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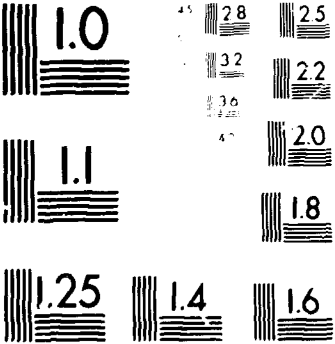

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OPTIMUM SCALE PRODUCTION IN DEVELOPING COUNTRIES: A PRELIMINARY REVIEW OF PROSPECTS AND POTENTIALITIES IN INDUSTRIAL SECTORS

Sectoral Studies Series
No. 12

SECTORAL STUDIES BRANCH
DIVISION FOR INDUSTRIAL STUDIES

Pate Gold

Main results of the study work on industrial sectors are presented in the Sectoral Studies Series. In addition a series of Sectoral Working Papers is issued.

This document presents major results of work under the element Supporting Research in UNIDO's programme of Industrial Studies 1982/83.

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Preface

This document is one of several studies prepared by the Sectoral Studies Branch, Division for Industrial Studies, as a contribution to the preparation for the Fourth General Conference of UNIDO.

The scale constraint is regarded as one of the most powerful obstacles for the industrialization of developing countries. Available technologies, based on economies of scale, combined with small or underdeveloped domestic markets, are considered as making domestic production in developing countries uneconomic or unfeasible in a number of sectors. This study is a preliminary review of the reality behind such assertions and of technological and other developments that may have shifted the level of optimum scale downward in several industrial sectors, hence increasing the scope for industrialization of developing countries, particularly smaller countries and countries at lower levels of income.

The technological options available in a number of industrial sectors were also examined by the International Forum on Appropriate Industrial Technology in 1978 and are also contained in the Monographs on Appropriate Industrial Technology published by UNIDO. The present study draws attention to additional factors which contribute to a trend towards a reduction of the optimum scale of production in several industries.

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I. THE PROBLEM

1.1 The scale problem in perspective

Providing an inclusive and exclusive definition of scale and specifically of optimal scale encounters special difficulties. Many times an arbitrary, often administrative, definition is used. This paper attempts to address the issue by examining whether there are possibilities of removing the obstacles which confront the industrialization process in developing countries by way of diseconomies of scale. Opportunities of different scales of production that have emerged due to recent technological developments will be explored and opportunities previously neglected will be looked at.

Scale constraints are widely viewed as being fundamental obstacles for industrialization in developing countries. Increasing competitive pressures in domestic and world markets have long stimulated efforts in many industries to gain perceived advantages of large plant size through building progressively larger operating units. The tendency towards concentration of industry in both industrialized and developing countries has been apparent in broad sectors of manufacturing - including chemicals, steel, pulp and paper, automobiles and cement - as well as in power generation, mining, shipping and agriculture. Parallel to this development perceived disadvantages of concentration and large scale led to a growing interest in finding technological solutions allowing economically justifiable industrial production at lower levels. The present study aims mainly at reviewing some of those solutions in order to indicate ways of reducing the optimal scale of production to a level more commensurate with the markets of the developing countries. Several possible solutions exist. Alternative technologies may be available, e.g. in other developing countries or in smaller industrialized countries or with small- and medium-scale enterprises. Large scale technologies may be modified. Technological breakthroughs are making possible decentralized production units at a high efficiency which at one time would have been considered impossible. Microelectronics based automation technologies have already revolutionized the concept of the giant plant.

The drive to increase the output and efficiency of manufacturing industries led initially to the division of labour and then to the introduction of essentially general purpose machinery to supplement labour strength. Later machines were more specialized (representing a division of tasks among machines) in order to permit the use of less skilled labour, achieve more speed and precision and to yield greater capacity per unit investment. This was followed by the increased use of mechanical devices and controls to enable machines to repeat complete work cycles quickly and precisely. The advent of the growing repetitive automation or the use of conveyers to move parts from machine to machine greatly increased the productivity of the industrial process. Such developments reached their most advanced form in extremely large automobile and other continuous manufacturing plants which combined highly specialized machines and equipment transfer into tightly integrated production lines.

These repetitive automation systems - representing the ultimate extension of the traditional drive for scale economies through increasingly specialized manufacturing plants - have demonstrated their capacity to produce enormous quantities of a standardized product of high quality at relatively low unit costs. And yet, despite decades of experience, they have never been applied to even one-fifth of total manufacturing operations in advanced industrial countries. Moreover, the construction of such facilities has slowed down considerably in the past few years.

The main reason for the slowdown in the trends towards large-scale production is that the potential economies of such systems can be fully realized only if operated at high levels of capacity utilization for long periods of time, thereby minimizing the cost per unit of output. However, this has proved difficult even in the so-called mass production industries to which such systems seem to be best adapted because cyclical fluctuation in the demand for such products has resulted in reducing the average capacity utilization rates actually maintained over the course of business cycles. The utilization rates have also been subject to declines over time because the limited adaptability of these systems have prevented effective adjustment to:

(a) Customer pressures for alterations in product designs and product-mix; and

(b) Changes in the availability, quality and prices of materials and other inputs.

Large-, intermediate- and small-scale solutions all have their place in industry and the optimum scale of technology will vary according to sector, product and the specific socio-economic environment as well as the industrialization strategy employed. The international growth dynamics of a country could be further stimulated by the pursuit of technological pluralism in accordance with its own conditions and requirements. Some industrial activities will inevitably continue to demand large aggregations of plant and capital. In some activities sector-specific technological breakthroughs will allow production on a lower scale. Even more important are the emerging technological advances which will affect the structure, organization and management of many industrial sectors.[1/]

The success of a country's industrialization strategy will depend above all on choosing the particular products and market niches which are most likely to maximize the utility of its particular natural resource endowments, human capabilities, available capital and technology. There are numerous sectors within virtually every category of industry in which small- and medium-scale plants can achieve effective competitiveness. The initial success of any such undertaking, however, may erode over time unless there is adequate response to changing competition and opportunities. Gains in the competitiveness through lowered production costs brought about by adjustments in scale or other means must be reinforced by the other essential determinants of economic success. Among these are: effective planning, procurement, marketing, distribution and servicing as well as sound and adequate financing.

In dealing with scale effect (the consequences which plant size has on input-output relationships in production systems), standard economic theory discusses the impact that the selection of a certain plant size has on the shape and position of the short-run average cost curve. It is assumed that a decision-maker is able to choose among plants of various sizes each with a unique structure of short-run costs. Assuming that up to a certain maximum

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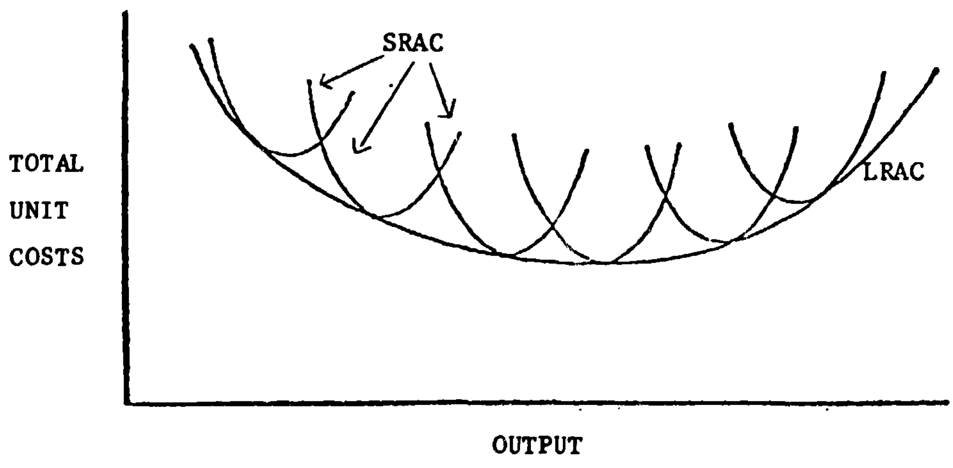
1/ For a sectoral analysis of the impact of technological advances see Technological advances and development: A survey of dimensions, issues and possible responses (UNIDO ID/WG.389/3).

level there exists an infinitely large number of possible plant sizes, each characterized by its short-run average cost curve, an envelope curve can be drawn tangent to all these curves. This envelope is referred to as the "long-run average curve" and is traditionally considered "U" shaped (figure 1). The downward segment of the "U" is governed by conventional scale economies and the upward thrust by diseconomies of scale.

An often given reason for diseconomies of scale is "diminishing returns to management".2/ The argument being that the planning, co-ordination and control of production in very large systems can become inefficient with resulting increasing unit costs. However, given the interaction of internal technological and economic forces and external market factors, one must look beyond managerial inefficiency as being solely responsible for diseconomies.

The theory behind the curves of figure 1 is based on simplified and sometimes controversial underlying assumptions. However, the long run and short run average cost curves and their relations can be useful conceptual tools and could serve as a shorthand symbols for a complex set of relationships between input and cost.3/

Figure 1. Theoretical effect of increasing scale on total unit costs



2/ G. Rosegger, The Economics of Production and Innovation, Pergamon Press, Oxford, 1980, p. 88.

3/ Ibid., p. 95.

It is important to point out, however, that whether variations in costs are due to differences in scale or are caused by other factors is very difficult to discern. Observed cost variation between two plants in an industry can result not only from differences in scale but also from such factors as unstable demand, non-homogeneous output, different locations where the cost of preparing the construction site has different access to inputs and management; and different technology resulting from differences in relative factor prices, etc.

Several reviews of the literature of empirical findings concerning economies and diseconomies of scale have been inconclusive.[4/] Shortcomings can be attributed partly to uncertainties concerning the appropriate measures of scale to be used, partly to inadequacies in the available data on input requirements and costs, and partly to evident weaknesses in each of the leading analytical approaches which have been used.

The single most important reason for the pervasive inadequacies of such empirical research is the overwhelming tendency to concentrate analyses at levels of aggregation which prevent conformance with the requirements not only of theory, but of practical evaluations by industrial executives and by government officials as well. Whether motivated by a desire to establish widely applicable generalizations, or by the ready availability of published data, most such studies have been concerned with average statistical relationships in individual industries, as classified by government agencies, between plant size categories (based on product value or employment) and some measure of cost or productivity. In view of the extensive heterogeneities among plants in most such categories, however, the findings which emerge, whether on the basis of cross-sectional comparisons or on the basis of time series analyses, can seldom be ascribed convincingly to scale effects - or even to the effects of size differences alone.

One frequently used technique to determine empirically short run average cost curves for entire plants is through engineering studies. In such studies capacity generally varies while relative factor prices, supply conditions,

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4/ Bain, Weiss and others found empirical literature on scale inconclusive. For a recent sampling and critique of findings, see Shepherd, The Economics of Industrial Organization, Englewood Cliffs, N.J., Prentice-Hall, 1979.

product homogeneity, location and so forth are kept constant. Engineering studies do permit analysis of changes in techniques but only within the limits of the technology available at a given time and optimal for each plant size.

Engineering estimates are subject to certain shortcomings which seriously limit their usefulness for policy purposes. Perhaps the most important of these is that most of the specialists consulted are likely to have very limited expertise in respect of estimating the prospective results of substantially different scales than have already been experienced. In most industries, scale potentials have been considered only within relatively narrow zones beyond such borders and most such estimates have apparently been based primarily on extrapolations of current experience. Large scale plants are not simply blown-up versions of smaller plants, but involve different techniques, different modes of organization, and different product mixes. Increases in size need not mean an increase in scale. An increase in scale would come about through changed organization of production.

A most significant feature for developing countries is the fact that work in technological innovation is not necessarily directed at larger and larger scales of operation. On the contrary much of the most sophisticated new technologies will result in opportunities for small firms to compete in industries which were thought to be closed because of the size of plants. These new opportunities can be especially important for developing countries which were previously excluded from economically justifiable production in certain sectors.

Presently a series of technological advances is being made which have a wide ranging impact on the industrial and technological infrastructure in which they are applied. Micro-electronics, genetic engineering and biotechnology are outstanding examples of such advances. UNIDO has since some time particularly studied the potential and implications for developing countries of these technological developments and tried to define adequate policy responses.[5/] Several of the new technologies, appropriately applied, could lend themselves to decentralized production and are particularly suited

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5/ See in particular UNIDO document ID/WG.389/3, Technological advances and development: *A survey of dimensions, issues and possible responses.*

to the resources of developing countries. The impact of these new technologies will be particularly significant for instance in the chemical industries, its impact cutting across the entire spectrum of products, plastics, resins, flavours, perfumes, medicinal chemicals, pesticides, fertilizers, primary products from petroleum, construction materials, etc. Micro-electronics could improve or create a wide range of products, processes or services. Advances in materials, particularly steel, composites, plastics and powder metallurgy would be of particular interest to developing countries in order to alleviate material shortages and minimize energy inputs needed.

A common feature of the technological advances referred to is that the distance between the basic research and actual production has been greatly shortened. Since production processes do not necessarily demand high cost equipment and are less energy-intensive they are particularly suitable for production in decentralized forms and at lower scale levels. The impact of the new technologies goes much further than traditional down-scaling and will change the structure of the industry itself, in a favourable scenario creating more science-based enterprises with greater flexibility in product development.

An obvious pre-requisite for the developing countries to reap the benefits of the production at smaller scales and in more decentralized forms that is being made possible by the new technologies, is of course that they get access to the new technologies. An example discussed below (section 1.2) in some detail, concerns one such area, namely CAD technology where the situation of developing countries is especially precarious. The development of this technology is already reshaping the structure of large segments of the manufacturing sectors and its diffusion seems likely to affect in particular such sectors where development countries have been particularly successful. At the same time, with very few exceptions, there are no signs that developing countries are on their way to catch up on the CAD technology. The evidence of a shift of comparative advantage in sectors such as textiles and leather products from developing countries, towards the industrialized countries has been clear for some time.

The impact of the new technologies and the connected problems for developing countries cut across many sectors and will eventually have a considerable effect on the industrial structure. But there are also sector-specific developments worth taking into account. In the second part of this study, a sector by sector examination of the issue of scale is carried out and alternatives available to developing countries are examined. These alternatives may be based on new technologies or sector specific technological breakthroughs but attention is also paid to the more traditional field of down-scaling or finding niches for small- and medium-scale industries. Necessary resources and incentives for stimulating alternative approaches are touched upon.

1.2 The impact on optimal scale of modern technology: computer-aided design as an example

Computer-aided design (CAD) provides an interesting example of the balance between small-scale and large-scale production, and how this has changed over time. In focussing on CAD one is able to gain insight into the small/large balance at both the production and consuming ends and to observe the crucial transition from traditional technology to the knowledge-intensive electronic era.

1.2.1 The technology

Traditional design technology involved the drawing board, drawing instruments and some form of primitive calculating device such as a slide rule. Even today, design offices using the traditional technology seldom involve an investment per worker of more than $US 1,000. In the late 1950s the light-pen linked to the computer screen was developed. General Motors Automobile Company pioneered the commercial development of this new technology and it was in the aerospace industry that the technology first matured (in the 1960s). The technology was further refined in the early 1970s, particularly in relation to the move from batch-processing to interactive use. After the mid-1970s the technology diffused to the manufacturing sector extremely quickly. The sector grew at an annual rate of over 70 per cent in this period with a turnover exceeding $US 1 billion by 1980. High growth rates are expected to continue over the 1980s and the technology's use will become necessary for many firms if they are going to survive international competition.

Basically three sets of technology are available. The first uses micro-computers, and is the least expensive. It has limited applications to draughting and a few design tasks.6/ The second involves mini-computers, although as computing power expands there is likely to be a move towards micro-computers. Each system can support about 4 to 6 terminals and design-processing capabilities are growing.7/ Finally there are mainframe systems in which CAD is merely one component of a firm-wide data processing capability. As can be seen from figure 2 there are significant scale economies to users; however, the three types of systems often serve different functions. The micro-computer-based systems are ideal for small, single-product users; the mini-computer-based systems satisfy medium-sized and design-intensive firms, and the mainframe systems serve the needs of very large corporations or medium-sized firms taking a comprehensive approach to automation. These differences are minor, however, when compared to the drawing board based traditional technologies.

1.2.2 Capabilities

At one level, the capital-intensive (and therefore inherently large-scale) CAD technologies are viable as a pure choice of technique. Given their high productivity (see below) compared to traditional systems, their use is justified when gross annual wage costs exceed about $US 9,000. However, in many sectors even these cost-advantages are outweighed by other benefits which the technology provides to successful users. By shortening product lead-time, optimizing the design of products8/ and being essential for other products9/ CAD technology is rapidly becoming a mandatory component of many production technologies.

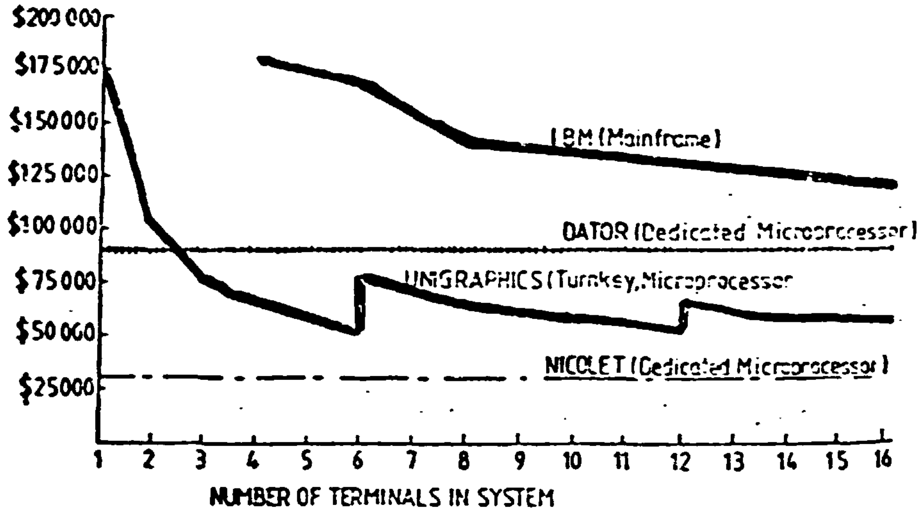
6/ For example, printed circuit board layout for the electronic sector.

7/ For example, they include electronics-programmes, e.g. PCB layout and auto-routing mechanical-design applications (e.g. finite element analysis and 3-D modelling) and CAD-CAM links (e.g. parts programming).

8/ For example in the automobile industry, where increasing fuel-efficiency is important, the use of CAD is crucial in reducing the weight of cars and the drag-co-efficients.

9/ For example in the electronics and aerospace industries.

Figure 2. Comparison of unit terminal costs for computer aided design (CAD)



Source: Computer Aided Design: Electronics, Comparative Advantage and Development, R. Kaplinsky, 1982, London, Francis Pinter. (Reproduced by permission of the author.)

CAD technology has an important impact upon the nature of work. Although designers often find that their design-skills are enhanced, numerous craft-based draughting skills are undermined. The machine-based technology requires multiple-shift utilization to take advantage of scale economies, and an individual rather than social working environment in which it paces the worker. It has often been stated that many design workers find the quality of their working lives significantly reduced by the introduction of CAD technology.

1.2.3 Skill implications

Four sets of skills are involved in the production and utilization of the new technology. First are the operator skills, where the skill threshold appears to be reduced. Second is the managerial component, which is crucial since many of the commercial benefits are reaped in non-design spheres. This usually entails a change in the type of managerial skills involved (incorporating a perspective on systemic organization) as much as the extent of training. Third is the back-up skill required to service and repair the new equipment. In the past this has been an important constraint on diffusion, but in recent years the development of modular designs, self-diagnosing machinery[10/] and self-healing[11/] systems have undercut a great deal of the skill required to service and repair the equipment. Finally, there are the software skills required to design CAD systems. Here, despite the introduction of structured-programming systems and the target of automated software, these skills are a major constraint on the development and extension of CAD technology.

1.2.4 Linkages

A variety of linkages are involved in the development and utilization of CAD technology. With regard to the production of the technology itself, both backward and forward linkages are involved. In the former case proximity and access to the electronics and computer-peripheral industries are important despite the fact that CAD technology has seldom pioneered the utilization of hardware technology. Perhaps more important is the fact that the industry developed largely due to the spin-off of highly qualified designers from the electronics industry. With regard to forward linkages the immaturity of much of the applications software has meant that suppliers need to interact closely with users in order to debug new applications packages. Similarly, the utilization of the technology also involves linkages whose importance is not so much one of stimulating the development of supportive industry, but rather to take advantage of synergies with complementary activities. In addition to the aforementioned user-supplier link, there is an important role played by user-groups in developing the technology and putting pressure on suppliers to up-date and refine their immature applications software.

10/ Machines which inform the technician which printed circuit board or integrated circuit to replace.

11/ This involves building redundant, duplicating systems into the machinery which automatically come into play when a sub-system fails.

1.2.5 Employment implications

There can be little doubt that the machine-based CAD technology displaces employment.[12/] However, the net effects are not clear in that there may be secondary and multiplier employment generating effects that offset any possible direct employment reduction, that arises to a large extent from the higher productivity achieved.

As can be seen from table 1 the general experience of user firms in the United States and the United Kingdom is that average productivity gains are in the region of 3:1.

1.2.6 Overall implications for the size of firms

The CAD industry has scale implications at both the user and supplier level. With regard to users, we must distinguish between firms using manual and machine-based design technologies. Smaller-scale firms which do not use the new technology may find it difficult to survive the increasingly competitive environment. However, for firms who utilize CAD systems, the development of distributed processing systems has the effect of reducing plant economies of scale (by allowing networked terminals to be linked to a centralized data-base) and increasing firm economies of scale.

There is a significant difference between traditional engineering technology and the new knowledge-based electronic systems regarding the production of CAD technology. The very heavy level of software investment in the new technology has meant that the difference between marginal and average costs of production are even more pronounced than in pre-electronic industries. Simultaneously, some of the mature applications programmes are individual-specific which has meant that a significant proportion of production now occurs in new small firms offering small, cheap, limited-capability microprocessor-based terminals. This development has few parallels in pre-electronic industries.

12/ Reference here is to employment in design and draughting. Even though the overall effect of successfully utilizing the technology may lead to greater levels of employment within particular firms, at the industry-level the technology (especially when linked to other CAD-CAM technologies) is also employment displacing.

Table 1. Productivity of CAD systems

Sector of activity	Location	Primary use of CAD	Average productivity ratio	Range of PR between different types of drawings
Integrated circuits	US	Design	2:1 after 6 months	NI
Automobile components	UK	Design	3:1 after 12 months	NI
Plant design	UK	Draughting	3:1	1:1 - 20:1
Process plant	UK	Design	NI	1:1 - 50:1
Electric motors	UK	Draughting	6.6:1	NI
Printing machinery	UK	Design/draughting	>2:1	NI
Architecture	UK	Design	3.5:1	NI
Automobiles	UK	Design	3:1	NI
Computers - pcb's	UK	Design/draughting	>5:1	NI
Process plant	UK	Design/draughting	4:1	NI
Petroleum exploration	UK	Design	2:1	NI
Automobiles	UK	Design/draughting	2.78:1 after 6 months	NI
Aircraft	US	Design	2.5:1 in 1979 3.32:1 in 1980	NI NI
Instruments - pcb's	UK	Design/draughting	>3:1	NI
Public utility	US	Draughting	>3:1	NI

NI = No information.

Source: Computer Aided Design: Electronics, Comparative Advantage and Development, R. Kaplinsky, 1982, London, Francis Pinter. (Reproduced by permission of the author.)

