.
>
> This is not to argue that institutional change is entirely dependent on formal research that leads to new knowledge in the social sciences and related professions. Technical change did not wait for research in the natural sciences and technology to become institutionalized. Similarly, institutional change may occur as a result of the exercise of innovative effort by politicians, bureaucrats, entrepreneurs, and others as they conduct their daily activities." [67]

The Japanese system of production engineering has, in recent years, thus become a powerful motivator of change world wide - both in the developed and the developing worlds. Although there are obvious differences in cultures, needs and structures, there has been an acceleration of change,

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66 Kaplinsky, 1991.

67 Binswanger, Ruttan, *et al.*, 1978.

with all countries learning from the Japanese experience, and the adoption of those elements deemed appropriate to individual cases.

What therefore has formed the cornerstone of this growth in competitive efficiency? Three basic features have been suggested:

(1) *Reliance on on-site information:* Instead of relying on centralized information and direction for problem direction for problem solving, Japanese organizations typically undertake this task in a decentralized manner, relegating it to the lowest possible level of the formal hierarchy.

(2) *Reliance on horizontal communications:* When problem solving must be dealt with jointly by multiple functional units, direct communication among the relevant units without clear direction from a common super-ordinate is typical (for example, the "kanban" system in the manufacturing process, the "ringi" system in administrative organization, etc.).

(3) *Ranking hierarchy:* In both manufacturing and bureaucratic organizations, personnel are evaluated by their contributions to collective problem solving rather than on the basis of more abstract measures of individual skills. Promotion often takes the form of transfer to other departments.[68]

Another analysis of the Japanese approach to manufacturing is as follows:[69]

- Learn from others;
- JIT/TQC are imperatives for improvement;
- Production people must control quality;
- Non-Japanese can use Japanese techniques;
- Simplify plant configuration -- break down shop barriers;
- Labour flexibility is the key to success;
- Have your suppliers deliver at least once a day;
- Production managers and workers can improve systems themselves;
- Simplify and reduce, simplify and integrate, simplify and expect results.

In evolving a strategy for computer-integrated manufacturing (and this can apply at national as well as enterprise level) there are two possible approaches:

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68 Mowery and Rosenberg, 1989.

69 Ingersoll Engineers, 1983, and Schonberger, 1982.

"Techno-centric": this 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.

"Organo-centric": in which the process of technological innovation follows that of organizational adaptation. The pattern here follows roughly the prescription offered by Ingersoll Engineers: (1983) "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.

3.2 NATIONAL AND INTERNATIONAL KNOWLEDGE

The importance of the underlying concepts of knowledge, science and technology for the processes of technological adaptation and development with respect to industrial automation and other advances has been outlined in Chapter 1. This section discusses some ways in which the different types of knowledge in developed and developing countries can interact, and what are the respective roles of policies and institutions in optimizing this process.

Foreign knowledge may stimulate the development of local knowledge-creating capabilities, but it may in other cases discourage such development, inducing arguments for protectionism. Engineering sub-contracting is given as an example, with a preference for foreign sub-contractors. The encouragement of local capabilities would bring social benefits that would outweigh the differences in quality, etc.[70] Returning to the positive features of foreign knowledge, they can best be realized only if the institutional capability exists for taking advantage of them.

Much of the focus for successful development must therefore rest on indigenous capabilities. While these may not currently be at the leading edge of technological and organizational change, the ability to learn from the experiences of others is crucially important. One way of doing this is by a strong concentration on raising the levels of competence within the developed countries. Both basic and vocational skills, tacit and explicit knowledge, require refining. Learning by doing is, in effect, the argument in favour of imported knowledge or technology, and this can be made quicker by adaptive research. Equally, a locally developed technology that takes account of the local skill endowments will also shorten the period for achieving maximum efficiency.[71]

In support of these skill and educational requirements are a wide range of intangibles is needed, such as logistics, information, and systemic and organizational changes:

While technological advancement is a precondition for growth, there are numerous institutional, structural, attitudinal and social factors which crucially affect the capacity to introduce or maintain the momentum of technological change required by short-and longer-term adjustment or structural transformation of an economy. These non-economic factors may in many instances strongly influence purely economic analyses of the role of technology in raising the overall output, productivity or competitiveness of an economy.[72]

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70 Cooper, 1980, quoted in Fransman, 1986.

71 Binswanger, Ruttan *et al.*, 1978.

72 UNCTAD, 1990.

This raises two further points for consideration by industrialists and policy makers in developing countries:

- How can local input be increased?

- Is it possible to reduce the reliance on and cost of, imported technology?

With regard to the first of these, this is highly dependent on the degree of technological complexity in the imported process. Without doubt much of the technological innovation in Japan and the West is overly sophisticated for use in the majority of developing countries. For example, neither robotics and FMS are immediately relevant to many developing country needs. Similarly, many of the computerized systems are too complex for use in these countries.

For the second, it has been suggested that it might be possible to "unpack" some of these technologies making them subsequently cheaper and easier to apply in developing countries.

> The process of unpackaging could be a way of reducing the cost of technology acquisition. More significantly, it could stimulate the development of certain technical skills and capabilities within the country or enterprise and thereby strengthen the total technological capacity and the domestic component in the technology mix. As the process of unpackaging increases, there would be a parallel increase in the mastery of technology through a learning process.
>
> The scope of enhancing the local content varies with the complexity of the technology and the mechanism of the transfer on the one hand, and the level of internal technological capacity (domestic design, engineering and consultancy agencies, availability of investible resources, local research and development infrastructure, human resources, level of industrial integration and the like) on the other.[73]

With regard to the levels of international capabilities and the transfer of their experiences to a developing countries context perhaps one example, that of Japan is sufficient to highlight a successful development from a country that possessed a comparative advantage in labour costs, but whose strategies were founded on other factors.

The success of utilizing international and external capabilities in the service of national strategies in the developing countries are however, conditioned by their abilities to approach industrial efficiency in a systematic way. But how could unbundling work in the area of industrial automation? The main focus of successful unbundling would have to be not only on the technology itself but also on what it is used for, i.e. the new flexible decentralized forms of production that automation has made possible and increasingly necessary. Thus, with respect to the technology itself, the possible aspects that could be substituted locally would eventually include software, management, maintenance and system integration skills. With respect to the organizational changes associated with industrial automation, there is scope for enterprises in developing countries to expand considerable their use of design change as a response to market change, for instance. Some of the infrastructure for this exists in the availability of improved telecommunication links between developed and developing countries. However, development of the different skills needed will require considerable efforts in design, marketing, and management training.

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73 UNCTAD, 1990.

3.3 GOVERNMENT, TRADE AND TECHNOLOGY POLICIES

It is obvious that there is no simple answer to the question of what role governments and markets play or should play in the advance of science and technology. Clearly, they have a valuable role in stimulating the framework of these two areas, and in providing some of the necessary education and training infrastructure. The role of the government as a facilitator of innovation by promoting the smooth transition to more advanced technologies is quite different from the role of comprehensive planner, controlling prices, investment and other firm decisions through a regulatory mechanism[74]. The importance of this role as a facilitator or innovation is crucial, since inadequate guidance and infrastructure at the applied level. The wider role of the state in championing industries growth is the more questioned one. In Europe, the trend in recent years has been away from such active targeting at the national level, although at EC level industrial R&D has received considerable emphasis. In the United States, there are increasing calls for government action to reverse what is seen as a lack of competitiveness and a specific challenge from EC, Japanese, and developing country producers.

In this context, it may well be that strong central government directives and support should be directed at specific sectors, rather than attempts to be made to compete in all sectors and be successful in none.

In this connexion, the experience of Japan is relevant:

> The Ministry of International Trade and Industry decided to establish in Japan industries which require intensive employment of capital and technology, industries that in consideration of competitive cost of production should be the most inappropriate for Japan, industries such as steel, oil refining, petrochemicals, automobiles, aircraft, industrial machinery of all sorts, and electronics including electronic computers. From a short-run static viewpoint, encouragement of such industries would seem to conflict with economic rationalism. But, from a long-range viewpoint, these are precisely the industries where income elasticity of demand is high, technological progress is rapid, and labour productivity rises fast[75].

If the role of the state is inadequate, then no matter how successful the education or science system *per se*, the benefits of this may not be exploited industrially. The failure of the united Kingdom to match the level of industrial research of United States manufacturing has been attributed not only to the industrial institutional agency of the past, but to the failure of government policy in trying to change this[76].

The above discussion can be summarized as follows: The focus of government policy should be directed towards developing a central, strategic and long-term role aimed at providing an efficient infrastructure and, in collaboration with its industrialists and research based, seek to achieve market

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74 Noll, 1982.

75 OECD, 1989.

76 Mowery and Rosenber, 1989.

penetration in a limited number of niches. In some cases this could even be facilitated by using its own power as a purchaser of goods and services towards promoting technological innovation.

In short, the best policy might be one aimed at providing:

- an adequate infrastructure;
- strategic guidance;
- support for a very limited number of technologies in limited market niches; and
- provision of a liberalized trade policy.

All developed countries have protected their domestic agriculture, industry or services at one time or the other, and behind the 'success' stories of some of the larger developing countries with an export-oriented trade policy has been a period of efficient import substitution, technological learning and dynamism. In determining the various elements that would comprise a trade policy, with adequate attention paid to technology, consideration would need to be given to inter-sectoral and intra-sectoral relationships so as to ensure a certain degree of technological consistency. The time element is also important, in that any trade policy entails suitable efforts to create a technological base and capabilities to sustain it. Technology transfer policies encompassing effective transfers from R&D institutes, innovations at enterprise level and imports from abroad could perhaps be made to contribute to the implementation of the trade policy objectives.[77]

In spite of the benefits of free trade, there are certainly some arguments remaining in favour of a limited degree of protection for industries in developing countries at an initial stage of development. It has often been pointed out that countries that were very successful in terms of manufacturing exports-led growth had nevertheless devoted careful attention to controlling foreign competition for their industries, especially at an early stage. However, reliance on import substitution and protection of "infant industries" can only be part of an overall development strategy, one which takes full account of linkage questions, for instance.

> The distinction has to be made between a strict definition of infant industries, and trade barriers to development. For example, the decision to prevent the import of machine tool controllers from outside Brazil, e.g. from Germany, Japan and the United States, *may* have been beneficial to the computer industry there, but was certainly counter productive for the Brazilian machine tool industry. The Argentinean machine tool industry, by contrast, was able to fit such more efficient controllers.

Similarly in the United States, it has been argued that artificial barriers to the import of semiconductors from Japan - in order to protect the indigenous industry, may prove to be a poor use of trade policy, because it restricts access of computer manufacturers to necessary components.

As Mowery and Rosenberg (1989) observe, this is leading to border crossing between technology and trade policies. In the case of the United States they note the challenge this presents to trade policy, which arises as a result of dynamic change within the technology field and the relatively rigid trade policies noted in the above quote.

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77 UNCTAD, 1990.

This raises a considerable dichotomy with regards to the free flow of trade and information between countries, particularly with reference to the growth of economic blocs in the world, and the frequently and increasingly resulting barriers.

There is little doubt that two of the factors which have influenced innovation have been (1) the interaction between governments and industries in order to promote change; (2) the growing level of dependence between economic and technological infrastructures.

