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INDUSTRIALIZATION AND PRODUCTIVITY

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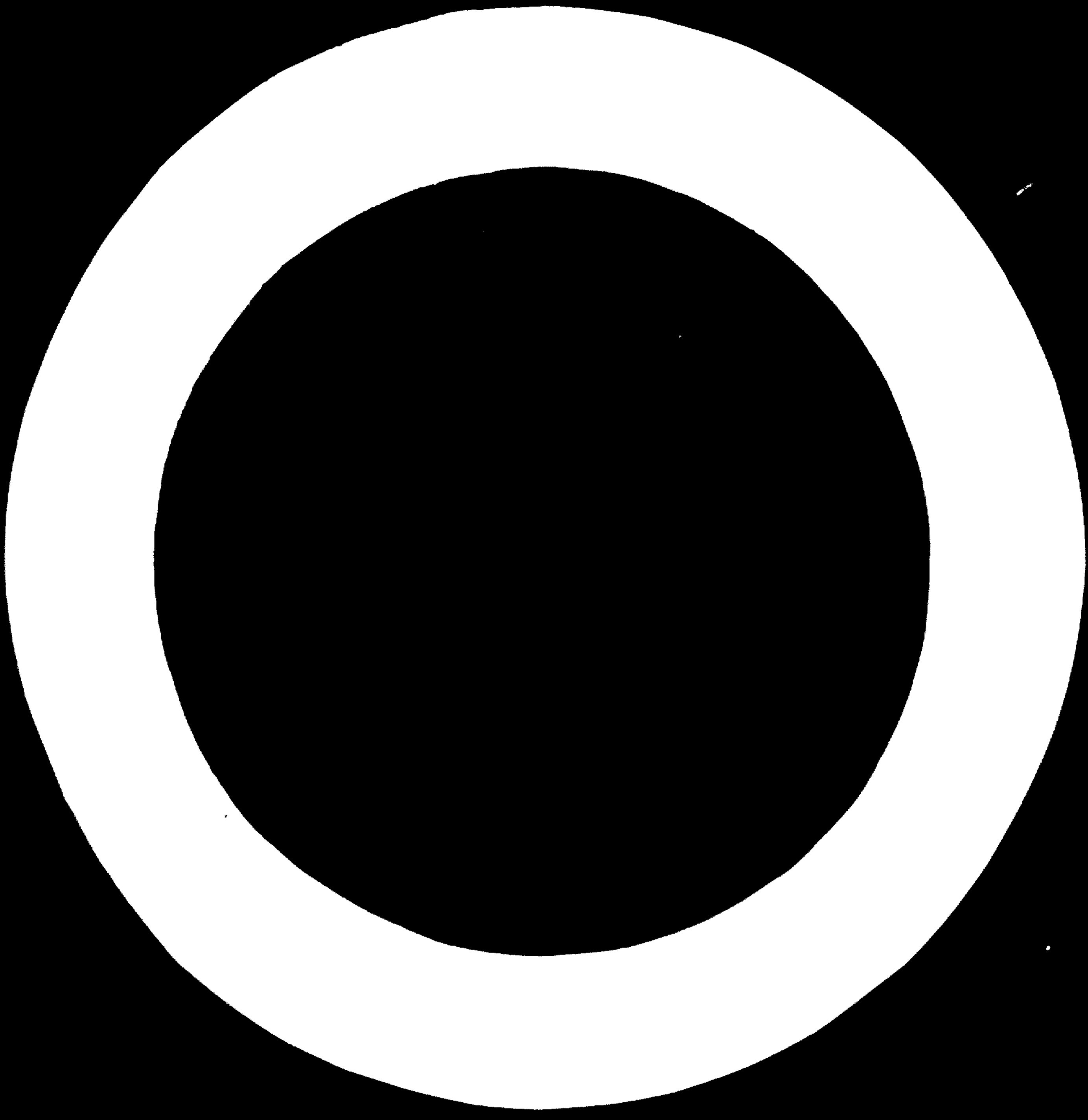
In this issue:

BULLETIN No. 16

UNITED NATIONS



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

INDUSTRIALIZATION AND PRODUCTIVITY

BULLETIN 16

UNITED NATIONS
New York, 1970

UNITED NATIONS PUBLICATION

Sales No.: E. 70. II. B. 31
Price: $U.S. 1.50
(or equivalent in other currencies)

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Preface

THE PRESENT ISSUE OF THE *Industrialization and Productivity Bulletin* introduces the first three articles in a series that will be devoted to industrial planning. Other articles will be published in later issues, as they become available. In due course, it may prove useful to publish the whole series, including addenda to the earlier articles where required, in the form of a manual on industrial programming. Initially, however, the object of the series is to stimulate an international exchange of ideas and practical experience in industrial planning, by providing a forum and inviting further contributions on the various aspects of this subject from the readers of the *Bulletin*.

The series is intended to serve as an operational guide and basic reference source for planners at various levels in the developing countries. It is hoped that industrial planning experts supplied by UNIDO under technical assistance programmes will also find these articles valuable in their work.

The first article, "An introduction to industrial planning", was prepared by Roy Helfgott and Salvatore Schiavo-Campo, and is based in part on unpublished contributions by Kazimierz Laski, Zoltan Roman and Louis J. Zimmerman. It begins by discussing the place of industrialization in the wider process of economic development and reviewing the theoretical framework of industrial planning. The second half of the article is devoted to the process of industrial planning, from the initial formulation of a plan, through the programming stages and feasibility studies that follow, to the formulation and evaluation of individual projects. Last but not least, the continuous process of implementation of the plan, of programmes and of projects – is given proper emphasis. The practical problems with which planners have to contend at all stages are described, and the authors stress the interdependent relationships between the various planning elements.

The second article, "Industrial development strategy" by Ignacy Sachs and Kazimierz Laski, deals with the basic concepts and principles of framing a strategy. Strategy and long-term planning are treated as complementary activities, which support each other at every level from determining the place of industrial development in the overall development, to discussing the relative importance given to heavy and light industries. The authors emphasize the value of starting with a sober assessment of the available resources, both human and material. Various alternative kinds of strategy are then described and criteria are proposed for use in evaluating them within the circumstances of a given developing country.

The third article is "Planning aspects of replacement, repair and maintenance", by Vaclav Nesvera. This study is also part of the UNIDO programme on repair and maintenance and may be the starting point for more detailed studies on the subject. There is always a danger that engineers and managers will deal with these problems at the micro-level solely on the basis of the interests of the enterprise and that national planners working at the macro-level will fail to give sufficient attention in their analyses to the consequences of the technical and economic depreciation of plant and equipment. This article endeavours to bridge the gap by describing the distinctive basic concepts involved and laying down guidelines for formulating and implementing policy decisions at both the enterprise level and the national level. Practical suggestions are given for assessing the evolution of demand for repairs and maintenance and the interrelationship is explored between replacement and modernization. The most effective ways of establishing repair and maintenance facilities for particular industrial sectors are also discussed.

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*An introduction to industrial planning**

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and
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Introduction

The Meaning of Success in Industrialization

MANY OF THE TERMS used in the literature on economic development with reference to countries of Africa, Asia and Latin America fail to convey a clear meaning of practical use. The terms "poor", "economically-backward", "underdeveloped"—even the term "developing countries", the one most frequently used today—imply the existence of an absolute yardstick against which to measure a country's poverty or underdevelopment, but such an absolute yardstick does not exist. Clearly, industrial development is a phenomenon far more complex than achieving some minimal standard that supports life, though the latter is of course a prerequisite for industrial development itself. It is, therefore, not satisfactory to think of industrial development in terms of an absolute standard of performance. Instead, relative standards must be applied.

Many people look at industrialization in relative terms, but only in so far as they compare the pace of industrial development in developing countries to the rate of industrial growth in the developed economies. This approach, although understandable, is likely to lead to incorrect expectations (either overoptimistic or overpessimistic), and even to fundamental errors in the choice of a strategy for industrial planning, since the developed countries do not necessarily present developing countries with a mirror image of their economic future. Broad historical patterns of development are identifiable, but each developing country possesses very specific characteristics, goals and prospects.

This is not to deny the possibility of making useful generalizations and formulating principles common to all developing countries. But each country has its own unique conglomeration of economic, political, social and cultural characteristics and these characteristics must form the basis of theoretical conclusions and technical approaches to industrial development. Most planners in the developing countries themselves are well aware of this, but the scientific literature on economic development in general, and industrial development planning in particular, often fails to recognize fully that the practice of industrial development planning involves modifying and adapting the theory of planning. To choose only one particular example among many: often, where information is faulty and programming skills insufficient, a simple planning tool may give far better predictive results than a very sophisticated analytical and planning model. Yet, many a programming treatise begins by assuming excellent information and knowledge.[1] On the other hand, planning that is not based on a minimum of theoretical knowledge and technical awareness is almost certain to fail and may even hinder industrial development.

The need for relativity in the standards of performance and selection of planning techniques

* Industrial planning in developing countries is also the subject of a recent UNIDO monograph (UN Sales Publication No. E.69.II.B.39, Vol. 17). The present article, by the same authors who prepared the monograph, provides readers with a somewhat different approach to the subject.

[1] A notable exception is a book by W. F. Stolper, *Planning Without Facts*, Harvard University Press, Cambridge, 1966.

must be emphasized, especially when evaluating industrialization efforts, for there is no absolute yardstick with which to evaluate the performance of the industrial sector of a developing country. No yardstick is provided by the rate of industrial growth of the developed economies, or by the average industrial growth rate of the developing countries, or even by the success of past industrialization efforts by the same developing country. Underlying economic conditions are not identical in different countries at different times. The only possible yardstick on which to base expectations, formulate plans and evaluate actual performance is the country's own potential performance during the same period of time. It cannot be concluded that the industrialization efforts of country A are more successful than country B' merely because A's rate of industrial growth is 8 per cent and B's only 6 per cent. If the maximum possible industrial growth rate during the same period, in the light of the different economic conditions prevailing in A and B, were 10 per cent in A but only 6 per cent in B, then in any meaningful sense country B's efforts at industrialization have been more successful. Again, this argument should not be used as a rationalization of poor performance, but as a recognition of the fact that industrial development, and the planning of it, must be based on an objective assessment of economic conditions and not on a voluntaristic view of economic development.

Industry and economic development

It is well known that developing countries are characterized by, among other things, a relatively small industrial sector and by a large proportion of the population engaged in agriculture. This is perhaps the most common characteristic of all developing countries, but other similarities in economic structure also exist, including poor facilities for credit, marketing, transportation and communication, an unskilled labour force and a low rate of savings. Above all, low *per capita* income and a low degree of industrialization can, for all practical purposes, be taken as co-existing phenomena.

Table 1 shows data for selected developing and developed countries. It can be seen that in developing countries agricultural production typically accounts for 30 to 50 per cent of total Gross Domestic Product (GDP), though many cases fall outside these limits, while in developed countries it typically accounts for only about 5 to 15 per cent of GDP. It is of interest to add that the proportion of population engaged in agriculture is considerably greater than the agricultural share of GDP in developing countries; on the average, about 75 per cent of the population is so engaged.

Table 1

SECTORAL ORIGIN OF GROSS DOMESTIC PRODUCT,[a] SELECTED COUNTRIES

(percentage of GDP)

Country	Agriculture	Manufacturing industry	Other activities
DEVELOPED COUNTRIES			
France	8	35	57
Germany, Fed. Republic of	4	41	55
Italy	13	28	59
USSR	22	52[b]	26
UK	3	36	61
USA	4	31	65
DEVELOPING COUNTRIES			
Africa:			
Algeria (1958)	21	11	67
Congo (1959)	28	13	39
Ethiopia (1963)	65	7	28
Kenya	36	11	51
Malawi (1963)	47	6	47
Morocco	32	14	54
Nigeria (1962)	65	5	30
Tanzania, Un. Rep. of	55	4	41
Tunisia	22	14	64
Uganda	59	7	34
Asia:			
Burma (1964)	33	15	52
China (Taiwan)	26	19	55
India (1964)	51	18[b]	31
Iran	30	28	42
Korea, Republic of	41	18	41
Pakistan (1964)	48	11	41
Philippines	34	18	48
Thailand	33	12	55
Latin America:			
Bolivia	23	16	61
Brazil (1964)	29	28[b]	43
Chile	10	18	72
Guatemala	28	15	58
Mexico	17	29	54
Nicaragua	35	13	52
Paraguay	36	16	48
Peru	20	18	62
Uruguay (1963)	15	22	63
Venezuela (1963)	8	12	80

SOURCE: United Nations, *Statistical Yearbook 1966*.

[a] At factor cost, for 1965 unless otherwise stated.

[b] Includes extractive activities and energy.

This is because in these countries labour has much lower productivity in the agricultural sector than in other sectors of the economy, particularly the manufacturing sector.

One major form of structural change accompanying development is, therefore, a change in economic structure from a predominantly agricultural society to one marked by a greater importance of manufacturing industry. Indeed, structural change is at the basis of the distinction between economic development and economic growth; the latter term is normally used to refer to increases in production in the developed economies increases which take place within a given economic structure. There are, of course, exceptions: some developed countries have very large agricultural sectors. It cannot be assumed, however, that the terms economic development and industrialization are completely interchangeable. Some developing countries, for example, have progressed rapidly by expanding extractive activities, particularly petroleum production, with very little industrial development. In general, however, economic development is accompanied by a shift away from agriculture and towards industry; for most developing countries industrialization is indeed the engine of growth.