1.2.7 Implications for developing countries

There are three significant, potential implications of CAD for developing countries. First is the importance of synergistic linkages in the development and utilization of the technology. Although there are some signs of utilization of CAD technology in the newly industrializing countries, there is no evidence of the developing countries producing the type of technology which makes extensive use of applications-software, i.e. with the exception of India where diffusion is very clearly constrained by the absence of synergistic users. Second is the threat to developing countries implicit in the development of CAD-type technologies. To the extent to which it is possible to anticipate the diffusion of the technology, it appears to be going precisely into those sectors in which developing countries made such remarkable progress in the 1970s (table 2). If this pattern is sustained and repeated in other sectors and if the developing countries fail to catch up in this technology, they will face mounting competitive disadvantages that may threaten continued industrial growth. The rapid development of appropriate synergistic linkages is a prerequisite to the diffusion of these new technologies in the South.

There is a third possible implication that merits attention. This is the changing skill composition that the introduction of CAD will entail and which may present advantages and disadvantages to the developing countries.

CAD is still a relatively new technology with a lot of room for development. However, this is definitely a design technology for the future manufacturing sector, and the industry should be aware of its applications and advantages. To accelerate the process of application, technology promotion should be taken more actively. At present, organizations in several developing countries, academic ones in particular, have begun to engage in the research and development of CAD systems for various industries, especially for the electronics as well as garment industries realizing the fact that future improvement in quality is bound to this technology.

Table 2. Developed countries' imports of manufactures from developing countries in relation to design and draughting intensity

	Value $US million		Growth	Ranking (N=15)			
	1970	1978	1970/78	Value (1978)	Growth	Draughting intensity	Design intensity
Traditional manufactures							
Semi-finished textiles	1,815	9,610	5.3	1	13	11	11
Leather	183	950	5.2	9	14	13	12
Clothing	1,181	9,502	8.1	2	10	12	14
Shoes	151	2,033	13.5	7	6	14	13
Higher-technology manufactures							
Chemicals	588	2,282	3.9	5	15	9	6
Metals and metal products	319	2,223	7.0	6	12	10	9
Machinery except electrical and business	81	1,136	14.0	8	5	4	3
(Farm machinery)	2	29	14.5	15	4	7	7
Electrical machinery	372	4,463	12.0	3	7	1	1
Business machines	81	600	7.4	12	11	2	5
Scientific instruments	24	359	15.0	13	3	3	4
Motor vehicles	23	603	26.2	11	2	8	10
Aircraft	18	737	40.9	10	1	6	2
Shipbuilding	40	355	8.9	14	9	5	8
Consumer electronics	214	2,391	11.2	4	8	..	..
Total manufactures	5,493	40,195	7.3				
Total traditional manufactures	3,330	22,095	6.6				
Total higher-technology manufactures	2,163	18,100	8.4				

Source: Computer Aided Design: Electronics, Comparative Advantage and Development, R. Kaplinsky, 1982, London, Francis Pinter. (Reproduced by permission of the author.) Table calculated from United States Department of Labour (1979) which provides information on ISIC sectors, and United States Central Intelligence Agency (1980), which provides information on Standard International Trade Classification (SITC) sectors.

2. SECTORAL REVIEWS

This section examines the scale problem in the following ten sectors within three broad industrial divisions:

Capital goods and basic investment industries

Iron and steel
Machine tools and workshop equipment
Agricultural equipment
Building materials

Process industries

Petrochemicals
Fertilizers
Pulp and paper

Light industries

Food processing (with a sub-sectoral study of cane sugar processing)
Textiles
Bicycle manufacture

The sectors have been chosen for their intrinsic importance, and also to illustrate the various constraints and factors that are concerned with scale. Emphasis has been given to appropriate technologies for developing countries, as well as analysis of the costs and benefits of smaller-scale plants. Finally, the potential of going beyond current alternatives is examined.

2.1 Iron and steel

2.1.1 Introduction

The general optimism associated with the expansion of steelmaking capacity in recent years has soured as there is now considerable overcapacity. This glut has been compounded by rises in oil prices and the wo~ld-wide economic recession.[13/]

A general restructuring of the steel production in industrialized countries has been underway for some time and may be expected to continue. At the national level, large capacities exist but operating levels are low as plants have become obsolete. As new capacity is established in developing countries, the developed countries are seeking ways of being more competitive by introducing innovations such as continuous casting and mini-mills (which make steel from scrap and which now account for over one-fifth of the steel made in the United States).[14/]

2.1.2 Minimum and maximum sizes of plants

Basic steelworks operations can be separated into three areas:

1. Iron making
2. Steel making
3. Rolling into profiles.

There is no quality disadvantage in separating these operations by delivering prepared iron for conversion into steel (from which ingots are cast for subsequent rolling). Local conditions still affect the economy of operation significantly. In cases where rationalization of an existing national steel industry is being considered, it is possible to isolate any of the three areas in order to improve utilization of an established plant as a service to a projected new facility.

2.1.3 Manufacturing route in iron production

Many alternative routes for metal reduction are emerging induced by higher fuel costs. Large integrated complexes use liquid iron from blast furnaces for conversion to steel by direct transfer to a form of converter.

13/ Report on Third Consultation on Iron and Steel, ID/WG.374/6.

14/ "American Steel Resurrection", The Economist, 2 April 1983.

The traditional shaft furnace, fuelled by coke to produce pig iron, is being increasingly challenged by direct reduction plants. Shaft furnaces established in developing countries successfully employ charcoal as a fuel in smaller-sized plants (up to 500 tons/day), which produces a low volume of slag and therefore yields potential advantages for countries with good forest resources and effective afforestation programmes.

An important challenge to the blast furnace is the well-established direct reduction plant employing a gaseous or solid process without a liquid phase. Natural gas and non-cooking coal are among fuels which could be used and would enhance adoption of such reduction plants in developing countries. Direct reduction iron has uniform chemical properties and fewer metallic impurities than recycled scrap which enhances the technical control in the later stages of steelmaking. An advantage of sponge iron over scrap is easier mechanical handling which also improves control.

2.1.4 Manufacturing route in steel production

A review of steelmaking processes throughout the world reveals great differences in technical choices which are influenced by the national characteristics of the economy. Apart from direct steel production from blast furnace iron, other methods exist for steel liquid manufacturing using cold iron charge with or without recycled steel scrap and mill returns. Traditional steel melting and treating furnaces continue to be used, but to a lesser extent since the open-heart and Thomas converters have given way to electric melting and oxygen-based processes. There are several individual processes which offer extensive scope for utilizing local fuels. They include:

- Bottom and side-blown converters, Stora Kaldo, Linz-Donawitz. Oxygen Botton Maxhutta, submerged injection, Creusot-Loire processes, etc.
- Numerous continuous processes including the spray process. Electric processes (resistance, direct arc and electro-slag).

Specific investment (investment cost/ton capacity) is observed to be smaller for smaller-scale steel production facilities. This can be seen from table 3.

Table 3. Comparative capital costs for raw steel producing facilities[15/]

Facilities	Annual capacity (tons)	Investment cost $US/ton
Electric furnace	50,000	240
Continuous casting		
Hot mill	100,000	230
Direct reduction	500,000	320
Electric furnace		
Continuous casting		
Merchant mill	1,000,000	606
Open-heart furnace		
Continuous casting		
Merchant mill	500,00	610
Electric furnace		
Continuous casting		
Hot mill	500,000	340
Merchant mill		
Electric furnace		
Continuous casting		
Hot mill	1,000,000	346
Electric furnace		
Ingot casting		
Hot mill	1,000,000	390
Blast furnace		
Basic oxygen furnace		
Continuous casting		
Hot mill	2,000,000	477
Direct reduction		
Electric furnace		
Continuous casting		
Hot mill	2,000,000	482

15/ Data supplied by Geoffrey Lamb (Consultants) Ltd., Birmingham, United Kingdom.

2.1.5 Plant complexity and operating prospects

It is difficult to evaluate the performance of plants of varying complexity due to the lack of common standards for comparison. This is coupled with the fact that the basic profitability of a given work may be completely tied to the manufacturing performance so that statistics are considered confidential and are withheld. Another factor to bear in mind is the level of external infrastructural support. Installations in developed countries can rely on the full support of local and national technological infrastructure (independently of scale). However, in a developing country the often inadequate technological infrastructure induces serious problems in operation and maintenance.

In steelworks production, three broad processes can be identified regarding the machinery involved:

- Mainly metallurgical iron reduction
- Jointly mechanized and metallurgical steel production
- Mechanical rolling.

In general, mechanical skills can be readily transferred because the operation can be directly seen and assessed, whereas the metallurgical elements require instrumentation and lengthy experience. The mechanical functions of furnaces and ancillary plants are readily measured, but elements such as the refractory condition need experienced observation to avoid the two costly conditions of:

- Overcautious replacement which increase down-time production loss and cause greater consumption of repair materials.
- Driving the equipment beyond the point of repair.

Therefore designing adequate maintenance systems must be given sufficient priority, but should not be an overwhelming one. It is also essential to distinguish between choice of a design for easy maintenance or choice of obsolete technology. In any event, in iron and steel technology transfers to developing countries there should always be simple routing production and maintenance procedures along with provisions to ensure a safe working environment.

2.1.6 Choice of scale

Over the past ten years, small, efficient and flexible mini-steel plants have been taking business away from the larger integrated steel producers. In Europe, countries employing a high proportion of mini-steel mills have weathered the recession in the steel industry better than those committed to very large integrated steel plants. In Italy alone, there are currently 120 mini-mills and since 1976, 15 million tons of crude steel capacity have been installed in the form of small-scale and mini-mill plants, while a further 25 million tons are envisaged by 1990. Table 4 indicates the importance of mini-steel mills in some major steel producing countries.

Table 4. Mini-steel production 1980 - per cent of overall output 16/

Italy	55
Spain	46
United Kingdom	32
Republic of Korea	29
United States	27
Japan	23

One advantage of employing separate melting and rolling facilities is the possibility of employing under-utilized foundry melting capacity for ingot manufacturing to level the peaks of demand. Another point to note is that strong links exist between the mini-mill and its melting methods. The electric arc furnace is currently predominant, but some interest is developing in electro-slag.

Raw materials for electric melting may be the following:

- Direct reduced (sponge) iron
- Recycled steel and iron scrap
- Pig iron.

16/ Data supplied by Geoffrey Lamb (Consultants) Ltd., Birmingham, United Kingdom.

In any given feasibility study for new steel capacity the availability of steel scrap, country reserves and recycling levels must be carefully evaluated. Sponge iron will become available from increasingly diverse sources in the future, but the overall expansion in the eighties is expected to be only about 20 to 25 million tons which represents about 1 per cent of the world installed steelmaking capacity. Even so, its importance to the developing world is likely to be significant. The impact of world resources and distribution of scrap metals on future melting trends may be crucial since increased electric arc furnace capacity will favour scrap as a raw material on cost grounds in some medium-scale plants. Also, export controls may become a factor in the availability of steel and iron scrap in the foreseeable future.

Rolling mills require the most capital investment in mini-steel plants. Equipment specifications depend on the accuracy of market forecasts. Specialist facilities are more economical at high operating rates while the introduction of flexibility into rolling programmes usually leads to reduced utilization.

A typical investment cost breakdown for a 150,000 tons per year plant is:[17/]

	Percentage
Melting	12
Casting	14
Rolling	52
Building	12
Services	10

A wide variety of alternatives is available, ranging from common roughing and finishing stands to sophisticated high-speed plants, with intermediate stands and controlled cooling. Developing countries often invest in rod mills first, due to the wide-spread demand for reinforcement bars. Sometimes the capacity of plant is restricted to simple sections such as flats and angles within the power available for an initial programme of rebar production.

17/ Data supplied by Geoffrey Lamb (Consultants) Ltd., Birmingham, United Kingdom.

2.1.7 Beyond current alternatives

In the steel making process, it is reasonable to project that refinements of the production sequence will continue to develop, while wider use of continuous casting and direct casting of flat slab (with larger areas and less thickness) can also be foreseen. Improvements will be made in preforming pipes and tubes.

Energy must be taken into consideration in metallurgical processes. The application of nuclear energy is a long-term possibility. Reactor heat may be used to obtain hydrogen from water which could be used for direct reduction of iron ore. Alternatively, heat from a high temperature gas-cooled reactor may be harnessed to reform hydrocarbon gas for direct reduction. Researchers in many countries are known to be working along these lines but it probably will not be possible to see effective industrial operation before the next decade.

Another novel route, claiming significant energy reduction, would be to remove most of the gangue material from an iron ore in its cold form, i.e. by mineral separation techniques, rather than by slagging in a blast furnace. A 99 per cent plus Fe content super concentrate which would be formed would then be reduced to sponge iron in a conventional direct reduction process. A process particularly suitable for developing countries applications, involves feeding the sponge iron directly into a rolling mill, without an intermediate steel-making process.[18/] The resulting high purity iron has properties comparable to conventional mild steel and popular thin sections (such as angle and rebar) can easily be formed.

Other equally important developments will concern skills, health and safety, and the improvement of working conditions, since almost all steelwork plants involve hostile operating conditions. In industrialized countries many of the traditional operating skills are currently being replaced by high-speed monitoring equipment, which means that skills are increasingly related to maintenance and calibration of instruments.

18/ Direct Rolling of Sponge Iron Pellets, S.J. Ahier and A.R.E. Singer, Iron and Steel International, December 1979.

Apart from better working conditions for direct production workers, the instrument interface facilitates off-the-job training. The trend towards mini-mills employing smaller staffs will lead to less formal management styles, and more operational responsibility for foremen and supervisors.

The overall trend towards mini-mills appears to be firmly established thereby offering an attractive option to those developing countries who although they have limited markets and capital resources, may wish to build up an indigenous capacity in this basic industry.

2.2 Machine tools and workshop equipment

2.2.1 Introduction

Before examining the impact of recent developments including numerical control (NC) and robotics on machining operations, it is helpful to review simpler mechanical forms of automation which enable the manufacture of a particular component or part to be repeated:

Jigs. The simplest method is using jigs or templates which the operator of a drill or lathe can follow.

Form cutting. The cutting or grinding tool is preformed so that it cuts the part to shape by moving the tool into the part at a preset depth.

Straight line cutting. Line milling and the turning of stepped shapes by manually setting a series of mechanical stops which provide a preset sequence of tool moves.

Copy milling. More complex mechanical automation can be achieved by making a three-dimensional model of, say, a die surface and then copy milling the model to form the complex shape. This is frequently applied to small batch manufacturing of complex shapes.

Cam automatics. Where relatively simple shapes have to be produced in large batch sizes a series of cams can be made for a specific part and these are used on a machine tool to cut that part.

A disadvantage of all these methods is that they require pre-manufacturing of a mechanical part, which is time-consuming and expensive (obviously less so for simple jigs and templates). The costs of storage and maintenance are also significant. Numerical control offers the advantage of flexibility, in that the movements of the machine tool are controlled by numerically-written instruction which are read automatically as numbers by the NC system which controls the machine tool.[19/]

2.2.2 Scale and changing technology

Machine tool manufacturing provides an interesting example of the impact of new technologies on the economies of scale. Prior to the introduction of NC, many machine tools were relatively standard items and markets could be won by price and cost reductions resulting from large-scale production. As the new technologies began to be developed, however, the value-added per item became significantly greater so that smaller-scale production could be profitable. On the other hand, research and development costs rose rapidly yielding scale economies to those businesses which could spread their overheads over larger production runs.

Flexibility is also important in view of the pace of technological change, and in order to compete, firms have to learn new electronic skills to supplement their traditional mechanical engineering know-how. There have been major advances in precision grinders through the application of sensors and microprocessor-based controls. Multi-purpose turning and machining centres, which are capable of changing tools automatically, are a further significant development. Other interesting innovations are adaptive controls that automatically compensate for tool wear, active magnetic bearings that permit ultra high spindle speeds, adoption of new hydraulic fluids compatible with coolants and lubricants and the replacement of gears with continuously variable drives. One effect of the higher speeds and metal removal rates made possible by NC techniques has been the need for stiffer machine structures to

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19/ A management guide to numerical control machine tools. The Institution of Production Engineers, London, 1978.

withstand higher stresses. This has led to increased interest in the use of concrete for machine tool structures for reducing structural vibration and giving a high dynamic stiffness to relatively small structures.[20/]

With automatic workpiece loading, most machine tool downtime comes from adjusting the position of cutting tools to compensate for wear. These stoppages of 15 minutes or so occur at least seven times in the lifespan of lathes and boring mills. Thus, there is a considerable saving in incorporating adaptive controls which adjust the tool position automatically after each workpiece is cut. For example, the Samsomatic control produced by Genicon Inc. can adjust tools with a reproducible resolution of 0.0001 cm, which is considerably better than most production line tolerances.

2.2.3 Robotics

A particularly interesting and controversial sub-sector is the manufacture of robots, which the Robot Institute of America defines as:

> "A reprogrammable multifunction manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks."

At present the robotics market is characterized by a compact group of large customers, such as the major motor manufacturers, served by a rather large number of robot manufacturers (although two manufacturers hold over half the market share between them in the United States). It is likely that economies of scale will eventually dictate a phase of concentration, particularly in view of the high cost of research and development as advanced technologies continue to develop. The phase of concentration may come about more quickly if the explosive growth in demand that has been forecast does not occur. The risks are currently high, and it has been stated that "the industry probably cannot support half the enthusiasm and resources that have

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20/ Machine Tools on the Move, Richard T. Dann, Machine Design, 12 March 1981.

been committed."[21/] It is clear that high levels of skill and innovation plus substantial amounts of risk capital will be required for success. Thus, only a few developing countries will be in a position to compete successfully in the manufacture of NC machine tools and robotics.

Computer-aided design (CAD) (section 1.2) is a development of considerable significance and can achieve as much as a 400 per cent increase in the productivity of industrial designers, as well as yielding an engineering data base which could lead on to computer-aided manufacturing (CAM). As the CAD study indicates, the development of CAD-type technologies requires strong backward and forward linkages which are often difficult to achieve in the operational environment of a developing country. Nevertheless, it will be beneficial for developing countries to build up their technological capabilities through education and training, as well as making the appropriate selection of technology.

2.2.4 Backward and forward linkages

The arguments for encouraging synergy through backward and forward linkages contain a lesson for those who live in scattered rural villages and whose lives will not be touched directly by developments in the fields of micro-electronics, NC machine tools and robots. By encouraging the local development of simple tools and workshop equipment, it is feasible to encourage industrial decentralization programmes which provide a route into the industrial sector and encourage self-sufficiency without urban migration. The remainder of this sectoral study will focus on the recent and potential developments of local production of basic workshop equipment.

2.2.5 Workshop equipment

Although many technological developments in numerically-controlled machine tools and robotics are popular, they are not appropriate for industrialization in rural areas of the developing countries. Instead, people

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21/ Micro-electronics and Developing Countries: Towards an Action-Oriented Approach. Note by UNIDO Secretariat to Expert Meeting Preparatory to International Forum on Technology Advances and Development, Moscow, November-December 1982. ID/WD.384/5/Rev.1, 1 February 1983.

in these areas need a new range of simple wood and metal working tools and equipment that could be brought together in rural workshops to enable local communities to be self-reliant in small-scale production of basic equipment. The equipment should be basic and capable of being easily repaired and maintained. It should preferably require a minimum of imported materials and components.

There are some organizations that are attempting to meet this need. One organization tries through a project to identify, design and develop a range of equipment for rural workshops in developing countries. The objectives of these efforts are to:

(a) Permit a wider range of projects to be made available;

(b) Introduce production/repair facilities not normally enjoyed by rural consumers;

(c) Raise quality standards in rural workshops;

(d) Reduce rural communities dependance on often remote producers;

(e) Enhance the status and influence of rural artisans.[22/]

Items are intended to be locally produced at operation without electrical power. Each design would involve production of a prototype, field testing and printing of a manual on manufacture and assembly. The step-by-step instructions of these manuals will assume availability of the most basic tools and welding equipment.

The first design produced in this series was for a simple, but versatile machine for working sheet metal. It would produce items such as ducting, steel boxes, trays, baking pans, chimney flues, funnels and agricultural equipment such as seed-hoppers, troughs, water and fuel tanks as well as components for vehicle building and repair. A manual was prepared that

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22/ Project Outline: Rural Workshop Equipment (unpublished), Intermediate Technology Industrial Series.

included numerous detailed illustrations and step-by-step building instructions, so that the machine could be made by a typical rural workshop from readily available channel, angle and hollow steel sections using basic welding and fabrication techniques. The only equipment essential to its construction is a drilling machine, an electronic welder, G clamps and basic hand tools.23/

The enthusiastic response to this initial equipment has encouraged development of a tube bender, a sheet rolling machine, a bench shear, a workshop drill and a treadle lathe. Future items to be addressed by the project are expected to include an angle bender, a log splitter, wood-lathe attachments, a jigsaw and bench presses (toggle and hydraulic).

All the future manuals will follow the same basic outline. Complete manufacturing instructions will include materials lists, templates, drawings of components and solutions to potential difficulties. There will also be a section on how to adapt the tool for specialized jobs.

2.3 Agricultural equipment

2.3.1 Introduction

Agricultural equipment has been described in a recent UNIDO study as a "basic sector at the interface between agriculture and industry".24/ While the study was specific to Africa, it remains generally true that "without efficient local production and use of the right kind of agricultural and rural equipment, food self-sufficiency will be delayed, job and higher incomes will not materialize in rural areas and the urban drift will not be halted. "The study suggested that a strong indigenous agricultural machinery industry facilitates progress of agricultural production, food supplies and food self-sufficiency. If the industry's output is broadly defined to include

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23/ "How to Make a Folding Machine for Sheet Metal Work", R. Hitchings, Intermediate Technology Publications Ltd.

24/ Agricultural Machinery and Rural Equipment in Africa: A New Approach to a Growing Crisis. UNIDO Sectoral Studies Series No. 1, Vienna 1983, (UNIDO/IS.377).

basic rural equipment such as vehicles and first-stage food processing machinery (such as depulpers, grinders, shellers and oil presses) there could also be a dramatic impact on employment, rural incomes and the quality of rural life. Furthermore, as a purchaser of industrial materials, semi-finished goods and components, the agricultural machinery sector could become the seed for developing new industry and stimulating related industrial activities.

The agricultural machinery and implements industry can be considered to be a capital goods industry involving engineering and technological activities which interlink engineering and allied metal working industries for the manufacture of appropriate agricultural machinery and implements.

The agricultural machinery and implements industry requires different infrastructure facilities, e.g. factory size, machine tools and equipment, labour requirement, manufacturing techniques, etc. The final output is also limited by the choice of machine tools and equipment and their productive capacities. Therefore, there is a close relationship between the production volume, choice and capacity of machine tools and equipment and the size of the required investment.

The optimal scale production for the manufacture of agricultural machinery and equipment in developing countries will be determined by four important aspects:[25/]

- Careful selection of product grouping based on manufacturing sophistication;

- Convenience and viability of manufacturing these products at different levels of rural industries;

- Methodical selection of machine tools and equipment for optimizing employment potential, particularly in rural areas;

25/ See UNIDO, Interlinkage in Agricultural Machinery Industry for Rural Industrialization in Developing Countries, 1978, p. 101.

- Basic minimum investment required for particular levels of industry (artisan, small scale and medium/large scale).

Table 5 presents a summary of the technological requirements in accordance with the different industry levels and its optimal scale of operation.

The following supporting industries are needed in order to facilitate the agricultural machinery and implement industry at a level optimal for production in developing countries.

- Integrated foundry, forging and diecasting plants;
- Integrated plant for hardware components and parts;
- Agricultural disc manufacturing plant;
- Integrated sheet metal and press work plant;
- Toolroom and tool maintenance plant;
- Woodworking and pattern making plant;
- Integrated plant for galvanizing, perkerizing, electro-plating, etc.;
- Integrated plant for spur and hypoid gear manufacture;
- Integrated plant for heat treatment;
- Integrated plant for the manufacture of automotive parts and accessories;
- Integrated plant for the manufacture of tyres and rubber products;
- Integrated plant for the manufacture of electrical components;
- Integrated plant for the manufacture of instruments and gauges;
- Integrated plant for the prototype manufacture and development.