In fact, with the growth of regional trading blocs in the world economy, and the increasing sensitivity of world markets to policy interventions, the convergence of industry, trade and technology policies is accentuated. Even in countries where such policy development is rudimentary, consideration of such interrelationships is essential. This set of issues will make the task of policy formulation and development in some developing countries even more difficult.

Developed countries, by contrast, review their technology policies on a continuous basis. The following are some considerations from a German perspective (emphasis added):

"*Thesis No. 1*
A long-range policy of active structural change and adaption to changing conditions within the world economy must attempt to make the best use of the present strong points of our national economy, i.e., it must first of all improve the preconditions and strengthen the structures for technical innovations in those industries holding a strong position on the world market, i.e. mechanical and electrical engineering as well as chemical industries, in which about 40 per cent of all jobs directly or indirectly depend on exports. We would not strengthen our competitiveness if we subsidized industries which are comparatively stronger in other countries.

Thesis No. 2
The input that can probably be increased most easily within the Federal Republic is the level of education of our people. Technological knowhow will be one of the major features of goods to be exported in the future.

Thesis No. 3
Apart from technological innovation, we shall have to promote social innovations for the population to improve the quality of life.

In order to increase the overall efficiency of our economy, private and public services will have to be taken into account far more than up to now. When the service sector expands, measures to improve efficiency will be of increasing importance for achieving a higher degree of productivity of the economy as a whole.

Thesis No. 4
The division of labour between countries must be conceptualized not only with regard to the developing countries, but between developed countries, too. The Federal Republic will have its place somewhere in between countries like the USA with a huge domestic market and countries like Switzerland and Sweden with small domestic markets and only a few top technology products to serve the world market.

Thesis No. 5
Small- and medium-sized enterprises will play a major role in this new concept, not because of some ideological belief in market forces - maybe in spite of it -, but because the potential of an economy to search for new changes and to have a high

rate of innovation depends on the right mixture of large companies and small and medium-sized enterprises and their interaction.

These theses are based on a specific view of the problem involved, and they include a conceptual element which:

- points to the task of working out, on a medium-term basis, a concept to be agreed upon by the groups concerned with and participating in the economic process;

- raised the problem of transforming this concept into social and economic realities.

Though written in 1976 it is obvious that these have tended to be long-term goals set for German industry, and strongly pursued as technology policy by the tripartite organizations of state, industry and workers. Such types of well-formed long-term policy objectives have been a central characteristic in many developed economy countries. The contrast between this approach and that in, for example, many African countries is quite profound.

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 one of the most successful market-oriented economy - Mauritius - with its quite comprehensive three-year national development plans. The countries usually had national plans for five year periods and sometimes specific longer term development plans. 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 were not always in line with either the longer term development programmes or the actual short term policies carried out.

In developing countries, autonomy in local decision-making is reduced and the scope for actual policy implementation is limited. The situation has been worsened by the debt crisis, which again wakened 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, a new commitment to private sector development and foreign direct investment is now evident. The kind of decision-making now required is less detailed and more far-reaching.

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: this further underlines the significance of technology.

Lessons learned from African experience, that may be more generally applicable, include the following:

- 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;
- 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 within 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.[79]

The formulation of policies is an important task that goes beyond the recognition of problems and the definition of objectives. Detailed attention has to be given to the selection of instruments and the improvement of mechanisms. The whole range of tools at the disposal of governments has to be assessed for its relevance to the task. The needs and perceptions of the industrial sector itself have to have the cardinal role in determining what policies are pursued. In this connexion the following recommendations on policy formulation, drawn up in Germany in 1976 by Krupp, are worth considering as a starting point:

Recommendations on Policy Formulation

It is the main objective of the recommendations below to improve the information recording and handling capacity of public and private decision-making bodies with respect to policies of structural change.

- Improve existing mechanisms and create new ones in order to achieve anticipative and sensitive problem perceptivity in government and industry (e.g.,look-out groups, technology assessment).

- Make sure that each identified problem is being taken up by at least one competent promoter (e.g., through the coordination powers of the Ministry of Research and Technology).

- Interconnect problem perception and identification between different governmental bodies as well as between governments and industry (e.g., co-motivation in joint teams, personnel mobility, joint ventures of government and industry).

- Intensify research on techno-economic change.

- Reorganize institutions of social science in order to increase their political relevance; establish teams integrating social scientists and technologists in close contact with practical problems.

- Establish and/or strengthen social science and planning groups in all public research institutions in order to increase the general awareness of the systems implications of R&D and innovation. Exchange personnel between these groups, government and industry.

- Promote the establishment of gate keepers in industry.

- Review major government programmes periodically and take action in order to relieve committed budgets in favor of flexible smaller-scale inputs. The rate of adaptation of the research and innovation system to changing priorities may be increased.

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[79] Riddell, 1990.

4. THE MACRO-LEVEL EFFECTS OF AUTOMATION

Chapter 2 discussed the firm- or micro-level aspects of automation. The starting point was that automation as such is no target, but only a tool for a company to enforce certain business strategies. It was also emphasized that there are no immanent, pre-set effects of automation technology on issues like work organization, skill structure or employment level of the enterprise. These all depend on the manufacturing, organization and business strategies chosen by the firm. Even very disparate organizational solutions seemed to be appropriate, depending on the strategic targets and market or other business environment related issues of the company.

Thus, strictly taken, it would be false to speak of any direct effects of automation on **macro** or **national economy level** either. The macro effects are more a statistical outcome of diverse, and often conflicting, changes in institutional behaviours. These macro effects of new technology diffusion have, however, been a major concern in all developed countries for a long time. Especially the labour market, employment, skill requirement and regional effects have been under extensive study and discussion ever since the first applications of microelectronic technologies became widely available. Negative employment effects are also one of the main obstacles for more active technology diffusion policies in developing countries.

So far, the vast body of research has not been able to produce any very consistent results. The research findings are often very contradictory, depending both on the methods used and on the data available.

In addition to automation impact on employment, effects on labour force training and education needs are another major question in most countries. These issues have already been touched in Chapter 2. This chapter examines - in addition to employment effects - the consequences of changing production technologies and automation on educational and training systems: what kind of new arrangements are needed to cope with technological change?

4.1 EMPLOYMENT EFFECTS

Employment effects of new production technologies have been studied at various levels, for example:

- at the level of **single technologies** (effects of one type of machinery on the direct labour needs);
- at the level of **the firm** (effects of technological change on labour needs in one firm, either only on the shop floor, in one single plant or in the whole firm);
- at the **sectoral level** (effects of technological change to labour needs in one industrial sector);
- or at the **national economy** level (effects of technological change on employment in the whole economy in one country).

It is actually only on the first, the simplest level, that we can speak of production technology effects only. On all the other levels various other changes enter the picture: new product designs and varieties, new organizational structures and managerial practices, economic consequences of changes in consumer preferences and market demands, economic multiplier effects etc. In the following, we briefly summarize some research results on various levels of employment effects of modern automation.

Direct effects on the production process level

The most elementary way to evaluate employment effects - growth of labour productivity achieved by using new production technologies - is to look at the possible machine level replacement effects. A very common method is to compare the amount of labour needed to reach a fixed production quantity with conventional and new technology. Theoretically, the effects of technology diffusion on the national economy level would then be easy to calculate.

For NC tools a common productivity effect estimate is that one NC machine tool is able to replace approximately two workers. Thus one man with one NC machine tool would be as productive as three men with conventional machinery. So, for example, the accumulated labour replacement effects of the US population of 222,356 NCMTs in 1988 would have been almost 450,000.

Similarly, it has been estimated that the replacement effects of one robot would also on average be two workers.[80] In the US case this would mean a reduction of approximately 65,200 work places by 1988, caused by a robot population of 32,600. There is, however, a wider variation in robotization effects, depending on the type of technology, products and process design.

The effects of CAD and FMS are more difficult to evaluate. CAD systems are applied to increase the productivity of various design personnel and drawers. The studies referred to above estimate that the introduction of one CAD system would decrease the labour input by on average ¾ of a worker.

The estimate is based on two assumptions: labour productivity will increase three fold, but only about one fourth of a planners/designers work time is spend in CAD work.[81] Thus, the United States stock of 210,000 CAD systems in use in 1988 would have caused a reduction of 157,500 work places.

In the case of FMS, the effects are even more complicated. The total outcome is more than the effects caused by individual FMS components - NCMTs, robots, etc. According to an IIASA inquiry, the actual implementation of FMS has, on the process level, decreased the labour input need by 50 to 80 per cent.

There are, however, remarkable country and system-wise differences. According to the IIASA survey, labour needs have decreased least in Finland (52 per cent), where both the systems and product series are small. Less flexible systems with many machines that produce very long series are the opposite examples. They may have led to reductions of hundreds of workers.

When calculated this way, the total reduction of labour force caused by the diffusion of flexible automation technologies vary between 2 and 7 per cent of the overall employment in engineering industries in the respective countries. This means, theoretically, that if production

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80 Edquist and Jacobsson, 1988.

81 *Ibid.*

volumes remain unchanged, industrial work places would be reduced quite notably, when conventional technology is replaced with programmable automation.

In practice, the estimated labour force effects are seldom realized. Neither do the production volumes nor product qualities remain unchanged. And the more comprehensive the change within the company, the more difficult it is to compare the previous situation to the new one after the introduction of new machinery.

This is especially evident in the case of FMS. FMS are practically never taken into use in static circumstances, without any changes in quantities or qualities of products manufactured or changes in the production structures and divisions of labour inside the company, within various departments.

Calculations such as this simplify the real situation even further. All indirect effects are left out of consideration. For example, the introduction of CAD is often a part of a more extensive change, where production is customized, the modernization of product variety is speeded up and the number of details to be designed is being increased. The number of plans and drawings to be done after the implementation of CAD is usually much larger than before, and the growth in the number of tasks often compensates for the growth in productivity.

Side functions are left out of consideration as well. Changes in repair, maintenance and cleaning are often important. It is, however, quite difficult to evaluate the changes in these spheres in the introductory phase, while the real needs only accentuate in later phases.

Effects on the factory levels and consequences on other departments of the company are still possible to evaluate. For example, for factory arrangement and design less people are - at least in principle - needed, while administration will be simplified. The further the move towards an integrated CIM conception, the tighter will administration and production planning be integrated in the same information system.

The most important savings in automation investments have often come from the rationalization, simplification and integration of production planning.[82]

Organizational changes bring new complexities into the picture. For example in implementing FMS the production arrangements are changed on many dimensions. Not all work done with the old machinery may move to FMS, it may move to other departments in the factory. Correspondingly, FMS is quite likely to get tasks from other units in the factory as well. Thus it is rather difficult to calculate the overall labour effects even on the level of one system. On the level of the whole factory the effects are even more complex.

Case studies may be more useful exposing the real effects of automation implementation. In a Finnish study on the implementation of a flexible cell in the manufacture of gearwheels decreased the workforce by one, and another had to take unpaid leave for a while. The introduction of FMS in the manufacture of gearwheels decreased the workforce by five with an additional two for unpaid leave. In two years since the implementation, the work force had continued to diminish and by the autumn of 1989 the overall decrease reached approximately 50 per cent of the original work force within the unit. Again, this study dealt only with the effects on a single production process level, the effects of e.g. changed division of labour within the plant were left out, as were the effects on all other departments of the factory.[83]

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82 Ollus *et al.*, 1990.