The need for structural change within the process of economic development has been taken into account by economists for a long time. In the 19th century, Friedrich List, for example, viewed economic progress as being accompanied and characterized by a change in the sectoral composition of economic activity. He postulated a process of development proceeding from an agricultural stage through an agricultural-industrial stage to an agricultural-industrial-commercial stage. Other writers also attempted to discern a pattern of economic development common to all countries.[2] Any classification of stages of growth has some validity in so far as it describes a particular aspect of historical change, and all may be of use in structuring a discussion on economic growth in providing, as it were, the chapter headings. But none of these stages-of-growth classifications is a theory, for none explains the mechanism linking the various stages and the conditions governing the move from one stage to the next one. One could elaborate with equal validity a theory of economic development which consists merely of grouping countries according to *per capita* income: the first stage would be *per capita* income below $100, the second from $100 to $300 (or to $165) and so on; the number of stages would be divisible at will, but none would add in the least to our knowledge of the process of development.

A more relevant attempt to draw conclusions from the historical facts of economic development has been made by A. Gerschenkron,[3] who does not attempt to define neat stages of growth. His notion is that economic development proceeds by big spurts rather than by gradual changes. Gerschenkron found that, in the process of industrialization in Europe, the more backward a country's economy was, the greater was the growth spurt experienced; the big spurt was accompanied by a concentration of investment on producers' goods and hence on relatively capital-intensive, large-scale activities. In turn, this called for a greater restriction of current consumption and reliance on coercive institutional mechanisms to raise investment finance. Furthermore, the increased production of producers' goods could not be wholly absorbed domestically, so that exports of such goods became increasingly important. For Europe, at least, the Gerschenkron model appears to fit the historical facts. It is doubtful, however, if, in view of the limited resources of developing countries and the greater capital-intensity of today's production methods, this pattern of industrial growth will be applicable to today's African, Asian or Latin American countries.

Obstacles to industrial development

While it is undeniable that industrial development is almost invariably associated with economic progress, it is only fair to state that industrial development is also particularly subject to the vicious circles hampering economic development. As B. Higgins has pointed out, "the road to development is paved with vicious circles".[4] This statement is particularly true of industrial development.

One vicious circle concerns the relationships between agriculture and industry. Low agricultural productivity is due partly to the lack of manufactured products which would serve as incentive goods to farmers and primary producers to rationalize production and increase productivity. Conversely, low agricultural productivity prevents the accumulation of resources which could be used

[2] The best known among stage theories is the so-called "take-off" model elaborated by W. W. Rostow (*The Process of Economic Growth*, Norton, New York, 1962). The "take-off" model has been subjected to criticism, however, particularly with regard to its historical substantiation. At any rate, even if the Rostow model did fit the historical facts for the now-developed economies, this would not necessarily make it applicable to today's developing countries. A country's economic progress is conditioned by the structure of the international economy, which is obviously radically different today from what it was in the 19th century.

[3] *Economic Development in Historical Perspective*, Harvard University Press, Cambridge, 1962.

[4] "Financing Economic Development", *International Conciliation*, 1955; also quoted in the same author's *Economic Development* (Norton, New York, 1968). A. O. Hirschman added to that statement that some circles are more vicious than others. Whereupon Higgins correctly remarked that: "The task of the analyst is to discover which of these vicious circles are the basic causes of the others, which can more readily be broken into, and which can be converted into feedback mechanisms contributing to sustained economic growth" (*Ibid.*, p. 52).

for the domestic production of, or imports of, manufactured goods.

Another vicious circle derives from the fact that industrial development is generally characterized by economies of scale and indivisibilities. As will be shown later, an attempt to increase industrial production gradually and continuously by small doses of expenditure, is apt to prove disappointing. Many economists conclude that a large initial effort is needed in order to carry the economy through the long period before the stage is reached when expenditure brings tangible results. This is a basic difficulty with many ramifications, two of which may be given as examples:

(a) The creation of infrastructural facilities, especially in the fields of transport and power, is necessary for industrial development. By its very nature, however, the process of building such facilities is expensive and without immediate returns. It would be much easier if a railroad could be built mile by mile, with each successive increment giving rise to an increase in the country's productive capacity. Unfortunately, this is impossible. Developing countries are poor partly because they have little industry; they have little industry partly because of insufficient infrastructure, and they have no infrastructure because they are poor.

(b) The development of a number of industrial projects simultaneously is easier to achieve, per unit of expenditure, than is the development of each of the projects in isolation. The balanced growth doctrine argues that with a number of projects each project can be the market for some other project and the supplier of yet another; and that the incomes generated by the various projects provide the purchasing power to buy their products. The unfortunate reality is that initial resources are generally lacking for large-scale industrial development on several fronts simultaneously. The simpler path would again be to make a start and move ahead gradually as the increase in resources permits, but this is also the less efficient path. Thus scarcity of resources, which is characteristic of most less-developed countries, makes diversified industrial development unfeasible, and yet the countries generally cannot achieve industrial development without such diversification.

The last illustration of the vicious circularity of industrial development problems concerns the political context within which development has to be carried out. In poor countries, it is generally the government that has to formulate the goals of development and translate them into action. A private entrepreneur class either does not exist or, if it does, it is not encouraged to assume a major role in determining the course of industrial development. This almost complete dependence of development on government has two significant implications. First, there is the problem of political stability, for where the economic institutions for development are governmental, political instability leads to confused, contradictory and abortive economic policies; but it is frequently this very lack of industrial and macroeconomic development that makes for political instability. Secondly, whereas prudence would dictate patience, i.e. waiting to proceed until enough resources for sizable and simultaneous investments can be accumulated, this course conflicts with the swelling tide of rising expectations of the peoples in the less developed countries.

This discussion is by no means exhaustive; but it does illustrate the universal interdependence of all things economic and highlights the prevalence of cumulative effects in the process of industrial development. Fortunately, in the logic of circularity it is inherent that a vicious circle becomes a virtuous circle if some means is found of breaking into it at its weakest link; domestically or externally, this means does, in principle, exist. Thus, one definition of the task of industrial development planning and policy making is: the search for weak links followed by the development of means of breaking into them. Such an approach, of course, has to be adapted to the economic and social conditions prevailing in the less developed country. One prerequisite for the success of this search and adaptation to local conditions is that it be effectively organized and co-ordinated. Efforts at economic development are unlikely to succeed unless they are planned. In this sense of organization and co-ordination of development efforts, planning is a clear prerequisite for successful development.

The need for industrial development

The need for industrial progress in order to achieve self-sustained economic development can now be discussed in broader terms. With the opening of the decade of the 1970s—the Second Development Decade—a shift is occurring in sectoral priorities. It is being increasingly recognized that, without industrial development, economic progress has a relatively low ceiling. A consensus has arisen among development theorists and planners that, for most countries, economic development must be viewed primarily in terms of industrialization.

Studies carried out by UNIDO and others lend support to this opinion by showing that the most significant structural change accompanying the increase in the level of *per capita* income is a decline in the share of agriculture and a rise in the share of manufacturing in a country's output. Unfortunately, some people have concluded incorrectly that there is a conflict between industry and agriculture and that a developing country must choose the former rather than the latter in order to achieve progress. But there is no necessary conflict between agriculture and industry. On the contrary, since it is typical for the agricultural sector in developing countries to be highly inefficient, technological progress is needed in farming as well as in manufacturing. Industry, moreover, can help to improve the efficiency of agriculture by supplying it with fertilizers and farm equipment and other inputs, and by processing its output in order to increase the value of exported products. Thus, industrial and agricultural progress should go side by side. The correct way to formulate the choice among investment projects is to forecast the comparative advantages, making dynamic assumptions, whether the project is in industry or agriculture.

Despite the importance of creating and expanding a country's industrial sector, industrialization is not an aim in itself. The ultimate aim of industrialization is to raise the living standards of the people through higher *per capita* consumption, extended social welfare facilities, better working conditions, wider dissemination of cultural benefits and the like. These are the goals of development, but only through rapid industrialization can a country attain them.

Despite the overwhelming need to achieve rapid industrialization, recent progress in this direction has been far from satisfactory. Only a few countries have experienced average annual rates of growth in manufacturing in the 7 to 9 per cent range; the rest have fallen far short of this. A variety of seemingly insurmountable problems confronts the developing nations in their quest for rapid and sustained growth. The population explosion means more mouths to feed, prevents increases in *per capita* income despite economic progress and impedes savings and capital formation. Since the mass of people live at a bare subsistence level, increases in income tend to lead to higher consumption, leaving little savings for investment in industry. As the developing countries have not been industrialized, they suffer from a lack of technical know-how to be applied in manufacturing. Similarly, their labour forces have not had the opportunity to acquire the skills necessary for modern industrial technology. Unfamiliarity with industry also means a dearth of individuals with the entrepreneurial spirit to undertake the risks of starting new manufacturing businesses. Domestic markets of limited size cannot support efficient production in many types of manufacturing. Finally, traditional habits and customs often prevent the cultural adjustments necessary to the changes in society that industrial growth brings.

Furthermore, industrialization itself is, in its early stages, a disruptive force, and some of its short-run effects are far from beneficial. Industrialization can cause disequilibrium in many areas, particularly in the balance of payments, the utilization of resources, the domestic price level and employment. The political and social stability of the nation may be threatened by the impact of economic change.

To eschew industrialization, however, is to settle for the economic *status quo* and to forego the benefits that growth eventually brings; thus almost all countries choose the path of change, no matter how rigorous it may be. The process of change might be more easily accommodated and industrialization more quickly accomplished if a socio-economic climate conducive to industrial initiative and to the implementation of well-formulated economic plans could be established. This is not easily done in a tradition-bound country, but there is wide scope for government action to overcome the impediments to industrialization and to provide the right social climate.

Creating a climate conducive to industrial development in mixed-economy countries

Probably the most important role that Government can perform is to ensure a minimum of domestic stability. A country in a state of complete turmoil is hardly a place in which people will invest their savings in industry, where the return on the investment takes many years to materialize. Even if the Government establishes manufacturing facilities, their successful operation demands the existence of reliable economic institutions.

Assuming that a country is not in a state of political turmoil, government policies can still be crucial to economic development. First of all, there is the whole area of fiscal, monetary and commercial policy. A credit network must be established and aided, directly and indirectly, by public policy. A tax structure must be evolved that will permit the accumulation of savings and encourage their conversion into capital investment. Rational import tariff schedules must be formulated to encourage the efficient domestic production of goods vital to industrial growth.

As long-term financing is lacking in most developing countries, channels must be opened for directing savings into industry. The evolution of credit institutions and a capital market are highly desirable. By establishing an industrial promotion institute to provide information on the country's advantages and on specific industrial projects, the Government can help to attract investment funds into industry. Positive inducements such as direct subsidies and tax incentives may also be helpful. For foreign investors, it may be necessary to grant currency conversion rights and freedom to employ some non-nationals in key positions.

Government itself can help to provide long-term financing. By so doing, it reduces the amount of resources the Government would have to invest if it undertook industrial projects on its own and reduces the cost of private financing through lower rates of interest. At the same time, it obtains the possible advantages of private management of government-supported projects, and ensures that indus ial investment proceeds in accordance with national planning objectives. Government support of industrial development is best channelled through a public industrial development bank, a specialized semi-independent institution. Its autonomous status usually renders such a bank less subject to political pressure than a government agency when scrutinizing and eeking to influence the implementation of industrial projects. A development bank can also provide a means of supervising industrial projects and providing technical assistance to their managements.

Several recent empirical studies have found a high correlation between a country's educational attainment and its income *per capita;* thus, emphasis must be placed on the quality of the human resource input as a factor in economic development. A Government must create an educational system that can turn out the types of manpower necessary to industrial expansion. The portion of the population that is to be absorbed into industry, even at unskilled and semi-skilled levels, must at least be able to read instructions and so must have gained a minimum of schooling. Even more important is the need for vocational training and secondary education to create a cadre of skilled workers and lower-level supervisors, and technically-oriented university education to provide the most highly qualified manpower—engineers, scientists, managers—required by industry. The stress should not be entirely on formal education, however, because there are other ways in which people acquire skills, the most important of which is on-the-job training.

Another key area for government action lies in prospecting for raw materials and in development of the industrial infrastructure. The latter inevitably falls to the Government, because the capital costs are high and cannot be charged to any particular user. Without proper infrastructure, particularly in transportation and power, industrial deve opment is al but impossible. Even in the United States, in which industrial development was accomplished largely under a *laissez-faire* policy, government road and canal building and subsidies to private railroads have been credited with playing a significant part in the development process.[5]

It is essential that the timing of infrastructure and industrial project construction be carefully co-ordinated. If a manufacturing facility is to be built at a particular location, transportation for raw materials and finished products must be available at the right time, as must electric power for the plant. Inter-industry linkages must also be taken into account in infrastructural planning, for example, infrastructural expenditure undertaken because a mineral deposit is to be exploited should be phased in relation not only to the requirements of the extractive industry but also to the anticipated requirements of mineral-processing industries that will arise. The creation of industrial estates can be considered part of the infrastructure necessary to industrial development, and so can social facilities, such as housing and health projects.