These supporting industries will have to play a greater role in the industrial development and require considerable magnitude of investment in terms of finance, machinery and equipment, technical know-how, trade and employment.

In the case of the manufacturing of hoes it can be seen how the different supporting industries are important depending upon the level of technology used in their manufacturing. The following paragraphs present a detailed analysis of the different production systems for the manufacturing of hoes.

Table 5. Summary of technological criteria in three industry levels

Industry level	Machine tool	Production techniques	Supporting industries	Minimum factory manufacturing programme
Artisan Level	Mostly manually operated machine tools, application of simple conventional machines, e.g. turning, drilling, grinding, welding, etc.	More manual operations based on job shop production with limited batch size. Dominant feature is hand forging with heat treatment.	1. Hardware industries 2. Woodworking industries	Mostly customer requirement, minimum batch production can be introduced, large product mix is essential.
Rural small scale industry level	Conventional machine tools, e.g. drilling, milling, arc welding, hammer forge, inspection tools, etc.	Based on minimum batch production with advanced heat treatment facilities. Process planning, method study, setting of standards quality control etc. can be introduced. Use of jig, tools and fixtures particularly welding fixtures.	1. Disc manufacturing industry 2. Foundry and steel industry 3. Hardware industry 4. Jig and tool manufacturing industry	Minimum economic batch size of production programme is required. Medium product mix is essential.
Rural medium/ large scale industry level	Conventional, automatic and special purpose machine tools are required e.g. 1. drilling, milling, boring machines; 2. bar automatic, chuck automatic etc.; 3. unit head special purpose machine tools.	Continuous, batch and split batch production system incorporating economic batch loading, process planning, estimation, setting of standards, quality control and rigid inspection, production and material control, wide application of jigs, tools fixtures, advanced tooling-high speed and carbide etc.	1. Foundry (grey cast iron, malleable, spheroidal iron) 2. Forging and die casting 3. Tyres, wheel and rim manufacturing unit 4. Sheet metal and press work industry 5. Gear cutting and transmission shaft manufacturing unit 6. Electrical and instrument manufacturing unit 7. Steering wheel and automotive parts manufacturing unit 8. Hardware industries 9. Rubber manufacturing industries 10. Paint manufacturing industries	A minimum manufacturing programme is required. With economic batch loading of each part to be manufactured.

2.3.2 The hoe

The hoe, known by a variety of local names in different parts of the world (jambe, pawrah, etc.) remains the most important agricultural implement for millions of farming households in Africa and Asia where hand tools remain the predominant method of cultivation in the small-scale agricultural sector. This tool has been chosen as the focus of this sectoral study partly because hoes are currently manufactured in developing countries over a very wide range of scales of production, from traditional village blacksmiths to large-scale national industries, and are also imported in large numbers from the People's Republic of China, India, Europe and the United States. Thus, the scope for scale, product and process comparison is much richer than for other types of agricultural equipment.

The hoe can be used as a digging, cultivating, weeding, levelling and scraping tool. It consists of a metal blade and the hoe head which is fitted at an acute angle to a wooden handle. It is the standard practice for the hoe head to be supplied separately from the handle which is often made by the farmer himself from local wood. Consequently, we will concentrate on the production of hoe heads.

Hoe heads can be categorized into two basic types which relate to the methods used for their manufacture:

(a) Single-piece hoe heads, in which a single piece of metal is forged or press-formed to produce the required blade shape and hollow-eye (or spike) for attachment of the handle.

(b) Two-piece hoe heads, in which the blade is rivetted to a forged eye or welded to an eye formed from steel tube.

Existing scales of hoe production

The following different scales of hoe production are found in developing countries at present:

2.3.3 Village blacksmiths

In certain countries the traditional skills of blacksmithing are long-established at the village-level. In some places these skills include iron smelting, but generally this is no longer economical because it is too time consuming and consumes too much wood. Traditional village blacksmiths now work predominantly with scrap materials, making and repairing a range of implements of which the hoe is usually the most important. A variety of scrap materials are used, including discarded motor vehicles, railway stock and agricultural equipment parts, and ship plates. Traditional blacksmiths work with a charcoal hearth, bellows, anvil and hand tools, and have the skills to hand forge spiked hoe heads from a single piece of material. The quality of the final product depends on the skill of the blacksmith in identifying the characteristics of the raw material and in forging.

A second category of village-level industry found in several countries, is the "modern" blacksmith. He provides the same type of services as the traditional blacksmith but lacks his skills in forging and familiarity of materials. The "modern" blacksmith generally produces hoe heads in two parts and may have welding facilities for attaching the blade to the eye. Like the traditional blacksmith, he uses mostly scrap materials. The scale of production of these village-level industries is small, catering to the needs of a single or a few villages.

2.3.4 Small- and medium-scale industries

In several countries there are small- and medium-scale urban-based industries producing hoe heads. Most of these industries produce two-part hoe heads by hand forging, drop-hammer forging or press forming. Some industries make single-piece heads from steel sheet either by using a spike-fitting, or by forming the fixing hole for the handle by a series of pressing operations. Industries at this scale are characterized by the use of electrically powered equipment and by mild steel instead of scrap materials. These industries generally produce a range of other products in addition to hoes.

2.3.5 Large-scale industries

There are two types of large-scale hoe manufacturing industries in developing countries.

The first type makes two-piece heads with the blade hot press-formed from medium carbon steel sheet, and the eye is cut from a length of steel tube and welded to the blade. A taper is sometimes formed in the eye by a pressing operation. Generally the head is not heat treated after forming. Examples of industries employing this process are found in Ethiopia and Mozambique, the latter having an output of one million hoes per annum. Both industries also produce a range of other hand tools.

The second type of large-scale industry produces single-piece hoe heads by die forging and rolling. The raw material is medium carbon steel and the heads are normally heat treated after processing. This is the most capital intensive manufacturing technology for hoe production and requires a minimum level of investment in equipment and tooling of about $US 1.2 million. Utilization of this plant on a one-shift basis gives an output of 250,000 hoes per annum, which is about the minimum level at which the technology is economically justifiable. This type of industry would normally produce other forged hand tools such as hammers and pick-axes. It is this level of manufacturing technology that is normally used in industrialized countries.

2.3.6 Characteristics of different scales of production

The different levels of hoe production often co-exist in a particular country, sometimes in competition with imported products. It is therefore useful to compare the characteristics of the different levels of production.

Raw materials supply

The major problems of supply of raw materials occur at the smallest and largest scales of production. The village blacksmith is dependent upon obtaining a regular supply of suitable scrap materials. He may have to obtain these himself or arrange deliveries from urban areas where most of the scrap is generated. His access to supplies is a disadvantage compared to small urban industries processing scrap material. Mild steel, which is also used by small urban industries is a general purpose material and is usually easily available.

Large-scale industries process medium carbon steels which often have to be imported by most developing countries. They consequently face the problems of obtaining foreign exchange and import licences to ensure a regular supply of materials. They also need systematic testing procedures to check the specification of the materials supplied.

Ordering and distribution

Village blacksmiths typically manufacture hoes to order, or in limited batches for sale in local markets. They receive payments in cash and their distribution costs are minimal. Because their products are hand made they can produce hoes to meet the specific requirements, such as the size, shape and weight of a particular user. Therefore, unlike large-scale manufacturers, village blacksmiths are responsive to local demands for tools to suit soil and crop conditions and customer preferences.

Large manufacturers need to produce large quantities of particular specifications of hoes in order to utilize their manufacturing equipment efficiently and to amortize the considerable investment in tooling. Large manufacturers normally produce hoes in a limited range of sizes, each of which requires its own set of tooling. There is evidence (e.g. in Tanzania) of village blacksmiths modifying hoes supplied by large industries to suit the requirements of local customers.

Large-scale industries normally supply their hoes in large batches to agricultural extension services, other government departments (e.g. public works department) and commercial trading houses.

Quality and cost

The best quality hoes are those made in a single piece with a hollow eye, by die forging and rolling using medium carbon steel that is heat treated in temperature and atmosphere controlled furnaces. This method of manufacturing produces a hoe which increases in thickness towards the eye end to provide adequate bending strength. It has a well-shaped eye to provide a secure fit of the handle, and the correct material properties to give high bending and impact strength and low wear rate. The quality of the products of a particular manufacturer depends upon the material specification, the quality of the forging and the rolling dies. The condition in which they are maintained, and the control of the heat treatment process are also significant. Hoes of this type can only be manufactured on a large scale.

Spiked hoes made by the traditional blacksmiths are the next best in quality. The use of hand forging allows the desirable variation in material thickness and, if the blacksmith is skilled, adequate material properties can be achieved. The latter crucially depends on the skill of the blacksmith in judging the characteristics of a piece of scrap material, and heat treating it appropriately over an open flame. However, this cannot achieve the consistent quality of controlled furnace treatment. These traditional skills are only acquired over many years of experience by working as an apprentice to a blacksmith, and are normally handed down from generation to generation.

The quality of two-piece hoes is limited by the inherent weakness of the joint between the blade and the eye. Rivetted joints inevitably loosen even if they do not break, and welded joints are prone to failure. Blades made from steel sheet, rather than by forging, lack the desirable increase in material thickness towards the eye. This steel has relatively poor strength and wear properties, which is also likely to be the case with scrap materials unless they are worked by a highly-skilled blacksmith.

The cost of manufacturing a hoe is directly related to its quality. Single-piece forged hoes cost more than two-piece designs, and hoes made from medium carbon steel are more expensive than those made from mild steel or scrap. In Africa and Asia, large-scale local manufacturing of forged hoes can be cheaper than importing. However, this will depend on the willingness of the farmer to pay more for a higher quality produ . Otherwise the required production scale to allow competition with imported hoes cannot be reached. The number of countries with traditional blacksmiths is fairly small. In other countries the choice for the farmer is between buying a locally made two-piece hoe, or a more expensive forged hoe which is either imported or made by a large national industry. The advantages of the latter are longer life, since the wear rate and likelihood of breakage are lower, and higher working efficiency. However, since many small farmers are financially constrained, they may well choose to buy a low quality tool which has to be replaced more frequently, because of its lower initial cost. This relationship is obviously affected by subsidized purchase of tools which occurs in some agricultural development programmes.

Employment

Village blacksmiths are inherently labour-intensive and the value-added is close to 100 per cent since scrap materials are used and most of the manufacturing equipment is self-made. Village blacksmithing provides employment in rural areas, and makes available to local communities general manufacturing and repair service. The skills of the "modern" village blacksmith can be developed through formal training courses, but those of the traditional blacksmith, particularly in working scrap materials, are not amenable to this process.

The small-scale urban industry remains fairly labour-intensive although it is characterized by the use of powered machinery and of new rather than scrap materials. The skills can be acquired through informal apprenticeship and formal training.

Large-scale manufacturing is capital-intensive, and relies on imported manufacturing equipment and materials. Machine operation is handled by semi-skilled labour. However, skilled tool-makers are required for the manufacture and refurbishing of dies.

Summary discussion on choice of scale

Currently, high quality hoes can only be produced on a large scale. The total demand for hoes in many countries is sufficient to make this level of manufacturing economically efficient and it would normally be combined with the production of other forged tools. However, its viability depends on the willingness of farmers to purchase high quality tools at a relatively high price, or alternatively, on measures to promote the use of better quality tools through agricultural development programmes.

Village blacksmiths offer the advantages of creating employment in rural areas and providing a service which is responsive to local requirements. However, except where "traditional" skills exist they generally make relatively poor quality implements and have a very limited financial base which limits their capacity for development. In order to upgrade this sector in terms of quality and scale of production, assistance would be required along the lines defined in a recent UNIDO document:[26/]

- Supply of raw materials of consistent quality;
- Training (in hand forging and open-flame heat treatment).

In order to achieve high productivity using labour-based methods, good quality tools are essential. They are subjected to intensive use and any shortcomings in quality rapidly become apparent. This has led to a number of initiatives to produce good quality tools on relative small scales. The experience of the road construction and forestry sectors could be very valuable in this respect. Substantial progress has been made in this direction on a variety of tool heads and handles, including shovels, rakes and machetes. The hoe head remains one of the most difficult to make at a high level of quality on a small-scale because single-piece forging of hoe and eyes is inherently a large-scale operation. However, in the Philippines some progress has been made on a forestry project by:[27/]

(a) Use of a single type of scrap material with the required properties (in this case discarded disc harrows);

26/ Background document for First Consultation Meeting on the Agricultural Machinery Industry 1979. First World-Wide Study on the Agricultural Machinery Industry, ICIS/119 and Add.1 and 2.

27/ Implementation of appropriate technology in Philippines forestry, ILO, Manila 1982 (draft).

(b) Modification of the head design. A two-part head is used, but the eye is fabricated and bolted to the blade which gives a stronger joint than welding or rivetting;

(c) Use of centralized, controlled furnace heat treatment facilities (in this case at the Metal Industries Research and Development Centre).

The small-scale manufacturer involved in this project is now successfully producing efficient high quality hoes for forestry work. The example illustrates the kind of approach which is required to "scale-down" the production of high quality hoes.

2.4 Building materials[28/]

2.4.1 Introduction

The range of materials used in construction is very wide, and generally heavy and bulky so that transport costs (both from raw materials source to manufacturing units and from manufacturing unit to site) are usually significant contributors to overall cost. The high cost of transport is a crucial factor in many developing countries with inadequate communications facilities, and frequently offsets any anticipated economies of scale through centralized production.

Hence: "Few building materials are manufactured on a large-scale; many are produced efficiently on a relatively small-scale. The industry is usually characterized by a large number of small producers."[29/]

Despite the impact of transport cost, technical and economic factors here caused large plants to predominate in such materials as plate glass and steel, including rolling mills and pipe-forming plants. On the other hand, timber

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28/ A UNIDO world-wide study on the building material sector will be issued in 1984 by the Sectoral Studies Branch.

29/ Building Materials Industry. UNIDO Monograph on Industrial Development No. 3, 1977 (77-1069).

processing and joinery manufacture are both frequently carried out in small-scale plants, the main disadvantage being that larger sawmills are able to install kilns for seasoning. Capital-intensive large plants, such as modern brickworks, may well yield apparent financial advantages if run steadily at high levels of output, but run into serious losses as output drops due to the impact of inescapable fixed costs. Meanwhile small, labour-intensive plants, which can adapt readily to changing circumstances, may in fact yield a higher aggregated financial surplus as well as reducing the need for imported items. In view of the heterogenous nature of the industry, we will focus on cement which is a key material and illustrates the need for a critical examination of the established trend of increasing concentration and larger plants.

2.4.2 The production of cement in developing countries

Cement is an essential and ubiquitous construction material. Its function of binding materials together is fundamental to building, and few, if any, projects can today do without it. Absence or shortage of cement is frequently the cause of delays and price escalation in construction projects in developing countries. Substitutions such as timber or steel are rarely feasible due to inadequate local supplies. In short, cement is needed for construction, which is a prerequisite to capital formation.

In virtually every developing country, the establishment and expansion of indigenous cement-making capacity has been a priority in industrial development. During the decade 1970-1979 cement production in developing regions of Africa, Asia and South and Central America increased at a rate exceeding 7 per cent per annum.[30/] In 1979, these regions produced about 300 million tonnes, over one third of the world's total production. The prospect for global cement production appears to be one of continuing expansion and, according to one forecast, could rise by about 50 per cent by 1990 (to around 1,300 million tonnes), with developing countries accounting

30/ United Nations Statistical Yearbook, 1980.

for as much as nine tenths of the increase.[31/] In India alone, during the sixth five-year plan period (1978-1983) investment in cement plants was envisaged to be 8.42 billion Rs (approximately $US 1 billion) for a capacity expansion of 13 million tons of cement per year. As expansion continues rapidly, the question of appropriate scales of production has elicited increasing attention. Furthermore, the traditional attachment to high quality Portland cement is being questioned in view of the potential cost advantages of producing alternative cements on a small-scale for non-specialist users.

2.4.3 Minimum and maximum sizes of plants

There is no theoretical upper limit to the size of cement plants.

Throughout this century, the trend has been steadily increasing scale of production. The average size of a kiln being installed today by one firm is 2,500 tonnes per day (tpd) while a number of kilns with capacities over 4,000 tpd are already in production. It seems unlikely that the maximum size has been reached yet.

At the other end of the scale, plants producing cement of the same quality at a scale of only 20 tpd are now beginning to come on stream.

Indeed, cementing materials can even be produced on a cottage-industry scale.[32/] One method of cement production from lime mixed with the ash from rice husks used as fuel in a domestic stove produced 30 kg per month (a scale of production four million times smaller than today's largest).

The difference between these two extremes is not just one of scale of production. The properties and uses of the materials made are widely different, as is the technology involved. But it is significant that there is active development work being carried out today at both ends of the scale, as

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31/ "Cement: Quietly Glamorous", The Economist, 17 May 1980.

32/ Technology Alternatives for the Use of Rice Husks, R.K. Mehta, 1983, Appropriate Technology, Vol. 9, Mo. 4, March 1983.

well as at many intermediate points. It is becoming increasingly clear that there is not one single best or appropriate technology for the production of cement.

One million tons of cement per year (which is enough cement to provide 50 kg/capita for a population of 20 million people) could be produced either in a single large plant, or in 200 mini plants each producing 10 tpd or even using the output of 3 million rice-husk burning stoves. It is now becoming possible to choose appropriate scales of production not only by the criteria of efficiency set by the cement plant manufacturers, but also as a response to each country's overall and regional needs. This latter criteria would take into account the pattern of demand for different types of cement, available raw materials and fuel resources, and technological, managerial and financial capability.

2.4.4 Economies and diseconomies of scale

Apparent economies of scale in cement production are substantial, as exemplified in the unit cost indices in the following table.

Table 6. Cement productivity: capital and unit cost indices[33/]

Capacity (tons per day cement)	Index of capital cost of plant	Index of unit cost
500	44	220
1,000	57	142
2,500	100	100

33/ Based on data in Oliver Jensen's, "Cost of New Cement Plants and Conversions", paper presented at the Interregional Seminar on Cement Technology, Beijing, People's Republic of China, 9 to 24 October 1980. UNIDO, ID/WG.326/12, 12 November 1980.

In practice these attractive economies of scale might not be realized in developing countries. Actual performance of large plants frequently fails to match forecasts and projections used in feasibility studies. For example, a recent study of the construction industry in the Sudan reported that of two major cement plants, production at Atbara for 1979/80 was 130,000 tons compared to a rated capacity of 200,000 tons per annum, while the other plant at Rabak produced 43,000 tons compared to a rated capacity of 100,000 tons per annum.[34/] Actual cutputs of around 50 per cent of rated capacity are common, and total financial investment, plant operation sophistication (implying a heavy demand for scarce technical and managerial skills) and increased construction time all increase with increasing plant size. The scope for labour-intensive operations to reduce unit capital costs is also generally greater for smaller plants. But perhaps the most important consideration is the cost of transporting the finished product, which can in fact be greater than the ex-works cost for remote projects (together with the likely deterioration in quality during transit). This factor will be discussed in a later sub-section.

2.4.5 Costs and benefits of smaller-scale plants

Production in a small number of small plants could offer direct savings in transport cost coupled with more assurance of supply through a multiplicity of suppliers. Of course dispersed production in small-scale plants would be possible only if the raw materials (mainly limestone and gypsum) are generally available. Fortunately these materials are widely available in most countries, and a further advantage of small plants is that they can usefully exploit small outcrops of these materials. Another advantage of dispersed cement production associated with production in smaller plants is that easier availability of cheaper cement in rural areas is likely to promote construction of rural infrastructure and spread the benefits of development more evenly.

34/ Democratic Republic of the Sudan: The Domestic Construction Industry - A Survey and Project Identification Report. World Bank/UNIDO Co-operative Programme Report No. 10, December 1981.

Many developing countries with their low density of cement demand may have commissioned larger unit sizes because only such plants are supplied by developed country manufacturers and/or transport costs are subsidized, thereby distorting economic analysis in favour of conventional large-scale solutions. In the following sub-section the four levels of production technology that are currently available are analyzed.

2.4.6 Analysis of available alternatives

Available scales of production

Although cements can be produced at any scale, it is possible to identify four distinct scales of production (table 7) based on the level of technology and types of material produced:

(a) Medium- and large-scale plants producing 500 tpd or more (sometimes very large plants more than 2,500 tpd are identified as a separate group);

(b) Small-scale plants, producing between 100 and 500 tpd;

(c) Mini plants, producing 20-100 tpd;

(d) Village-scale plants, producing less than 20 tpd.

The two largest scales of production, both produce a range of cements, the most important of which are Portland cement (PC), Portland pozzolana cement (PPC) and Portland slag cement (PSC). The raw materials are limestone, a siliceous or aluminous material such as clay or blast-furnace slag, with gypsum and sometimes a pozzolan as an additive. These cements satisfy internationally accepted (ISO) standards, and can therefore be used in virtually any type of building project, or sold readily on the world market.

Table 7. Cement technology profile

Scale of production	Kiln	Materials produced	Quality index (a) (Q)	Technology availability (b)	Other technological considerations
Medium/ large 500-3,000 tpd	RK	PC PBC PPC	1.0 1.0 0.9-1.0	Import (some local mfr)	
Small 100-500 tpd	RK (300+ VSK)	PC PBC PPC	1.0 1.0 0.9-1.0	Import (more local mfr)	
Mini 25-100 tpd	VSK	PC	0.8-1.0	In-country manufacture	May not meet full standard for strength
Micro 25 tpd	VSK	Low-grade cements (c)	0.6 max	In-country design and rural mfr	Standards not universally available

Notes: (a) Implies the quantity required to replace 1.0 ton PC.
(b) Import or local depends on technology capability: this refers to developing countries.
(c) Substitutable for Portland cement only in low-strength applications, mortars, plasters, soil-stabilization, block-making, etc.

Large-scale plants are based on rotary kilns (RK) which are subject to marked economies of scale. For the small-scale plants (100-500 tpd) there are two distinct technologies available. Most existing plants of this size use rotary kilns, but there is an alternative technology based on the vertical shaft kiln (VSK). This technology has for a long time been less favoured than rotary kiln technology, because there is an upper size limit, and there are some control problems. But VSK plants tend to have good fuel efficiency, and with recent developments in discharge and draught control, this has again become a viable technology where availability of raw materials or market size limits production.

The majority of the world's mini plants (20-100 tpd) are in the People's Republic of China, where national industrial development policy in the 1960s and 1970s, promoted the production of cement at county and commune levels for local use. The technology is based on Portland cement, using shaft kilns, but it seems clear that the strength of the cement produced is sometimes below that required in international standards for Portland cement. Unlike other countries, however, the People's Republic of China has a range of standards for siliceous cements, specifying different strengths applicable to different production levels and appropriate to different end-uses. In India, on the other hand, where a single national standard prevails, development efforts for over 20 years to develop mini-plants producing cement that would meet those standards are only now reaching fruition. The principal arguments in favour of mini-scale production is that such plants can use fewer raw materials sources and save on transportation costs. Also, the capital required can be found from local investment and they can quickly be brought into production.

Village-scale cement production is different in nature to the other three levels of technology. The materials produced are hydraulic limes and lime-pozzolana mixtures and may best be described as low-grade cements. A whole range of raw materials may be used; limestones which would be quite unsuitable for cement production at any other scale, volcanic tuffs, ground brick waste, and the ash from burning agricultural wastes. The cements are slower setting and are weaker than Portland cement. They can nevertheless be used for purposes in which much strength is not required (and for which their other properties may make them more suitable than Portland cement). For such specific purposes it is quite feasible to formulate mixtures which meet relevant performance standards. The production of such low-grade cements is considerable in some developing countries. They are mainly used for rural building, and their production flourishes when there is a shortage of manufactured Portland cement.