83 Seppälä *et al.*, 1988.

New jobs created by changes in new production technologies

Flexible automation equipment not only decreases the need of labour. It also creates new jobs. A new workforce is needed to plan, produce, install and maintain the equipment and systems. In this respect, there are significant differences between the different technologies and equipment.

NCMTs are basically rather "old technology". The production of new NCMTs mainly replaces the manufacture of older machinery. Thus NCMT manufacture does not really create new jobs, it rather replaces old. The case of robots is different: they replace workers, not old machinery. Correspondingly their manufacture is not replacing the manufacture of older machinery, but it is a completely new branch of industry.

According to one evaluation, there are about 0.32 new jobs created by robot manufacture in the United States in relation to every deleted work place in the USA.[84]

Basically, the manufacture and design of FMC and FMS are also creating new jobs. In addition to the manufacture and delivery of FMS and their components, maintenance and implementation are creating new jobs. Flexible manufacturing systems are technically complex, and many large systems have functioning problems still many years after the implementation. Problems in running the systems increase the need for maintenance work, and they also delay the decrease in the number of production workers.

Employment effects on sectoral and national economy level

In the long run technological development has been the main originator of economic development, productivity growth and new jobs. The short run consequences are a much more complex phenomenon. The diffusion and ways of using technology depend on company decisions, but economic structures and mechanisms affect both the conditions in which technology is applied and the consequences at the level of the whole national economy. Political factors both control the ways of using technology and the effects of it.

The further we move from the direct firm level effects, the more uncertain the forecasts and evaluations become. It was already mentioned above in a study on the effects in one firm, all aspects have to be taken into account. There are

- the effects in the departments where new technology is employed,
- changes in departments and production sites that are not directly touched by new technology. Long term changes have also to be included: how sophisticated in use the new production process will be, and how the so-called everyday rationalizations and learning by doing smoothens the production and causes raises in productivity.

Changes like this are especially important in complex technological renewals, such as implementing an FMS, or making radical changes in a comprehensive process such as an industrial production control system.

On the national economy level there are many issues that have to be to be taken into account, in addition to the direct economic and technological relations: [85]

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[84] Hunt, 1983.

[85] Ulrich, 1982.

- Structural changes in the end product markets caused by births, changes and deaths of products;
- Changes in the intermediate (and end) product markets caused by alterations in the input-output relations within the production chain;
- changes caused by substitutions in raw materials, intermediates and sources of energy;
- effects mediated through economic mechanisms to the firms and branches, where the technology in question is not employed at all;
- changes in international economic relations caused by technical development;
- changes in societal, political and other institutional conditions as well as in supportive measures taken by public bodies.

Thus, when evaluating the employment effects of technological change, many issues have to be considered. Job losses in one firm, one branch or one region can be more or less compensated by jobs created elsewhere in the system. Theoretical calculations on the employment effects of individual technical appliances do not reveal much anything about the real effects, and case studies on individual firms are not easy to generalize from.

On the other hand, the cause-effect chains are not one-sided. The employment situation also affects the implementation of technology. In developed countries, high unemployment often retards investments in labour-saving new technologies. This is caused by issues such as labour union resistance and governmental fear of growing unemployment.

The effects of automation on various industrial sectors has often been evaluated with technologies as the starting point: how much the diffusion of flexible automation could increase productivity in a given sector. A German study from 1990 can serve as an example (Table 4.1).[86]

In this study, the employment effects of automation and other new technologies are assessed through the possibilities of increased productivity in various sectors. Technologies increase productivity through various mechanisms:

- Automation of production processes usually increases productivity directly;
- New production technologies save labour by reducing interruptions in the production process and making quality control more reliable;
- Some sectors are already so extensively automated, that further progress is difficult in the medium term;
- New technologies facilitate organizational changes which increase productivity; e.g. some service/assembly activities may be passed to customers or deliverers;
- New technologies offer possibilities to take advantage of increasing returns to scale either by allowing the production of larger lots, or by favouring concentration;
- In some sectors the achievement of further scale-effects is difficult because of the already advanced level of automation diffusion;
- In many sectors, automation promotes flexibility, through which firms can obtain economies of scale though economies of scope;
- New technologies reinforce dynamic competition, and thus create pressure for process innovations in sectors unable to gain competitiveness by product innovations.

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86 Blazejczak, 1991.

Firms not able to cope with the rate of technological change are forced out of the market. In these sectors, the average level of productivity increases.

Table 4.1 gives the assessment of employment substitution in different industrial sectors in Germany. The possibilities in other countries depend, of course, on the level of automation reached, and thus the figures even for other developed countries might look quite different.

Table 4.1 Employment effects of automation by industrial sector

Industrial sector		Possibilities for employment substitution by automation		
		Direct	Indirect	Total
321	Textiles	3	3	6
(35)	Chemical industry	3	3	6
369	Fine ceramics	3	3	6
382	Machinery	3	3	6
383	Computers, office machinery	3	3	6
383	Electrical goods	3	3	6
384	Road vehicles	3	3	6
384	Air- & spacecraft	3	3	6
385	Precision and optical instruments	3	3	6
(37)	Drawing & rolling mills	3	2.5	5.5
(37)	Foundries	3	2.5	5.5
371	Iron and steel	2.5	3	5.5
361	Stones and clay	2.5	3	5.5
311	Food	2.5	3	5.5
355	Rubber	2.5	3	5.5
362	Glass	2.5	3	5.5
372	Non-ferrous metal products	2.5	3	5.5
356	Plastic	2.5	3	5.5
(33)	Wood processing	3	2	5
341	Paper processing	3	2	5
(37)	Structural metal production, rolling stock	2.5	2.5	5
381	Tools and finished metal goods production	2.5	2.5	5
384	Shipbuilding	2.5	2.5	5
389	Musical instruments, toys, sports goods etc.	2.5	2.5	5
322	Wearing apparel	2	3	5
325	Leather and footwear	2	3	5
341	Pulp and paper	2	3	5
342	Printing	3	1.5	4.5
313	Beverages	2	2.5	4.5
314	Tobacco	2	2	4
331	Millwork and wood production	2	2	4
353	Crude oil processing	1	2	3

Note: 0 = non-existent
1 = small
2 = existent
3 = large

Source: Blazejcak, 1991.

The effects of technological change on various sectors can be translated to the national economy level by using an input-output framework to break down the overall effects of technology. In an input-output framework, technological change has a number of effects. With technological change, the shares of large components of final demand change: private consumption, investment in equipment and exports increase while public consumption and investment in structures recede. This would affect sectoral production and employment figures even if the output structures of all sectors - as described by the input-output table - were to remain the same.

But technological development will also change the output structure, i.e. the shares that the sectors contribute to the final demand of each category, by bringing about either improved or completely new products:

- **private consumption** shifts towards technologically more advanced products and towards improved services.
- the introduction of technological development takes place by restructuring of the capital stock. Therefore, the structure of **investment demand** changes, while better equipment and productive systems become available in the market.
- international competitiveness improves for sectors where new production technologies are applied to produce advanced products.

As a consequence of shifts in sectoral production caused by shifts in final demand, deliveries of intermediate goods change as well. This effect can be formally evaluated with the static I/O model.

In addition, product and process innovations in supplying and receiving sectors generate changes in relations between industries.

When new production technologies are applied in a dynamic and growing economy, they are actually advancing employment. If they are applied in a retarding and static economy, they will lead to labour replacement and growing unemployment.

This is also confirmed by many calculations on the national economy level effects of modern production technologies: the employment effects of technological change are actually outcomes of complex economic mechanisms, where technological change can as well promote the growth as decrease of employment, depending on the total development.

In the latter situation, would it then be more reasonable not to introduce new production technologies? Generally, the situation would only worsen: by lagging behind in productivity, efficiency and product quality, the national industries would only be wiped out of the international competitive picture. Here a study made on Taiwan Province, a developing economy successful in raising the technological level of production can serve as an example.

An econometric study on technological change and labour absorption in Taiwan Province between 1952 and 1986 indicates that growth of employment in Taiwan Province was determined, in descending order of importance by:

- the output expansion on the domestic market,
- the growth of exports, and
- the increase in the growth rate of capital investment.

Employment reduction effects due to technological change have been relatively insignificant, and overcompensated by the rapid growth of total output and increase in capital investment. Chow continues:

"Hence, despite the moderate increase in the capital/labour ratio in overall production, labour employment continued to increase. It is interesting to note that the substitution effect of technological progress was much stronger in non-farm employment than in total employment. This implies that the industrial and service sectors were more influenced by rapid technological progress than was the agricultural sector."[87]

The reorientation of the development strategy in the mid-1960s towards export promotion caused a structural shift in the total labour employment and also had an indirect effect on accelerating technological progress and capital accumulation. Thus its export-promotion strategy has generally been considered as the primary factor contributing to the structural shift of labour employment in Taiwan. However, Chow argues that:

"... In the long run, the growth of non-export output has a stronger impact on labour absorption than did export growth. This result bears important policy implications for Taiwan as well as for other developing countries. Even though an export-promotion strategy had many advantages over one of import-substitution, a successful labour absorption strategy in developing countries ultimately cannot ignore the expansion of domestic market demand. In view of the raising international protectionism in the 1980s, the policy makers in today's developing countries need to emphasize both domestic and foreign markets in order to maintain full employment in the long run.

Given that for labour employment the output expansion effect is much stronger than the substitution effect, a policy that emphasizes technology-intensive methods of production in the export-oriented industries would not necessarily increase future unemployment. Thus, policy makers in developing countries need to focus also on structural unemployment and to implement appropriate manpower policies that are conducive to upgrading the industrial structure rather than only concerning themselves with probable unemployment caused by technological advancement." [88]

The discussion on employment effects of advanced production technologies can be concluded:

In the short run, introducing flexible automation and other new production technologies can have either negative or positive employment effects, depending on economic situation of the firm and the country and on the way technology is implemented and managed.

In the long run, withdrawal from utilizing modern production technology only cause negative employment effects.

4.2 EFFECTS ON LABOUR FORCE COMPOSITION

The effects of advanced production technologies on the structure of the labour force may be even more important than the overall employment effects. These include changes in the occupational, skills and educational structures of the labour force. The skills issues have already been touched from the individual firms point of view in Chapter 2; in this section, the concentration is more on the

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87 Chow, 1990.

88 *Ibid.*

educational/training effects and conditions of flexible automation and other advanced production technologies. However, occupational and skill changes are behind all new educational and training needs.

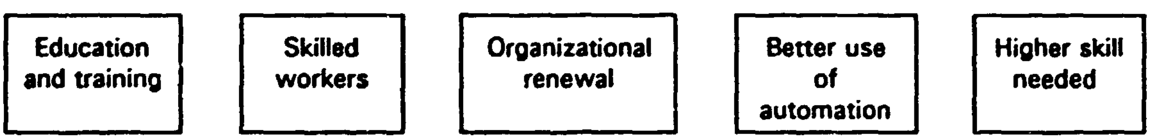
It is a relatively common belief that automation will lead to a gradual transformation of employment structures on the national level. There are several trends involved. In occupational terms, the basic tendency seems to be a shift from manual to mental work - an increase in indirect production/support work tasks and a decrease in direct, physical work. This is documented by both national and individual enterprise employment data. In terms of occupations, there has been a general shift from industrial occupations to service and further to information occupations.