Since developing countries lack industrial traditions, the level of technical knowledge possessed by entrepreneurs and managers is usually deficient. Governments can help to rectify the situation and thus promote the efficient operation of industrial projects by offering technical assistance to industry, particularly small firms. A government-sponsored technical assistance bureau can engage in research, provide information and offer consulting services in engineering, accounting, manpower training and so forth. The dissemination of quality control techniques and preparation of standards can also be most helpful to industry.

Finally, Governments can help by removing unnecessary government-imposed obstacles to private investment in manufacturing. In some sectors, private control may quite legitimately be thought undesirable. But many countries ostensibly look toward private business to develop industry, while at the same time hampering the process by so many unnecessary restrictions that individuals are discouraged from following up potential opportunities. A reduction in such administrative controls would make it simpler for new industrial enterprises to come into being and reduce the time lag between formulation and implementation of projects.

Industrial planning theory

The Need for Planning

As the developing countries suffer from many serious impediments to industrial development,

[5] C. Goodrich, *Government Promotion of American Canals and Railroads*, Columbia University Press, New York, 1960.

their Governments can not, and should not, take a merely passive role in the process of industrial expansion. Planning has become an essential and integral part of industrial development programmes, for market forces, by themselves, cannot overcome the deep-seated structural rigidities in the economies of developing countries. The detail of planning and the relative weight of the contributions of the public and private sectors may be different in different countries but, almost without exception, all developing countries engage in some degree of planning.

Two fundamental propositions underlie planning. The first is that economic growth, in general, and industrial growth, in particular, are largely the results of action based on analysis and reasoning and not the consequence of pre-ordained events or political or religious dogma. The second proposition is that, by systematically examining both the policies and the investment projects as parts of a whole, consistent and complementary patterns of such policies and projects can be formed, as a result of which the entire economy can be made more efficient.

These propositions are often taken for granted in developed market economies, and these countries find it less necessary to spell out targets and aspirations in explicit programmes. The need for planning in developed market economies is less urgent, because the machinery for co-ordination within the private sector, and between the private and public sectors, functions relatively well. The greater complexity of a developed economy as well as the advantages that flow from decentralized economic decision-making also tend to lessen the need for explicit planning.

Although the industrialization of developed market economies took place originally under conditions of *laissez-faire* competition, it would be misleading to point to that historical experience as showing that planning by developing countries today is unnecessary. Those countries did not face the obstacles that confront most developing countries today; moreover, they engaged in more planning than is normally assumed. Examples are Colbert's Royal Manufactures, to launch French industrial development; the programme of modernization following the Meji restoration in Japan; and the policy of the United States Government in creating the infrastructure, import tariff and land regulations to foster industrial growth.

Today the need for some degree of economic planning is universally recognized. It is, of course, an integral part of the economy of the Soviet Union and the other centrally planned countries. Planning, on a more decentralized and indicative basis, has become an integral feature of the economies of many developed market economy countries, such as France, the Netherlands, Norway. In the developing countries of Asia, Africa and Latin America, economic planning is widely accepted, and almost all these countries have worked out some kind of advance co-ordination of economic decisions.

In developing countries, planning is more feasible and more desirable than in developed market economies. The greater feasibility is a result of the smaller number of variables that must be taken into consideration, and the greater desirability stems from the fact that the automatic mechanisms for co-ordination of individual actions function less satisfactorily in developing than in developed economies. Planning in developing countries is made necessary by, *inter alia*, the inadequacies of the market as a mechanism to ensure that individual decisions will optimize economic performance in terms of society's preferences and economic goals. In the words of a leading exponent of a market organization of the economy:

> "...private enterprise in any underdeveloped area seems a rather weak candidate for the assumption of heavy developmental responsibilities; and the free market as a central agency in the direction of resource use leaves much to be desired".[6]

The inadequacy of the market mechanism as a means of allocating resources for industrial development sometimes results from government policy itself or because the theoretical assumptions (particularly with respect to the mobility of the factors of production) do not apply to the actual economic situation. Even more importantly, the market mechanism cannot properly allow for the external effects of investment. External economies—the reduction in unit cost of production in one economic entity arising from expansion of output in another—arise mainly from the provision of infrastructure, from inter-industry relations and from indivisibilities in the supply of savings. A given expenditure on infrastructure, once made, yields benefits to all economic units that can utilize the social overhead capital created and not just to those units for which it was originally made; e.g. once a road exists, everyone can use it at little extra cost to the economy.

The individual firm's estimate of infrastructural cost, which is based on its own expected usage, is much greater than the real cost to the economy; thus, the market form of organization often leads to serious underinvestment in infrastructural facilities. Similar external effects result from the interdependence among different industrial activities. Since external effects, by definition, cannot be

[6] E. S. Mason, *Economic Planning in Underdeveloped Areas*, New York Fordham University Press, 1958, p. 61.

taken into account by an individual productive unit, isolated investment decisions do not necessarily result in the level and mix of industrial investment that would be best from the national economic point of view. Only through some form of economic planning can proper account be taken of externalities.

Not only is the need for planning greater in developing than in developed countries, but the approach to planning also differs in many respects. While planning in the developed market economies is the result of economic development, in the developing countries it is a precondition for development.[7] Thus, the main function of planning in the developed countries is the rational utilization of resources, the development of new resources being a by-product. In the developing countries, on the other hand, the main function of economic planning is the development of resources, which also requires the proper utilization of existing resources.

In developed market economies, the economic role of Government is mainly to effect income redistribution and to ensure short-run equilibrium of the domestic economy and the external sector. The major tools for accomplishing these goals are fiscal and monetary policy, which are normally sufficient and efficient precisely because of the high level of economic development. The economy is so well integrated that production will quickly respond to such stimuli as changes in credit conditions and in government expenditures and receipts. Planning, therefore, can be more aggregated and indicative.

In the developing countries, the role of Government is to help change the structure of the economy, particularly with respect to industrialization. Fiscal and monetary policies are not sufficient for this purpose and must be supplemented by specific measures, such as direct public investment, licensing of new enterprises and controls over the composition of foreign trade. Furthermore, planning must be more detailed than in developed countries, largely because building a new industry causes structural changes in the economy. Starting a new line of production may lead to bottlenecks in the supply of energy, materials or labour unless the changes and their consequences are planned in advance and necessary measures taken.

The case for a well-formulated industrial plan can be stated simply: explicit targets are better than implicit ones; clear definition of hidden or imperfectly understood lines of approach is necessary for a correct evaluation of the policy alternatives; and taking account of the mutual interdependence of economic activities is a more efficient procedure—whatever the national economic goals or ideology—than duplication and overlapping of isolated efforts. In a broad sense, planning means advance co-ordination of ideas and efforts toward the attainment of certain economic goals. In its details—level of aggregation, of centralization, of quantification, of formality and of authority and responsibility—planning conforms to the ideology and economic structure of the country. But the essential task of planning in every country is to co-ordinate the actions of the elements comprising the economy in the most effective way for attaining the goals that are set, subject to the constraints imposed by the over-all socio-economic environment.

All of these arguments for economic planning apply with particular force to the planning of industrial development. In view of the key role played by industry in the growth process, the massive financial and economic requirements of industrialization and the greater significance of inter-activity relations in industry, planning is essential for industrial development. Although it is not easy to elaborate planning machinery that effectively integrates all elements of plan formulation and implementation in a consistent manner, the attempt must be made. Adequate formulation and evaluation procedures as well as realistic measures for implementation are required to convert a plan into actual industrial development.

A simple analytical framework

The central problem of industrial development is: "How can production capacity be increased?" No answer can be given until a satisfactory answer is found to the question: "How will industrial goods be produced?" The concept of a production function is a basic one: the production function expresses the relationship between the output (the dependent variable) and the inputs necessary to produce it (the independent variables). Theoretically, the production function concept can have unlimited analytical application—from the solution of very detailed production difficulties in a specific industrial plant to the analysis of problems of aggregate sectoral or national industrial growth. In the latter case, a strong feedback effect can be expected; output depends on inputs, but the available quantity of inputs is affected by a change in aggregate output itself.

The complexity and form of the functional relationship between inputs and outputs depend, *inter alia*, on the number and types of different inputs deemed relevant. In turn, the degree of detail in the classification of inputs depends on the purposes of the analysis. In macroeconomic

[7] G. Myrdal, *Asian Drama: An Inquiry into the Poverty of Nations*, New York, Pantheon Books, 1968.

work, it is legitimate to adopt fairly broad categories of inputs; finer classifications would make it practically impossible to extract generalizations out of the complexity of the relationships postulated. The traditional broad classification aggregates under the headings of labour, capital and land (natural resources) different categories of inputs sharing some common characteristics. A useful engineering production function for a particular plant or industry, however, would have to be based on a far more detailed breakdown of inputs.

Graphically, a simple production function with two factors (conventionally, labour and capital) can be depicted by an "isoquant" map. The points on a given isoquant all represent the same output, produced with different combinations of capital and labour. (The isoquant map is conceptually analogous to the "indifference" map; whereas the isoquant map depicts the characteristics of the production process, the indifference map—the set of indifference curves—depicts the patterns of tastes.) The actual shape of the isoquants depends on the assumptions made about the nature of production in the sector or economy examined, and, in particular, on the degree of technical substitutability between different factors. In figure 1, for example, substitutability is gradual, continuous

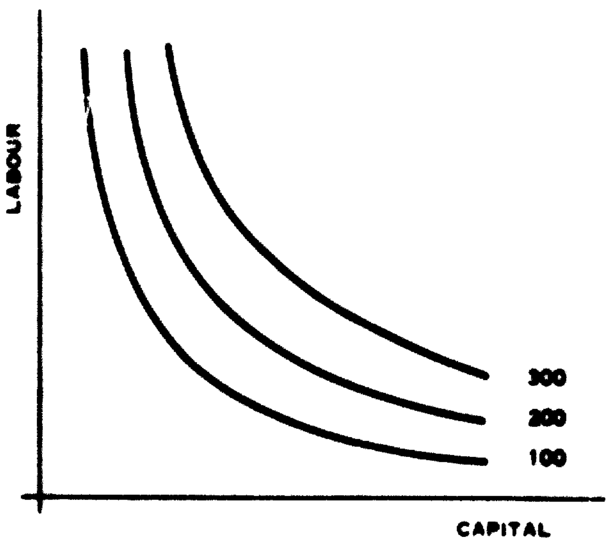

Figure 1

and theoretically unlimited (the slope is at all points greater than minus infinity and less than zero). In figure 2, substitutability is nil: a given level of output can be produced with only one particular combination of labour and capital; additions of labour will not result in an output increase unless capital is also augmented, and *vice versa*.

If the shape of all isoquants is identical and if the isoquants are equidistant for equal output increases

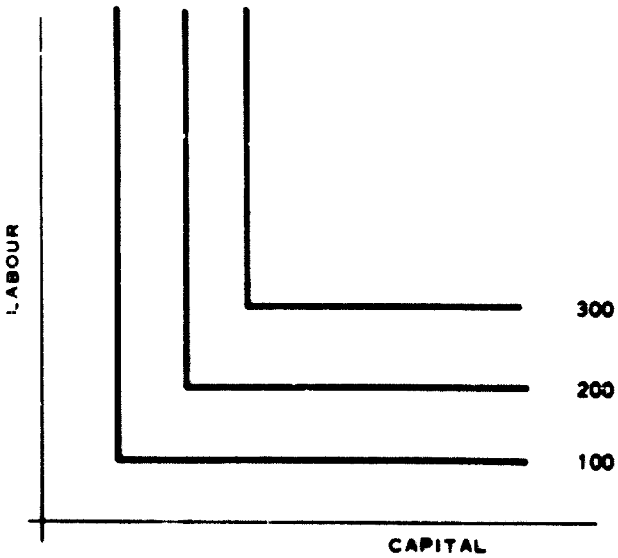

Figure 2

(i.e., if equal increases in inputs bring about equal increases in output), the input coefficients are constant at all levels of output (for a given set of factor prices). This is the case in figure 3. Growth can be identified, in this simple model, as the shift from one isoquant to a higher one; the over-all pattern of growth can thus be depicted by a line—the "expansion path"—connecting the points of equilibrium on the different isoquants. The form of the expansion path depends on the nature of the production function itself. When, as in figure 3, the path is a straight line (if the above conditions concerning the shape and distance of the isoquants are true), the production function is said to be homogeneous of degree one (the sum of the coefficients of all inputs is equal to unity). This is the form of the well-known Cobb-Douglas func-

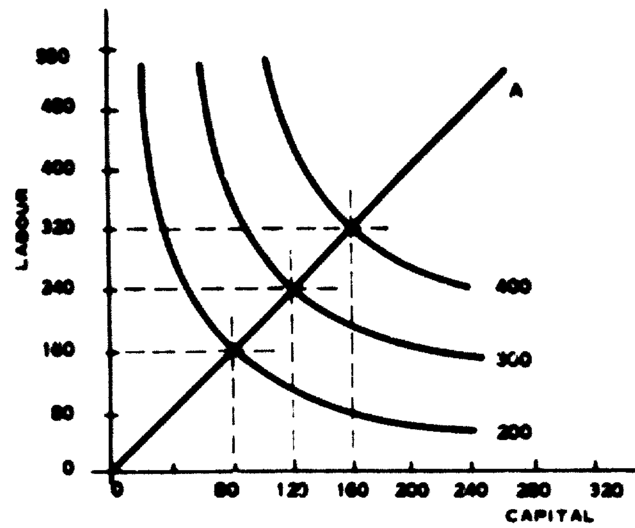

Figure 3

tion, the main characteristic of which is constant returns to scale.[8] In this case, factor proportions are considered to be constant at all levels of production. In turn, constant factor proportions allow one to identify as constants both the marginal productivity of labour (change in output divided by change in labour) and the marginal output/capital ratio. The reciprocal of the marginal output/capital ratio is the well-known Incremental Capital Output Ratio (ICOR), which is used as a convenient proxy for the state of technology. In figure 3, the capital/labour ratio (the index of factor proportions) is constant at 0.4, marginal labour productivity is constant at 1.25 and the ICOR is constant at 0.4.