Table 7 summarizes the most significant characteristics of the four levels of technology defined above. The bulk of the equipment for both large- and small-scale plants will have to be imported and may also have to be operated, at least for some time, under the guidance of the plant manufacturer. Downtime for repairs and maintenance may be drastically higher than expected. Indeed, there is evidence that in the larger plants recently installed in developing countries, over-sophisticated control systems have resulted in much lower output than anticipated. Plants providing lower levels of production, on the other hand, require very little imports of manufactured equipment or expertise, and repairs and maintenance are more easily executed by local people using local materials and components.

Cement quality is frequently regarded as constant. There could be real economic advantages in using, where possible and safe, cements of lower strength than standard Portland cement. It is true that there would have to be safeguards against the use of lower strength cements for structural purposes, such as reinforced concrete beams, columns or slabs, but close inspection of materials is already necessary (and provided for) on projects of that kind. The potential savings are attractive. Although no definitive figures are available, it is estimated that only 20 per cent of world-wide consumption of cement requires the full strength of international Portland cement standards. Approximately another 40 per cent is used for structural purposes where a somewhat lower strength would be adequate if it was well-controlled. The remaining 40 per cent has uses (such as mortars and plasters, foundation concretes, concrete blocks, soil stabilization) for which low-grade cements would be perfectly adequate. Thus, for about 80 per cent of all cementing materials needed, there is a potential for a real choice of technology, which could be made on the basis of local considerations. Two major factors influencing that choice will be transportation and energy.

Impact of transportation costs

Cement is a material with a very low manufacturing cost per unit weight, which means that the transport cost forms a significant proportion of the price which the consumer pays. In India, where most cement is delivered by rail, there is an average freight charge of about 28 per cent of the production cost, but there are many parts of developing countries distant from existing cement plants, where the transport cost even exceeds the production cost. The choice of appropriate scale of production should be based on the total cost at the intended points of use, rather than the cost of production alone. A dispersed pattern of small-scale plants, situated at a distance from existing or planned large plants, may therefore show an economic advantage even if the unit cost of production is somewhat higher than in a single large plant.

National pricing policies which equates the price of cement for all consumers, consequently eliminate the transportation cost advantage to the local producer and thus create a bias in favour of large centralized plants. This encourages a wasteful use of scarce transportation resources. In such cases overload of existing railways or lack of trucks can seriously inhibit cement distribution. India, which has operated such a policy since 1956, has now begun to change it and to provide additional incentives for small plants. Packaging is a further consideration since cement must be bagged or moved in closed wagons if it is to be transported over long distances. However, re-usable sacks can be used for local distribution from a mini plant, further reducing transport costs. An intermediate alternative to integrated local small-scale cement plants is the split-location plant, in which cement clinker is moved from the large-scale central factory, where the kiln is located, to a number of smaller local grinding and bagging plants. Clinker can be transported more cheaply than bagged cement, and without loss.

The role of energy and fuels

Cement is an energy-intensive industry, and electricity and fuels constitute the largest part of the production cost. The bulk of the fuel is used in the kiln, where a temperature of 1,450°C must be reached. The theoretical heat requirement for burning clinker is slightly over 400 kcal/kg, and most kilns operate at thermal efficiencies between 25 and 55 per cent.

Among rotary kilns there are clearly established economies of scale in energy consumption. The increase in the scale of kiln along with the introduction of more energy efficient kiln technologies, dry-process plants, preheaters and precalciners have all led to increased efficiency. Today's large plants have a kiln energy consumption of only about 750 kcal/kg, or about 65 per cent of the theoretical efficiency.

Shaft kilns have smaller heat losses because of their compact configuration, and even small plants can compete with the most efficient rotary kilns on energy grounds. Old small VSK plants had lower specific energy consumption than recent RK plants, but no figures are available for recent small VSK plants outside the People's Republic of China. In the People's Republic of China energy consumption between 800 and 1,000 kcal/kg are reported for various shaft kilns with outputs from 100-200 tpd. Smaller shaft kilns incur greater energy losses, and mini plants can be expected to use 20-25 per cent more fuel than small VSK plants.

There is considerable scope for energy savings by increased use of fly-ash or slag in cement, since these are industrial waste products which can be introduced at the grinding stage, thereby reducing kiln energy per unit weight of cement. Blended cements can be produced in any scale of plant. The use of low-grade cements can result in overall energy savings. Although the kiln processes for burning limestone are relatively inefficient at a small scale, these cements contain a high proportion of naturally occurring or waste products which need no calcining. Thus, economies in energy consumption over conventional cement production can be achieved either by scaling up, or by scaling down, or by producing cements of different types.

2.4.7 Beyond current alternatives

Spurred by the increasing world-wide demand for cement and cement-based materials on the one hand, and by high energy costs on the other, the cement industry has been experiencing an active phase of technological development. The primary objectives have been to reduce energy costs through greater thermal efficiencies to use alternative fuels, and to reduce unit capital costs. There has also been a recent trend to devote research and development achieving efficient output at smaller scales of production. Present trends will continue in the near future and large plants will continue to provide for the bulk of the expansion of capacity. However, as the technologies become established, there is also likely to be a rapid rise in the number of small and mini plants located mainly in areas away from existing large plants, and lower-grade cements produced at a very small scale will increasingly be used in the rural areas. Industrial development plans will have to consider and balance the contribution of production at all technological levels to make the best use of available resources.

2.5 Petrochemicals

2.5.1 Introduction[35/]

The chemical industry has been described as "huge, bafflingly technical and hard to pin down".[36/] It is also ubiquitous, since "petrochemical products and their derivatives run into many hundreds ranging from fertilizers, solvents, plastics, fibres, synthetic rubber, detergents, dyestuffs, explosives, drugs, proteins, speciality chemicals, to many derivatives which find application in various parts of industry and everyday life".[37/] The industry is generally perceived as heavy, commodity-based and capital-intensive as a result of its dependence on high technology and high added-value products. Therefore it is an industry in which the arguments for economies of scale are overwhelming. This impression is broadly correct for the production of basic petrochemicals, although "as one moves further downstream to end products, the economic capacity becomes smaller and smaller".[38/] Indeed, for dispersed markets and specialist applications, smaller entrepreneurial businesses (whether producing simple plastic cups or a sophisticated fluorescent solution to identify faults in compressor blades) are more likely to possess the flexibility that is required to respond to their particular market.

35/ A Plant Cost Evaluation System is being worked out in UNIDO which will help to analyze the cost of production under different assumptions.

36/ "Chemicals: A Survey", The Economist, 7 April 1979.

37/ Opportunities for co-operation among the developing countries for the establishment of the petrochemical industry, UNIDO Sectoral Working Paper Series No. 1, UNIDO/IS.376, March 1983.

38/ Ibid.

2.5.2 Growth, technology and scale

The original inorganic chemical industry in developed countries employed relatively low technology using raw materials such as animal fats, salts, limestone, pyrites and phosphate to produce intermediate products such as dyes and bleaches for the textile industry and simple phosphate fertilizers for agriculture. The startling growth in size and complexity came with the development of organic chemicals made from oil and gas after the Second World War. For example, ethylene and propylene, major basic petrochemicals, had a growth rate of 17 per cent per year between 1950 and 1973. Over the 20 year period from 1950 the world consumption of synthetic fibres increased by 68 times and that of plastics and synthetic rubbers by 18 and 9 times respectively. The consumption of low-density polyethylene (LDPE) in Western Europe increased from just under 100,000 tons per year in 1955 to just over 3 million tons per year in 1973.[39/]

The most obvious outcome of this dynamic growth was a blurring of the industry's boundaries. Even the split between organic and inorganic products ceased to hold. For example, 60 per cent of the PVC is derived from inorganic chlorine and 40 per cent from ethylene. Defining the industry itself has become more difficult. Indeed, it may be that this blurring of the industry's boundaries has been a factor in the encroachment on the industry by enterprises originating in other sectors. The major oil transnationals led the way in the 1960s, as they grasped the opportunity to participate in the sustained growth of petrochemical demand. They were able to finance investment in bigger, capital-intensive plants as new technologies were developed (from compressors and valves to chemical catalysts) that could yield productivity gains of 6 to 10 per cent a year.[40/] Not only was the market growing rapidly, the feedstock was relatively cheap and ample, and the numerous technological advances yielded quick profits to investors in new, large plants. Such plants were able to reduce unit costs and the

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39/ Ibid.

40/ The Economist, 7 April 1979, op. cit.

manufacturers could build a market share through the replacement of traditional products. The surge of new plant building led inevitably to some, frequently temporary, surpluses of capacity, but the rapid growth of consumption made the ever larger plants ever more financially-enticing.

2.5.3 A changing cost mix

The rise of oil prices in 1973 changed the picture. The oil companies now had a new incentive to invest in petrochemicals since their traditional profit centres were squeezed by acute supply problems. They were encouraged to expand downstream in order to regain control over their pricing system. This was despite the fact that petrochemical manufacture rapidly became a much more risky business as the raw materials component became a significant cost factor. For example, in the case of ethylene production, the cost of naphtha feedstock in 1972 was in fact covered by the credit value of by-products, whereas by 1983 it contributed more than half of production cost.[41/] This changing cost mix began to undermine the almost automatic advantage enjoyed by investors in - "bigger and better" - plants which, with high break-even points, needed a steady and massive throughput to produce an acceptable financial performance. Meanwhile the major oil companies were finding that chemical technology and oil refinery technology were not so compatible as they might have appeared, since chemical processes are usually more capital-intensive leading to more rapid depreciation of the plant. Anticipated benefits from controlling the whole chain of production proved elusive, as transnational oil companies experienced enormous losses due to their inability to foresee and cope with a violently fluctuating demand. British Petroleum (BP) invested £550 millions in the chemicals sector between 1976 and 1981 and suffered losses of more than £180 millions during the last two years of that period. These losses persisted, and during 1982 BP ceased PVC manufacture in a swap arrangement with Imperial Chemical Industries (ICI), which was estimated to result in an extraordinary write-off of a further £110 millions.

41/ UNIDO/IS.376, op. cit.

The pattern observed was clear: high growth rates, new technologies favouring newer and larger plants, the influx of investors with a massive cash flow from their primary activities who thought it was advantageous to control the entire chain of production. But this confidence proved misplaced and they learned the hard way that (as stated in the opening paragraph of this section) "as one moves further downstream to end products, the economic capacity becomes smaller and smaller". Yet large plants still have real advantages for the manufacture of bulk products, and the most popular plant size for ethylene production appears to be in the order of 300,000 tons per year, with oil-producing countries as well as oil transnationals the most prominent investors. These two groups share the belief that, by moving downstream into petrochemicals, they can achieve a higher added-value to enhance the return on their basic product. This raises the important question of transfer value of the feedstock. If the transfer price for a plant at the well-head in an oil-producing country is set below market value, the plant can appear to be profitable. But the financial position can only be realistically assessed on the basis of realistic opportunity costs, which may alter the calculation dramatically.

Since in most developing countries other economic and social considerations are involved in deciding on the establishment of this industry it would be proper to take into consideration analysis of all costs and benefits related thereto.

2.5.4 Costs and benefits of smaller-scale plants

"In planning the development of the petrochemical industry in developing countries, it will not always be practical or correct to use the same technical and economic considerations with regard to selecting the type and size of plants as is currently applied in the developed countries. On the contrary, developing countries may have to protect the young local industry in order to enable it to take root and grow to become competitive".[42/] However, an infant industry is only worthy of protection if there are resulting benefits. Thus, if an oil-rich developing country is considering investment

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42/ Ibid.

in a downstream facility that will manufacture products far in excess of domestic demand, the costs and benefits should be realistically evaluated. A series of small, relatively simple plants could yield social, employment and training benefits, while being susceptible to local participation in repair and maintenance. These considerations may well offset the apparently better technical efficiency and target financial performance of larger plants built and operated in other circumstances and environments. There is evidence that even the sheer investment attractions of building large plants in oil-producing countries are being eroded. For instance, it is reported that the cost of building such a plant in Western Asia is now up to two-thirds more than for an identical plant in Europe because of logistic problems. Thus, an estimation of capital investment costs for a steam cracker, using some 1.7 million tons/year of naphtha and producing 500,000 tons/year of propylene or its equivalent produced a figure of about $US 3,700 million if built in Western Asia as against about $US 2,600 million if built in Europe.[43/] However, the deciding factor in building such a plant or not is the cost per unit of production and its how competitive it is with other producers, particularly traditional ones. To this must be added the possibility to market these products successfully. In this respect it would be interesting to see the performance of the Saudi Arabian plants during the coming years.

2.5.5 Analysis of alternatives

Although the capital cost of large petrochemical complexes in developing countries is distinctly higher than in developed countries, it is also true that fixed costs are now a less significant factor in overall costs. For ethylene, the leading base petrochemical, the index of production cost rose from 100 to 861 over the period 1972-1980, while depreciation (related directly to capital cost) rose only from 100 to 215. Meanwhile the feedstock index dramatically rose from 100 to 1,465.[44/] It is difficult to evaluate

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43/ How to Learn from Project Disasters, O.P. Kharbanda and E.A. Stallworthy, Gower Publishing Co. Ltd., 1983, p. 163.

44/ The Second World-Wide Study: Process of Restructuring, UNIDO ID/WG.336/3 and UNIDO ID/WG.336/3/Add.1, 19 May 1981.

the countervailing attractions to siting plants close to fuel and feedstock sources, or close to the market. All the signs point to a continuing heavy weighting of demand towards the developed countries (table 8). The combined effect of growing demand and feedstock of energy availability in developing countries would reinforce the tendency to build basic and commodity petrochemicals close to the raw material source in these countries.

Table 8. Forecast per capita consumption of major petrochemical products (kg per capita)

	World		Developed countries		Developing countries	
	1981	1990	1981	1990	1981	1990
Ethylene	7.9	13.5	25.7	46.7	0.9	3.5
Thermoplastic	9.4	15.4	24.7	48.0	2.2	5.5
Synthetic fibres	2.7	2.9	7.6	8.2	0.8	1.3
Synthetic rubber	1.9	1.9	6.1	6.6	0.3	0.5
Methanol[a/]	3.5	5.3	9.7	19.8	0.4	0.9
Ammonia[a/]	21.8	20.1	38.4	47.5	13.6	11.7

a/ Figure relate to 1979, not 1981.

Source: The Second World-Wide Study: Process of Restructuring, UNIDO ID/WG.336/3 and UNIDO ID/WG.336/3/Add.1, 19 May 1981.

Large plants are unlikely to secure a strong local market and their financial viability will depend upon their ability to offer competitive products to remote customers, which is most likely to be possible in bulk chemicals. This is a possibility for oil-producing countries, who will be able to play an important role in industrial restructuring if they concentrate on bulk products where their favourable overall cost structure might allow them to receive and regain substantial export markets. Specialty chemicals, which are likely to increase their share in the total market, depend much more on identification and interaction with specific groups of customers and this market could be more difficult for manufactures in developing countries to penetrate. For example, it is now recognized that there are serious ecological (and economic) costs in the indiscriminate spraying of crops with pesticides and herbicides, which will make it necessary for new technologies to be developed to produce specific agrochemicals for specific crops in specific geographical areas. This implies a close and flexible response to increasingly segmented markets.

Increasing market segmentation may provide the inputs to develop technologies to enable smaller plants to operate more economically by making use of locally favourable conditions (lower financial requirements, shorter construction period, use of local materials, manpower and other resources) and responding to local market needs. The UNIDO-sponsored seminar on the fertilizer industry (held in Lahore, Pakistan, 15 to 20 November 1982) confirmed the feasibility of this approach in respect of ammonia production, where "even a 100-ton/day ammonia plant becomes in certain circumstances feasible and attractive".[45/]

The increasing costs, and financial risks arising from higher break-even points in a fluctuating market, have led to a more balanced research and development effort. A recent UNIDO document[46/] notes that "attention is being paid to develop smaller economic size units to suit the developing countries, and it is expected that by 1990 there will be greater flexibility in selecting and designing plant capacities". One example is the "higee" distillation unit developed by ICI, a 30,000 tonne per year plant, which is compact enough to be transported on the back of a truck and more adaptable than conventional plants (closing down or starting up in about 2 hours rather than around 2 days).[47/] Although the demonstration plant costs nearly $US 1.7 million, it is estimated that capital costs will come down to roughly half those of a conventional distillation plant. The chemical sector, with its fragmented and dispersed markets appears to offer substantial scope for

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45/ UNIDO/PC.61 Report, 8 December 1982.

46/ UNIDO/IS.376, op.cit.

47/ The Guts of a Chemical Plant Will Now Fit on a Lorry, The Economist, 13 November 1982.

economic co-operation among developing countries (ECDC). For example, individual countries within a market region could agree to allocate the production of various products between themselves. One country might, for example, produce a plastics intermediate, another a synthetic fibres intermediate and another fertilizers for the specified joint market.

2.5.6 Beyond current alternatives

Oil is a non-renewable and limited resource. Despite recent over-supplies and dips in price, forecasts that production will peak at some stage during the 1990s will probably turn out to be correct. Research is already focussing on alternative fuels and feedstocks. One possibility is a return to making organic chemicals from coal, which had been replaced by oil and gas because processes based on the latter are both easier and more economic (at current prices). Gasification, liquefaction and pyrolysis are the main alternatives, although none are as economical at the current ratio of coal to oil prices. Another possiblity is to manufacture fuels or chemical feedstock from vegetable matter of biomass. Brazil has a fermentation industry which manufactures ethanol from sugar, although it has been estimated that it would need to boost its crop yields of sugar and manioc by a factor of ten to have a viable chemical industry based on them.[48/] Technologies based on coal or vegetable matter are still tentative, and their economic viability will depend upon future rises in the real price of oil and gas. Thus, it is premature to forecast the effect of these alternatives on the scale argument although it can be stated that, in an increasingly uncertain operational and economic environment, simple bulk chemical plants with a low break-even point may well turn out to be less risky than large conventional plants. Therefore they will be particularly attractive for non oil-producing developing countries with limited markets and financial resources.

48/ The Economist, 7 April 1979, op.cit.

2.6 Fertilizers[49/]

2.6.1 Introduction

Prior to 1974 fertilizer demand developed at a relatively stable rate. In 1975 world consumption declined for the first time in recent history. In 1979/80 and 1980/81 declines occurred again in some major areas, including North America, Western and Eastern Europe. The fertilizer market became characterized by periods of oversupply, followed by brief periods of shortages.

Demand for fertilizer continues to increase annually at a rate of 4-8 million tons of which 3-4 million tons is in nitrogenous and the balance in phosphate and potash fertilizers. The largest portion of this increased demand can be attributed to the developing countries such as the sub-continent of Asia and Central and South America. In Africa, where the food deficit is equally great, the demand for fertilizer remains at the lowest level.

This inequality between the various regions in fertilizer use indicates the existence of large potential demand and the possibility for further development of the fertilizer industry.

2.6.2 Development of capacity and capacity utilization

To supply the growing demand between 1975-1981, additional capacities were built all over the world, however, much more extensively in the developing countries, where several new fertilizer production centres have emerged. At the same time, a number of old and less efficient plants in the developed world have been closed or idled. Except for potash this transformation has changed the pattern of capacity share between the developed and developing countries (table 9 and 10).

49/ The section on fertilizers is extracted from Mini-Fertilizer Plant Projects, Sectoral Studies Series No.7, Vol.I, December 1, 1983 (UNIDO/IS.416).

Table 9. Share of developed and developing countries in fertilizer capacity development (per cent)

	Ammonia N Capacity mid		Phosphoric acid P_2O_5 Capacity mid		Potash K_2O Capacity mid	
	1975	1981	1975	1981	1975	1981
Developed countries	76.9	70.8	83.2	81.3	99.7	99.9
Developing countries	23.1	29.2	16.8	18.7	0.3	0.1
Total world	100.0	100.0	100.0	100.0	100.0	100.0

Source: Based on paper of FAO/UNIDO/World Bank, Working Group on Fertilizers, June 1982.

2.6.3 Structural developments in the fertilizer industry

Increasing raw material and energy costs, inflation and a poor market are the most important factors causing the structure changes within the fertilizer industry in the world, particulary in the developed countries.

In the United States, for example, a total of 4.7 million tons of annual ammonia capacity has been shut down from 1977 to 1981. There are many plants that are operating at reduced production rates. The United States, once a major nitrogen producer in the world and a net exporter are losing their position by the rising price of domestic natural gas.

In Japan the nitrogen industry closed a total of 1.2 million tons annual ammonia capacity. Over 40 per cent of the Japanese urea capacity will be closed as a part of a restructuring plan.

Phosphoric acid producers in Japan are also closing about 20 per cent of the capacity in the older and smaller plants. They find an advantage in importing phosphoric acid and ammonia from the countries having raw materials. Also in Europe the markets and sources of supply are changing.

Table 10. CAPACITY CHANGE, BY REGIONS

Region	Ammonia /1975 - 1986/ Additional /+/		Ammonia Closed /-/ or idled a/		Phosphoric acid /1975 - 1986/ Additional /+/		Phosphoric acid Closed /-/ or idled		Potash /1975 - 1986/ Additional /+/		Potash Closed /-/ or idled	
	Thousand tons of N, P_2O_5, K_2O											
Developed Market Economies	12,578	/22,4%/	8,613	/92,7%/	3,289	/25,4%/	903	/70,5%/	6,361	/37,8/	1,952	/86,7%/
North America	7,532		4,241		2,445		496		3,551		1,032	
Western Europe	4,523		3,198		448		317		1,830		920	
Others	523		1,174		396		90		980		0	
Developing Market Economies	19,667	/35,0%/	522	/5,6%/	6,767	/52,3%/	377	/29,5%/	1,098	/6,5%/	300	/13,3%/
Africa	590		0		3,345		130		0		300	
Latin America	5,542		0		1,361		89		378		0	
Near East	5,188		109		1,236		158		720		0	
Far East	8,347		413		825		0		0		0	
Centrally Planned Economies	23,972	/42,6%/	153	/1,7%/	2,880	/22,3%/	0		9,370	/55,7%/	0	
Asia	6,641		153		0		0		0		0	
Eastern Europe	17,331		0		2,880		0		9,370		0	
All Developed Countries	+29,909	/53,2%/	-8,613	/92,7%/	+6,169	/47,7%/	-903	/70,5%/	+15,731	/93,5%/	-1,952	/86,7%/
All Developing Countries	+26,308	/46,8%/	-675	/2,3%/	+6,767	/52,3%/	-377	/29,5%/	+1,098	/6,5%/	-300	/13,3%/
World Total	+56,207	/100%/	-9,288	/100%/	+12,936	/100%/	-1,280	/100%/	+16,829	/100%/	-2,252	/100%/

Source: Based on paper of FAO/UNIDO/World Bank Working Group on Fertilizers, June 1982.

a/ Idled plants are those which are mothballed until economic conditions are such as to bring them into production. Closed plants are those permanently closed and will not be brought into operation regardless of economic conditions.

During the 1970s a new trend in the development of the world fertilizer industry has been initiated, which is expected to continue for the foreseeable future. With the increase of energy and raw material costs the locations of the new plants are moving towards the place adjacent to the cheap and abundant feedstock.

Energy cost, inflation and raw material prices will be the major pressures faced by world fertilizer producers, primarily in the United States, West Europe and Japan. In this connection the advantage has been moving to fertilizer plants located adjacent to cheap feedstock, although some of this advantage is being lost due to higher capital/operating costs and escalating freight costs. The natural resource availability is becoming the prime determinant in project determination.

Many of the traditional fertilizer producers in the developed countries, most of all those processing imported raw materials, are losing their leading position in the fertilizer trade. Increased ammonia output in Mexico and Trinidad and Tobago will penetrate the United States market, where local production will no longer be competitive with imported products.