A second observation is that automation is causing changes in skill requirements both in existing work and, in particular, in the new jobs created. Productive qualifications - practical skills - have to be complemented by more theoretical skills, technological and scientific knowledge. Even in practical terms, multidisciplinary skills are required to a growing extent. In addition, as mentioned in Chapter 2, normative skills - motivation, commitment and cultural coherence - as well as innovative qualifications become more important.

The skill changes are linked to an organizational transformation. The traditional work organization, characterized by specialization, fragmentation and narrowly-defined work tasks gives way to flow-oriented work organizations with less division of tasks, and work carried our by teams of workers with broads, multi-disciplinary skills. Identification of this trend is based on, as discussed in Chapter 2, the empirical experience that the use of modern technology - and the efficiency with which it has been used - depends very much on user skills and management objectives in applying the technology.

Consequently, the possibilities of implementing new work organizations depend on the supply of a skilled workforce. If there are not enough skilled workers available, the company has to rely on more traditional division of tasks, with an important share of unskilled workers just overseeing and serving the machinery, while skilled programmers do the programming and supervisors are needed to clear all more complicated situations.

There seems to be a circular relationship between skills and use of automation: with better skilled people, new organizational forms can be applied and technologies used more effectively. Then again, by developing team cooperation and through learning by using technologies, skills are developed further, the technological system can be refined and new benefits be reaped from it.



Occupational and skill changes of individual technologies

The occupational effects of the technologies relevant in this study - NCMTs, CAD, Industrial Robots and FMS - are quite disparate. Industrial robots are perhaps the only technology clearly diminishing the number of skilled workers. They will be usually replaced operators with varying skills, and more trained programmers. However, even in the case of robots broader occupational descriptions can be applied.

NCMTs have more effects in terms of skills than of occupations. They may be operated both by operators with conventional machining skills trained to programming, or by personnel divided into skilled programmers and relatively unskilled machine operators. The more complicated the use of the tools, the more likely it is that the operators need good qualifications both in traditional machining and in programming.

The use of FMS especially has also led to a considerable coming together of skills traditionally defined as direct (blue collar) and indirect (white collar). This has taken place almost independent of the organizational strategy employed by the company: generally, when the company becoming more computer driven white collar workers are becoming more involved with shopfloor work than before.

The introduction of CAD can also have widespread effects on occupations. The effects of CAD on occupational structure have been assessed as follows: [89]

(a) The proportion of parts (detail) draughtsmen tends to decline while fully qualified draughts men and designers strengthen their position;

(b) The recruitment of supporting staff for hardware and software maintenance and development (e.g. system analysts, mathematicians, parts programmers, computer operators) increases. These occupations may be new in design offices but, with the exception of the parts programmer, are not new occupations as such;

(c) In technical and design offices where strict hierarchical divisions prevail instead of a more integrated, team-work approach, the lower categories (e.g. junior draughtsmen) are threatened by redundancy;

(d) The content of occupations in design and production planning tends to change through job enrichment while many "new" occupations are specializations of existing ones, e.g. CAD coordination and data teleprocessing programming. Some functions such as tracing and filing disappear;

(e) There is a tendency for design office staff to be recruited at a higher educational level than in the past (e.g. technical engineering diploma for design positions instead of secondary school diploma or draughtsman apprenticeship certificate) and the use of CAD tends to enhance their status;

(f) CAD is generally considered a new and efficient tool since it relieves its users of much routine work, but the consequent change in working practices is not very significant since there is no change in the sequence of tasks, the same basic knowledge requirements prevail and CAD software generally uses the same working procedures with which draughtsmen are familiar from the drawing board. A basic understanding of computer technology is generally considered to be just an additional knowledge requirement.

In addition to shop floor level occupational changes related to flexible production technologies, there are also comprehensive changes on the level of an entire firm. A notable change is the growing need for highly skilled personnel, e.g. technicians and engineers with university education.

The PSI referred to earlier, notes in the United Kingdom context the need for highly skilled personnel. The firms surveyed complain that even if the training had markedly increased, the supply was not keeping pace with demand:

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89 Ebel and Ulrich, 1987.

"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 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.

Profound changes in the types of workers and the levels of skills they employ can be expected in those countries and companies wishing to make effective use of advanced automation technologies. Nordic countries are quite good examples of this. For example in Sweden the share of workers with graduate levels in companies adopting FMS increased from just under 3 per cent of the workforce in 1981 to approximately 10 per cent in 1986.

In Finland, where flexible automation has spread quite rapidly during the 1980s, there was a clear shift within the engineering industries towards occupational groups with higher basic education. The technical occupational groups that diminished and increased most in the late 1970s and in the early 1980s are shown in table 4.2. Growth has moved from basic shop floor jobs to more educated occupations.

This shift is based partly on shop floor changes, partly on changes in the supply of educated labour force. Generally, countries showing good results in technological innovations and technology adoption have invested remarkably on educational development for a long time. This is evident both in e.g. the Nordic countries (table 4.3) and in Japan or the East Asian NICs.

Table 4.2 Technical occupations diminished and increased most in the Finnish engineering industries between from 1975 to 1980 and from 1980 to 1985

(a) Occupations increased most from 1975 to 1980	(b) Occupations increased most from 1980 to 1985
Machinists Toolmakers Welders Teletechnicians	Machine technicians Teletechnicians Mechanical Engineers Computer specialists

(c) Occupations diminished most from 1975 to 1980	(d) Occupations diminished most from 1980 to 1985
Miscellaneous work Mechanics Assembly line workers Electrical technicians	Machinists Assembly line workers Welders Unskilled workers

Source: Vuorinen, 1991.

Table 4.3 Participation in education in 1987, by level of education (per cent share of the relevant age group)

Area	Year	Educational level (ISCED classification/UNESCO)		
		First	Second	Third
World	1987	99.6	48.6	12.6
Europe	1987	103.0	89.4	25.2
Denmark	1986	99.0	107.0	29.6
Finland	1987	101.0	106.0	37.6
Norway	1986	95.0	95.0	32.9
Sweden	1987	100.0	91.0	31.2

Source: Haavio, 1990.

Japan is another interesting case of long-term technological development largely based on extensive investment on training and education. There the absolute number of young people acquiring secondary and higher levels of education is among the highest in the world. In addition to this, the scale and quality of industrial training carried out mainly at enterprise level is also 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.[90]

> "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 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." [91]

The Japanese example highlights the importance of not only extensive and high quality education, but also the need to have training closely linked to industry. In this sense the German system of vocational training is also a good example. Germany is another country - in addition to Japan and Nordic countries - where the skill based model of flexible automation is applied to a growing extent.

The German system for vocational education is based on apprenticeship contracts, where the trainees learn the work in a firm in real industrial milieu, and then acquire theoretical learning in school environment. The advantage of this system is the living contact to real industrial work and the interaction of theoretical and practical learning.

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90 Freeman, 1988.

91 *Ibid.*

The German dual system of vocational training is often held up as the model for a pervasive diffusion of enriched skills as well as technical change. In addition to good interaction between theory and practice, every institutionalized system must assure its continuity. In e.g. France, upgrading of basic vocational training more of less automatically involves training for the CAP (certificate d'aptitude professionelle) while in Germany this occurs within the dual system. In both cases, there are proposals for making increased use of general qualifications as well as improving them. In developing their systems for vocational education Germany and France have the same: there is a necessity to intertwine training on the job and in the classroom more frequently and systematically.[92]

Recently the tenuous contact with the reality of industrial work has often been assessed as one of the main weaknesses in the Nordic systems of vocational education. This has led to reforms in the Nordic vocational education systems, where features of the German apprenticeship system are introduced to them.[93] There are two basic reasons for this:

- theoretical learning without real connection to practical applications is often not learned well enough and will be lost;
- trainees that have chosen the vocational line of education often lose their motivation in too 'schoollike' studying.

However, educational and training systems are the basic condition for successful technological development. A UN/ECE report notes on the French perspectives of education and training needs raised by advanced automation:

> "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.[94] 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 the planning of education in such a way, that it can answer to the needs of future working life becomes critical for all countries trying to reach higher levels of technological development. This is true for both the secondary vocational education as for higher scientific and technological education. An example of a model for long term educational planing based on changing manpower skill needs is presented in Figure 4.1.

For example, in Taiwan Province a similar model for educational planning has been used since 1966 relatively successfully. Educational planning is based on Manpower Development Plans (MDP) renewed every third of fourth year. The plans are highly normative, including e.g. targets

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92 Sorge, 1990.

93 See e.g. Ekola *et al.*, 1991.

94 ECE, 1985.

to keep unemployment under 4 per cent and reduce the share of agricultural employment and increasing it in industry and services.

Figure 4.1   A manpower based model of education planning

DEMOGRAPHIC DEVELOPMENT
- Size of population
- Age structure
- Initial training

DEVELOPMENT OF WORKING LIFE
- Changes in occupation structure by industrial sector
- Labour need
- Exit and mobility
- Need for labour force and trained workers
- Placement of diploma and degree holders
- Participation of diploma and degree holders in working life
- Unemployment of diploma and degree holders

EDUCATION NEED
- Need for young people's education and training by education
- Need for adult education and training by occupation
- Educational needs by types of training

OTHER FACTORS
- Prevalent views concerning educational policy
- Other, e.g. cultural policy aspects
- Separate surveys and studies
- Other expert information

QUANTITATIVE OBJECTIVES FOR EDUCATION
Overall objectives:
Young people's education and training
Adult education and training
Initial and re-training
Post-degree and post-diploma education and training
Further education and training
Other objectives

EDUCATION SYSTEM
Legislation
Administration
Planning
New Students and educational output
Graduation/drop out ratio
Continued studies (Multiple education)
Planning and acquisition of information
Financing
Other factors

<u>Source</u>:   Haavio, 1990.

A specific feature in Taiwanese educational development is the high emphasis on vocational education. The ratio of general to vocational education between 1963 and 1986 has changed from 60:40 to 31:69.[95] The ratio in developed countries is on average 50:50, and in developing countries 90:10, which generally is too low to supply skills for any advanced industrial development.[96] East Asian NICs have put a high priority on developing the vocational line of education.

However, the formal educational system is not enough. The need to upgrade skills of people already in working life is as pressing. In a rapidly changing technological environment several million people will actually need retraining and further training to cope with the demands. 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. This is done widely in the countries mentioned above - the Nordic countries, Japan, and Germany - where human resource development and the role of technology users has been seen as a critical factor in manufacturing success.

In recent educational plans, adult education, further education and retraining has been taken as a major emphasis in these countries. The concept of "continuous education' or 'lifelong education" is widely seen as a basic theme in all education and training development, even from the point of view of vocational training.

The same issues is also taken up in many surveys on technical change. The authors of a review of mechatronics (the combination of mechanical and electronics equipme[illegible] Europe 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."