Increasing returns to scale (economies of scale) can be depicted by an isoquant map in which the distance from every isoquant to the next higher one decreases for equal output increases; this implies decreasing input requirements per unit of additional output. Decreasing returns to scale (diseconomies of scale) correspond to an isoquant map in which equal increases in output are associated with a greater and greater distance between isoquants.

To the reader familiar with basic economic principles, it will be apparent that, just as the quantity demanded of a commodity depends on its price, the proportions of factors actually used in the production process depend not only on technological relations, but also on the relative prices of these factors. (Arrow, Chenery, Minhas and Solow have worked on a production function characterized by constant elasticity of substitution; this constitutes a definite improvement over the Cobb-Douglas function and has wider applicability.)[9] The prices of factors are partly determined by factor supplies, i.e. the factor endowment of the economy in question. One major implication is that, according to a static analysis, a country should tend to be more efficient than other countries in producing commodities that make intensive use of its relatively abundant (and thus cheaper) factor. (Readers familiar with international trade theory will recognize here the Heckscher-Ohlin theorem.) Other important implications relate to the optimum choice of technology by developing countries, to shadow-pricing of factors of production and to investment criteria, all of which will be discussed later.

The existing degree of technical and economic substitutability between different inputs is basic to the analysis of economic development. The following aspects should generally be examined: the quantitative role that each input plays in the production process; the degree of substitutability between different inputs; the conditions governing the growth in the inputs themselves; and the technological and other general conditions which also determine industrial growth.

The concept of production constraints has been applied to the analysis of economic growth possibilities and of the elements influencing growth. To say that one factor of production cannot be completely replaced by other factors (that substitutability is not unlimited) is equivalent to stating that a minimum application of it is indispensable for production and that a minimum increase in the quantity of that factor is essential in order to increase output by a given amount. The rate of growth cannot be greater, therefore, than the most severe constraint permits. The crucial factors in development are those which cause the most severe constraints. No matter how large the requirements of a given input to production may be, its relevance to economic growth is limited if the required increase in supplies of any other factor of production, even though small, cannot be attained and thus constitutes the most effective limitation on growth.

In the conventional view of economic growth, a sacrifice in current consumption is sufficient to bring about an increase in productive capacity and thus an increase in future production. Under conditions of perfect technical and economic substitutability among all components of productive capacity, future production can be increased by increasing the availability of a single input. Thus, provided that savings are sufficient to generate the desired growth of capacity, the higher output will be achieved no matter which particular input is increased. The only limit on growth is then the rate of saving.

When the assumption of unlimited substitutability in production is relaxed, the outcome is different; it is then no longer generally true that any increase in output can be achieved by a sufficiently large increase in a single input. Substitutability still exists—and its range may be quite considerable—but it is not unlimited and, after all substitution possibilities have been exhausted, there will still be a need for some minimum increase in the supplies of several inputs in order to increase output.

The notion of limited substitutability in production is at the centre of the rapidly growing literature about constraints on growth and the two-gap (or three-gap) approach to development problems. Several studies conducted during the past decade focus their attention on models explicitly incorporating more than one constraint on growth. While earlier models assumed that the rate of

[8] P. Douglas, *The Theory of Wages*, Macmillan, New York, 1934.

[9] "Capital-Labor Substitution and Economic Efficiency", *Review of Economics and Statistics*, 1961.

saving was the only constraint, the two-gap or three-gap approach emphasizes the lack of complete short- and medium-term flexibility and modifies the traditional models to include explicitly structural limitations on output growth other than, and independent of, the rate of saving.[10]

Limited substitutability implies, in the traditional classification, the need for a minimum increase in both capital and labour if output is going to increase. In developing countries, with their abundance of unskilled labour, labour shortage can be narrowed down to a shortage of skilled labour. In a closed economy, there would then be both a saving (capital) constraint and a skill constraint on growth.

Limited substitutability between different categories of domestic inputs is not the most relevant hypothesis with respect to an open economy; particularly for industry in developing countries, substitutability between domestic and foreign resources may be as limited as that between different types of domestic resources. If growth requires an increase in imported inputs as well as an increase in domestic resources, we then have an import constraint on growth, additional to, and independent from, the domestic resource constraints.

It has been realized, however, that natural resources may also constitute a constraint at some stages of industrial growth. Also, greater recognition of the importance of residual factors has led to the identification of an absorptive capacity constraint on growth. The term embraces all economic, social, cultural and institutional factors that can limit the growth rate attainable but which are not explicitly taken into account because they cannot be subjected to quantitative measurement or analysis. Some of these non-economic factors (a better term would be non-quantifiable factors) may play the dominant role in the industrial development of a country at a particular time. E. Hagen[11] and G. Myrdal[12] are among those who have stressed the importance of these factors in development. When these factors are taken explicitly into consideration, the 'residual' becomes smaller; but the planning model may become so complex as to be of little use operationally.

The absorptive capacity argument broadly states that, beyond a certain point, an increase in availability of capital or of other production factors cannot influence the rate of growth, for a country reaches the limits of its social, institutional and political capacity to absorb the increased capital and labour. In the short run, this argument is undoubtedly true. In the longer run, the non-economic bottlenecks, just like the economic constraints, can be expected to become less severe, since time makes it possible to effect the necessary adjustments. It is, in general, reasonable to presume that most developing countries encounter a savings, skilled labour, or import constraint before the non-quantifiable constraints have a chance to become operative.

Finally, a constraint on growth, by definition, cannot be looked at in a static context. Growth takes place not only by means of greater factor supplies within a static technical framework, but also as a result of technological improvements. The rate of technical innovation and the possibilities of accelerating the transfer of industrial technology are, therefore, also important variables in the industrial development process.

The concept of an input gap follows directly from the notion of constraint. If the target or planned growth rate of output is defined as the rate that is attainable by reason of the effective constraint, the quantitative gap between the supplies of the other inputs can be calculated. If the limit on the growth rate imposed by input X is higher than that imposed by input Y, a Y-gap can be identified, because input Y is then the operative constraint on growth and the X-limit is not effective. In another country at a different level of development, or within a given country at a different rate of growth, the situation may change so that X becomes the operative constraint on growth.

It follows from the above that, at a given point in time, an input gap will be of a different magnitude for different target rates of growth. For example, a savings gap (the difference between the level of investment required by the planned growth rate and the savings available) will disappear if the target growth rate is lowered sufficiently. At the limit (for a planned growth rate of zero), there can be no savings gap unless consumption is greater than net product. Similarly, the magnitude of the import gap (the difference between the foreign exchange required in order to achieve the planned rate of growth and the available foreign exchange) will increase the higher the planned rate of growth is set. Therefore, unless the two gaps vary according to the same pattern, there will

[10] The first widely used constraint model of growth is the well-known Harrod-Domar model, in which the over-all structure of the economy—as summarized by the incremental capital/output ratio—is assumed constant, thereby making the rate of saving the only limit on growth. The Harrod-Domar assumption is clearly ill-suited to problems of industrial development, with their attendant implications concerning structural changes. More recently, several constraint models have been elaborated, chiefly by H. Chenery with various associates, incorporating an import constraint separate from, and independent of, the general saving constraint.

[11] *On the Theory of Social Change*, Dorsey Press, Homewood, Ill., 1962.

[12] G. Myrdal, *op cit.*

normally be one target growth rate at which the savings gap is equal to the import gap, i.e. when the growth rate attainable in view of the saving constraint is equal to the growth rate attainable in view of the import constraint, and a range of growth output rates over which the two gaps are of roughly similar magnitude.

It is also clear that there can be no such thing as an input gap *ex post*. If an input does not grow at the rate required by the target growth rate of output, output will actually grow at less than the target rate and will be only as high as warranted by the actual increase in the input considered. With two constraints, the *ex post* savings gap must necessarily be equal to the *ex post* trade gap. The notion of an input constraint (and, by implication, of a gap between input requirements and availabilities) has meaning only *ex ante*, i.e. from a planning point of view.

The above analysis leads to two important propositions. First, to some extent, the difficulties encountered by a developing country can be considered as symptoms of the fact that growth is taking place; the severity of a given constraint on output depends by definition on the target growth rate of an economy (as has been shown, there is no such thing as an *ex post* constraint; the very fact that something has been produced indicates that the inputs necessary for it were available). A stagnant economy is thus likely to encounter lesser difficulties than a rapidly growing economy; indeed, many observers mistake stagnation for stability and view the absence of problems as an accomplishment worthy of notice. Secondly, and most importantly, it is to be expected that the role of the various input constraints will change at various stages of development, in different historical or planning periods and in different developing countries. This makes it much less profitable to try to identify in advance a *primum mobile*[13] of development, a king among inputs, a crucial bottleneck, on which every other element of growth is dependent in a systematic, consistent and permanent fashion. In reality, all depends on what one should look at first, and this is, to some extent, a matter of strategy, of time horizon, of the characteristics of a country, or of a combination of all three. The basic operational issues can be stated as the identification of the most severe input constraint (given a planned rate of growth in a particular country at a specific time) and the elaboration of policy measures to relieve that constraint and implement the planned industrial objectives.

[13] A. O. Hirschman's term (*The Strategy of Economic Development*, Yale University Press, New Haven, 1958, Chapter 1).

Industrial development strategy

Although most concrete industrial programmes cover a four to five year (or medium-term) period, a sense of the general direction in which the economy is intended to proceed is an indispensable element of successful economic effort. A long-term strategy of industrial and general economic development must be set, and medium-term plans must be consistent with the underlying strategy itself. The long-term blueprint will have to be continuously revised in the light of the results already achieved and events which were not foreseen at the time the plan was elaborated.

Basically, the strategy of planning is the same for all developing countries. In principle, a country should stimulate investment in those sectors where it is or could become comparatively most efficient. The principle of comparative advantage cannot be interpreted in a static manner in developing countries, however, for development is, by definition, a dynamic process. To formulate an industrial development strategy on the basis of the current comparative advantage of a country would result in plans that reinforce rather than change the existing state of underdevelopment. The strategy should stimulate investment in those sectors in which the country can acquire a comparative advantage in the future. Comparative advantage derives from the country's endowments of the factors of production and from the technological characteristics of different activities. It is a well-known economic principle that a country tends to have a comparative advantage in those commodities, the production of which is intensive in the factors of production which are relatively abundant in its endowment. Reinterpreting the principle of comparative advantage on a dynamic basis therefore implies that attention should be focused on future rather than present factor endowments and production processes. Some of the changes which may occur in technology and in a country's factor endowments are of an autonomous nature; other changes may be brought about by conscious policy decisions. Thus, for example, while the rate of growth of the labour force as a whole may often be considered outside the realm of public policy control, the future skill level of the labour force is clearly a planning variable, for the desired upgrading of a country's labour supply can be achieved through planning. To a large extent, therefore, analysis and planning are interrelated: well-implemented plans can create a comparative advantage in a specific activity to conform with explicit long-run economic goals.

The controversy over whether balanced-growth or unbalanced-growth should be the general strategy for industrial development merits special attention. It must be realized that economic development means growth plus change. The magnitude of the tasks to be carried out as well as the complexity and inertia of social and economic structures are such that gradualism is not a realistic aim. Although nature may not proceed by jumps, industrial development does. A significant number of theoretical insights has been gained from this realization. One approach, which has come to be called balanced growth, views discontinuities in the process of development as dictating the need for a balanced and large-scale effort to get an economy moving. On the basis of the same discontinuities and inter-relations, another approach has been formulated which has been termed unbalanced growth, to the effect that development is fostered by an optimally unbalanced sequence of sectoral investments.