Important ammonia/nitrogen production centres, many of them export oriented, are appearing in Africa, the Near East and Asia. The production, based on domestic natural gas of Algeria, Libya, Nigeria, Tanzania, Kuwait, Bahrain, Qatar, Saudi Arabia, Bangladesh, Thailand, Malaysia, Indonesia, etc., will supply not only the nearby markets but also developed countries in Europe and/or Asia.

A similar role will be played by the development of the phosphoric acid and phosphate fertilizer industry in Morocco, Tunisia, Senegal and Togo, although the United States will continue to maintain a competitive cost position in the world phosphate trade due to its abundant natural phosphate resources.

As for potash, the United States has long lost its self-sufficiency and is dependent on Canada and other countries for about three-fourths of its agricultural requirements.

Substantial structural changes will take place within the production structure of the fertilizer industry in developed countries. Present plants, particularly ammonia units, will be further modified and old plants that cannot be modified will close.

A new generation of thermally efficient plants will start to appear in the 1980s, due to the need of conserving energy, hence, to produce ammonia at a more economically attractive level. With the increasing imports of phosphoric acid or phosphate fertilizers many sulphuric acid plants are expected to shut down, although the by-product capacity is expected to continue to grow, because of restrictions on SO_2 emissions.

2.6.4 Technology and scale

The production of three nutrients in fertilizers was in 1980/81 in the order of 125 milllion tons and is expected to increase to 173 million tons in 1990/91. A considerable part of the new capacity will be installed in the developing countries, particularly where local raw materials are available.

On analyzing the evolution of the fertilizer industry, it is noted that there have been no major breakthroughs in the chemical technology during the past decades.

Basically, the fertilizer industry continues to be a derivate of ammonia, sulphuric acid, phosphate rock and potash salts. The change, which has taken place in the meantime has mainly been of a physical nature. For example, the unit capacity of all manufacturing plants has grown considerably. Thus, whereas an ammonia plant of 200 t/d or a sulphur acid unit of 100 t/d was not considered small three or four decades ago, a 1,000 t/d unit would not be considered exceptionally large in the 1970s.

There have been also considerable changes in downstream conversion of basic chemical raw materials into more concentrated final products. The conversion into high analysis fertilizers like urea, triple superphosphate, ammonium phosphates have reduced the share of low analysis products such as ammonium sulphate, single superphosphate, ammonium nitrate etc., in the total production and consumption of fertilizers. For example the fertilizer production in the developing countries is almost entirely based on urea, because it can be delivered to farmers at less cost per unit N than in any other form. Other development is the granulation of fertilizers, which has substituted pulverous products from the past.

The development of the fertilizer industry can be attributed to the accelerated expansion of the fertilizer market in developed countries. In general, when the market expanded it has been found more economical to build large tonnage plants instead of multiplying the number of small units. This way, the industry benefited from the economy of scale and a general increase in efficiency.

On the other hand, this situation does not necessary apply to the developing countries, where the fertilizer market size is comparatively limited. This fact and high investment which is necessary for large units and for the infrastructure have in many cases hampered the development of the fertilizer industry in these countries.

The present fertilizer industry has been developed under conditions of low-cost energy, which encourage equipment-intensive and energy-intensive manufacture and long distance transport. The rise of energy prices directly caused a rise in fertilizer prices. Consequently it gives a strong incentive to develop processes that have higher energy efficiency.

The general trend in technological development in fertilizer industry could be summarized as those directed towards:

(a) Energy saving technologies;

(b) Improvement in the input/output co-efficients, i.e. higher yield from same raw materials;

(c) Improved application of fertilizer, i.e. decrease the amount of work;

(d) Diversification of raw materials, i.e. new sources of raw materials and improved method of the utilization of minerals of low concentration;

(e) Long-term research in direct plant fixing and new biological varieties (genetic engineering).

The size of capacity has been steadily going up over the last few decades. The main reason for this has been the economy of scale, but in case of ammonia a breakthrough in technology has played an important role, too.

Many of the modern fertilizer plants have a very large size. These sizes have been reached gradually, thanks to continuous improvements in technology allowing increasing scale economies due to the fact that investments increase less than proportionally to capacities. A large size unit is chosen particularly for export oriented plants. However, problems arising from the need to provide huge financing, from delays during the period of construction and from the high cost of transportation of the products particularly in the developing countries where infrastructure is generally lacking have posed doubts about the viability of these very large plants. Moreover, these problems and the cost involved in their solution are pressing towards the reconsideration of the advisability of building large plants.

The level of demand for fertilizer in many developing countries is so small that only smaller units could improve their fertilizer supply situation. This may apply also to larger countries with isolated and distant agricultural locations where it may be economically viable to establish several small plants (100-200 TPD ammonia) near the centres of consumption rather than a large unit centrally placed. Such solutions would be important for countries that have sources of raw materials and energy in small natural gas fields, oil, coal and phosphate rocks spread throughout the country.

It is estimated that under such conditions there would be a need to establish between now and the year 2000 some 215 ammonia plants, 214 urea/ammonium nitrate plants and 110 P_2O_5 plants. The total direct investment cost of these plants is estimated at some $US 25,000 million with an additional $US 10,000 million to be invested for developing adequate handling and distribution systems.

The possibilities for international co-operation to implement such a huge programme are unquestionable in the fields of financing, construction, equipment delivery, training, technology transfer and research and development. Moreover, it would provide a much needed activity to reduce the problem of hunger in the world.

2.7 Pulp and paper

2.7.1 Introduction

Over the past 50 years or so paper manufacturing faced with booming demand in the industrialized world has pushed steadily at the frontiers of scale, in terms of size and speed. The boom continued until about twenty years ago when the first signs of recession began to appear. Since then the industry has declined and polarized and under the current recession it is amongst the most affected of the major industries. Many of the older, smaller mills have closed down. This could be taken as an argument for the greater viability of larger-scale production but there have been casualties amongst the larger mills also, less perhaps in the form of closures than in take-overs so that the largest have become larger, but not necessarily more profitable. Over the whole period, activity was concentrated in the industrialized world, chiefly in the countries with softwood resources. Only a very small proportion of the total new production found its way to the developing countries. As these countries are increasingly considering ways of entering the sector, it is opportune to review those factors that are relevant to decisions on appropriate scale.

2.7.2 Wood-based pulp mills

The advantages of scale are formidable when adequate wood supplies with the right quality are available. Production costs are lower because the same crew services greater capacity and capital costs are lower per unit of production. The paper machine can be compared to a bridge with rotating members, costing more as the span increases. The pulp mill is more like a container whose unit cost decreases as volume increases. Pulp quality is more uniform with greater volume, steam and power consumptions lower, and chemical recovery more efficient, often yielding also valuable by-products. The maximum capacity seems to have levelled out at around 1,000 tonnes per day (tpd) as brown stock, the limit being set by the size of the washers where the bridge analogy applies again. It does not follow that associated paper machines should have equal capacity, and except for some liner board machines they do not. Pulp mills of this capacity normally serve more than one machine or have an export pulp market. Although the technical advantages of large-scale wood-based pulp mills are clear, they are practical only when sufficient wood is available at the right price. Furthermore, if the cost of forest maintenance, felling, roads and transport equipment are taken into account, the apparent direct economic advantages may often be offset. Smaller plants using predominantly waste wood for pulp may require minimal additional infrastructural investment, and thereby prove a useful addition to rural development schemes with a forestry component.

2.7.3 Non-wood pulp mills

Pulp mills for non-wood fibres have several limitations to scale. With the exception of bamboo, which acts like wood, the materials most used are agricultural residues such as straw and bagasse or grasses, reeds, etc. These materials will not flow naturally through the continuous pulper designed for wood and they cannot be properly loaded or emptied as cooked pulp from standard stationary digesters. In continuous cookers they must be impelled by screws through the cooking zone; batch digestion can be achieved in small-capacity spherical digesters with large loading and emptying lids or in open vessels.

Continuous pulpers are limited in scale by the screw operation because straw or bagasse have relatively short cooking times and the pulp strength and yield are adversely affected by over-cooking. The cooked pulp is also much less free than wood-pulp so for a given area of washer surface the throughput is reduced. The washer for 1,000 tpd of long-fibre wood-pulp is only capable of handling around 150 tpd of bagasse pulp and this represents the upper limit of capacity for a single line. The lower limit for continuous pulping is now as small as 15 tpd, since mills of this size have become viable over the past five years as a result of development in controlled continuous cooking and efficient chemical recovery. Even smaller levels of production can be achieved by using batch-type spherical digesters (around 4 tpd) or pulper-cookers.

However, the physical limitations to scale are matched to the limitations imposed by the availability and collection of the raw material. If the collection zone is greater than around 50 miles, the cost of delivery can seriously affect viability. If this is accepted as a limit and only surplus straw or bagasse is available the mill is unlikely to be capable of approaching the maximum scale and 20/50 tpd is more normal. The scale can reach a maximum level when all the bagasse from a large sugar mill can be obtained, either because substitute fuel is economically available or through efficient organization where all surplus straw is collected. However, mills as small as 10 tpd can be viable in remote areas with no other source of supply.

Capital costs for small-scale non-wood mills are not significantly higher per unit of production than those for wood-based mills particularly if bleached pulp is required; three-stage bleaching is sufficient whereas the wood-based pulp requires 5-stage bleaching.

2.7.4 Paper-making machines

There are a variety of factors that impinge on the choice of scale in a paper-making plant. These will be examined under eight headings:

(a) Quality
(b) Speed
(c) Instrumentation and control
(d) Stock preparation plant
(e) Efficiency of production
(f) Production costs
(g) Capital costs
(h) Market.

(a) Quality. The conventional large-capacity paper machine, which is both wide and fast, has no intrinsic quality advantage over narrower machines. Indeed, the opposite could be argued, since the very highest quality papers, such as bank-note paper or formica inlay, can only be made on slow, narrow machines (admittedly these are speciality papers with a limited market). However, this consideration also applies to more commercial papers, such as sack-kraft. One of the most important characteristics of good quality paper is cross-machine directional strech, which is distinctly easier to obtain on a narrow machine. Width also creates problems of level drying (i.e. uniformity of thickness, moisture across the sheet width) and finish, which are vital for all grades of paper, particularly where high speed is concerned. These technical problems affecting large machines have gradually been solved by technological developments (such as special flow-box and slice design, self-cambering "swimming" rolls for presses and calenders and double steam and condensate nozzles for drying cylinders), which have added to both cost and sophistication. Automatic substance, moisture and level controllers have also significantly raised quality standards for wide machines as has computerized control but again, at a cost.

Generally, it should be recognized that quality, with the exception of speciality papers, is subject to price and the emergence of the large capacity machine has almost eliminated some of the paper grades which at one time were bought on quality alone. Although cost is more important than quality for most customers, it is clear that in terms of quality, larger-scale production has no inherent advantages and often fails to meet standards which are readily attainable on smaller machines.

(b) Speed. The critical speed of a paper machine is an inverse function of the deflection of the rolls which is in turn a function of their width to the third power. Therefore, for a wide machine the rolls have to be disproportionately larger to run at the same speed and for some of the widest machines material of a higher modulus elasticity must be used, such as stainless steel. Protected mild steel (standard tubes) or bronze is suitable for the narrow machines. Parity can only be achieved by additional cost.

The cost of speed in terms of energy should also be considered, since a high price has to be paid for the increased vacuum requirements to support high operational speed. Time is required for water removal and the higher the speed the less the time available. Furthermore, special expensive synthetic felts are necessary to support high operational speeds. Empirical evidence suggests that the minimum energy per unit of production is obtained at speeds of around 200 metres/minute, and a heavy price is paid for scale achieved by speeds of about 1,000 metres/minute, the current maximum.

(c) Instrumentation and control. Here the large capacity machine has a decided advantage, on the assumption that all machines need similar controls. With one exception the "hardware" costs are the same for a machine of about 100,000 tonnes per annum (tpa) capacity as a machine of 10,000 tpa. The exception is the substance and moisture gauge where the cost, a significant element of the total cost, is disproportionate to width (and will remain so), whereas the other elements tend to decrease with miniaturization. However, sophisticated control is essential for the wide, fast machine but is not necessary for the narrower, slower unit.

(d) Stock preparation plant. For the purposes of this discussion stock preparation plant is included with the paper machine because a pulp mill is not an inevitable adjunct to a paper mill and even when it is, additional stock perparation equipment will be required. However, there would seem to be no particular advantage for either large- or small-scale in this respect. Pulpers, refiners, etc. have been standardized over quite a wide capacity range and are normally used as multiples to achieve a given result. The cost or performance difference in terms of capital or energy is insignificant in the overall scale.

(e) Efficiency of production. Given equal standards of operation and maintenance, experience suggests that the balance is decidely in favour of smaller units due to easier and quicker repairs and maintenance. For example, a press roll can be changed on a small machine (say 3 metres width) in less than two hours and a calender roll in about the same time. For a large machine (up to 7 metres width), 4 and up to 12 hours are required respectively. The incidence of breakdown can, of course be minimized (by costly sophistication which is now a feature for some of the latest machines) but accidents still occur. Another factor is the time taken to clear a machine after a short break, which is generally much less for a small machine.

(f) Production cost. There are no appreciable scale advantages in terms of material utilization, fibre recovery and steam or power consumption per unit of production. Economies of scale arise essentially from savings in labour costs as crew sizes for small and large machines are comparable (although fewer maintenance and materials handling staff are required in small mills). A broad indication is that a mill with one large machine (say 100,000 tpa capacity) would employ about one-third of the number needed for ten mills with 100,000 tpa capacity, but it does not follow that unit labour costs for the small mills, will be three times as great. Large sophisticated paper mills depend heavily on highly skilled and motivated (and highly paid) operation and maintenance staff.

Economies of scale through labour saving are much harder to attain in developing countries, where a large-scale mill could often require expensive expatriate support. Indeed, labour costs for the large Canadian mills are actually higher than the labour costs for the small mills producing similar grades in India because the wage rates are more than five times as high. On socio-economic grounds it can also be argued that it is better to employ three men than one if labour costs are not prohibitive and that it is even better to have ten mills in ten districts than one mill at a single site.

(g) Capital costs. The trend towards larger and more complicated machines has reached a stage where the risk/reward ratio of such investment is daunting, and payback periods are extended. Unfortunately, most of the established machine manufacturers, having tooled up expensively to produce large machines, are no longer capable of producing smaller machines economically. Lathes, planing machines and grinders capable of machining heavy rolls and components 400" long are expensive and seldom used for more than one shift per day. For manufacturers possessing these resources this cost is also reflected in their price for smaller machines, making them less competitive than would be the case for a manufacturer set-up only for machines of moderate size. The capital cost difference would be more in favour of the small machine but for this situation, as it is in India where simple and unsophisticated machines with a capacity of about 10,000 tpa are highly competitive. The quality of paper produced on these simple machines does not always match that of the large plant but this is mainly due to an almost complete absence of instrumentation and control which could be added to a sufficient degree without significant additional capital costs.

(h) Market. The effect of scale on the market so far as the industrialized world is concerned has been to polarize it so that paper production has concentrated more and more in countries with natural wood resources. There has also been a trend towards mergers to secure a market which has led to the largest companies becoming larger and the smaller companies being absorbed. In countries without sufficient timber resources, paper manufacture has turned to waste recycling or specialized grades. In a saturated market the impact of new giant plants has been one factor in holding prices down at unprofitable levels, because the higher break-even points have forced manufacturers to pursue market share at the expense of margins in order to cover the additional overheads.

For developing countries market considerations could be expected to favour smaller-scale production because the total market is likely to be too small to accept the impact of largest-scale production. In many of these countries also, distribution from a central plant may entail excessive transportation costs. This is certainly the case for India where the small mill, serving a local area, can usually compete advantageously with the paper produced by the large mill many miles away. A possible exception to this general rule is newsprint where the consumption may justify a large mill and the market is concentrated among a few major publishers sited in the large towns (the limitations for this product are adequacy of fibre resources and water supplies).

2.7.5 Beyond current alternatives

An unpublished study by the Intermediate Technology Development Group Ltd. on the impact of scale economies and diseconomies trying to determine the machine width representing the minimum cost indicated that the least weight per ton of product was for machines between 2.2 and 4 metres with little difference between. Although the weight of metal is a reasonable index, it is not conclusive. The type of metal and machining costs are also factors and the smaller machines have advantages. Special metals are less necessary and standard tubes can cover a greater proportion. The same is true for components such as bearings. The exercise stipulated equal speeds and control equipment at the highest practical levels, for large and small machines. Subsequent work has indicated that the lower unit cost for the small machines would be lowered further at reduced speed which should be around 200 metres/min for minimum energy. Several feasibility studies were subsequently made in which the output of a group of two or three small machines was compared to that of one large machine. In each case the smaller machines were viable but, not sufficiently so to recover the cost of development on a single project. One interesting factor emerged: there was a significant reduction in cost (around 25 per cent) for two identical machines against one because of the elimination of design for the second machine and the repetitive tooling. In other words, if machines could be standardized, costs would be lower. Apart from the advantages in terms of cost and energy there would be economies in maintenance and cost spares and in simplicity of operation. Training would also be facilitated. Thus, standardization of equipment is logical and would be beneficial. It is inconceivable that it should be based on the current large-scale and the addition to scale has postponed the emergence of standardization.

An interesting approach to standardization is the "Monopulp Concept" offered by a Swedish consortium sponsored by the National Swedish Board for Technical Development, the Swedish International Development Authority and the Swedish Export Council. This offers a complete, integrated 30,000 tpa facility to produce newsprint, writing and printing papers from hardwood chemimechanical pulp, using component standardization and package design and using local fuels. There is certainly a case for those developing countries with ample timber resources and a substantial local or potential export market examining the case for large-scale production. The wide spectrum of scale offers the option of gradual entry into the market so that the investment risk may prove less daunting.

A small-scale pulp moulding process has also been developed beginning of 1969 to manufacture from locally available waste paper and other pulp products, egg, fruit and food packages that would improve food distribution, better people's diet and reduce imports of packages.50/

At that time the moulding technology took the form of large machines producing many thousands of egg packages each hour, whereas what was needed was small equipment making a few hundred packages in every hour economically. This small-scale development was successful, there are now 40 paper pulp moulding systems of different sizes installed in 20 countries from Albania to Zambia producing a variety of packages using local waste paper at rates of 200 to 4,000 each hour.

2.8 Food processing

2.8.1 Introduction

In view of the enormous range of technologies that are available to process and preserve different types of food products, it is impossible to generalize on the merits of small-scale versus large-scale in food manufacturing and preservation. In lower-income developing countries, preparation of food entails repetitive activity such as the pounding of grain in mortars by hand. This tedious activity could be eliminated by the introduction of small mechanical hammer mills, which would retain the benefits of low cost and dispersed production as well as providing a potential avenue for agribusiness based on rural industrial development. The cost need not be onerous, particularly if the power source is not exclusive. For example, small static engines, carefully related in size to the biogas generation potential of the village animal production unit are used in much of the People's Republic of China, south of the Yangtze River, to power a village hammer mill by day and drive an electric generator for a few hours in the evening.

50/ Package Deals. K. Marshall, Intermediate Technology Publications Ltd., 1983.

2.8.2 Cost and benefits of smaller scale plants

Food processing has the complementary roles of preservation, improved security of storage and of providing greater convenience in the feeding of urban communities. Furthermore, transport, both of raw materials and products can easily assume a high proportion of the cost to the consumer. Therefore, a strong case for decentralized production exists. Much of food processing in developing countries is hardly organized on an industrial basis at all. Attempts to set up large town-based industries, or to open up the market to packaged foreign substitutes have often had an adverse effect on the local food industry without yielding any real compensatory benefits to the consumer.

In addition to economic considerations, there are technological questions dealing with quality control, including packaging and sociological questions connected with the demonstration effect and demand for high quality products that must be addressed when a small-scale plant is under discussion. If these questions can be satisfactorily resolved, then the multiplier effect arising from large numbers of small, successful processing units, would appear to be very attractive. The attraction is enhanced if local, small-scale plants involve local resources and require little long-distance transport.

2.8.3 Presently available alternatives

The following table 11 was derived by drawing upon many sources of information coupled with a general assessment based on comparative experience. It presents a starting point for the assessment of scale suitability for 41 separate food processing technologies.[51/] Clearly, generalization over the full range of possible technologies would be outside the scope of this paper.

The following sub-sectoral study illustrates some of the considerations that must be taken into account in formulating policy at specific schedule levels for food processing.

51/ Data supplied by Dr. C. Leaky, Consultant to Intermediate Technology Consultants Ltd. (publication pending). Reproduction by permission of the author.