> "Not only is there a need for higher levels of skill but also for greater breadth and flexibility to move between and across skill boundaries." [97]
>
> "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." [98]

Long-term strategies have to be adopted, and for developing countries this will mean in many instances 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

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95 Woo, 1991.

96 Salam and Kidwai, 1991.

97 Senker, 1983.

98 Bessant and Haywood, 1991.

place social systems which have created skilled, educated workforces capable of moving along consensus lines to highly developed economies. Changes in learning and skills are essential and this is only possible with a fully developed educational system at all levels, including vocational and adult education.

- Mastering technical change implies, to a large extent, mastering the generation of skills and knowledge, i.e. vocational education and training.
- The key role of vocational education and training is closely connected with the organization of work. We should be more concerned with the organizational requirements from generating and utilizing skills than with their technical causes.
- Mastering technical change through skilling raises the problem not only of individual but also collective skills. Differentiated specialist skills have to be integrated. This requires an organization and a strategy based on team work, cooperation and altering task descriptions.[99]

For smaller firms, supportive networks ought to be developed to make training, specialist human resources, consultancy, development, marketing and other services more available to them. This is required in order to assist them in turning their asset of organizational flexibility to more effective use, in the prevailing context of technical change. Relations between companies or other units and their environment are increasingly characterized by greater interdependence, as discussed earlier in Chapter 2.

Further training appears as a new, strategically important element in companies. It poses acute problems to small and medium-sized companies, which can only be solved through supportive networks.

Thus, a concept of skill-based production where continuous training and flexible automation are combined needs a total approach. In conclusion, the approach has to include:

The development of coordinated skills;
Design and re-design for manufacture;
A joint technological/organizational approach to change;
Closely coordinated buyer/supplier relationships;
Allocating to the computer what it is best at;
Allocating to people what they are best at.

99 Sorge, 1990.

5. NATIONAL DIFFERENCES IN TECHNOLOGICAL DEVELOPMENT

5.1 FROM TECHNOLOGY TRANSFER TO TECHNOLOGICAL DEVELOPMENT

Reference has been made to the complex nature of technological change. From the developing countries' point of view, technological development may sometimes be seen as a matter of technology transfer. However, it is not a simple question of transferring technology, but an outcome of many interrelated issues. As such, transfer of technology should not be a plain act of implanting a piece of technology only. It should be a diffusion process, where innovative aspects are always involved - even in the case of relatively simple technologies.

This is true in relation to automation and other production technologies as well. They cannot be isolated from overall technological change. New production technologies are successfully transferred only when they create a cumulative process of technological development. This is conditioned by the factors creating the dynamics of the national innovation and production system.

Thus the issues in creating the ability to carry out a successful technology transfer process are many. By successful transfer is meant here a process that does not end when the transplanted technology is introduced into the new context, but a process that continues, develops further in use and diffuses into other companies and organizations in the receiver country. Successful technology transfer is a means to continuous and sustainable technological renewal, not a target in itself. This should be a self evident starting point in all technology transfer projects.

The importance of various infrastructure issues to technological development have already been discussed. The present chapter takes a somewhat deeper look at the national differences - the institutional, organizational, cultural and policy related issues - conditioning the possibilities for using automation and technological development even more generally.

National development models

When new technologies are taken into use in disparate countries, they are also introduced into dissimilar economic, institutional and historical environments. The firms that are utilizing the new technologies operate in these national institutional settings. In this context, among the main questions to be considered are: What is the influence of the institutional and historical scene in adapting flexible automation and other new production technologies? What might be the characteristics of successful national models for adoption of new technology? And further: can a successful national model be transferred into another cultural environment, so that it could serve as a framework for technological change?

For example, it has been argued that the competitiveness of a nation depends on the capacity to innovate and upgrade the products, manufacturing technologies, marketing methods and services of its industry. The competitive success depends on national values, culture and other institutional factors. Among the attributes of a nation that constitute the determinants of national competitive advantage are the supply of skilled labour, strong domestic competition, aggressive home-based suppliers and demanding local customers.[99]

Thus national differences are put among the most important factors in determining the capacity of the industry to innovate and upgrade. The above conclusions were drawn from the situation in developed countries, but it is safe to assume that these culturally determined issues are even more important in developing countries. It seems to be a plausible hypothesis that country specific factors also play an important role in the adoption and use of integrative automation technologies. These technologies are used to enhance flexibility and productivity, upgrading the manufacturing capacity.

Engineers, R&D managers and other professionals of technology have traditionally shown rather limited interest in the institutional and cultural issues involved in technological renewal. Development, adaption and transfer of technology are usually seen as narrowly defined, relatively simple processes determined by technical rationality. However, attitudes are changing. A major reason behind this new, broader concern seems to be the remarkable performance of Japanese industry during the last decades. The Japanese success cannot be explained with technological and economic aspects only. It arises from a cultural, historical and institutional background obviously very different to the Western market economies.

Japan's success has led to an enormous number of studies on the cultural and historical features specific to the Japanese economy. And, indeed, to understand better the reasons behind the Japanese achievements, a deeper understanding of the society, the cultural background and the institutional settings is necessary. This is also the main message in the MIT report "Made in America: Regaining the Productive Edge".[100] The MIT report emphasizes the role of cultural issues and institutional dynamics when looking for an explanation to the differences in the development of the American and the Japanese industries. Similar studies of Japan have also been done from the European point of view.[101]

Technological development itself is an extremely complex process. The incentives for technological innovations come on one hand from the changes in the market and the global economy, and on the other hand from technological inventions. New technologies are, however, applied by economic agents active in pre-existing national institutions. Thus the use and applications of new technology in economic activity are deeply rooted in the national institutional context.[102] In countries with a shorter history of technological and scientific development, the difficulties in combining national institutions, political practices and cultural traditions with more technological thinking are likely to be even more complicated than in countries with a long history of technological development.

In discussing the most developed manufacturing technologies, the problems multiply. Computer Integrated Manufacturing (CIM), in its full sense, is not just an improved methodology for carrying out conventional manufacturing. It is a wholly new approach to the operation of manufacturing in its entirety. It is a new manufacturing "philosophy", changing both the

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99 Porter, 1990.

100 Dertouzos, *et al.*, 1989.

101 See e.g. Freeman, 1987.

102 Dosi, *et al.*, 1988.

technological approaches to products and processes and the managerial approaches to the operation of manufacturing enterprises.[103]

The technical facilities for CIM - CAD, NCMTs, Industrial Robots, computers for production control etc. - are available world wide. Many studies comparing their diffusion in developed countries, however, show that the pace and scope of adoption of these technologies is different in different companies and countries.

The most striking country specific differences could be expected to be found in the development of new manufacturing systems that combine these technologies with managerial and human oriented approaches. Terms like "orgware" and "social software" are sometimes used to describe this synthesis of technical, organizational and human consideration.[104]

This means that no general and common to all pattern for diffusion of CIM technologies and flexible automation exists. The technologies are nationally introduced in various fashions for many reasons. Institutional, nationally specific settings involve at least the following issues:

- Relations to the international market and the openness of the economy define the urgency to cope with global changes;
- Production structures (by industrial sector, by firm and plant size) - set up many framework conditions for the needs and possibilities for introducing new technologies;
- Productive linkages (relations between users and producers of technologies, subcontractor linkages, etc.) create the basic institutional dynamics necessary for domestic technological development;
- Labour market factors (supply of skilled labour, the structure of education and training institutions and labour market relations between employer and employee organizations) define the start up situation for introducing new technologies.

Thus the institutional set up in a country for introducing new manufacturing technologies varies considerably. But are the models for technological development transferable? When discussing CIM technologies, the Japanese experience has usually been taken as an example for successful introduction. Many aspects of the Japanese model have diffused quite widely to other industrialized countries. The institutional solutions are, however, usually different and even the actual patterns for change are - in spite of the formal resemblances between methods used - often by content very dissimilar to the model.

The need for a broad socio-economic strategy for technological development is emphasized e.g. by the OECD report "New Technologies in the 1990's".[105] When analyzing the success in adaption of new technologies, the report identifies cultural and institutional differences as a main explanation to the national differences between various OECD countries when using similar

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103 Merchant, 1989.

104 OECD, 1988.

105 *Ibid.*

technologies. The transformation of potential productivity gains inherent in new technologies to actual ones is a complex process. It is a process of social adjustment involving training, reskilling, development of new managerial practices and new organizational structures in addition to new patterns of workforce collaboration and other institutional changes. Therefore comprehensive national strategies with a set of interrelated policies including social and institutional changes on all societal levels is needed.

The OECD report emphasizes that an "active society" - where all members have the skills to make use of the technological possibilities, is taken as a target, changes in the national systems for education and training will have a critical role in the strategies. Education combined with in-plant training in industrial companies is the key item, also in order to gain full benefits from the technical and economic potential of new technology. This is true not only in regard to the "active society" aim; it seems to be highly necessary even for reaching more modest targets of gaining the full benefits from the new production technologies.

The OECD report points out that the Japanese and Nordic models have some issues in common on the policy level. They both have an intense process of workforce involvement and consultation together with extensive training and retraining. This is a clear difference in relation to, for instance, the United Kingdom model of applying new manufacturing technologies.

5.2 THE INSTITUTIONAL SET UP

What could then be the relevant issues to compare technological development models in various countries? Edquist (1988), while explaining the differences of technology diffusion between Sweden and other countries, touches many important aspects. Based on his list, the following issues can be taken up:

- The structure of industry. Are the products in Sweden more suited for flexible automation than in some other countries? Is it of great importance for instance, whether or not the country has a developed car industry?

- Does the rate of automation diffusion depend on the variation of relative factor prices -e.g. the wage levels - between countries?

- Is it important that regional wage differentials are much lower in Nordic countries than for example in the USA? A company in Detroit can move production to Missouri as an alternative to automation.

- What is the role of trade openness and the size of the local market? For example, the large Swedish engineering companies have to emphasize export production. Does this force them to invest more in new production technology?

- Is the organization of production more flexible in Sweden than in other countries? Are the organizational structures "flatter" and is this facilitating - or even forcing towards more - automation?

- Is the fact that unemployment is lower in Sweden - as in Japan - connected with the introduction of new technology? Does low unemployment lead to a shortage of certain types of labour which encourages the rapid diffusion of technology? And, conversely, does high unemployment lead to reduced incentives for, or greater resistance against, the introduction of new technology?

- Do the attitudes and degrees of influence of employees and unions play an important role? In Nordic countries employees are involved in introducing new technologies usually from the beginning, and the trade union attitudes towards technological development are positive.

- Have Sweden and Japan more effective systems for research and development and general diffusion of information on new technology than other countries?

- Has a shortage of financial resources led to limited access to new technology in a number of countries?

- Have official technology policies for the stimulation of the diffusion of new technologies been more comprehensive and/or effective in Sweden and Japan than in other countries?

- Are shortages of know-how and educated labour less significant obstacles to technology diffusion in Japan and Sweden?

Edquist concludes that it is very difficult to point out any single factor as the most important. It is a combination of all these aspects, a complex social phenomenon. Thus he actually emphasizes the role of complex national development models: the techno-economic development models in Japan and Sweden, as in other Nordic countries, seem to have been more successful than the model adopted e.g. in the United Kingdom. The success can be measured on most every dimension of technological and economic development during the last 50 years.