Balanced industrial growth

The principal exponents of balanced growth are Lewis, Nurkse, Rosenstein-Rodan and Scitovski.[14] Balanced growth advocates have stressed the need to avoid imbalances in supply or to ensure that demand is diversified. In the first case, sustained development is thought to call for balanced growth of the individual industries of an economy; thus, depending on the characteristics of the production function, if steel output is to rise then some 'balanced' increase is necessary in iron ore and coal supplies, in steelworkers etc. Clearly, in an *ex post* sense everything is balanced: if steel output has increased, the necessary inputs must have been available somewhere. Though this reliance on supply considerations is useful for planning purposes, it has little analytical interest; it is of assistance in working out the implications of certain sectoral or national growth targets, but does not provide guidelines for a strategy of development. According to this technique of planning, it is necessary not only to expand inputs and outputs but also to avoid broad structural imbalances. The imbalance might arise from planning an increase in agricultural productivity while neglecting industrial or infrastructural problems; or from building dams, railroads, hospitals and harbours while neglecting investment in the so-called directly productive activities; or from any approach that focuses attention solely on one major sector of the economy. This doctrine of balanced growth is a healthy reminder that all-out efforts in one sector can be self-defeating, but it rules out the possibility of large-scale structural change in the course of development. It may well be an accurate view of economic progress, of economic growth, in developed economies but it does not provide an adequate perspective on development.

The alternative version of the balanced growth doctrine, stressing the demand side, appears to be more relevant. It stems from consideration of external economies, i.e. those economies of large-scale national production over which no individual producer has control and the benefits of which are spread over a number of producers. A new road, for example, may bring financial benefits to all producers using it, but these benefits are indivisible; that is, they can neither be appropriated by any individual producer nor be apportioned in such a way as to form an adequate basis for cost-sharing. Thus, even though the new road is nationally profitable, it is not commercially profitable for any individual investor to build and will not be built unless the Government undertakes it. On the demand side, important external economies can accrue to a producer from the existence of internal scale economies in another sector from which he buys intermediate goods.

Finally, there are indivisibilities giving rise to external economies in the supply of savings. This is the third type of indivisibility and underlies Rosenstein-Rodan's example of a new shoe factory. To build the factory by itself will turn out to be self-defeating, because the majority of the country's population is at near-subsistence income levels and cannot afford to buy the shoes it would produce. The income generated by the shoe factory would be sufficient to absorb all its output, if spent solely on shoes but the income of the newly employed workers would be spent partly on other commodities. Faced with the limited size of the market, therefore, no individual producer has sufficient incentive to invest, looking at his own project in isolation; the investment will simply not take place, production and income will not increase and the domestic market will remain as small as before.

The vicious circle can be broken — so this version of the balanced growth theory concludes — only if a sufficiently large number of projects is initiated, at one and the same time, so that the new industries can be each others' customers through the purchases of their workers, managers and investors.

Nurkse expanded the argument to include consideration of productivity, capital formation and consumption patterns. The situation is depicted as follows: low average productivity in agriculture stems from the existence of a large

[14] W. A. Lewis, *The Theory of Economic Growth*, Irwin, Homewood, Ill., 1955; R. Nurkse, *Problems of Capital Formation in Underdeveloped Countries*, Oxford, 1953; Rosenstein-Rodan, "Industrialization of Eastern and Southeastern Europe", *The Economic Journal*, 1943 (see also "Notes on the Theory of the Big Push", paper for the International Economic Association, mimeographed, 1957); and T. Scitovski, "Two Concepts of External Economies", *Journal of Political Economy*, April 1954.

volume of disguised unemployment, so that the marginal productivity of labour is negligible. The small real surplus of the more efficient farmers has to support the subsistence of the unemployed and thus no net savings emerge from the agricultural sector to finance productivity improvements. Even if some means could be found to transfer the under-employed labour out of agriculture, thus releasing potential savings, a second vicious circle would come into play. At low levels of productivity, total purchasing power is low and the size of the market is thus relatively small; the small size of the market, in turn, reduces the incentive to invest (particularly in domestic industrial ventures); without new investment productivity and income remain low. Thus, some means must be found of exerting a large-scale investment effort on several fronts simultaneously, in order to build, in the shortest possible time, a new complex of industrial projects interacting with one another and generating a substantial amount of new income.

Unbalanced industrial growth

"The advantages of multiple development may make interesting reading for economists, but they are gloomy news indeed for the underdeveloped countries. The initial resources for simultaneous development on many fronts are generally lacking."[15] The important positive contribution of the balanced growth theory is undoubtedly its explicit incorporation of considerations relating to market size and external economies in development thinking. This may be regarded as the true starting point of a theory of economic development and the first major attempt to incorporate dynamic elements into a systematic model of economic progress. There are, however, serious difficulties with some of the premises underlying balanced growth literature, and the validity of its policy conclusions is doubtful. Though it is easy to advocate a co-ordinated, large-scale and simultaneous investment effort, where is a developing country to find the technical, financial, managerial and skilled labour resources necessary for such an effort? The country is likely to suffer from a scarcity of precisely those types of resources that are necessary for achieving a balanced pattern of development. A balanced growth strategy would appear, therefore, to be unsuitable for economic development in developing countries (although, as Hirschman points out, it may be the correct policy to cure cyclical unemployment in developed countries).[16] If balanced growth were a requirement for sustained industrial development, prospects for most developing countries would be bleak indeed. According to many development economists, however, the balanced growth prescription is not only unrealistic but unnecessary; a strategically chosen sequence of investments is a feasible and realistic alternative.

Among the resources which are particularly scarce in developing countries, but which a balanced growth would require in great quantities, Hirschman identifies "the ability to invest" as the most relevant constraint. Upon the same general premises as the balanced growth theory, Hirschman has built an alternative theory involving strategically unbalanced investments.[17] The notion of ability to invest may be viewed as an expansion of the notion of the role of entrepreneurship in economic growth.

Entrepreneurship has long been recognized as an essential ingredient of economic progress, and the Schumpeterian model of growth, in particular, assigned it the central position.[18] In this model, growth depends primarily on the rate of applied technical progress (innovation), and the rate of innovation is made to depend on the supply of entrepreneurs. In this view, the entrepreneur is the dynamic agent of change, the catalyst without whom no increase in physical, natural or human resources can be transformed into a production increase. The supply of entrepreneurs, in turn, depends on the over-all "climate" of a country, and a climate favorable to the formation of vigorous entrepreneurs can exist only if the social structure is not directed toward penalizing changes and deviations from accepted practices. Hirschman also views the supply of entrepreneurs as a determinant of development prospects but puts it into a broader context by considering it part of the general capacity to undertake investment decisions. In turn, such general capacity—the ability to invest—depends not only on a vague concept of climate, but on a very concrete economic fact—the size of the market.

> "The ability to invest is acquired and increased primarily by practice; and the amount of practice depends in fact on the size of the modern sector of the economy. In other words, an economy secretes abilities, skills, and attitudes needed for further development roughly in proportion to the size of the sector where these abilities are

[15] H. W. Singer, "Economic Progress in Underdeveloped Countries", *Social Research*, March 1949. See also "The Concept of Balanced Growth and Economic Development: Theory and Facts", *University of Texas Conference of Economic Development*, April 1958.

[16] A. O. Hirschman, *The Strategy of Economic Development*, Yale University Press, New Haven, 1958, p. 54.

[17] *Ibid.*

[18] J. Schumpeter, *Business Cycles*, New York, McGraw-Hill, 1939.

already required and where these attitudes are being inculcated."[19]

A large-scale, simultaneous investment effort of the kind implied by the balanced growth doctrine obviously cannot take place unless the ability to undertake it exists. But the ability to invest depends on the size of the domestic market, which is small by definition. Since a balanced growth strategy requires a great deal of that "resource" – the ability to invest – which may well be in scarcest supply in a developing country, it can prove to be incorrect. The correct approach would then economize on ability to invest by maximizing induced investment decisions and limiting autonomous investment decisions to those strategic sectors where they are most necessary to initiate a process of growth.

The unbalanced growth strategy thus rests on the recognition of the importance of the size of the market and of the structural interdependence (in both demand and supply) between various sectors of an economy; on the notion of ability to invest as the operative constraint; and on the identification of strategically correct sequences which maximize induced investment.

The appropriate sequence will depend on the structure of the country. One country may concentrate investment on infrastructure and hope that investment in directly productive activities will follow because it has then become more profitable (a permissive sequence). Another country may neglect infrastructure in favour of directly productive investment in the expectation that this will create such pressure that the decision to build the infrastructure will then become inevitable (a compulsive sequence).

Similarly, inter-industry linkages can be forged either from a forward sequence – investment in production of intermediates followed by investment in the industry using the intermediates – or from a backward sequence. The forward sequence economizes on the ability to invest, for it is easier to make an investment decision when the production of inputs is already taking place (a permissive sequence). The backward sequence forces investment in the production of inputs by undertaking a project which depends on those inputs for effective operation (a compulsive sequence). Thus, one deliberately puts oneself in a position whereby further progress is permitted or compelled by the interdependence of events.

According to this strategy, one cannot plan for building roads and an automobile factory at the same time; an attempt to proceed in this fashion would leave the country without either roads or cars. Instead, one may focus planning attention on cars, for example, knowing that when enough cars have been produced, someone, somewhere in the country, will have to begin building the roads. Alternatively, one may build the road knowing that it will increase the feasibility of car production and marketing, and in the expectation that this will make it easier for a prospective investor to start a car plant. Hirschman admits to a general preference for compulsive sequences, but leaves the determination of the concrete strategy of development to the specifics of the individual cases; his general principle is to initiate a development sequence by investing in those projects which have the greatest number of linkages, backward as well as forward.

A synthesis of balanced and unbalanced growth strategies

To some extent, the controversy between the balanced and the unbalanced growth strategies rests on definitional differences and on the view that the two approaches are mutually exclusive. This point has been well put by Higgins:

> "It is important to distinguish between balanced growth as a technique of development and a goal; even Hirschman's zig-zag growth must have some kind of 'balance' as the ultimate aim. One might, that is, deliberately create *ex ante* imbalances in order to produce subsequent *ex post* balance at a higher level of *per capita* income. Once we recognize that we are not dealing with an 'either-or' proposition, we can stop talking about balanced and unbalanced growth altogether, and talk instead about functional relationships among the major sectors and regions of an economy."[20]

It would be as ridiculous as a matter of systematic policy to spread all resources thinly over an economy as to concentrate everything on one specific sector. Nevertheless, there is a difference between balanced and unbalanced growth strategies. They are both correct, in so far as they stress the same relevant variables in the process of industrial development, but they are both incorrect because they are incomplete: balanced growth, by pessimistically failing to take into account the "mechanism of change"; unbalanced growth, by optimistically looking at the "ability to invest" as practically the only operative constraint. It will make a difference to the development prospects of a country, however, whether its Government and planners are generally oriented towards achieving a balance or are constantly on the lookout for strategic sectors on which to concentrate their efforts. To be sure, it is a difference of degree and not of kind. Moreover, a practical approach

[19] A. O. Hirschman, *op. cit.*, p. 36.

[20] B. Higgins, *Economic Development*, 2nd edition, Norton, New York, 1968, p. 342.

is more strongly influenced by the surrounding environment than by economic development ideology. Finally, the margin of truly free play, of decisions not deriving directly from previous events, is inevitable small. This is not to deny that, at any point in time, there is some choice whether to attempt a large-scale programme of simultaneous investment in related sectors or to channel resources more towards one sector than another. The relevance of the controversy in actual planning experience is shown by the fact that the choice is being exercised in different ways by countries at similar levels of development.

THE PROCESS OF INDUSTRIAL PLANNING

Plan formulation

As has been discussed, if a plan is to be converted into actual industrial development, it should incorporate an explicit strategy for doing so. Plans formulated in accordance with a long-run strategy of industrialization provide the basis by which sectoral programmes and specific projects can be evaluated. In the absence of such a strategy, industrial plans are merely a collection of individual project plans which do not usually add up to a consistent whole, a set of logically related investments. The individual projects often may not be successful because the complementary inputs, infrastructure, foreign exchange and finance which could have been available are absent. It is necessary, therefore, that the plan include systematic consideration of the interdependence among economic activities, and particularly of inter-industry linkages.

The plan should seek to avoid contradictions between targets, contradictions in the operation of different plan instruments and contradictions between short- and long-term dispositions. Furthermore, the plan should compel policy-makers and investors to think in terms of the balance between resources and economic targets. Finally, a plan should seek to decrease economic uncertainty by the information it contains, for unless potential investors are aware of what other projects are under way, of infrastructure facilities and of trends in consumer purchasing power, they may not undertake projects that would be commercially and nationally profitable. All individual economic enterprises should be familiar with the targets and strategy of the plan so they can determine the role they should play in conforming to the plan.

The first tasks facing planners, therefore, are to define targets and to identify the resources necessary for achieving them. Although a great deal of debate has taken place concerning which of these two tasks should come first, much of it resembles the "chicken and egg" controversy. Both elements of plan formulation are essential: target-setting can be realistic only if it is grounded on a minimum informational base, and resource identification serves no purpose unless an explicit set of goals and a general direction of development have been laid down.