Table 11. Suitability of various

Process description	Examples of crops & products	Suitability for: Traditional & domestic	Small plant	Large plant
1. Low temperature drying without chemicals	Numerous, e.g. tomatoes - salsa (Arab); dried okra (major Sahel region food; small fish: dates.	9	6	1
2. Drying with simple chemical treatment such as sulphiting, sodium carbonate or gaseous fumigant.	High quality okra; starchy root crop or breadfruit chips; raisins or other dried succulent fruits. Ginger (with the use of sodium benzoate).	1	5	5
3. Drying (high temperature) with the use of pneumatic driers, flash drying. drum drying fluidized bed drying.	Cassava meals from wet slurries; high protein extracts from oil seed meals, etc.	0	1	6
4. Vaccum dehydration.	Reduction of fruit liquids to powders, milk drying, coffee.	0	1	5
5. Cracking, dehulling.	Removal of groundnuts from shells; opening cashewnuts & other nuts; removal of testas from leguminous oils & pulses. Stripping cereal grains from husks.	6	8	4
6. Controlled splitting & cleaning.	Many legume pulse crops, e.g. split peas, pigeon peas, lentils.	4 (localized)	8	2
7. Milling/grinding (destructive)	Preparation of meals and flours from dried cereal grains, dried root crops, etc. Roast cocoa beans to liquor; roast coffee beans to consumer coffee.	9	9	9

scales of production in food processing

Notes	Plant requirements for energy Heat	 Mechanical power	Plant requirements for toxic or hazardous chemicals
Sunlight reduces carotene and vitamin C Protein losses in fish and meat.	Open sunlight; improved solar driers.		-
Sodium carbonate reduces or destroys thiamin and Vitamin C. Sulphiting reduces or destroys thiamin.	As 1. (above)	-	Sulphiting very mildly hazardous fumigants may need special precautions.
High temperature, pneumatic dried starch crop flours may usefully be blended with moist, high protein materials, to produce pelleted mixes at storable moisture.	High grade fuel (oil) usual, but low grade heat can be used additionally by suitable design.	Powered movement of inputs $ products usual.	-
	Low heat.	Mechanically powered vacuum pumps.	-
Reworking (air or mechanical screening) of the shells or hulls can often lead to recovery of useful amounts of commodity, e.g.coffee from husks.	Local heat source often required.	Technology suitable for most 'renewable' power sources, esp. water, wind biogas, animal power.	-
Recovery of broken (not just split) grains is worthwhile.	-	Suited to low power sources.	-
Crude meals & flours retain most nutrients but liable to rancidity.	-	Versatile according to scale N.B. water, wind power historically of major use.	-

Table 11. Suitability of various scales

Process description	Examples of crops & products	Suitability for: Traditional & domestic	Small plant	Large plant
8. Controlled abrasive milling/polishing.	Rice, sorghum, barley, wheat (modern mills).	2	3	6
9. Light cooking (par-boiling)/re-drying.	Rice (with nutrient availability.	2	4	2
10. Parboiling & micro-biological fermentation	Dawa-dawa (from Parkia), idli (from black grams), tempeh (from soya beans).	8 (localized)	8	2
11. Parboiling & salt fermentation.	Oriental fish products; oriental soya products (miso & shoyu), *patent sauces*.	5	6	6 Few but very popular *bottled* sauces.
12. Toasting (light roasting)-mainly for enzyme destruction.	Soya beans, breadfruit (Reef Islands).	1 (very local)	8	3
13. Pressing without preheating.	Fresh fruit juices for sale in retail trade or further processing.	3 (local)	5	3
14. Pressing/expelling with preheating.	Groundnut, sesame, sun-flower and local oil-bearing crops. Oilpalms, etc.	7	7	4 (usually preliminary to solvent extraction)
15. Sprouting.	Small-seeded grain legumes.	3 (S & SE Asia only)	6	2

of production in food processing (cont'd)

Notes	Plant requirements for energy Heat	 Mechanical power	Plant requirements for toxic or hazardous chemicals
Low extraction flours lose energy value (flat) protein, thiamin, riboflavin, niacin, minerals.	Low	Fossel fuel and electricity (with good control)	-
Parboiling before mills ing improves nutrient recovery.	Local heat source with im- 'improved' solar relevant	Low (or zero).	-
Convergent technology from many areas of the world is remarkable.	Low grade.	-	Probably low disregarded traditional processes.
Many products have very strong flavour, high nutritional value.	Low	Low	Low
The traditional S.Pacific storage technology for breadfruit failed to be transferred to other areas.	Good control, fossil or electric most convenient.(Residual heat from firestones in Reef Islands)	Not required in batch toasting but motive power desrable.	-
Produces juice of low shelf-life -easy spoilage.	1 -	Harnessing of cheap local power sources possible.	-
Heat assists coagulation of protein & freeing of the oils.	Local heat sources including burnt hulls etc. often available.	Water, wind, animal power appropriate Note Chinese type draught animal mills also in W. Sudan.	
Digestibility & nutrient value usually increased. Natural toxins often removed,Vit.C.synthesized and riboflavin increased.	-	-	-

Table 11. Suitability of various scales

Process description	Examples of crops & products	Suitability for: Traditional & domestic	Small plant	Large plant
16. Extrusion cooking.	Soya beans, grain legumes, cereals, etc.	0	8	3
17. Puffing.	As above.	0	2	2
18. Popping (form of roasting).	Popcorn; grain amaranthus, Nuña beans (Peru).	3	5	2
19. Roasting/deep frying (high temperature with heating of endogenous or exogenous oils)	Coffee benas, cocoa beans; pop grains (see above) sliced starcy roots & tubers; cereal & mixed dough products; protein curds.	3	6 (fire hazard)	6
20. Sugar-based osmotic preservation (syruping, candying, glazing, etc.).	many raw materials; fruits, stems (angelica), rhizomes (ginger), breadfruit male inflorescences, flowers, nuts, (marrons glacés).	4 (local)	8	3
21. Pickling in alcohol, vinegar or fermented rice water.	Fruits & veg. to picles & chutneys. Eggs. Fruits in alcohol.	5	8	3
22. Solvent extraction.	Primary or secondary extraction of vegetable oils from oil seeds. Cocoa butter separation from cocoa liquor, oleo resins from spices.	0	2	6
23. Liquid or wet milling of oil-bearing seeds.	Soya (oriental), coconuts (esp. Thailand).	5 (soymilk)	6	3
24. Wet pulping to remove unwanted soft tissues.	Coffee (cherry to parchment).	1	5	2

of production in food processing (cont'd)

Notes	Plant requirements for energy Heat	 Mechanical power	Plant requirements for toxic or hazardous chemicals
Developed in USA initially for vegetariuan foods,but now widespread and a valuable technology.	None (generated in extruder by pressure & fric.	High and controlled, B-phase electrical.	
Rather unimportant; attempts to scale down 16.	As above	Manual or small power source.	
Originally an Andean technology applied to 3 plant families.	Local	-	-
Believed criginally Portugese, but has spread worldwide. Fire & burning danger from boiling oil.	Local, or electricity or oil.	Little.	-
Most valuable, under-exploited technology. Protectior of products from insects necessary.	Local or exogenous heat sources, but only moderate temps.	-	-
Very ancient technology for seasonal food preservation, capable of expansion in non-traditional areas.	Minims - washing & preparation only.	-	-
The norm of modern oil technology,but much use-oil seed processing can be done without it.	Well controlled electrical or fossil fuel fired.	-	-
Almost all traditional oriental use of soya beans is based on wet processing.	Controllable heat hot break generally better than coldbreak also for enzyme destruction.	Electrical or fossil fuel for driving high speed mechanical breaker.	-
Removal of sugar-rich outer fruit may result in serious pollution of water ways. But pulping residues may be converted for biogas and/or animal feed.	-	Elec. or fossil fuel (or biogas) or producer gas (from coffee wastes).	-

Table 11. Suitability of various scales

Process description	Examples of crops & products	Suitability for: Traditional & domestic	Small plant	Large plant
25. Green forage or leaf vegetable pulping/ fractionation.	Alfalfa, amaranths, basella, jute leaves. Vegetable processing residues.	0	3	7
26. Steam blanching.	Usually preliminary to drying or curing, canning or apertisation. Okra, vanill-, pulse veg. freezing, peeling.	0	2	5
27. Autoclaving & high temperature drying.	Meat and fish meals	0	3	5
28. Apertisation (canning and bottling).	Vegetables, fruits, meat and fish.	0	3 (e.g. village produce guilds)	6
29. Freezing.	Fruits, veg. etc. Meat, fish including cooked products.	0	2	5
30. Freeze drying. (lyophylisation)	Specialized high value products, e.g. durian powder for flavouring.	0	3	3
31. Salting/brining.	Vegetables such as lima beans peas, okra etc. Fish, shellfish, olvies, etc.	2 (local)	6	2
32. Conserving with sugar (jams, marmalada, sweatmeats).	Many fruits (special interest marmalada from fruits with seasonal surpluses, guava, mangoe, durian, etc.)	5	7	4
33. Evaporation concentration.	Tomatoes, blackberry juice, citrus juices. Milk.	0	2	4

of production in food processing (cont'd)

Notes	Plant requirements for energy Heat	 Mechanical power	Plant requirements for toxic or hazardous chemicals
Fractionation as an aid to dehydration & for leaf protein extration are now developed technologies. Veg.protein should become a by-product of jute.	Controllable heat for protein co-agulation.	Controllable power, electric, fossil fuel or biogas (from wastes).	-
Purpose mainly of surface sterilization & enzyme destruction.	Controlled electric or fossil fuel.	Movement of materials in plant because of high temperatures.	-
Steam hazard and need for regular maintenance and inspection of equipment.	Electrical or fossil energy or renewable energy possible.	-	-
precise conditions process times and temps. required for safety.Bottles of local glass industry.	Well controlled heat but non-fossil sources applicable.	Low	-
Creates major requirement for frozen transport and storage.	Electrical, or by absorbtion refrigeration from other heat resources.	Mechanized movement of frozen material desirable.	
Expensive technology but possibly great value for specific products.	As above.	Low.	-
Only appropriate with plentiful supplies of edible grade salt.	Low (making up brine).	-	-
Need for insect-proof work spaces. Local sugars can be used	Any heat source, but temp.measurement in pans essential	-	
Most plants are large but successful down-scaling in India.	Low.	Electrical or fossils for vacuum pumps.	-

Table 11. Suitability of various scales

Process description	Examples of crops & products	Suitability for: Traditional & domestic	Small plant	Large plant
34. Distillation.	Alcohol. Fermentation followed by distillation possible from many fruits and juices.	6	7	3
35. Re-distillation (fractionation).	Conversion of bush alcohols to potable or food grade and fuel or industrial fractions.	0	2	4
36. Steam distillation.	Flavours and fragrances from herbs and spices, e.g.cardomom oil, clove oils, natural vanillin, peppermint oil.	1 (local)	6	2
37. Smoking.	Fish, lean meats, cheeses.	4	5	5
38. Formulation (dry product mixes).	Infant foods, school mea acks, emergency packs, service ration packes, convenience foods.	0	6	6
39. Composite flours.	Preparation of baking flours containing significant proportions of local ingredients.	5	6	6
40. Pre-packed convenience foods for retail trade.(Platscusinès)	Legume pulse products, peas pudding, soup mix, bean mash. Meat & veg. mixes, cassoulet, pork & beans, etc.	0	2	5
41. Integrated food production and fast food retailing.	Soup kitchens, canteens, pizza parlours, etc.	6 (local)	6 (exp. for urban dev.)	3

Note on score: A higher score indicates greater suitability for the type of plant indicated, although the relationship between the score and suitability is not necessarily linear. Overall scores are based on summation of individual scores (not strictly objective) for following criteria:

(a) requirements for product uniformity and quality contro in different circumstances
(b) suitability to probable available energy sources
(c) acceptable level of hazard within the limits of expected management expertise

of production in food processing (cont'd)

Notes	Plant requirements for energy Heat	 Mechanical power	Plant requirements for toxic or hazardous chemicals
Design and leak-proof of systems important but good local technologies are widespread.	Any source, but avoid naked flames.	-	Fire hazard from alcohol. 'Bush' alcohols be dangerous to drink.
Uganda case study with 'waragi' as alternative to outlawing bush stills.	Well-controlled electrical	Mechanized handling with pumps, etc.	Fire &
Extensive R&D undertaken by IPI London. Experience callable.	Any heat source	-	Low.
Scottish kipper industry (small & large scale) a useful model.	Suitable bark with non-toxic volatiles giving acceptable aroma e.g.oak or hicory.	Low.	Despite traditional use of smoked hazard is sugg.if food excessive.
Has received substantial attention but with much emphasis on food aid components.	-	Handling & portioning advantageous.	
Extensive R&D experience available, e.g. FAO programme to underpin practical applications.	-	Power for mixing and handling.	
Rapid expansion and with potential for substantial fuel saving.	Well controlled & regulated heat.	Probalby mechanized handling & packaging.	-
Growing worldwide quality control and hygiene should be combined with positive attitude.	Positive at both processing and distribution.	-	-

(d) ease of sustainability and maintenance
(e) probable marketing and distribution problems
(f) suitability for fluctuating labour availability or raw materials
(g) management capability

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2.8.4 Cane-sugar processing[52/]

An analysis of the relationship betwen small and large-scale sugar processing technology is significant for three major reasons. First, it is one of the dimensional-product industries whose central processing technology involves inherent scale economies of the so-called "six-tenths rule" type. For instance, in India it is the second largest industry after textiles, and in many island economies the industry accounts for over 10 per cent of GNP. Third, it is one of the industries in which an indigenous developing country technology provides a viable alternative to the large-scale, capital-intensive sugar-mills.

2.8.5 The technologies

The two major families of technology in sugar manufacturing are vacuum-pan (VC) and open-pan sulphitation (OPS). The main difference between the two processes stems from the use of multiple effect evaporation in VP mills, leading to very high thermal efficiencies. VP technologies are inherently subject to economies of scale. OPS is a batch process and increases in capacity are achieved by multiplying the number of units, thus making economies of scale incidental to the basic technology.

In figure 3 these economies of scale are illustrated for both sets of technologies. In the case of VP, data exist for both fixed investment and total operating costs, while for firm, data only exist for investment costs.

One can see from figure 3 that fixed investment costs are the major source of scale economies in VP plants, declining from around 30 per cent of unit costs at 1,250 tcd to 17 per cent at 10,000 tcd. However, the major scale economies are realized at a capacity of 5,000 tcd. The major source of scale

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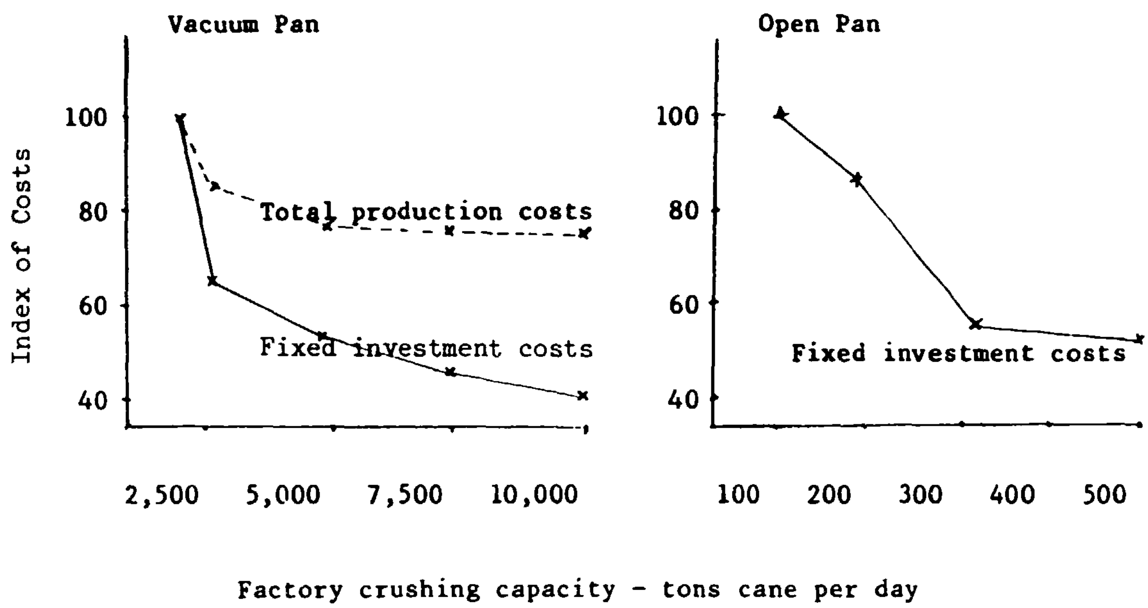
52/ Although beet-sugar accounts for around 40 per cent of global production, it is a temperate-climate crop and is almost exclusively produced in developed economies. Therefore "sugar" in this sectoral study refers only to cane-sugar. The production of non-crystalline jaggery and liquid-sugar, and coru derived from high fructose sweeteners are also excluded.

diseconomies in VP plants arises from transporting the cane to feed the mill. These rise from around 4 per cent of unit costs at 1250 tcd to 10 per cent at 10,000 tcd.

Figure 3. Economies of scale in sugar processing



Source: Tribe and Alpine, and Kaplinsky 1983 b.

Although the question of scale economies within each type of technology is relevant, the key concern is the balance between technologies. This is a controversial topic, but two recent technological advances made by Indian technologists may have altered the balance in favour of the small-scale OPS plants (unless VP plants operate at a capacity in excess of 5,000 tcd).[53/] The major disadvantages of the OPS plants are their lower sugar recovery rate and their inferior energy-efficiency. They are able to compete with VP mills despite these disadvantages because of their lower-unit transport and labour and investment costs. Moreover, VP plants characteristically operate at lower levels of capacity utilization due to their organizational difficulties in ensuring adequate supplies of cane.

53/ The median plant size in India is around 1,400 tcd. In Africa it is about 2,500 tcd.

2.8.6 Product characteristics

A well functioning, properly equipped VP plant is able to produce refined sugar which is white and has an even crystal size. The existing OPS technology is unable to meet these product specifications, although it is possible to supply a product which is very similar to the mill-white sugar generally produced for domestic consumption in developing countries. It is often asserted that this represents an inferior product but the only real disadvantage arises in the use of sugar in the food-processing industries since the higher molasses content of OPS sugar has a slight effect on taste and colour. However, insofar as direct consumption of sugar is concerned, consumer preference is relative. For instance, in India OPS sugar sells at a discounted price while in Kenya the two products are marketed interchangeably.

2.8.7 Linkage and skill implications

The extent to which each of these technologies are associated with backward and forward linkages varies between countries. In the larger and more industrialized developing economies, local industry is able to supply VP equipment. In these cases the issue is not so much one of the extent of backward linkages but rather their locus. This is because there are scale economies in the manufacture of the equipment and therefore only a limited number of large factories will be able to operate (generally sited in large towns and cities). Given the relative technological complexity of the VP technology[54/] there is a tendency for the equipment suppliers to be part of a large diversified enterprise so that many of the learning effects are internalized within the firm. On the other hand, the production of OPS technology is much more dispersed, both in relation to the number of firms involved and their locus. Its production is much more likely to be associated

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54/ In India, for example, some VP equipment suppliers use numerical-control machine-tools, which is relatively unusual in their industry. In an analogous way in the VP vs. OPS plants, working conditions in OPS equipment supplies tend to be worse than those producing VP equipment.

with the emergence of rural growth poles. However, since many of the equipment suppliers also make a range of other equipment, and labour mobility tends to be relatively high, many of the learning-effects are externalized.

As far as skill is concerned, plant operation in both types of technology is similar, although the introduction of process controls in the large-scale VP mills makes them less susceptible to variations in worker performance. However, in plant construction the manufacture of VP mills has been significantly more skill-intensive and in developing countries has generally been associated with technological licensing from developed country machinery suppliers.

It is likely that the small-scale OPS plants will be more susceptible to local repair and maintenance to the extent that these operations involve learning effects, their external economies within rural areas may exceed those involving VP plants.

2.8.8 Relative factor productivities

Notwithstanding the broader social issues involved in the choice between the two types of plant (such as the distributional implications, the quality of work and the social relations involved in production) it is instructive to observe their relative factor productivities.

It can be seen from table 12 that both in India and Kenya if total existing sugar production were to be met by either vacuum pan[55/] or OPS, the operating implications would vary significantly. OPS involves many more dispersed plants, a reduction in capital investment and an increase in aggregate employment. However, the lower sugar recovery rate which is currently inherent in OPS production means that the small-scale technology is significantly more land-intensive, requiring around 20-30 per cent more cane

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55/ In India, 1250 tcd plants are considered since this is the officially encouraged capacity. In Kenya, plants aim to expand over time and 7,000 represents the largest and most efficient VP mills.

to provide the same output of sugar. Hence, defining the optimum balance between the two types of technology involves considering the availability and price of all three factors of production.

Table 12. Investment and labour utilization required to meet total existing sugar production: India and Kenya

		Annual sugar production (tspa)	No. of plants	Capital cost (Rsn;K£m)	No. of employees
India	1250 tcd VP	5,150,000	327	26,160	284,490
	200 tcd OPS	5,150,000	2,682	18,492	836,784
Kenya	7000 tcd VP	380,000	2.6	520	4,420
	200 tcd OPS	380,000	81	91	25,920

2.8.9 Attempts to change technology

Recent improvements in OPS technology have had a significant impact in changing its relative balance with the VP alternatives. For example, in Northern Indian operating conditions, the average VP mills operate at a 9.6 per cent recovery rate. Equivalent OPS plants have achieved around 7.2 per cent, but with the recent improvements introduced in crushing and furnace design, the OPS average is likely to improve to around 8.2 per cent.

It is interesting to note that the Indian technologists responsible for the recent improvements in OPS technology are now turning their attention to additional advances. It is unlikely that the existing recovery differential could be significantly narrowed with the use of current types of technology because of the essential difference between the two types of technology (involving the temperature at which the juice is boiled). Traditionally. the OPS method is to extract the first crop of crystals from the concentrated juice and then to reboil the molasses and take a second crystal crop. This process is operated for a third and sometimes a fourth crop. This is obviously a tedious procedure requiring additional plant capacity. Thus there is a proposal under consideration to take the first crop of sugar as before but then to treat the first molasses by an ion exchange process. This would remove all the inorganic impurities from the molasses, leaving a clear solution of invert and non-invert sugars. At this stage, the liquid sugar could either be marketed or else evaporated and treated by another process to produce a fine powdered sugar (called "bura" in India).

If one or both of these technological developments are successful, the existing recovery-inefficiency of OPS technology - which has historically been a major obstacle to its widespread diffusion - is likely to be eroded. In either case sugar processing technologies represent a major example of developing countries' indigenous technological capabilities which have led to the maturation of a viable small-scale technology.

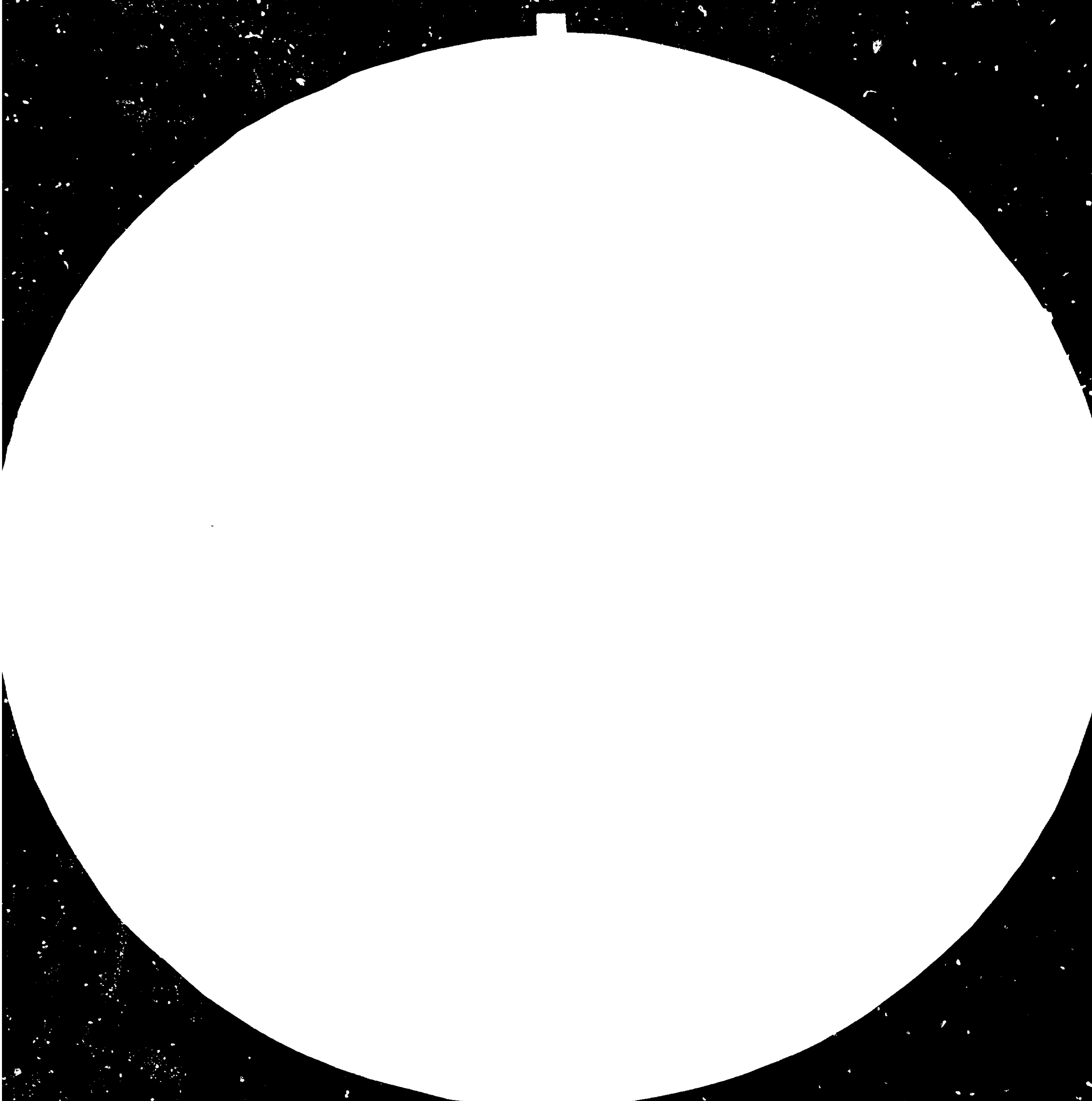
2.9 Textiles

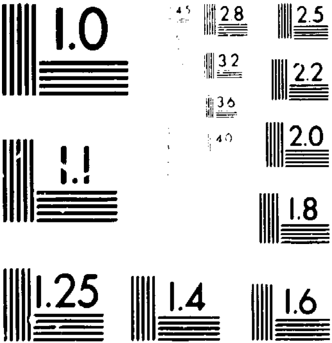
2.9.1 Introduction

Textile manufacture is comprised of three basic processes:

(a) Spinning - making fibres into a thread, generally referred to as yarn.
(b) Fabric production - principally weaving and knitting.
(c) Finishing - bleaching, dyeing, printing, etc.