But can a model be relocated to a new national environment? Experiences from attempts to transplant the features of e.g. the Japanese model elsewhere accentuate the need for a broader understanding of the historical and institutional differences. Many Japanese ideas (e.g. total quality control) have not proved out to be altogether as successful when introduced on their own into foreign surroundings. The results are usually rather modest (less effective, lower productivity gains etc.) in comparison to the Japanese equivalents. On the other hand there are examples of plants in the United States and in Europe owned by Japanese companies which are more effective than locally owned plants with similar technologies.

A plausible explanation of these contradictory findings has been given in an analysis of introducing new technologies in Sweden.[106] It has been argued that whole models for technological development cannot be exported, but elements of models can be transferred and assimilated. Characteristics of the national model deeply rooted in the cultural and political institutions - like union strength or loyalty to the employer firm - cannot be exported. Specific elements - like JIT philosophy - may, however, be transferred and implanted into the new environments if the pre-existing institutional and cultural issues are well taken into consideration. Hence they state that different models cannot be placed in the same basket. Thus, for example, the Swedish approach to new technologies is not a variant of the Japanese one or *vice versa*.

Most studies on national development models and CIM technologies concentrate on developed countries. To go deeper into the discussion from the national development point of view, some features in the development models of Japan, the neighbouring East Asian counties and some other developing countries are now examined.

106 Edquist and Glimell, 1989.

5.3 JAPAN AND NICs: SUCCESSFUL MODELS FOR TECHNOLOGICAL DEVELOPMENT

Japan and the East Asian NICs are usually taken as examples of a successful, technology driven path from underdeveloped to industrialized countries. Japan has served as a model to the NICs (Republic of Korea, Province of Taiwan, Hong Kong and Singapore), which have partly taken features from the Japanese pattern, but adapted them to their own economic, cultural, political and technological histories and practices. There is also relatively active interaction between Japan and NICs; in fact, Japan has given many initial impulses for developing various industries in the four countries.

The regional development model has continued further to the four ASEAN countries (the Philippines, Thailand, Indonesia, Malaysia), that now seem to be following the NICs development path. And again, Japan and the NICs have given initial impulses to development in these countries by e.g. transferring labour-intensive industries to them. Also, their national development models have assimilated some features of these countries.

Thus East Asia gives a very interesting comparative environment: in relatively near proximity, countries on all development levels can be found. In fact Asian countries have been classified on the basis of their industrial development stage from (1) early industries, (2) middle industries, (3) late industries and (4) fourth industrial revolution (FIR) stage industries (Table 5.1.). All stages except early industries - represented in the Asia Pacific region by countries like Bangladesh and some Pacific islands - are present. In this respect, the region clearly differs from other developing areas. There are successful examples to follow, on all stages of development, and within all sizes of countries.

Table 5.1 Asian countries by stage of industrial development, 1984 and estimate for 2000

Country	Stage of Industrial development	
	1984	2000
China	Early to middle stage	Late stage
Indonesia	Early to middle stage	Late stage
Philippines	Middle stage	Late stage
Thailand	Middle stage	Late to FIR stage
Malaysia	Middle to late stage	FIR stage
Republic of Korea	Late stage	FIR stage
Taiwan Province	Late stage	FIR stage
Hong Kong	Late to FIR stage	FIR stage
Singapore	Late to FIR stage	FIR stage
Japan	FIR stage	FIR stage

Source: Lee *et al.*, 1988.

The case of Japan

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.[107]

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: a 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, centered in the role of the Ministry for International Trade and Industry (MITI), is a second important point.

> "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".[108]

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".[109]

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:

- 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.

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107 Freeman, 1988.

108 *Ibid.*

109 Allen, 1981, Ref. Freeman, 1988.

- 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.

- 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.

- 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 "quality circles" (originally an American 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.[110]

This experience contrasts with that of the former Soviet Union, and on the other hand that 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.[111]

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".[112]

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110 Freeman, 1988.

111 *Ibid.*

112 Goto, 1982, ref. Freeman, 1988.

The final, but not least important features of the Japanese innovation system, are 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 United States by 1973[113] - 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 of 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 already had extensive high level technical training before the First World War.[114]

> "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 flexibility and adaptability in the workforce and high quality standards. The Japanese system of industrial 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 workforce and not only at top management level".[115]

The story of Japanese development model highlights the importance 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.

5.4 JAPAN, NICs AND THE ASEAN FOUR: SOME REGIONAL DEVELOPMENT PATTERNS

The four NICs (Republic of Korea, Taiwan Province, Hong Kong, Singapore) have shown remarkable economic growth and technological development since the 1970s (Table 5.2). According to some classifications, they are about to break away from the category of developing countries and areas. For example, the United States does not any more give developing country status to Korean exports.

Even if their developments and institutional solutions have often followed the Japanese example, they are far from straight forward copies of the Japanese pattern. There are many fundamental differences. In policy terms, none of them has as long standing, uniform policy aimed

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113 Lemola, 1990.

114 Freeman, 1988.

115 *Ibid.*

at technological development as Japan. Even the basic conditions differ. Unlike Japan, only the Republic of Korea with a population of over 40 million has been able to rely on domestic markets. One basic thing, however, is common: none of the NICs has relied on the "natural" comparative advantages.

Table 5.2 GDP Growth rates in eight East Asian countries (per cent)

Country	1986	1987	1988	1989	1990	1991
The NICs						
Singapore	1.8	9.4	11.1	9.2	8.3	6.8
Hong Kong	11.9	13.9	7.9	2.3	2.4	3.7
Taiwan Province	11.6	12.3	7.3	7.3	5.2	6.2
Republic of Korea	12.4	12.0	11.5	6.8	9.0	8.0
The ASEAN four						
Malaysia	1.2	5.2	8.9	8.8	10.0	8.0
Thailand	4.5	9.5	13.2	12.0	10.0	8.2
Indonesia	5.9	4.9	5.7	7.4	7.1	6.1
Philippines	1.4	4.7	6.3	5.6	3.7	3.3

Source: Euromoney Supplement, September 1991.

During the 1980s the group of four ASEAN countries (Malaysia, Thailand, Indonesia and the Philippines) seem to be following the example of NICs. Their growth is partly a regional consequence of the Japanese and NICs success: labour-intensive production, that during the first phase was moved from Japan to the NICs, is now to a growing extent moving to the tigers ASEAN countries. Even if they are still basing their economic development mainly on abundant supply of cheap labour, they also have more ambitious targets towards more technology driven development.

The growth figures illustrate this development. Malaysia and Thailand especially have shown remarkable growth rates in the late 1980s, while Hong Kong and to some extent Taiwan Province of the original NICs are showing decreasing growth figures.

Changes in the sectoral breakdown (Table 5.3) portray the same development. Of the NICs, the share of industry is growing only in the Republic of Korea, while the structures are changing more towards services in the others. Of the ASEAN four, Malaysia and Thailand are showing a rapid transition from an agricultural to an industrial society. The Philippines is still, to a high extent, an agricultural country.

The role of Japan in Asian development has been emphasized in many studies. The figures for Japanese foreign investment illustrate the situation. In 1986 the eight Asian countries received roughly 9 per cent of all direct Japanese foreign investment. By 1990 the share had grown to 11.6, even though Japan during the late 1980s also remarkably increased the investments to the United States and Europe.

In 1986 the NICs were clearly the most important areas of activity for the Japanese in the Asian area. Table 5.4 shows that between 1986 and 1990, however, Japanese investments to the NIC countries had grown much more slowly than to the four ASEAN countries. Taiwan Province was still the most important target country in 1990, but is now followed by the Philippines and Malaysia.

Table 5.3 Sectoral distribution of GDP (1980/1990) in eight East Asian countries (per cent)

	Agriculture		Industry		Services	
	1980	1990	1980	1990	1980	1990
The NICSs						
Singapore	1.1	0.3	38.8	35.9	60.0	63.8
Hong Kong	0.9	n.a.	47.0	n.a.	67.2	n.a.
Taiwan Province	7.9	4.2	46.0	43.4	46.1	52.3
Republic of Korea	14.2	8.3	37.8	45.5	48.1	46.1
The ASEAN four						
Malaysia	22.9	19.4	35.8	41.7	41.3	38.9
Thailand	20.6	14.2	30.8	35.3	48.6	50.1
Indonesia	24.4	19.7	41.3	40.6	34.3	39.6
Philippines	25.6	26.9	36.2	33.0	38.3	40.1

Source: Euromoney Supplement, September 1991.

Total investments in the NIC countries have only about doubled during the four years, while the total investments to the ASEAN countries were in 1990 more than six times that high as in 1986. Investments to Singapore have actually declined, and Hong Kong figures show only a very modest growth. The relative growth of investment was highest to Indonesia. In this case, however, the starting level was very low.

The figures show an evident shift of Japanese activities towards the ASEAN countries. Simultaneously the NICs have also increased their operations in the area. On average, NIC investments to the four ASEAN countries grew by 20 per cent from 1988 to 1989. The country with highest growth in investments - 116.5 per cent from 1988 to 1989 - was the Republic of Korea; and the target country showing most growth was Malaysia with a growth of 127.7 per cent.[116]

Table 5.4 Japanese direct investment in eight Asian countries 1986 and 1990

Target Country	1986 US$ million
Taiwan Province	502
Singapore	436
Republic of Korea	302
Hong Kong	291
Malaysia	250
Thailand	158
Philippines	124
Indonesia	21
Total	2084

Target Country	1990 US$ million
Taiwan	1785
Philippines	1154
Malaysia	1105
Republic of Korea	840
Thailand	725
Hong Kong	446
Singapore	284
Indonesia	258
Total	6597

Growth 1986 - 1990
255.6%
830.6%
342.0%
178.1%
358.9%
53.3%
-34.9%
1128.6%
216.6%

Source: Euromoney Supplement, September 1991.

116 IEEE Spectrum, June 1991.

Table 5.5 reveals that Thailand and Indonesia are the most important target areas for NIC investment in Eastern Asia, even if most growth between 1988 and 1989 took place in the Philippines. Thus there seems to be a regional division: Japan is concentrating more on the Philippines and Malaysia, while NICs are targeting their activities more on Indonesia and Thailand, and to a lesser extent to Malaysia.

This is further endorsed by figures in Table 5.6 which shows, that Japanese trade with Malaysia and the Philippines is also on a higher level than with Indonesia and Thailand. However, only trade with the Philippines comes to the level of Japanese trade with NICs.

The joint share of Japan and NICs of all foreign investments to the ASEAN four varies between 41.7 per cent (Indonesia) and 72.8 per cent (Malaysia). This supports the assumption, that economic growth in Eastern Asia is, to a high degree, based on regional economic dynamics.