The time dimension of the plan is most important. A country should adopt a long-range strategy of development, but it cannot formulate a specific plan to cover a long period of time, say 30 or 40 years, because it is impossible to make realistic forecasts for such a period. Very short-term plans, covering one or two years, are equally meaningless, because the formulation, evaluation and implementation of the projects envisaged by the plan take longer than the period covered by the plan. Most plans, therefore, cover four or five years. Such a medium-term plan should be formulated in conformity with a longer-range strategy of development that has been adopted and possibly incorporated in a so-called perspective plan. This medium-term plan, in turn, must be converted into shorter-term concrete programmes, usually on an annual basis, which become the tools by which the plan is implemented.

Once the strategy of development has been determined and broad goals have been established, the planners can direct their attention to exploring systematically the proper allocation of resources needed to attain those goals. At this point, they should also convert the plan into sectoral programmes and specific projects, bearing in mind the need for consistency. The planners must also take account of the constraints to which various inputs are subject and focus attention both on the means to be used in relieving the most severe constraints and on the policy adjustments to be made. As a consequence, the plan should include the identification of substitution possibilities and a set of qualified statements about expected results under various different conditions.

Ideally, all elements of plan formulation should be elaborated at the same time, but this is not feasible in practice; according to many prominent economists, simultaneous solutions are often neither necessary nor desirable.[21] Planning by stages can proceed efficiently as long as the set of equations describing the structure and operation of the economy is such that causal ordering and identification is possible, or if the matrix of coefficients is close to a causally ordered structure. The data and planning skills needed for simultaneous solutions are just not available in most developing countries,

[21] See, for instance, J. Tinbergen, *Central Planning*, Yale University Press, New Haven, 1964, p. 95 ff. or J. Tinbergen, "Planning in Stages", *Statsøkonomisk Tidsskrift*, No. 1, 1962.

and so simple iterative techniques of plan formulation will probably lead to results as good as the attempt to use highly sophisticated techniques, and at much less cost. As long as each stage of planning is constantly reviewed, with reference to the formulation of the other stages, and effective mechanisms for feedback of information exist, planning in stages (iterative planning) seems preferable to the simultaneous determination of all basic relationships needed for planning.

The planning stages can be outlined in general terms as follows[22]:

I. Aggregate Stage:
- *(a)* Elaboration and transmission of instructions on basic development aims from the Government to the planning agency;
- *(b)* Collection of data and forecasts of supply and demand;
- *(c)* Macroeconomic forecasts;
- *(d)* Confrontation of forecasts with development targets;
- *(e)* Formulation of the macroeconomic plan.

II. Sectoral Stage:
- *(a)* Collection of estimates of income-elasticities of demand;
- *(b)* Collection of sectoral data on technical possibilities;
- *(c)* Translation of macroeconomic targets into sectoral goals;
- *(d)* Confrontation of sectoral estimates and forecasts with sectoral development targets;
- *(e)* Formulation of sector programmes.

III. Project Stage:
- *(a)* Formulation;
- *(b)* Evaluation;
- *(c)* Implementation.

IV. Final Stage:
- *(a)* Revisions;
- *(b)* Adoption;
- *(c)* Publication of the plan and programmes.

Planning, by itself, does not produce development; plans must be translated into realistic programmes in order to make and implement investment choices. Thus, the programmes should take into account the inherent administrative managerial, institutional, financial, political and social potential of a country and the limitations on its growth prospects. A typical shortcoming in the planning process is exclusive concentration on the macroeconomic framework, dealing with aggregates based on broad generalizations (e.g. over-all capital-output ratios), without providing a mechanism for translating sectoral plans into individual projects. Moreover, special precautions must be taken to guard against inconsistencies, since they may result in the establishment of targets that cannot be achieved.

[22] Adapted and expanded from J. Tinbergen, *op. cit.*, pp. 88–89.

Economic planning is only a tool of economic policy, and this policy must be determined by the highest officials of the Government, not by the planners. Government officials should, of course, set policy on the basis of the advice that the planners give them concerning what is feasible and desirable, but the policy directives must emanate from them. Economic planning does not consist solely of plotting rates of growth for various sectors; rather, the country must establish its over-all aims and objectives, survey the available means by which to attain them, and then map out a course of action.

Industrial planning, too, must start with a strategy of industrial development (over-all and by sectors) that is consistent with the resources available to the country. As mentioned earlier, the targets must be consistent with each other; for example, it may not be feasible to achieve a maximum rate of industrial expansion and regional decentralization of industry at the same time. The priorities in national objectives, therefore, must also be spelled out clearly. In other words, planning is a technique of co-ordination to ensure the development of the economy as an interdependent set of components, placing the necessary actions in chronological order and embodying the mutual and hierarchical interdependence of aims, objectives and instruments. Plans for industrial development, therefore, must be co-ordinated with the training and distribution of manpower, the acquisition and spread of technical knowledge, the raising and allocation of investment funds and the input needs and output targets of other sectors. Such co-ordination is necessary not only in the original planning stage, but throughout the period of implementation of the plan.

The interdependent stages of planning

Forecasting the future

A plan establishes targets to be reached in the future and outlines the steps necessary to attain them. Since what is possible in the future depends upon what future circumstances will be, planning is bound up with forecasting. The planners must attempt to predict the future course of the national income, population, labour force, rates of saving and investment and other key economic factors.

The simplest form of forecasting is extrapolation, i.e. a projection of past trends. Thus, if a country's industrial production has been growing at an average rate of 3 per cent per year, this method of forecasting would project a 3 per cent growth rate in the future. But this is precisely what is wrong with extrapolation as a method of forecasting for developing countries — it is based on the assumption that future production will be affected by the same forces as those that affected earlier development. Extrapolation can make sense for long-range forecasting in advanced industrial countries, because industry is already developed and annual accretions in most lines of production are fairly predictable from past experience. The use of extrapolation is dangerous, however, in developing countries, where the aim of planning is to change the economic *status quo*, not to maintain it.

One method that partially overcomes this problem is to extrapolate the ratio of the growth rate of a particular sector to the growth rate of total industrial production, instead of extrapolating the growth rate of the sector itself. The use of this ratio, which is called the coefficient of structural change, though more refined than straight sectoral extrapolation, still assumes that many factors will remain unchanged. Forecasting can be improved by examining the relationships between the level and structure of production, the state of economic development and the growth rates of individual sectors. If the statistical data are available, a country can select other countries that have recently reached the level of development that it is seeking to attain at the end of the plan period, and use as a rough guide the coefficients of structural change experienced there (i.e. by multiplying the planned rate of growth of total industrial production by those coefficients).

The pioneering work in this field was done by H. B. Chenery, who examined the relations between *per capita* national income, size of population and pattern of industry.[23] The application of this method in planning and a description of the experience gained are discussed in depth in the sixth volume of the Development Programming Techniques Series.[24] In addition, a complete description of such a model, with instructions for using it to predict the "normal" growth of some thirteen manufacturing industries, has been published by the United Nations.[25]

[23] See, for example, H. B. Chenery, "Patterns of Industrial Growth", *American Economic Review*, December 1960.

[24] *Sectoral Aspects of Long-Term Economic Projections with Special Reference to Asia and the Far East* (Bangkok: United Nations Economic Commission for Asia and the Far East, 1967, p. 439 ff.).

[25] *A Study of Industrial Growth*, United Nations Centre for Industrial Development; Department of Economic and Social Affairs, 1963, Sales No. 63.II.B.2.

Although these forecasting methods are a great advance over simple extrapolation of growth rates, the computations provide only statistical relationships and not normative guides for a particular country. Their major shortcomings are that they disregard the comparative advantages that a country may possibly have or acquire in time, the particular conceptions of development that its Government may hold, and the likely effects of general technological progress.

The output of an individual sector can be planned with reliability only by forecasting the total demand for its products, i.e. intermediate goods as well as those that will be used in the consumer sector and for investment purposes. Allowing for changes in inventories and subtracting the share of domestic demand that is expected to be covered by imports, one is left with an estimate of the share of domestic demand that is to be supplied by domestic production. To this figure must be added possible exports.

Such forecasting can be carried out with relatively simple statistical techniques or more sophisticated ones such as multi-variable econometric models. It can even make use (especially in the developed market economies) of market research, which has been defined as "gathering, recording, and analysing all facts about problems relating to the transfer and sale of goods and services from producer to consumer".[26] Whatever techniques are utilized, they are likely to prove more effective in forecasting domestic demand than exports and imports of the sector's products. Domestic final demand, for instance, can be forecast by establishing the income-elasticity of demand for the sector's products and forecasting personal income. The sector's output of investment goods can be forecast on the basis of the rate of growth of national income and the marginal capital-output ratio.

The use of input-output tables, which show the interrelationships among all the sectors of the economy, is most helpful in sectoral planning, because it is always essential to check forecasts for consistency. Among the techniques for forecasting export and import changes are the comparison and ranking of sectors with the help of efficiency indicators[27] and the application of mathematical programming procedures based on decomposi-

[26] "1948 Report of the Definitions of the American Marketing Association", R. S. Alexander, Chairman, *The Journal of Marketing* (American Marketing Association, October 1948).

[27] See the papers by G. Cukor and Z. Roman in *Evaluation of Industrial Projects*, UNIDO Project Formulation and Evaluation Series, Volume I, United Nations, 1968, Sales No. E.67.II.B.2.

tion.[18] The latter method, although far more complicated, provides a control of the consistency of the sectoral programmes. It must always be borne in mind, however, that complicated techniques require accurate data and trained personnel, both of which are often lacking in developing countries.

Sectoral and industrial programming

The over-all plan for national development must include the setting of growth targets for the broad sectors of the economy—industry, agriculture and services. In sectoral programming, it is most important to pay careful attention to inter-sectoral co-ordination. Complementarity and mutual support characterize the relations between industry and the services sector and likewise between agriculture and industry—for example, the synthetic fertilizer industry provides inputs that improve agricultural output.

Inter-sectoral co-ordination, however, is often thwarted by administrative difficulties arising from the fact that different ministries and government agencies are responsible for the development of different sectors. For example, the implementation of plans for expanding fertilizer production, under the aegis of the Ministry of Industry, may be dependent on the timely construction of warehousing facilities, which may be the responsibility of a separate Ministry of Construction, and on an educational campaign by the Ministry of Agriculture to acquaint farmers with the advantages of the new fertilizer. If any of these agencies fails to perform its role properly, the entire programme may fail, no matter how well it was formulated.

Inter-sectoral co-ordination is most important for the joint implementation of industrial and infrastructural programmes. Infrastructure projects, particularly those involving power and transportation, generally require heavy capital investment. To increase the rate of utilization and reduce the unit operating costs of these facilities, they should be constructed in conjunction with a number of industrial production projects. The infrastructure must be ready when the industrial projects are, lest the latter suffer from severe inefficiencies. This should not be interpreted to imply a need for a "balanced" rather than an "unbalanced" pattern of industrial development. The point being made is that there must be joint implementation of all parts of an industrial plan, whether the underlying strategy is one of multiple development or one calling for sequential investment decisions. Since different government departments tend to be responsible for 'industry, road building, railways, house construction, etc., the problems of co-ordination are not easily solved.

The over-all plan must be elaborated by drawing up programmes in further detail for each of the major sectors of the economy. Industrial programming begins with the setting of growth targets for the various industrial sectors, such as metal transforming, textiles and clothing.

In order to disaggregate the sum available for industrial investment, the output of the various industrial sectors can be projected for the plan period on the basis of income-elasticities of demand, as explained above.

Great care must be taken in projecting demand for a sector's output, for overestimation can result in the creation of surplus capacity, which is a waste of resources, while underestimation generally causes bottlenecks. The difficulties are manifold. In most developing countries the relevant income-elasticity data are not very reliable, if available at all, but this problem can be partially overcome through the use of data from other countries. Furthermore, planners are prone to subjective bias, tending to overestimate the income-elasticity of demand for the products of those industrial branches that they believe to be most important. To guard against this difficulty, the planning authority should not accept income-elasticity data from planners at face value but should insist on substantiation and documentation on the methods used and should examine all implications of the data. Finally, projections based upon income-elasticity of demand indicate only how the economy would develop if market forces were allowed to operate with the same degree of intervention as in the past by the Government.

Co-ordination within a sector itself is very important, and industrial programming entails a dovetailing of specific projects into a consistent sectoral programme. The setting of priorities must not conflict with policy measures. Public and private projects within the same industrial sector must be co-ordinated. The existence of forward and backward linkages means that some industries are very dependent upon the proximity of their major suppliers or of industrial purchasers of their output; thus, the feasibility should be explored of building industrial complexes rather than individual projects.

The financial aspects of plan implementation must also be considered, including working capital as well as requirements for fixed assets, the timing of needs over the period of the plan and the availability of foreign exchange. A margin of error in forecasting financial needs is inevitable and contingency funds should be established to prevent such errors from blocking plan implementation. This

[18] See, for example, J. Kornai, *Mathematical Planning of Structural Decisions*, Budapest, 1967, p. 526 and following.

applies with particular force to foreign exchange, which must be available throughout the plan period in the amounts necessary for the imported inputs.