These three basic processes have little in common in relation to scale of production. The classical methods of production, prior to 1750, employed 10 to 20 spinners to keep one weaver supplied with yarn. The finishing of all the cloth produced by a weaver in one week could very easily be dealt with in half a day by one dyer. Mechanization has largely removed the imbalance between spinning and weaving, subject to the employment of a greatly increased scale of operation in spinning. These two processes will be examined in greater detail in the remainder of this section.





MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

STANDARD REFERENCE MATERIAL 1010a

(ANSI and ISO TEST CHART No. 2)

2.9.2 Minimum and maximum sizes of plants

(a) Spinning

The basic sub-processes involved in spinning staple fibres such as cotton, wool and man-made staples are:

(i) Opening and cleaning
(ii) Carding
(iii) Drawing
(iv) Attenuation
(v) Spinning proper.

An important determinant of the minimum economic size of a spinning plant is the consideration that none of the major machines installed for the various sub-processes should be grossly under-utilized. In this consideration the sequence of machines which constitute the opening and cleaning line is almost always the decisive element. Typical modern opening and cleaning lines have a productive capacity in the range of 500 to 1,000 kg per hour. It would entail serious under-utilization if a mill were planned to have a throughput of less than 400 kg per hour.

Hourly capacity however does not uniquely determine plant size. Although the fineness of the yarn to be spun has only a marginal effect on the productive capacity of the opening line, it has an increasingly striking effect on successive machines in the processing. The magnitude of this effect is shown in table 13 which gives the numbers of spindles and approximate costs of all machinery for mills able to fully utilize one opening and cleaning line with a productive capacity of 500 kg of fibre per hour. It is not practicable, for a number of reasons, to spin yarns over the whole range of fineness on one set of machines. The count ranges (English cotton system) used in this table are as wide as is commercially and technically practicable. The costs are based on the use of fairly up-to-date ring spinning machinery and on prices obtained in 1983.

Table 13. Sizes and costs of mills
(based on a single opening and cleaning line of 500 kg/hour capacity)

Counts range	8 - 16	12 - 24	20 - 40	30 - 60	40 - 80
Average count	10	15	25	40	55
Number of spindles (thousands)	7.1	12.5	25	55	78
Cost of machinery ($US million)	4.2	5.5	10.0	17.5	22.5

(b) Weaving

There are no overriding technical considerations which dictate a minimum plant size. The preparation of warps is the only preparatory operation involving appreciable capital outlay and in most countries this may be avoided by purchasing warp yarn already prepared on weavers' beams. Many spinners are able to supply yarn on beams and, in addition, there are commission beamers who will prepare warps on their customers' behalf.

There are also no serious operational reasons dictating a minimum plant size. Although large scale weavers generally have in-house facilities for maintenance and repair, this is only a marginal advantage. In most areas in which textile manufacture is established there are adequate supporting facilities and units as small as 5 looms can be profitably operated. Still, most weaving is done in units with numbers of looms within the range of 50 to 250.

2.9.3 Economies and diseconomies of scale

(a) Spinning

There are no significant economies of scale resulting from the use of plant sizes greater than the minima given in table 13. Nevertheless, because of the large demand and total output (roughly two thirds of the weight of all cotton spun) in the count range of 8-24, the spinners of these coarser yarns commonly have mills several times larger than the minimum. A typical modern mill spinning counts in the range of 8-24 has five lines, a total of around 45,000 spindles and produces approximately 16,000 tons of yarn per year. At the other end of the scale there is a much smaller demand and output as only about 3 per cent of all cotton spun is in the count range 40-80. Consequently, mills in this section of the industry are often smaller than the strictly economic minimum size. A typical mill spinning in the range of 40-80 has only one opening line which is by no means heavily used. Such a mill has a total of around 60,000 spindles and produces about 2,400 tons per year.

Multi-line, coarse-to-medium, count mills enjoy no economies of scale in regard to manufacturing costs. Although, they may gain some advantage in the market place - both in the buying of raw materials and in the selling of the yarn they have spun. There are some diseconomies of scale, perhaps the most important of which are connected with the logistics of textile manufacture. The movement of scutcher laps, cans of silver and bobbins of roving through the various processes requires careful planning and monitoring if the right intermediate-product is to be at the proper place, at the right time and in the right quantity. For technically efficient operation, a mill covering the count range of 8-24 will need to use roving of at least five different hank numbers and probably four or more different blends of raw materials. Not only is the organization of this expensive, but there is also a high risk of mistakes being made.

(b) Weaving

Potential diseconomies of scale arise from logistic requirements in weaving but they are less severe than in spinning. The importance of production planning has long been appreciated and simple manual procedures are capable of keeping even the largest mills operating as efficiently as the smallest ones. It could be argued that the use of computer based planning methods will give the larger mills an advantage, but this will be offset as the capabilities of cheap mini-computers advance.

Substantial economies of scale have been gained in high-labour-cost countries by the use of automatic, computer-based loom-performance monitoring, recording and analysis systems. The use of these systems gives a lower fault rate in the cloth, increased machine availability and a greater number of looms which one weaver can tend. In mills producing basic, standard fabrics this development enables one weaver to tend up to 120 high speed looms. In so far as the effect on the cost-competiveness of mills in low-wage-cost countries is concerned this development cannot be entirely disregarded but its effect on cloth quality is even more important. This is because successful employment of these systems requires meticulously prepared, high quality yarns and a very high standard of maintenance of the mechanical condition of the looms. These two factors virtually eliminate both yarn and weaving faults and as a result the cloth is in great demand by mass-production garment makers.

(c) Costs and benefits of smaller-scale plants

Using commercially available machinery there is no direct cost advantage in the setting-up and operation of small scale plants. In spinning, the capital cost per unit of productive capacity is substantially independent of plant size for all sizes greater than the minima indicated above. In weaving, capital cost is completely independent of plant size from a single loom upwards.

In some situations in both spinning and weaving, savings in capital cost can be made by buying older types of machinery but, generally, this will induce increased operating costs and reduced durability and product quality. In regard to both capital and operating costs, the cheapest way of producing textiles of internationally marketable quality, in any country, is in a full scale mill equipped with first class modern machinery. This is the cheapest way of producing textiles and is the only way in which textiles of the highest quality (in terms of freedom from defects) can be produced. If textiles are being made for local consumption through small scale marketing channels this latter factor may not be important, but for export and mass marketing it is of great importance.

One of the few benefits conferred by small scale operation is the facility which it offers for intensive product specialization. The effect of undue variety on the cost of manufacturing is very great. This is true in spinning, weaving and finishing. Investigations have proven that the actual cost of increased variety is always much greater than the directly identifiable cost attributable to such factors as machine down-time, terminal losses, etc. The reason for this appears to be that intensive specialization leads to far fuller optimization of all relevant variables than is possible when the variety of products being made is greater. The high cost of variety was at first thought to be a length-of-run effect but closer investigation revealed that it is, in fact, a fewness-of-sorts effect and the fewer the number of different products made in one plant the lower will be the cost. As examples, the reduction of the number of yarns made by a well run spinning mill of 30,000 spindles from twelve sorts to five sorts, reduced manufacturing costs by 40 per cent. Reduction in the number of different fabrics made in a 300 loom mill from thirty to six reduced manufacturing costs by 55 per cent. This factor could be of great value to small plants equipped with standard machinery and engaged in the manufacture of speciality textiles for export.

2.9.4 Analysis of available alternatives

(a) Spinning

Many alternatives exist but none are really viable. Most need to be subsidized and the earning of individual spinners is minimal.

Single-spindle spinning is practiced in many parts of the world but, except for the coarsest woollen yarns, the productive capacity is so low that it can only be economic if wage levels are very low or if a hand-made product commands a substantial premium in the market place.

Many forms of pedal or hand-driven multi-spindle devices are in use in rural India. The earliest of these 'charkas', introduced about 30 years ago, had four spindles and was hand-driven. Subsequently, a six spindle hand-driven model and a six spindle pedal-driven one were developed. Based on these machines, a widespread Khadi (home spun) industry has been established with state aid and supervision. About one million spinners are engaged in this industry and they provide the yarn needed by about 100,000 hand loom weavers. Sale of the products is aided by substantial subsidies but, despite this, spinners' earnings are very low indeed. In addition, the capital investment of production per unit in Khadi is almost twice as great as that required for full-scale mill manufacturing. It seems that justification for this type of small-scale production must be sought on social rather than economic grounds.

Work has continued on the development of human powered spinning machines and an improved pedal-driven charka has now been available for some years. This has twelve spindles and a number of other features which raise yarn quality above that produced by the earlier machines. So far the twelve spindle charka has not found widespread acceptance largely because it requires cotton in the form of a roving of significantly higher quality than that used in the earlier machines. Service centres are being developed which will prepare rovings of the required quality and supply them to the charka spinners. Standard mill rovings would be technically satisfactory but attempts are being made to produce a small-scale service centre which will be able to make roving of a satisfactory quality at a low cost under rural conditions. Substantial progress has been made and a prototype centre, with the capacity to process about 50 kg of cotton per hour (approximately one tenth of the capacity of a standard mill line) is now in use.

Experience with the new twelve spindle pedal charkas has made it clear that a further increase in the number of spindles would be counterproductive. This is because of the greater effort which would be required to drive the machine. However, local entrepreneurs have found it worthwhile to take two or three of the new charkas and gang them together to make 24 or 36 spindle units and drive them electrically. These enterprises appear to be commercially successful despite the fact that cloth made from the yarn they produce does not qualify for the Khadi subsidy. It seems likely that a small-scale industry based on simply constructed, power-driven ringframes of 40 or so spindles, provided with roving from small-scale service centres of the type already developed, could be truly viable.

Although the foregoing analysis relates to the spinning of cotton, the situation is almost identical in woollen spinning. However, woollen yarns tend to be coarser than cotton yarns, thereby the spinning of them tends to be less tedious.

(b) Weaving

Viable alternatives to modern mill-scale weaving are available in a wide variety: primitive backstrap looms, pit looms, horizontal frame looms of mediaeval times, power looms of the 19th century and automatic looms of today. All are suitable for use on the smallest possible scale. The only proviso which must be made is that a supply of yarn of adequate quality must be available. The simpler looms can be operated reasonably efficiently using yarn of indifferent quality, but modern ultra-high-speed looms are critically dependent on yarn quality for their viability.

In selecting the type of loom to be used in a small-scale weaving industry the most important considerations are the market for which the cloth is intended and the quality of yarn available. Cloth must be almost completely fault-free if it is for sale to international mass-market garment makers. In practice this means that these markets are effectively closed to any small-scale weaving concern dependent for its yarn on small-scale spinners. When it comes to domestic consumption much higher fault rates are acceptable as, in general, the common minor faults do not substantially affect durability of the product. In this situation, probably the best buy for small-scale use is the simple power loom, without automatic weft replenishment means, which was widely used in Europe from about 1840 to 1940. When power is not available there is a wide range of hand looms to choose from on the basis of the traditional activities and skills of the people for whom they are required.

2.9.5 Beyond current alternatives

(a) Spinning

Currently available alternatives are all based on the ring-and-traveller system or, in the case of wool, the spindle-and-flyer system. Both these systems require a fairly high power input. This fact is clearly limiting their potential for manually driven use. Traditional jenny spinning requires much less power and also produces yarn more uniformly thick than the roving with which it has been fed. Another feature of the jenny spinning which contributed to its initial popularity is its simplicity and the low standard of engineering expertise required for its construction and maintenance. On these grounds it could well be suited to manual operation and also in rural situations where power is available but engineering skills are lacking. Manually powered jennies with 50 or so spindles were once quite common and power-assisted jennies with as many as 500 spindles were installed in large mills. There is currently considerable interest in the possibility of a modern version of the jenny being developed for small-scale use.

An alternative which has not yet been developed would be a small-scale machine using the principle of open-end spinning. Such a machine could achieve a very high production rate per spindle (3 to 6 times that of a ring spindle). It would require less driving power and would not need a well prepared roving but could work satisfactorily when fed undrawn silver. All current commercial open-end spinning machines, although essentially simple, are built to very high engineering standards. The extent to which these high standards are strictly necessary has not been explored. It is possible that for small-scale, rural use, as opposed to intensive, high speed use in ultra-modern automated factories, much lower standards of engineering would suffice. This approach is therefore worth investigating.

(b) Weaving

There is probably no need to seek alternative methods of weaving, nor are there any features of the newer principles of weaving which appear to have anything of value to the small-scale weaver. Efforts should, however, be directed towards rationalization of the design and methods and materials of construction of looms of proven value for small-scale use. This would likely lead to enhanced performance, lower cost and easier maintenance.

2.10 Bicycle manufacture

2.10.1 World bicycle production

The bicycle is the most common wheeled vehicle in the world with a large market in both developed and developing countries. In developing countries it is essentially a utility vehicle, widely used in both urban and rural areas for personal transport and for the movement of goods. The demand is predominantly for the traditional heavy duty roadster model, usually fitted with rod brakes. Bicycle manufacture can be efficient over a wide range of outputs, and there is scope for gradual industrialization through frame manufacturing followed by component manufacturing as demand rises. Cycle repair and maintenance operations also offer an important avenue for the encouragement of skills relevant to rural industrialization.

A comprehensive breakdown of world bicycle production is not available but table 14 gives estimated output in 1981 using data from several sources. The table shows that manufacture is concentrated in Japan, United States, USSR, Europe, Brazil, People's Republic of China and India. There is considerable international trading in complete bicycles and cycle components. Bulk transport costs are low in relation to product value and international trade is stimulated by:

(a) The low unit cost of many Asian and East European products; and

(b) The reputation for product quality of certain developed country manufacturers.

Table 14. World bicycle production 1981

Country	Output (millions)
People's Republic of China	14.0
United States	6.9
Japan	6.3
USSR	6.0
India	5.3
Federal Republic of Germany	3.0
France	2.35
Italy	2.2
Brazil	1.8 a/
United Kingdom	1.5
Netherlands	1.0 a/
Others (less than 1 million units each)	18.0 b/
Total	68.0

a/ 1980 figures.
b/ Approximate.

Source: Intermediate Technology Transport Ltd.

2.10.2 Minimum and maximum scales of production

Several manufacturers in the United States, Europe, India, Japan and the People's Republic of China have outputs close to or exceeding 1 million units per annum. The two largest manufacturers are in the People's Republic of China and the United States. However, while the United States' output is made up of a wide range of different models and components, the Chinese manufacterer's range is much more limited and hence on a disaggregated basis, its scale of production is higher.

Additionally, there are examples of small bicycle businesses operating successfully in both developed and developing countries at outputs of less than 200 units per annum. They achieve this by either:

(a) Making specialized products which do not compete in the mainstream market; or

(b) Restricting their activity to final assembly of bicycles purchased in component and sub-assembly form. (However, this adds 2 to 4 per cent to the value of the bicycle and, for the purposes of this document, is not considered to be manufacturing.)

The lowest level of output at which manufacturers are able to compete effectively in the mainstream bicycle market is about 3,000-5,000 units per annum. In both developing and developed countries there are manufacturers operating on the entire range of production scales. This implies that bicycle manufacture is efficient over a wide range of outputs and at different wage rates. To analyse this further it is necessary to distinguish between frame and component manufacturing.

2.10.3 Frame manufacturing

The simplest element of bicycle production, and those which are economic at the smallest scale are related to the manufacture of frames, forks and handlebars. Together these account for 50-60 per cent of total production cost. They involve the following common operations:

- Press forming of lugs;
- Cutting, profiling and bending of tube;
- Joining of components by brazing;
- Painting or, for the handlebars, plating.

Below an output of 15,000-20,000 units per annum, production of lugs and plating of handlebars is not economic and the smallest manufacturers normally buy these components. The most difficult component of the frame to make, because of its shape, is the bottom bracket shell. It is made by casting or by a complex sequence of press forming operations, followed by a series of machining stages. The minimum economic level of output is about 100,000 units per annum, and it is therefore a bought part for smaller manufacturers.

2.10.4 Component manufacture

In order to be economic the manufacture of the wheel, transmission and brake components require a substantially higher level of output than the production of frames, forks and handlebars. The minimum levels of economic output range between 50,000 and 150,000 units56/ per annum. Consequently:

(a) Smaller cycle producers are essentially frame, fork and handlebar makers, all the remaining parts being bought;

(b) In general, the proportion of the bicycle manufactured in-house increases with the level of production;57/

(c) The number of countries with cycle component industries is much smaller than those making bicycles;

(d) Specialist component manufacturers form an important element of the total cycle industry.

Certain components - tyres, tubes, fasteners and chains are almost universally supplied by specialist manufacturers. They involve capital intensive production technologies and manufacturers supply a range of markets of which the bicycle industry is one. The remaining cycle components require specialized manufacturing processes with relatively expensive equipment (e.g. rolling of wheel rims) and a range of special steels which in some cases are heat treated after processing. Certain components involve a range of

56/ Units of bicycles not components, i.e. 1 bicycle requires 2 wheel rims, 144 spokes etc.

57/ However, some larger manufacturers in industrialized countries are now beginning to utilize low-cost imported components.

non-complementary processes (e.g. pedal manufacture involves forging, machining, pressforming, rubber moulding, heat treatment and plating). Consequently, minimum economic production level is much higher than for frames.

2.10.5 Issues of scale

Bicycle manufacture, at whatever scale, remains relatively labour-intensive. There are a range of manufacturing options, for frame production from manual to semi-automatic, which can be used according to scale. For example, frame-brazing can be done by hand, dip, and manually or automatically controlled unit brazing.58/ For cycle components the range is from operator controlled machine tools to fully automatic processes. For certain components, semi-automatic processes are the lowest level that is economically feasible with present technology. There are developments in the industrialized countries to scale-up manufacturing processes, by introducing a greater degree of automation. For example, automatic equipment is now available for wheel truing, which until recently was a labour-intensive operation, even in large plants. This innovation has been made possible by the availability of microprocessor technology. Methods have now been developed to mould59/ joints around frame tubes which greatly reduces the labour-intensity of manufacturing. These recent innovations require fairly large-scale production to justify the capital investment.

In technical terms increasing the scale of manufacture beyond the present maximum offers little benefit since at this output all production equipment is replicated. The prospect of innovations which are only economic at outputs above 2.5-3 million is small. The major diseconomies of scale appear to be problems of management of very large-scale plants, and a slow response to market demands. The bicycle industry is characteristically conservative with product innovation occurring slowly. The major innovations of the last thirty years - small wheeled bicycles in the 1960s, and BMX juvenile bicycle in the 1970s - have come from small manufacturers and subsequently been adopted by large industries.

58/ In unit brazing, measured amounts of brass and flux are located at the joints prior to applying heat.

59/ By die-casting or injection moulding.

As far as developing countries are concerned, the major factor which determines maximum scale of production is the market for the products. India and the the People's Republic of China, which have large-scale bicycle industries and significant export, are characterized by:

- A very large home market;
- An indigenous industry able to supply the range of steel required to manufacture a bicycle;
- Low labour costs.

Very few other developing countries have the potential to become significant exporters to the industrialized world since they lack the above characteristics and consequently would not be able to compete on price and quality. Thus, for most developing countries the market is limited to domestic consumption plus possible exports to neighbouring countries. In several parts of the world neighbouring markets are constrained by both tariff barriers and cultural factors. Apart from a very small number of highly populated countries, no developing country has a home market exceeding 200,000-250,000 units per annum. Market size relates to population, level of economic development, geographic conditions and social attitudes, and short-term fluctuations in economic circumstances.

A further constraint on scale of production in developing countries is the ability of local industries to compete with imports of bicycles and components from the People's Republic of China and India. Because of the nature of their home industries, and the need to generate foreign exchange, bicycles exported from India and the People's Republic of China are very cheap. Most developing countries cannot compete in their home markets, in the supply of components or bicycles, without some form of protection through tariff or volume restrictions on imports. However, there are examples of local industries with links to developed country manufacturers competing on the basis of quality. In these countries the products of certain European manufacturers have a long-standing reputation for durability and reliability.

Thus, for most developing countries, issues of scale of production using existing technologies are primarily concerned with:

(a) Scale of production of bicycles frames;

(b) Whether local manufacture of cycle components is economic, and how this should be related to frame production.

2.10.6 Beyond current alternatives

There is potential for scaling down bicycle manufacturing by increasing the value that can be added efficiently and improving quality in small-scale plants in developing countries.

In frame manufacturing one promising approach is to modify frame designs on incorporate lugless welded joints rather than the lugged brazed joints which currently predominate in developing countries. This type of frame design is widely used on new-generation bicycles such as MBX models in the industrialized world. It eliminates the need for pressformed lugs and replaces the complex bottom bracket sheil by a relatively simple threaded tube. The use of MIG welding techniques and suitable jigs and fixtures would allow semi-skilled labour to produce complete frames efficiently and of high quality at levels of about 5,000 units/annum. The technique is already practiced in industrialized countries by small-scale manufacturers of certain types of bicycles, often in conjunction with electrostatic coating techniques using epoxy powder paints, which give a high quality finish.

The Oxtrike load-carrying tricycle takes this concept one stage further by using a frame formed mainly from square-section tubes. The use of square section eliminates the need to profile the ends of the frame tubes. This type of frame can be produced economically in developing countries at a rate of 500 units per annum. At this level of output, the value-added by the production unit is about 50 per cent of the total manufacture cost.

The scaling-down of cycle component manufacture involves:

(a) Development of efficient, smaller-scale manufacturing techniques; and/or

(b) Adaptation of components designs to suit smaller-scale manufacture.

The thrust of research and development efforts in bicycle manufacturing has been directed towards increasing automation. The innovations that result tend to increase the minimum economic scale of production, thus limiting their applicability to developing countries. There has been no comparable effort to develop more efficient small-scale manufacturing techniques suited to developing country conditions. Because of the close link between design and manufacturing processes, such an approach is likely to be most effective if it includes re-design of components and sub-assemblies. There appears to be potential for scaling down production in this way without affecting the utility of the final product.

This concept can be taken a stage further. The bicycle in developing countries is a basic means of transport subject to arduous use. The traditional roadster model remains popular because of its durability. However, little or no serious effort has been made to design bicycles to suit the conditions in developing countries. Developments in this direction merits serious attention and support.

3. CONCLUSION FROM THE SECTORAL REVIEW

The sectoral reviews have clearly shown that in a number of sectors or subsectors the optimal scale of production has been or can be expected to be shifted downwards, accordingly opening up wider possibilities for industrial production in developing countries, aiming in the first place at the domestic market. The reasons are manifold. New technologies, such as computer-aided design (discussed in section 1.2) or robotics (see section 2.2) affect a large range of industrial sectors. Branch specific technological breakthroughs have taken place in sectors such as iron and steel, fertilizers and segments of pulp- and food-processing industries. Similar breakthroughs can reasonably be expected in petrochemicals and textiles. In sectors such as agricultural machinery, building materials and bicycle manufacturing small scale solutions that can be promoted and applied are available as alternative to traditional technologies.

The following is a summary of some of the salient points from the sectoral analysis.

3.1 Capital goods and basic investment industries

(a) Iron and steel

An interesting feature of this sector is the surprising impact over the past decade of small, efficient and flexible mini-steel plants, which have been taking business away from the established large, integrated steel producers in most industrialized countries. This significant change in the optimum scale of technology will have a great impact on the future of the steel industry in developing countries.