Many sectoral and institutional studies have documented this as well. For example, it has been noted in our earlier report that the now flourishing footwear industries in both the Republic of Korea and Taiwan Province have their origins in Japanese establishments in the respective countries. In time, Korean and Taiwanese entrepreneurs took over the business, and now they are relocating the more labour-intensive segment of the industry to the ASEAN countries, generating a rapid growth in the countries' footwear industries.[117]

Table 5.5 Direct foreign investments from the NICs to the ASEAN four in 1989 and change from 1988 to 1989

Source Country	Target country			
	Malaysia	Indonesia	Thailand	Philippines
	Investment in 1989, US$ million			
Republic of Korea	70	466	171	18
Taiwan Province	800	158	867	148
Singapore	338	166	407	24
Hong Kong	130	407	561	132
World total	3205	4719	7979	800
	Change from 1988 to 1989, in per cent			
Republic of Korea	367	123	57	800
Taiwan Province	161	-83	2	36
Singapore	118	-35	48	1100
Hong Kong	17	75	26	388
World total	78	7	28	77

Source: IEEE Spectrum, June 1991.

[117] UNIDO, 1992.

Table 5.6 Japanese trade with eight Asian countries, 1990 (US$ million)

Target Country	Exports from Japan	Imports to Japan	Balance to Japan
The NICs			
Singapore	17457.2	11706.7	5750.5
Hong Kong	15429.8	8496.2	6933.6
Taiwan Province	13071.6	2173.1	10898.5
Republic of Korea	10707.8	3571.2	7136.6
The ASEAN four			
Malaysia	9126.0	4147.2	4978.8
Thailand	5511.4	5401.6	109.8
Indonesia	2503.9	2157.0	346.9
Philippines	5039.5	12721.3	-7681.8

Source: Euromoney Supplement, September 1991.

5.5 POLICY COMPARISONS

In many respects the NICs - and the ASEAN four later - have followed the Japanese policy examples. In **trade policies**, for instance:

> "One thing the South Koreans did try to adopt from Japan, very consciously, was the system of sogo shoshas (the trading chamber system/PV). Seoul's intentions was to repossess a large part of the country's trade from the Japanese soho shoshas and give it to their newly-established South Korean counterparts. In Indonesia, Panglaykim among others called for the creation of organizations which, like the Japanese sogo shoshas," could implement the provision of an assortment of products and services' Some general trading companies were set up in Indonesia and the functions of existing ones broadened to resemble those of the Japanese sogo shoshas. Likewise, Taiwan Province, Thailand and the Philippines experimented with their versions of the sogo shoshas. There have been no immediate, major successes outside South Korea, but this apparently does not shake the faith of East Asians in the validity of the concept.
>
> In a general sense, the Japan campaigns have posited, if not proved, that the Japanese have been successful not because they have been victimizing the rest of Asia, but because they have been doing some things right. Southeast Asians may decide that the Japanese experience has, with qualifications, useful lessons for them." [118]

Infrastructure policies have also followed partly the same path: training, education, research and development are highly emphasized. In **education and training**, however, the other Asian countries - even in the Republic of Korea - are still lagging far behind Japan. In all these countries, information technology education has a high priority, and it is seen as basis for technology-led development:

> "Apart f delving into explicit areas of the IT (information technology) education curriculum, identification of different segments of the IT population is needed to

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[118] Awanohara, 1991.

ensure that the right message is delivered where it counts most. Education in IT is only a means to an end; that end is IT-led development. Without the support and confidence of decision makers and users, IT will obviously have no role commensurate with its potential beneficial impact on development. Without human resources, IT-led development will similarly be stymied. Studies in APO (Asia Productivity Organization - Authors) Countries have shown irrevocable links between the two. Where the relationship exists and remains strong, IT-led development leading potentially to the evolution of an information society is clearly visible. Examples of this are Japan, the Republic of Korea, Singapore, India and others. Where this relationship has yet to materialize in APO member countries, the level of activities in IT-led development is expectedly low".[119]

Following Iau's classifications of levels of information technology education as presented in Table 5.7, the NIC countries are already well concentrating on the "Specialization"-level, while the main emphasis in the ASEAN countries is still in "Basic Skills". The other East African countries are still working with the "Literacy" level developments.

When comparing this to e.g. the African countries, it is easy to see that they are mostly still short of the basic training schemes for the "Literacy" level. Generally, their IT education and training policies are still very thin and much less conscious than in ASEAN countries, or even in some less developed Asian countries.

In **technology policies**, the NIC countries have generally followed the Japanese examples both in institution development and contents of policies. This is especially true in the Korean case, where the technology policy governance structures are very centralized. The substantial concentration on especially electronics, telecommunication and other information technologies is also common fort the countries.

Table 5.7 Short-, medium- and long-term approaches to information technology education

	Literacy level	Basic Skills	Specialization
Short term	1) Train the trainers: 2) Train for rudimentary knowledge only 3) Quantity vs. quality	1) Establish courses in tertiary institutions 2) Foreign staffing 3) Award scholarships to nationals 4) Adjunct appointments from industry 5) Relevancy to needs	Staffing by foreigners in accordance to needs
Medium term	1) New resources from local institutions 2) Upgrade existing resources 3) Quality vs. quantity 4) Discontinue training trainers	1) Output from institutions to main industries 2) Scholarship holders to main institutions 3) Increase quality and quantity 3) Upgrade programmers for outdated technology	1) Nationals to take leadership role after training, and: 2) To go overseas attachments for specific skills 3) Foreigners to continue in selected fields of expertise
Long term	Steady state	Steady state	Move toward: - leading edge technology - R&D - technology integration - sophisticated applications

Source: Iau, 1990.

119 Iau, 1990.

Table 5.8 Important technology development projects administrated by Japan's MITI

Project	Period	Funding	Goals
Superhigh-performance Electronic Computer Development	1966-1971	10.2 billion yen	To kick off AIST's ongoing National Research and Development Program on technologies important to Japan
New Energy Sources (sunshine Project)	1974-1991	29.9 billion yen (fiscal 1991)	To study solar, geothermal, coal, hydrogen, wind, ocean, and biological energy sources, to limit dependency on imported energy
Very Large-Scale Integration (VLSI) Project	1976-1980	US$ 150 million	To extend optical micro-lithography to submicrometer levels and to develop new technologies for 16M and 65M-obit memories
AI-based Parallel Computer architecture (5th generation Computer Project)	1982-1991	50.4 billion yen	To devise AI-based parallel-computing hardware and software, a project that put Japan on the advanced R&D map, MITI supported the project entirely, though some researchers were sent from academia and industry
Software Productivity (Sigma Project)	1985-1990	25 billion yen	To develop standardized, UNIX based software tools and productivity aids to combat a growing shortage of programmers and software engineers
Electronic Automobile	1971-1976	5.7 billion yen	To develop electric-powered vehicle prototypes to address oil dependency and city pollution
Super/Hypersonic Transport Propulsion system	1989-1990	3 billion yen	To devise a combined-cycle engine for subthrough hypersonic flight

Source: Balk, 1991.

However, there are also important differences. Table 5.8 lists examples of important technology development projects administrated by the Japanese MITI, Ministry of Trade and Industry. Already the list tells a tale of ambitious long term development targets with very heavy investment in technological research and development. No other East Asian country has comparable resources, especially not for basic research.

The differences are manifested in the lists with corresponding information from the respective Korean, Taiwanese and Singaporean ministries - institutions, that all have been established with the Japanese example in mind (Tables 5.9, 5.10, and 5.11). It is evident that these countries have a shorter history for technology driven development, and they have less comprehensive technology development projects.

Table 5.9 Important technology development projects administrated by the Republic of Korea's RDAS

Project	Period	Funding	Goals
Electronic Switching Systems	1960s	N.A.	Basic infrastructure
Super Alloy Project	1978-1987	205 million won	Import substitutes in ultra-hard materials
Silicon Semiconductor Materials Project	1982-1985	401 million won	Basic technologies in fledgling electronics industries
Freon Alternative Development	1982-1987	119 million won	Substitutes for chlorofluorocarbons (CFCs)
Development of HIGh-Quality VTR Magnetic Head	1986-1990	235 million won	For videotape recorders segment

Source: Balk, 1991.

Table 5.10 Important technology development projects administrated by Taiwan's ITRI

Project	Period	Funding	Goals
Submicrometer	1990-	US$ 220 million	Submicrometer geometries by 1993 and 0.5 micrometer by 1995 (a continuation of the completed Microelectronics Project)
High-definition television (HDTV)	1990-	US$ 192 million	Working prototype by 1995, using ATV standard being promoted in the US (funding from Ministry of Economic Affairs)
Sparcstation clones	1988-	N.A.	To license Sun Microsystems' Sparc chip for development
Notebook computers	1990-	N.A.	To develop 80386SX notebook PC in a joint venture between ITRI and 47 companies
*Electro-optics	1985-	N.A	Smaller, high-capacity drives (2-inch hard-disc, optical) and computer peripherals, and to build advanced laser printer engine by 1992

Source: Balk, 1991.

Table 5.11 Important technology development projects administrated by Singapore's RDAS

Project	Period	Funding	Goals
Robotic Transportation System	Fiscal 1988	US$ 538.000	To develop system with help of Real Time Systems Pte Ltd
Optical Fiber Communication System	Fiscal 1988	N.A.	N.A.
Compact Optical-Disc Storage device	Fiscal 1988	N.A.	To develop the system with participation of Seagate Technology (Singapore) Pte. Ltd and the National University of Singapore
Microprocessor Applications Center	Fiscal 1988	N.A.	N.A.
Machine Vision for Automated Inspection	In progress	N.A.	To develop the system through National Semiconductor Pte. Ltd of Singapore

Source: Balk 1991.

5.6 THE CASE OF THE REPUBLIC OF KOREA

The case of industrial and technological development in the Republic of Korea can be taken as an illustrative example of the NICs development model especially in the field of 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.[120] So far, the Korean industrial performance has been quite outstanding. In 1953, agriculture produced some 47 per cent and manufacturing under 9 per cent of the Korean 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 7.12).

Table 5.12 The breakdown of labour force between agriculture and manufacture in the Republic of Korea in 1960 and 1982

Year	Labour force in	
	Agriculture, per cent	Manufacture, per cent
1960	66	9
1982	33	20

Source: Rushing and Brown, 1986.

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 7.13.) has risen from under 11 per cent in 1960 to over 25 per cent in 1982.[121]

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 5.13 The share of the engineering sector of the Korean manufacturing industry in 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.

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120 Rushing and Brown, 1986.

121 Jacobsson, 1986.

Korean industrial development is well illustrated in Table 5.14, which compares the revealed comparative advantages (RVA) of manufactured products in some countries in 1970 and 1980. The RVA index shows the relative competitiveness of a product (group); if the value is over 1, the country possesses a comparative advantage in that category. During the period, Korean competitiveness increased especially in group B, human capital-intensive goods, but also group C, technology-intensive goods shows a growing tendency. At the same time group A, unskilled labour-intensive goods has decreased even if it still clearly highest of all the countries compared. However, the ASEAN group shows an evident increase in competitiveness in this group.