Many economists have reached the conclusion that instability of export earnings can severely curtail development, particularly industrial expansion. If sufficient foreign exchange is not available, a country cannot import the capital and intermediate goods necessary to attain plan targets nor can it substitute domestic production for those imports, and thus the success of the entire industrial plan is endangered. Even if foreign exchange earnings over the total period of the plan are in line with the forecasts made when the plan was formulated, a shortfall of exports in a given year may cause damage that cannot be compensated for a surplus of equal magnitude in another year of the planning period.[29] The low substitutability of domestic for foreign inputs can cause an import constraint on growth. Surpluses of foreign exchange earnings above anticipated levels cannot be translated into faster industrial expansion, because complementary domestic inputs needed in order to add industrial projects to the current plan will not be available.

Given the importance of the financial aspects of industrial programming, government measures must facilitate the raising of equity capital either directly – by creating credit institutions, such as an industrial development bank or by selling bonds to the public – or indirectly, by guaranteeing loans obtained by private investors, to obviate the need to build up a full financial infrastructure as a prerequisite to implementing the plan. Willingness to accept foreign financial participation in industrial projects offers several advantages such as access to larger sources of capital, the obtaining of foreign exchange and, possibly, lower interest rates. Foreign sources of aid should be thoroughly explored in formulating an industrial development plan.

Effective implementation of industrial programmes requires the establishment of clear channels of authority and responsibility in the administrative machinery of industrial development. There is a pressing need to improve the machinery for conducting economic surveys, periodically appraising the implementation of programmes and reviewing plans. New techniques, such as CPM (Critical-Path Method) and PERT (Progress Evaluation and Review Techniques), which involve displaying a diagrammatic form the logical sequence of steps from project formulation to completion, can be utilized in the implementation process. A plan must be broken down into its constituent parts and each organizational unit concerned with implementation must be aware of its responsibility. Critical points must be identified to ensure that they do not become roadblocks to effective implementation, and a central agency must maintain continual vigilance over the crucial interrelationships between the parts of the whole plan.

Co-ordination between national agencies engaged in plan implementation and outside sources of financial and technical assistance is likewise essential, for the latter have experts who are in a position to offer advice that could prevent serious shortcomings in implementation. Furthermore, if the outside agencies are kept appraised of current development, they are likely to be more sympathetic to requests for further aid, should it be called for.

Identifying industrial opportunities

The formulation of sound projects and their careful and systematic scrutiny represent the foundation of industrial development. An industrial project involves a proposal for a capital investment to build facilities to manufacture goods. Projects vary greatly in size, character and complexity and can involve the creation of entirely new industries, the building of additional plants to increase the output of products currently being manufactured, or the expansion of the productive capacity of existing plants.

Despite the low existing level of industrial development and a strong desire by governments to achieve industrialization, there is undeniably a shortage of well formulated industrial projects in less developed countries. The problem lies not so much in the mechanics of preparing projects as in the existence of conditions adverse to the formulation of projects – in other words, in the basic causes of the current state of underdevelopment. The shortage of industrial projects has been attributed mainly to the absence of a properly qualified entrepreneurial class, prepared to take initiatives and assume risks, and to the inadequacies of government economic policy.

The problem cannot be solved by someone sitting in a central planning agency who, by comparing his country's level of industrial development with that of industrialized countries, maps out and formulates dozens or even hundreds of projects that might be undertaken; few of them could be successfully carried out. The determination of the feasibility of a project in the actual circumstances

[29] The International Monetary Fund instituted in 1963, and expanded in 1966, a facility for compensatory drawings to assist countries suffering from instability of foreign exchange earnings through exports. See IMF, *Compensatory Financing: A Second Report*, Washington, D.C., September 1966. Proposals for further supplementary financing are now being examined.

of a particular country is a painstaking process known as project evaluation.

The pattern of a country's current consumption of industrial products is a fruitful source of information on the possible opportunities for industrialization; although much of that consumption may at present come from imports, domestic production of many of these items may be possible. Generally, import substitution is taken into consideration by planners in terms of its effect on the country's balance of payments. More attention should be paid, however, to its impact upon the country's industrial structure. It is important to seek out the kinds of project that could act as catalysts in the industrial development process. Emphasis should be placed on the establishment of new enterprises that serve to consolidate existing industries, raise the technological level, improve manufacturing processes and train the labour force, as was done in the programme for the metal-transforming industries in Venezuela.[20] Projects are particularly worth while, therefore, that use the output of other domestic industries (backward linkages) or manufacture products that will be the inputs for other domestic industries (forward linkages).

Not only must a particular project be feasible, but it also must be consistent with the country's over-all industrial programme and must be evaluated in the context of the development needs of the economy. The importance of macroeconomic planning and sectoral programming is not to be minimized, but broad sectoral targets have to be translated into specific projects. The very formulation of an industrial programme implies that a group of sectoral targets has been established according to a system of priorities; the formulation and evaluation of specific projects will have to take place within the framework thus set up, because a lack of consistency will render effective implementation impossible.

Conducting feasibility studies

Once a project consistent with the industrial programme is formulated in its broad outline, the next step is to conduct a study of its feasibility. It is essential to determine how closely its technical requirements can be met. This investigation analyses the extent to which the country's resources and facilities meet the needs of the proposed project. It requires a study of the availability, quality and accessibility of the input needs of the industry—raw materials, power, fuel, transportation, labour, intermediate products and even the suitability of various sites. Another crucial object of the technical feasibility study is to determine the appropriate scale of operations and input coefficients.

Once the technical feasibility of a project is established, the next step is to analyse its economic feasibility, which requires a thorough analysis of the present and potential market for the product, including export possibilities, a detailed analysis of comparative production costs and a determination of the project's capital requirements. To assess profitability, estimates must also be made of the anticipated revenue from sales (and any other source).

The financial aspects, including investment in fixed assets and working capital requirements, must also be included in the study of project feasibility. The financial structure of the project—the distribution between equity capital, long-term loans, and short-term loans—should be carefully formulated. Special attention must be devoted to the time factor, for funds must be available when required at each stage of implementation of the project—construction, machinery purchase, labour force training and the like. The requirements of foreign exchange also help to determine a project's feasibility; most developing countries have a precarious balance-of-payments position and large requirements of foreign exchange relative to prospective earnings may doom an otherwise feasible project.

Auxiliary factors to be considered in evaluating the feasibility of a project include the availability of an appropriate infrastructure, the supply of manpower, and the possibility of recruiting and training a cadre of managerial and professional personnel. Some of these questions will have already been reviewed in the study of technical feasibility, but it is prudent to check them again to make sure that no significant elements have been overlooked. For example, an industrial project that will use large amounts of power may be judged feasible because cheap hydroelectric power is available in the country, but the specific location chosen for the plant may necessitate the construction of transmission lines that will significantly increase the cost of that power. It is often assumed that there is a surplus of labour in all developing countries and that recruitment of an industrial workforce is relatively simple. This, however, is a naive assumption, for finding workers with the requisite skills is a formidable task. Finding the management for the project is even more difficult and many observers of industrial development have concluded that the most common reason for the failure of projects is poor management. Special attention, therefore, must be paid to the recruitment of managerial and professional personnel

[20] Economic Commission for Latin America, "The Metal-Transforming Industry in Venezuela: An Import Substitution Development Programme", *Industrialization and Productivity Bulletin*, No. 11, United Nations, 1968, pp. 29–54, Sales No. 67.II.B.10.

for production and plant maintenance, accounts and finance, personnel relations and marketing.

Locational and regional aspects

The spatial dimension of industrial development—question of where to invest—is of extreme importance; often the decision on location of a new project can be as crucial as the decision when or whether to undertake the project at all. Regional planning is as necessary as sectoral planning: a failure to regionalize a sectoral plan will cause serious errors which will jeopardize its success and, conversely, a failure to take full account of the characteristics of the various industries proposed for inclusion in the regional plan will impair the latter's effectiveness.

The well-known conflict between the claims of national growth and industrialization of the less developed regions within a country is central to the consideration of the regional and locational aspects of industrial planning. The early stages of industrialization are characterized by increasing geographical concentration of production, induced by the economies of scale which enable a few large-scale producers to replace a number of dispersed smaller-scale producers (often pre-industrial, handicraft workers). External economies can also result from the geographical concentration of industry, because they arise from inter-industry linkages.

Production will usually be cheaper, therefore, in areas in which other industries are already operating. In most developing countries, the industrial concentration breeds a concentration of population, especially in the capital city, where most of the auxiliary industries and services required by a new project are available, skilled labour can be obtained more easily than elsewhere and direct contacts with the Government are possible. These economies of urbanization are reinforced by the attraction of cities as cultural, scientific, artistic and political centres, where entrepreneurs and managers of industrial establishments are more willing to live.

Governments envisaging measures to counteract the geographical concentration of industry, for whatever motives, should weigh the possible detrimental effects of industrial decentralization on the achievement of other national objectives. The regional development objectives of the plan must be carefully balanced against other objectives, particularly that of economic growth. From the point of view of national industrial development (admittedly only one of the objectives of planning), concentration of industry must be regarded as a necessary condition for success in most developing economies.

The principal factors affecting industrial location are land, labour, capital, transportation, interindustry linkages and the economies and diseconomies of urbanization. In planning the geographic distribution of industry the choices available will depend upon the level of development and the characteristics of the country in question. Three general criteria of location planning can be applied. First, there should be consistency between aggregate location programmes and the location of individual projects, because the locational factor is an inseparable part of the national process of planning. By applying this criterion, moreover, planners are forced to take account of expected changes in regional factor endowments and locational advantages. Secondly, location planning should seek to minimize aggregate transport costs, because minimizing the distances between the project, its input sources and its markets makes for efficiency of location. Minimization of transport costs does not necessarily give the best location for an industry, however, for the interaction between economic activities must be taken into account. Thirdly, therefore, location planning should seek to maximize external economies deriving from interindustry relations and urbanization, preferably through joint programming of related activities. These criteria cannot be used in isolation, they must be applied jointly to secure correct location planning.

Since it is impractical to carry out a detailed location study for every region in a country and a feasibility study for every industry that might be possible in a region, a general classification of industries according locational requirements can help the planner to select the industrial sectors for which specific location studies are worth conducting. As industrial development proceeds, location freedom becomes greater for individual industries, but manufacturing industry as a whole will tend to be even more strongly oriented towards urban areas. Since some industries show wide geographical dispersion in all countries, planning measures to influence industrial location are more likely to be successful if applied to these industries rather than others.

While industry location analysis can show the relative effect of various location factors, regional analysis assesses the availability of these factors in a given geographic area. Among the location and regional planning techniques that have been elaborated are: industrial complex analysis, which aims at determining the optimum combination of plants of different industries and the optimum degree of technical and economic integration; the regional multiplier, a tool to assess the regional impact of a new industry; interregional linear programming; and regional input-output analysis.

Planning tools and techniques of regional planning, however, should be adapted to the amount of information and the planning skills available in developing countries.

Formulation and evaluation of projects

Formulation and evaluation criteria

Significant problems arise when the projects undertaken are unsuitable for the current stage of development. This happens when the evaluation of the projects is unsound. The fact that an industrial project is feasible does not mean that it is desirable; it must be evaluated and in the light of prevailing circumstances in terms of predetermined criteria based on the country's objectives.

One group of criteria concerns the proportions in which factors will be used. In the simplest case, the planner concentrates on a single scarce factor and estimates the output value from alternative uses. In view of the shortage of capital in the developing countries, projects would be ranked according to their output-capital ratios. Many experts, however, criticize the employment of this criterion for a variety of reasons, including the fact that it implicitly assumes zero shadow prices for other factors.

The severe problem of underemployment that plagues most developing countries has led other experts to favour labour-intensive projects. The criterion put forth is the utilization of those factors that the country has in abundance. In practice, projects are then evaluated in terms of the degree to which they maximize employment or maximize the use of domestic natural resources. This criterion, however, has serious shortcomings: it can lead Governments to sanction uneconomic projects; there are technological limitations to factor substitutability domestically and between domestic and imported inputs; and finally, given the small size of the industrial base of most developing countries, this criterion would probably contribute very little to the solution of the surplus labour problem.

The shortage of technical know-how and skilled manpower characteristic of underdevelopment has led others again to put forward the criterion of technological simplicity. According to this stepping-stone theory of development, a country should move on to technically more complicated projects only as it accumulates the experience needed to operate them efficiently. Although there is some merit to such a criterion, an overemphasis on it would lead a country to concentrate exclusively on small-scale manufacturing and to overlook genuine opportunities for undertaking large-scale, technologically advanced projects. Furthermore, this criterion ignores the nature of modern technology and does not conform to the experience of many of today's advanced industrial countries. Finally, as has been argued, industrial development is not a smooth and gradual process, but usually proceeds by jumps.

A variation of the scarce factor criterion relates to the projects' requirements for foreign exchange. Since developing countries generally suffer from a shortage of foreign exchange, this criterion would give preference to projects that require little foreign exchange, that save foreign exchange by replacing imports with domestically produced goods or that increase foreign exchange by generating new exports. As in the case of other scarce-factor criteria, this implies setting all other economic input costs at zero — an unrealistic approach. Yet foreign exchange considerations are very important in project evaluation; experience shows that many projects have come to a halt in developing countries because the depletion of foreign exchange reserves prevented the purchase of certain capital goods or raw materials. In fact, each of the criteria mentioned should be given appropriate weight, but not to the exclusion of the others.