(b) Machine tools and workshop equipment

Analysis of the impact of the new technology of numerical control upon the machine tool industry, as well as its potential impact during the remainder of the 1980s of the expansion of robotics reveals that economies of scale at the advanced technology end of the spectrum appear to be growing more important. Among simpler technologies, the study reviews recent approaches to the development of simple workshop equipment that is appropriate for manufacture and use in the rural areas of developing countries.

(c) Agricultural equipment

In view of the disparate nature of the industry, the analysis has focussed on the hoe, which is the most important agricultural implement for millions of farming households in Africa and Asia. This tool can be manufactured at virtually any scale, from the mass production capital-intensive die forging and rolling industry to the level of the village blacksmith. Unfortunately, quality is generally directly related to scale, although a recent UNIDO study suggests that, with appropriate technical assistance, a village production unit could be viable with an output of 4,000 tools per annum.

(d) Building materials

Cement is a key construction material, and its absence or shortage is frequently the root cause of delays and price escalations on capital projects throughout the developing world. Quality is a factor that has favoured the larger plant, but it is estimated that only 20 per cent of the worldwide consumption of cement requires the full strength of international Portland cement. For the remainder, there is scope for a genuine technological choice on the basis of local considerations, particularly transportation costs of the finished product (which can exceed production costs) and the potential for energy savings. Thus the attractions of a network of small and mini-plants, to supplement basic supplies of high strength cement, are likely to grow and lead to a better use of resources.

3.2 Process industries

(a) Petrochemicals

Petrochemicals is a sector that showed startling growth during the period 1950-1973, coupled with technological advances which yielded quick profits to investors in new, large plants. However, the adjustment of oil prices since

1973 led to a drastic change in the cost mix, increasing the cost of feedstock and undermining the economies of large plants with high break-even points. There are now indications that the flexibility of small, relatively simple plants may well offset the apparently better technical efficiency of large, sophisticated complexes. This is particularly true in the increasingly uncertain operational and economic environment that will appear when oil production peaks (probably) in the 1990s, and new (or revised) technologies based on coals or biomass become viable alternatives.

(b) Fertilizers

UNIDO's mini-fertilizer study looks at the trend in development of the world fertilizer industry. It shows that the new plants are moving towards locations which are adjacent to cheap and abundant feedstock, although some of this advantage is being lost due to higher capital/operating costs and escalating freight costs. The natural resource availability is becoming the prime determinant in project determination. Many of the traditional fertilizer producers in the developed countries, are losing their leading position in the fertilizer trade.

The size of capacity has been steadily going up over the last few decades. The main reason for this has been the economy of scale but in case of ammonia a breakthrough in technology has played an important role, too. Recently, a new philosophy has been introduced concerning the possibility to locate several small plants near various centres of consumption regions rather than a large unit installed centrally. This can be important for those countries that have sources of raw materials spread throughout the country, such as fields of natural gas, oil or coal.

(c) Pulp and paper

In the pulp and paper industry, innovation has been concentrated on the large-scale plant, due to a production-oriented market and a vigorous machine-manufacturing industry. Large-scale wood-based pulp mills do retain distinct technical advantages, although these may be offset if the real costs of forest maintenance, felling, roads and transport equipment are taken into account (smaller plants might not require any major specific infrastructure provision). On the other hand, technical developments in non-wood pulp mills have brought down the lower limit for continuous pulping to 15 tons per day, and small plants have distinct advantages in reducing transport costs due to smaller raw material collection zones. Choice of scale in a paper-making plant is more complex, and is analyzed under the eight headings of quality, speed, instrumentation and control, stock preparation plant, efficiency of production, production costs, capital costs and market considerations. The conclusion is that there is a need to develop simple, standardized machines, for which the inherent cost and energy advantages would be bolstered by economies in maintenance and cost of spares, simplicity in operation and easier training.

3.3 Light industries

(a) Food processing

A general review of the effects of scale on the food processing industry was presented. A sub-sectoral study of the cane sugar industry as an illustration indicates that besides being a very important industry in its own right in many developing countries (second largest after textile in India), it is one of the dimensional-product industries whose central processing technology involves inherent scale economies of the so-called six-tenths rule type. However, it is also one of the few industries in which an indigenous developing country technology provides a viable alternative to the large-scale, capital-intensive sugar mills.

The divergence between the proponents of large- and small-scale is exemplified by the discussion of appropriate sugar technology.[60/] Here the issue is essentially a question of the relative importance of internal, technical economies of scale vis à vis possible external economies of scale.

60/ D. Forsyth, Appropriate Technology in Sugar Manufacturing, World Development, Vol. 5, No. 3, 1977. G. Hagelberg, Appropriate Technology in Sugar Manufacturing - a rebuttal, World Development, Vol. 7, 1979.

Given certain assumptions, some research results[61/] showed that the most economic small-scale plant (producing 10,000 tons p.a.) is that which uses the most labour-intensive set of techniques, while the most economic large-scale plant (producing 50,000 tons p.a.) is the most capital-intensive. However, the profitability of the best small-scale option is well below that of the best large-scale (50,000 tons) option, and is in fact lower than 20 enumerated large-scale options.

On the opposite side of the argument, a number of issues are brought into the discussion.[62/] One point often mentioned is that technology is a package involving hardware, organization, management, supply of materials and skills. In addition, other factors are important: infrastructure, location, distribution of project income, degree of external dependence, market size and timing of benefits. One of the results of an unbalanced package (i.e. large-scale capital - intensive technology but underdeveloped infrastructure - transport, power etc.) is that there is considerable excess capacity. Excess capacity is a prevailing problem for many developing industrial sectors[63/] which prevents plants from reaching rated capacity or achieving the theoretical economies of scale.

(b) Textiles

Plant size is a relatively insignificant factor in the viability of textile manufacturing. In spinning, the capital cost per unit of productive capacity is substantially independent of plant size above a threshold of about 500 kg of fibre per hour, while in weaving it is completely independent of plant size from a single loom upwards. Future developments among small-scale spinning machines and looms are likely to be directed towards simplification to achieve enhanced performance, but with lower costs and easier maintenance.

61/ Research carried out by the Livingstone Institute, Strathclyde University.

62/ Op. cit.

63/ D. Phillips, Choice of Technology and Industrial Transformation - the Case of Tanzania, Industry and Development, Vol. 1, No. 5, 1981, (UN).

(c) Bicycle manufacture

The bicycle is the most common wheeled vehicle in the world, and is in fact a primary utility vehicle for the movement of both people and goods in developing countries. It is frequently manufactured in large factories, although the assembly process is relatively labour-intensive, and small-scale operations are feasible in terms of physical facilities and services. Certain components (such as rims, spokes and bottom brackets) are also successfully manufactured on a small-scale in certain Asian countries. The study explores the potential to encourage scaling-down by appropriate design, such as the Oxtrike load-carrying tricycle which can be economic at production levels of around 500 units per annum. The feasibility of widely dispersed (village level) repair and maintenance facilities is also discussed.

3.4 Scope for small-scale production in the traditional sense

It would clearly be convenient for policy-makers if some form of league table could be drawn up, listing those industries which should be conducted using large-scale plants, those where small plants are more appropriate, and those industries in the middle which should be considered on a case-by-case basis. The implications of the sectoral studies, however, are not so clear cut, and there are only a few industries which fall clearly into either of the former categories. Certainly there are a group of industries for which internal economies of scale are significant enough to limit downscaling to levels which would still require large amounts of investment, employment (and infrastructure) per plant. These include metal processing, petroleum, petro-chemicals, certain types of paper and certain industrial chemicals. Heavy engineering would also come into this group, because the tooling and set-up costs would be large. Rotary kiln cement plants would also be confined to larger scale, although we have noted the recent revival of smaller vertical shaft kiln plants.

There remains potentially extensive scope for small industry production outside the above group of industries. In India the estimated share of the organized small factory sector (defined as units with less than Rs 1 million in fixed assets) has been over 50 per cent of registered output in industries such as grain milling, fruit canning, oil extraction, sugar, textiles, garments, knitwear, leather, sawmilling and furniture. Lowest shares have been applicable to steel, chemicals, non-electrical machinery, cement and vehicles.[64/] In the Republic of Korea[65/] in 1975 small enterprises employed more than 50 per cent of workers in a wide group of industries. These included manufactures of a wide range of engineering products in more than 1000 small enterprises, ranging from handtool to pumps, instruments and machine parts for the textile, food, chemicals, paper, printing, glass and plastic machinery sector. There was no obvious pattern discernible in the shares of small-scale industry. Shares were lowest (below 25 per cent of industry employment) in a range of industries which included milk products, tobacco, fertilizers, fuel oil, vehicles, sugar, cotton spinning, tyres and tubes, plywood, newsprint, cement, radio and TV receivers, electronic tubes. A number of industries reported as having an insignificant small-scale production share were surprisingly industries in which economies of scale would not normally be considered important.

Finally, a point should be made about one of the major single justifications for small-scale production - i.e. capital saving. An early study[66/] showed a clear relationship between scale and capital-intensity (capital-value-added ratio) in Japan, implying that capital is used more efficiently at smaller scale of plant (but not below 10 workers). These findings were confirmed elsewhere but a frequent finding has been that the most efficient users of capital tend to be plants of around 100 workers in the small factory sector.[67/] In other studies (e.g. Philippines)[68/] the general

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64/ Source: Statistics of the Development Commission for Small-Scale Industries, Government of India.

65/ Ho. P.S. Sam, World Bank Working Paper No. 284, 1980.

66/ B. Hoselitz, The Role of Small-Scale Industries in the Process of Economic Growth, Nouton 1957.

67/ International Bank of Reconstruction and Development. Employment and Development of Small Enterprises - Sector Policy Paper, February 1978, p. 67.

68/ D. Anderson, Small Enterprises and Development Policy in the Philippines, World Bank, Working Paper No. 468, 1981.

finding is that capital-efficiency has risen with scale. In the Korean study mentioned above the most capital-efficient firms were those employing 100-199 workers. Large plants (employing over 200 workers) were generally more capital-efficient on the aggregate than those employing below 100 workers.

Such findings cast doubt on the case for promoting small-scale industry on capital saving grounds. The general case for small-scale production would therefore be based largely on external economies of production. For particular industries there is no substitute for a case-by-case evalutation of efficiency, since external conditions (e.g. infrastructure, location, etc.) are highly variable.

4. SOME CONCLUDING REMARKS

4.1 Overall conclusions

Prevailing conceptions of scale economies continue to be based largely on past beliefs and are unable to provide a persuasive basis for evaluating the industrialization alternatives open to developing countries, particularly smaller countries and countries at a lower level of income. This paper has been concerned with evaluating the prospects of removing scale constraints that have posed obstacles to industrialization in these countries.

It would not be correct to imply that all countries face similar practical options in this respect. The nature of the most appropriate effort by each country in this area will depend on its particular situation, strength and constraints.

Technological development, particularly in the areas of electronics, micro-processors and computer-based support has drastically pushed the level of optimal scale downwards in a number of sectors. Other technological trends, e.g. in the areas of iron and steel and fertilizer production, have introduced a new dimension to the scale problems in those sectors. Similar breakthroughs can usually be expected in other sectors. The obvious problem for developing countries is to participate in and get access to this technological development. Without international co-operation the technological development will only lead to a new form of dependence of developing countries.

However, looking for an instant at the more traditional concept of small- and medium-scale enterprises there are a number of observations worth making. The following three sections deal in turn with international co-operation with respect to small- and medium-scale enterprises, the role of sub-contracting and the problem of financing smaller enterprises. Staying with this traditional concept, it can be concluded that there are numerous sectors within virtually every category of industry in which small- and medium-scale plants can effectively compete. This paper has also covered trends in prospects of small-scale production in developing countries and their economic potential. Briefly, some of the conclusions that arise are as follows:

(a) Small-scale industry should be treated, for development purposes, not as a technical category (e.g. restricting assistance to industries below a certain number of employees), but as a functional category involving decentralization, less managerial and technical sophistication, employment potential, wider dispersal of income and production both geographically and between social classes, and greater use of local materials.

(b) The relative efficiency of small versus large plants is not easily assessed. The economic case for small plants is often associated with external diseconomies associated with large plants in particular developing country circumstances, e.g. where the infrastructure is inadequate and markets and sources of supply are dispersed geographically. Given these factors, wide scope appears to exist for decentralization of production except in a group of industries where internal technical scale economies are predominant. For example, the light engineering sector has shown rapid growth at small-scale and is not generally subject to significant technical scale economies. At the same time it is a critical industry with regards to skill generation and innovation.

(c) The trends in small-scale production are subject to conflicting interpretations. On the one hand, there appears in some countries to be a problem of deepening dualism and erosion of the small factory sector. On the other hand, the experience of other countries suggests an expanding and dynamic small factory sector, acting as a link between the traditional artisan industry and medium- to large-scale production. These two different interpretations entail different promotional approaches. The first appears pessimistic about possibilities for small-scale industry development, regardless of what promotional measures are in force, and suggests that active intervention by the state in production is essential. The second interpretation implies that small-scale industry promotional policy is likely to be more effective since the underlying investment conditions for small-scale industry are more favourable.

4.2 The role of international co-operation

International co-operation in small-scale industry has been affected, along with co-operation in other sectors, by the world economic crisis. However, the lower dependence of small-scale industry on imports and exports may have given it some advantage over larger-scale production during the crisis. Assistance schemes must be carefully designed and co-ordinated and must concentrate on lowering the transaction costs (facilitating easier access) to smaller plants or seeking external inputs, both financial and technical. This can be partly achieved by concentrating on package deals of industrial finance, combined with technical and managerial advice.

Assistance in the following areas could also be provided to small-scale industries:

(a) Support of the development and application of industrial products and processes which are amenable to small-scale production techniques and for which the overall demand is too dispersed to attract conventional commercial investment in research and development.

(b) Promotion of specialist state-of-the-art meetings in various industrial sectors to assist decision-makers in the optimum choice of technology.

(c) Dissemination of information and publications on choice of technology to ensure that the various advantages and disadvantages of various scales of industrial operations are understood across the gamut of potential alternatives.

(d) Technological Services Delivery Systems (TSDS) need to be devised.[69/] Particular efforts should be made to ensure that extension centres and their satellite units are equipped with machinery and equipment which are of a similar technical level (e.g. type of power source) to that which is actually used by existing and planned local small enterprises. Along

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69/ Technological Services Delivery System (UNIDO/IS.424) with equipment it is essential that an adequate stock of tools, spare parts, and instruction manuals are provided. In countries with underdeveloped engineering skills, provision of assistance should include installation testing and commissioning of equipment, and provision of personnel for training and interim operations of extension centres.

(e) Along with technical extension work, advice should be available involving aid with project studies, loan applications, government procedures and available fiscal and monetary incentives. Operational assistance is also essential in financial control, marketing advice, facilities for raw material provision (or aid in identifying them in situations of scarcity). This type of assistance should be closely tied to financing institutions.

4.3 National and international sub-contracting

One feature of reducing the scale constraint which has attracted attention is the possibility of setting up satellites, or ancillaries, of large-scale production. The Japanese experience has been the model for this. In Japan, sub-contracting has been important in a number of industries, including fabricated metal products and transport equipment. In sewing machine manufacturing, for example, between 1941 and 1965 the average number of components produced by each enterprise fell from 60 to 3[70/] while production increased from 0.25 million units in 1950 to 4.8 million units in 1969.

In the Republic of Korea[71/] contract sales have been important in textiles, chemicals, rubber, paper, metals and machinery. Rapid growth of the engineering industry is generally supposed to have been due to growth of sub-contracting. Seventeen per cent of total sales are contracted to other industries. But the level of sub-contracting rises with scale of enterprise. At the below 10-worker scale about 8 per cent of sales are on contract to domestic industry, rising to 25-30 per cent at the 100-worker level.

70/ S. Watanabe, Sub-contracting, Industrialization and Employment Creation, International Labour Review, 1971.

71/ Ho. *Op. cit.*

International sub-contracting has emerged significantly especially in electronic equipment. A number of Southeast Asian countries have recorded very high growth rates of exports. Singapore recorded 66 per cent per annum over 1967-1973 rising in 1976-1978, and also the Republic of Korea recorded similar rates of growth. An export oriented strategy tends to encourage economies of scale in production by widening potential markets. Certain implications follow in the present context - namely that international sub-contracting is relatively insignificant for smaller enterprises, and that the domestic market is still predominant for small-scale industry products. This implies that, even for a major developing country exporter such as the Republic of Korea, small industry production must remain largely concerned with domestic markets.

4.4 Financing of smaller enterprises 72/

Despite the efforts of many countries to increase the supply of finance to small firms, certain problems occur in the provision of funds, particularly when the credit supply is in the hands of traditional banking institutions. The problem lies in the risk factor associated with defaults on small-scale industry loans, which are relatively frequent. In addition, there are the extra administrative costs of dealing with a portfolio of small enterprise loans. A high default rate with high associated administrative costs means that in order to cover the cost of supplying funding, banking institutions would have to raise interest rates to small enterprises to relatively high levels. These higher interest rates tend to attract high risk borrowers, so that the probable default rate on high interest rate loans would be still greater. In fact, the risk adjusted interest rate often would be unacceptable from a social point of view. In many countries interest rates charged to small enterprises are in fact lower than for industry in general. Consequently, credit is restricted largely only to low-risk (larger-scale) borrowers or to well-connected small entrepreneurs.

72/ For a detailed analysis of the important issue of industrial financing see documentation for the Fourth General Conference of UNIDO (ID/Conf.5/13 and 19) and studies prepared by UNIDO's Sectoral Studies Branch (UNIDO/IS.417, 418, 419 and 432).

In order to boost the credit supply to smaller scale industry from the banking system it is necessary to lower the risk factor and, simultaneously raise the profitability of small enterprises. The cost of funds should be more realistic. In other words, it is necessary to shift both supply and demand curves for funds. This will probably require state intervention through various mechanisms, such as loan guarantee schemes. Extension services could also improve enterprise profitability and operating efficiency, record keeping and financial control, provide data for assessing the bankability of particular enterprises, and lower the transaction costs of finance for example by making access to finance easier for small enterprises.

Another important issue concerns the financing of working capital. This is usually handled by separate institutions (e.g. commercial banks), which adds to the problem and raises the transaction cost of access to credit for small enterprises. The banking systems in developing countries also tend to favour fixed capital finance rather than operational finance - i.e. finance for expansions and working capital.[73/] However, the combination of working and fixed capital finance in one institution would probably provide several advantages: (1) Since working capital loans are less risky and self-liquidating, the overall risk element on loans would be reduced, so that general interest rates to small-scale industry borrowers would be reduced. (2) Working capital financing involves closer ongoing links between bank and borrower, allowing more control over the efficiency of fund utilization and an opportunity for regular consultation between enterprises and lenders, thus raising operating efficiency and lowering lending risk. (3) Access to a package of finance would lower transaction costs to borrowers. Banks offering a package deal could take on an extension role themselves.

Schemes that are in operation include (a) direct financing (subsidised) by state banks, (b) rediscounting by central banks, covering a proportion of risk and administrative cost, (c) loan guarantees by central banks against a

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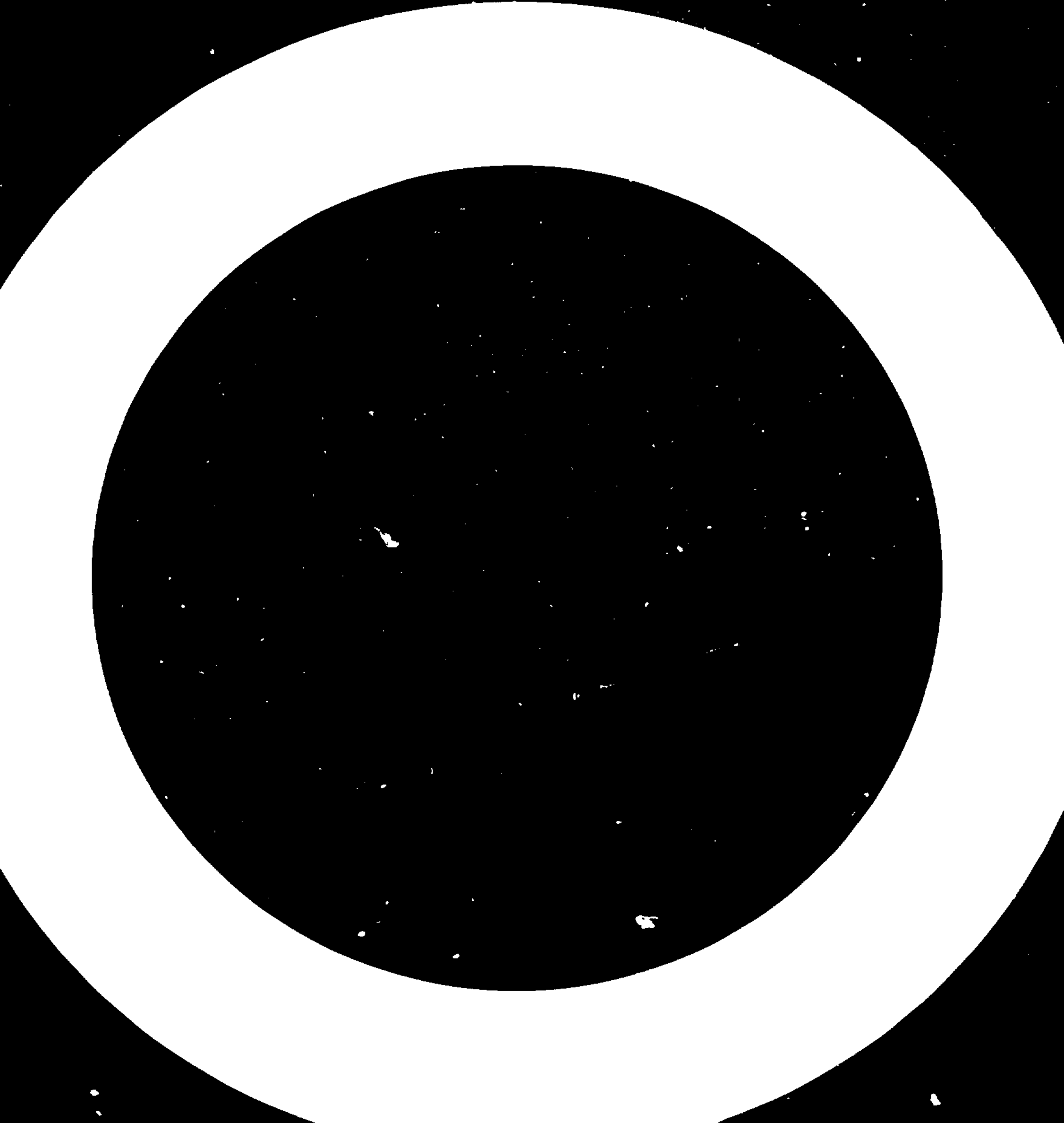
73/ D. Anderson, Small Industry in Developing Countries; Some Issues, Op. cit., World Development, 1982.

percentage of loss.[74/] A final possibility is the hire-purchase type of scheme which is operated in India and some other countries. Here machinery supplied under credit is mortgaged to the credit supplier and therefore remains the property of the credit supplier. This reduces risk since fixed assets can be repossessed, at least in principle.

A final point concerns the extent to which small enterprises require outside finance, given its accessibility and acceptable interest rates. It is pointed out in many studies that up to 90 per cent of small-scale industry funds are internally generated.[75/] As a result, the long-run elasticity of demand for external financing may be relatively low. However, the experience of the Indian hire purchase schemes during the intensive campaigns mentioned earlier suggests that upward shifts in the demand curve can be induced, particularly when finance is supplied as a package, along with machinery, technical advice, and other promotional measures.

74/ S. Sinha, **Planning for Rural Industrialization; A Review of Developing Countries Programmes**, IT DG 1983.

75/ Ibid.



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