Table 5.14 Revealed comparative advantage index from selected economies and country groups by industrial category, 1970 and 1980

Country/ Country group	1970			1980		
	A	B	C	A	B	C
India	0.70	0.05	0.03	0.50	0.06	0.04
Indonesia	0.02	0.01	0.03	0.08	0.01	0.03
Republic of Korea	5.10	0.19	0.31	4.73	1.16	0.48
Thailand	0.14	0.04	0.03	1.21	0.14	0.06
Japan	2.36	1.80	1.06	1.15	2.16	1.29
USA	0.55	0.66	1.88	0.60	0.59	1.53
ASEAN four	0.09	0.05	0.04	0.45	0.06	0.16
NICs	4.31	0.37	0.50	3.97	0.86	0.66

Source: Kakazu, 1990.

Industries with a high technological content, such as automobile manufacturing and machine tools have been a striking feature of developments in the Republic of Korea.[122] The electronics sector is another that has seen spectacular growth. In 1989 the industry bypassed textiles as the country's biggest exporter. In 1990 the Republic of Korea's electronics industry became the world's sixth largest in terms of output, and it was expected to race ahead of France and Britain into fourth place in 1991, approaching Germany on the third place. In DRAM semiconductor production the Republic of Korea is already the third in the world.[123]

> "... South Korea has amazed the industry by growing from a minor supplier of discrete semiconductor devices and IC package to a major presence in the world IC market. Today, South Korea furnishes about 3 percent of the total world market for ICs and 15 percent of the world market for DRAMs".[124]

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122 UNIDO, 1992, Chapter 12.

123 Clifford, 1991b.

124 Jurgen, 1991.

Joint ventures with United States firms have been important, because Japanese firms have been reluctant to cooperate. For example, Samsung has joined Hewlett-Packard in research on RISC chips. However, e.g. Goldstar is producing 4M chips in volume on a Japanese (Hitachi) license.[125]

Even if semiconductors are also the largest and most rapidly growing single sector within electronics in the Republic of Korea, Table 5.15 also shows, that consumer electronics - TVs, audio equipment, microwave ovens - are far more important for the country than e.g. computers.

Table 5.15 Growth of the Korean electronics production by sector, 1988 - 1990 (Won billion)

	1988	1989	1990
Computer total	860	1.180	990
Semiconductors	2.240	3.220	3.610
Colour televisions	1.260	1.170	1.440
Microwave ovens	740	680	490
Audio equipment	1.720	1.690	1.820
Fax machines	60	100	170

Source: Clifford, 1991a.

Large Korean conglomerates diversified rapidly into information technologies, after the government had taken high technology industries as focal development areas. For example, the textile company, Kolon International Corporation, started making TVs and other consumer electronics, and then added cooperation with Fanuc by starting a joint robot-making company in 1983. The same giant corporations that are the most important in other industries are also leading in electronics (Table 5.16). Out of these, Samsung and Goldstar have electronics as their main sector, while Daewoo and Hyundai have their main strongholds in heavier industries. Samsung and Goldstar have also diversified to almost all sectors within electronics, with very internationalized productions strategies. For example, Samsung manufactures colour televisions in Portugal, Hungary, Turkey, Thailand, Mexico, the USA and Indonesia. In the late 1980s Goldstar has had problems with its lack of focus in production.

After the four enterprises mentioned in Table 5.16, the most important electronics company in the Republic of Korea is the relatively small but innovative Trigem (Sambo), that has produced both the first PC and the first IBM PC clone in the Republic of Korea. It has also developed the first on-line generator for Chinese characters, and, latest, the first laptop engineering workstation.[126] Trigem is an interesting case of a relatively flexible business strategy in the generally rather rigid and massive Korean industrial enterprises with very broad production varieties. Trigem is concentrating on computers and computer equipment only.

125 Balk, 1991.

126 Clifford, 1991a.

Table 5.16 The most important Korean electronics companies

Company group	1990 sales, (US$ billions)	Main products
Samsung Group	43.3	Semiconductors, information systems, computers, consumer electronics
Hyundai	39.6	Automobiles, machinery, steel and metal products, shipbuilding, semiconductor ICs, computer hardware
Lucky-Goldstar	25.0	Semiconductors, computers and communication equipment, consumer electronics, electronic devices
Daewoo group	15.0	Consumer electronics, home appliances, computers, components

Source: Jurgen, 1991.

As Table 5.17 shows, the Republic of Korea shows much higher penetration of rates of NCMTs as other developing countries. Even generally, the diffusion rates of automation technologies in the early 1980s was already on a higher level in the Republic of Korea than most other developing countries with similar industrial development.[127] The only exception was the relatively low figure for the diffusion of industrial robots, which bares that the industrial structure in the Republic of Korea was still rather labour-intensive.

Table 5.17 Stock of NCMTs in some developing countries and areas (thousand units)

Country	1981	1985	1987	1989
Republic of Korea		2.7	5.0	7.5
Taiwan Province		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.

However, robot imports have grown rapidly, by about 50 per cent per year since 1986. By 1989 there were 1,200 industrial robots installed in Korean factories, mainly for arch welding but also for spot welding and assembly.[128] The domestic robot industry is also developing quite well; according to plans robot exports are to reach US$ 3 billion by 2000. Domestic production are not yet, however, competitive on the leading edge of the market.

There is a very strong policy emphasis on supporting automation in Korean industry. The Ministry of Trade and Industry has published ambitious plans for automation that would, for instance, reduce the manufacturing work week from 55 hours - the situation in 1987 - to 48 hours by 1993. This would be largely done by automation, including a relatively rapid robotization.[129]

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127 Edquist and Jacobsson, 1985.

128 Balk, 1991.

129 *Ibid.*

In the Republic of Korea, analysis suggests that[130] 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 straight forward 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. United States 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, vertically integrated conglomerates - chaebols - are the backbone of the economy. While usually controlled by a single family, they resembles more the prewar Japanese Zaibatsu than the postwar Keiretsu system. In addition, the government is more interventionist than the Japanese government, and regulations and directives are more straight forward and more compelling than in Japan, intervening more directly into single companies. The government, for example:

> "... granted monopolies to import products and enabled relatively fed companies to obtain low-cost credit. It also selectively awarded companies opportunities to acquire formerly Japanese-held assets and to receive military contracts from its own defence department as well as from the U.S. government".[131]

Recently, the economy is under a process of reorganization. The government is pressing the chaebols to more concentration: they are asked to concentrate on three focal areas, and only these areas will be exempt in the new credit control system. The government is also encouraging more small and medium sized companies as well as joint ventures with foreign enterprises. The target of the latter is, especially, to speed up transfer of foreign technology into the country.

Technology imports to the Republic of Korea have grown quite steadily, and as Table 5.18 shows, the very dominant role of Japan as the main source for technology has slowly decreased.

Table 5.18 Korean imports of foreign technology by country

Country	Number of cases			per cent		
	1962-71	1972-81	1981-87	1962-71	1972-81	1982-87
Japan	214	911	1,302	67.3	54.9	51.7
USA	74	392	626	23.3	23.6	24.9
Germany	10	83	141	3.1	5.0	5.6
UK	5	65	89	1.6	3.9	3.5
France	1	45	114	0.3	2.7	4.5
Others	14	163	245	4.4	9.8	9.7
Total	318	1,659	2,517	100.0	100.0	100.0

Source: Kakazu, 1990.

130 UNIDO, 1992.

131 Rosenblatt and Perry, 1991.

Systematic technology transfer combined with strengthening domestic research and development has been crucial for the development. Even in this respect the Republic of Korea has largely followed the Japanese examples by transferring the basic technologies and developing further from that. Kakazu describes this:

> "The Republic of Korea also patterned its technology importation policies after Japan which further strengthened institutional technology capabilities. One important strategy was to carefully select, stage and digest imported technologies according to its level of technological development".[132]

There were also other prerequisites for success per cent in the Republic of Korea. These include a good infrastructure of roads and communications as well as rather long manufacturing tradition and good work ethics. The industrial planning agencies are designed according to the MITI model. In trade, the Republic of Korea has profited from both rigid import barriers and the open US export markets.

In fact, the issues related to more traditional infrastructures and to governance and organizational aspects of the economy seem to be even more important to the economic development in the Republic of Korea. A comparative study on technology based competitiveness in the most industrialized developing countries and some OECD countries showed, that:

> "According to our measures, Singapore and South Korea have achieved substantial success in high-technology markets without having achieved levels of technological infrastructure and productive capacity comparable to those of the major OECD nations. National orientation and socio-economic infrastructures may thus be more important than technological infrastructures and productive capacity in the process of technology absorption and institutionalization...".[133]

This does not mean, that technological infrastructure would be unimportant. The implication is that socio-economic infrastructures and national orientation - issues related to organization and policy issues - are even more basic in creating a technology led economic system.

5.7 FOLLOWERS ON THE NICs PATH

Both the Japanese and NIC examples emphasize the importance of long term systemic policy based on capability building. The ASEAN countries are at least partly trying to rely on the same issues, even if they usually have shorter histories of development to support this. Their development is also still mainly based on cheap labour; and, - in the East Asian context - to proximity to Japan and the NICs. However, infrastructure and capability building for more technology development is taken as a concern of future also in these countries.[134]

There are, however, some background features facilitating the formulation of long term policies, that are important especially in the NICs and some other but not present in most developing countries. Common features between the developing countries that have ' : some success in

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132 Kakazu, 1990.

133 Roessner and Porter, 1990.

134 See e.g. Takahashi, 1990.

industrial development (the NICS, India, Brazil etc.) in contrast to African and other less successful developing countries may be summarized as follows: [135]

All these countries share a long-standing culture associated with writing and printing.
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.
Unlike most other 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.
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.
In their education and research effort they all reveal a will to break free from their dependence upon the industrialized countries.

Source: Salomon, 1990.

The Indian case has been described as illustrating how technological effort can lead to advanced capabilities, and yet these capabilities can be misdirected and remain unexploited. This is attributed largely to a regime that is highly inward-oriented and interventionist in a control-oriented way.[136]

Building up a systemic, long term policy for technology led development is by no means an easy task. And extensive automation could be successfully introduced only in a context of this kind of long term policy. In creating such policy, the following aspects may be important:

> "Its achievement must be based on a set of national decisions to ease the way for its development, that is, on an explicit or implicit national strategy for translating the capacity for competitiveness in to reality. Second, scientific and technological capacity incorporates elements of technological mastery and technological infrastructure. Requirements of parsimony in the model restrict primary attention to factors that are directly related to technology, but elements of a country's economic system and its overall productive capacity are also important. Third, national "will" is embodied in directed action to achieve competitiveness through government policies, business decisions, or both. It also includes individual attitudes conducive to innovation and entrepreneurship, and a collective commitment to the economic and political stability necessary to implement national strategy".[137]

However, there is no unilinear development similar to all countries. Even a superficial comparison of East Asian countries' development patterns shows this readily. In discussing information technology-led development in Asian countries it has been pointed out that:

135 Salomon, 1990, quoted in UNIDO, 1992.

136 Lall, 1987.

137 Roessner and Porter, 1990.

"... there exist many alternative perspectives on the future of each country. Since the vision of the information society has often been sated in the form of a stepwise historical development, people are apt to consider that the process of socio-economic development of a country is an accent of a development 'ladder', from the lowest rung to the highest. But ... there are many alternatives routes possible for each country. As with other technological innovations, the very essence of information technology introduces new dimensions in which a new action space can be constructed drawing on a wide variety of visions of the future." [138]

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138 Takahashi, 1990.

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