A different type of criterion, used by private enterprises undertaking industrial projects, is that of commercial profitability. There are different ways in which to express profitability, including the pay-back period (the length of time required for the return flows of income to equal the original cash outlay), the rate of return on investment (profit as a percentage of capital employed, either initially or over the duration of the project) and discounted cash flow methods (which take into account the financial opportunity costs of the resources invested). The major advantage of the commercial profitability criterion is that it is objective. Nevertheless, it is not the best criterion by which to evaluate industrial projects for national development whenever there are divergencies between private and national (social) opportunity cost, i.e. divergencies between commercial profitability and profitability in terms of national economic objectives.

The criterion of national profitability

In developing economies, social benefits and costs normally do not coincide with private benefits and costs. It has been advocated, therefore, that social cost-benefit analysis be utilized in project evaluation. Social cost-benefit analysis is essentially a tool to formulate and evaluate projects in terms of the explicit national objectives underlying development planning for the country as a whole.[31]

[31] A. K. Sen, "The Role of Policy-makers in Project Formulation and Evaluation", *Industrialization and Productivity Bulletin* No. 13, United Nations, 1969, pp. 25–36, Sales No. 69.II.B.3.

A major shortcoming of the evaluation of projects in terms of commercial profitability is that it fails to take account of external effects. Social cost-benefit analysis attempts to fill this gap, as part of the over-all evaluation of projects. It brings into the analysis the effects of the formation of a skilled labour force, the development of technical know-how, the creation of social and economic infrastructure and interindustry relations (backward and forward linkages). While commercial profitability is calculated in terms of the market prices of inputs and outputs, national profitability is calculated on the basis of shadow (or accounting) prices for inputs and outputs which reflect their economic scarcity in the context of the multiple targets of the national development plan.

Since in economies with a labour surplus the social opportunity cost of labour is, by definition, zero, some economists have suggested setting the shadow price of labour in developing countries at zero. A more realistic approach would be to set the shadow price of labour equal to the wage rate for agricultural labour. In practice, however, it is rarely possible to obtain unskilled labour in urban areas at wage rates as low as those paid to agricultural workers. Planners should realize, moreover, that a project which becomes feasible only when such shadow prices are used will have to be subsidized. Even if the true opportunity costs of labour are far below market wage rates, the management of a project must pay the going rates. Since Governments in developing countries can hardly afford to cover the difference in wage costs, the practical significance of the introduction of accounting prices for labour in project evaluation can be seriously questioned. At best, as Harberger argues,[32] the shadow price of labour should reflect the wage differential required to attract workers from agricultural to industrial employment, plus an adjustment factor to compensate for the higher cost of providing social overhead facilities for the workers and their families on transfer from rural to urban areas. For skilled labour, which tends to be in very short supply in developing countries, the shadow price should be nearly as high as the market wage, or possibly even higher. Planners should be aware of the fact that, as development proceeds, the gap between market and shadow wages is reduced.

It may also be necessary to set shadow prices for the raw material inputs of a project, because the social costs of producing them may differ from their market prices. Even when shadow prices for some material inputs are justified on this basis, however, one can arrive at the same conclusions by using market prices and treating the surplus of benefits over costs created in the material-producing industry, if the project is implemented, as a special, indirect benefit. By setting the level of indirect taxes to reflect the true opportunity cost of a commodity or service, the Government can ensure that the social benefit of a project can be measured by its output value plus indirect taxes.

The setting of shadow prices for foreign exchange is less controversial. When developing countries face serious balance of payments problems, they sometimes establish a series of official rates of exchange, different for essential and non-essential imports and for exports, according to the competitive situation of the commodities in world markets. Since the official rates of exchange, especially for non-essential imports, tend to overvalue the national currency, black market rates of exchange often exist that are closer to the equilibrium rate than to the imposed exchange rate and may be adopted as shadow prices.

It may also be necessary to establish a shadow price for capital and this may yield a different evaluation of a project from that obtained when the market rate of interest is used. The choice of time horizon and rate of interest to be applied within it may be very different when made from the individual rather than from the national point of view. The time preference of the population will tend to favour present, rather than future, consumption. Rapid industrialization may require the sacrifice of present consumption in favour of capital accumulation, and on this principle, low rates of discount would be preferable. The use of low rates, however, may lead to the acceptance of more projects than can be financed; and this, in turn, can result in the subsequent selection of wrong projects and to insufficient savings within public projects, which should contribute to national capital formation.[33]

Income distribution within the present population, as well as between this generation and the next, can be influenced by the weights assigned to

[32] A. C. Harberger, "Survey of Literature on Cost-Benefit Analysis for Industrial Project Evaluation", in *Evaluation of Industrial Projects*, United Nations, 1968, p. 240, Sales No. 67.II.B.23.

[33] A. K. Sen, *op. cit.*, states that the rate of discount today can be calculated from the premium that today's consumption commands, compared with tomorrow's consumption, because of the expectation that living standards tomorrow will be higher. He offers the following formula for calculating it:

$$i = m \cdot \frac{\dot{C}}{C}$$

when i = the social rate of discount
m = the elasticity of the marginal utility of consumption with respect to the increase in consumption
C = the level of consumption, and
$\dot{C}$ = the rate of change of consumption over time.

various national objectives when evaluating the national profitability of projects. Very often, planners decide that output should be valued more highly if created in a lagging region than if produced in a more developed region, because it contributes to a more equitable interregional income distribution. There is a risk, however, that such policies may result in a slower rate of national industrial growth detrimental to the long-run interests of the people in both poorer and richer regions.

In summary, social cost-benefit analysis can be defined as a technique for measuring the profitability of proposed projects in terms of national economic objectives by taking account of their external effects and of the goals and the time preference of the country as a whole. Its use enables a Government to assess which industrial projects deserve priority and which should be discouraged. The difficulty of constructing proper shadow prices, however, is not easily surmounted. The simplest approach to applying social cost-benefit analysis has been to use commercial profitability estimates as a base and make adjustments to reflect true social costs and benefits, as determined by the national objectives. The use of linear programming models for the entire economy to obtain appropriate shadow prices is not easily applicable in developing countries. For one thing, data are lacking, as are technicians capable of applying such techniques. Secondly, the characteristics of the economy must be so oversimplified as to make the resulting shadow prices unreliable.

Technological choices

One of the fiercest debates in development planning continues to rage over the question of the capital intensity of investment. On the one side are those who argue that countries should select technologies in conformity with their resource availabilities. In the developed countries, capital is plentiful and manpower is relatively scarce; thus capital-intensive technologies should be used. Following this logic, the developing countries should concentrate on labour-intensive projects and technologies because capital is scarce and manpower is abundant.

Grouped on the other side of the debate are those who contend that the use of capital-intensive technologies is advantageous in developing countries precisely because of the scarcity of capital. Capital-intensive technologies will generate more savings than labour-intensive ones, these savings can be reinvested, thereby maximizing production and growth and leading in the long run to higher employment.[34] Several other arguments for the use of capital-intensive technologies in developing countries have also been presented.

The theoretical arguments aside, developing countries, in practice find their options with respect to scale of operations and input ratios severely constrained by reality. Since modern technology generates economies of scale, i.e. reductions of input requirements per unit of output, in many industries only large plants can be efficient. Furthermore, there is little opportunity for substituting labour for capital in such continuous process industries as chemicals, where input coefficients are largely predetermined by technical complementarity. Thus, once a country decides to produce a particular item, it may have virtually no choice as to the technology to be used. For example, there is no labour-intensive method of producing electricity which is not absurdly expensive.

A further constraint upon using labour-intensive technologies in developing countries is that technology transferred from the developed countries tends inevitably to be highly sophisticated and capital-intensive. Many argue, therefore, that a prime requisite for industrial development is to create labour-intensive technologies. Whatever merits this argument may have, the fact is that the industrially advanced countries have no incentive to do so because such technologies are not needed in their economies, while international organizations and the developing countries lack the capability to do so. Finally, experience indicates that even when there is some degree of choice, enterprises in developing countries tend to select the more advanced machinery, because their shortage of skilled mechanics makes it easier to maintain newer, more advanced equipment.[35] In this way, the plants economize on skilled maintenance labour.

Although the possibilities of substituting labour for capital may be severely limited in basic production processes, they may be more abundant in such peripheral matters as materials handling and automation. A recent study of the practices of American companies[36] indicated that, when establishing industrial plants in developing countries, the companies introduce virtually the same technology as they employ in industrially advanced

[34] W. Galenson and H. Leibenstein, "Investment Criteria, Productivity, and Economic Development", *Quarterly Journal of Economics*, Harvard University Press, August, 1955.

[35] W. P. Strassmann, *Technological Change and Economic Development*, Cornell University Press, Ithaca, 1968, Chapters 4, 5, 6.

[36] *Manpower Planning by U.S.-Based Companies for the Transfer of Skills and Technology to New Plants in Developing Countries*, a study by Industrial Relations Counselors, Inc., prepared by Roy B. Helfgott with the assistance of Veera M. Dalal, for UNIDO, New York, April 1968.

countries. They do, however, restructure technology somewhat to conform to the factor proportions available in the country, for example, by using fewer overhead conveyors and more manual handling of parts between successive production processes. Similar findings were reported by Strassmann with respect to American companies in Mexico, but he also found that Mexican companies tended to use the most sophisticated equipment in order to economize on skilled labour.[37] In summary, it can be concluded that the nature of modern technology makes it very difficult to adopt highly labour-intensive techniques, but that some degree of technological adaptation may be possible.

Implementation

Programming as a continuous operation

Probably the most important step to be taken in the implementation of industrial projects is to see to it that programming does not cease when provision has been made for investment of funds but that it continues into the period when the project is expected to be fully profitable. Development planning, programming and plan implementation thus have to be treated as a continuing dynamic process.[38]

As a number of years may elapse between the first formulation of a project and its implementation, constant review of the original formulation is necessary. A project that may have been favourably evaluated when the industrial programme was first drawn up may seem less desirable later because of endogenous or exogenous changes that have occurred. For example, the programmers may have sought to enhance export earnings by the processing of a domestic raw material, but in the interim a developed country may have perfected a process for manufacturing a synthetic substitute for that raw material.[39] On the other hand, a project that was rejected originally may later prove to be quite feasible. For example, a project for industrial processing of a domestic raw material may have been rejected because of high extraction costs, but later, an increase in world demand or a decrease in transport costs may make the domestic price internationally competitive.[40] Whatever the type of change, plans, programmes and projects need continuous re-evaluation to ensure effective implementation.

Problems of project implementation

Planners have to bear in mind that a traditional economy cannot be made modern and dynamic overnight. Literally thousands of unforeseen and often unforeseeable events will interpose themselves to hinder the successful execution of plans and programmes. One of the most serious problems in developing countries is the seemingly interminable delays in completion of studies and in construction of plants.

To guard against such delays in completing industrial projects, realistic schedules must be developed showing the time required for construction of each detailed item and the sequence in which items should be ordered, built and installed. If private firms are employed, the contracts with them should include heavy penalties for failure to complete construction or deliver equipment on time. Government administrative inefficiencies, e.g. failure to approve speedily a request for importation of necessary equipment, may cause unnecessary delay. On the other hand, the fault may lie with the project management, which ought to apply for all necessary licenses and permits well in advance and should include in project scheduling an estimate of the time required for obtaining these documents. Government agencies should seek to streamline their procedures so as to avoid becoming stumbling blocks to industrial implementation.

Another problem that commonly occurs in the implementation of an industrial programme is how to ensure the continuity of financial assistance. Often, funds are provided for plant construction and equipment, but not for operating the plant efficiently when it goes into production. Determining the financial structure of a project is extremely important, and funds must be provided to cover the total cost, including fixed assets and working capital. In practice, amounts already spent and estimates of future expenditures should be detailed so that no major category of costs is overlooked. The source of the funds—government and private—and the form in which the funds are to be contributed—equity capital or loans at varying terms—should be determined in advance.

Another reason why plans fail is poor organization. The structure of the management responsible for implementing a project is of paramount importance. Every stage of implementation must be carefully planned, and each aspect—engineering, manpower recruitment and training and finance—should be co-ordinated and integrated into the operational plan.

[37] W. P. Strassmann, *op. cit.*

[38] E. P. C. Fernando, *Implementation of Industrial Development Programmes Using Critical Path Network Theory*, United Nations, CID/IPEA. 2, 11–29 October 1965.

[39] Thailand has been exhorted to expand its output of silk, for which there is a strong demand in the world market, but the American chemical company I. E. du Pont de Nemours has developed a substitute for silk, Qiana, that may curb silk exports.

[40] Again, Thailand can be used as an illustration: with the depletion of Bolivian tin reserves and disruption of Indonesian production, tin mining and smelting has increased in Thailand.

Too many industrial projects, although apparently well-conceived, turn out to be inefficient, high-cost operations suffering from excess capacity, poor equipment and faulty technology. A major cause of inefficiency in many cases is that external assistance is linked exclusively to the initial development of new projects, neglecting the need to provide working capital in the form of raw materials, spare parts and other industrial components. Planning implementation should see to it that financing is available, that the equipment and machinery as well as raw materials, fuel and power, and other inputs are suitable and available on time, and that training is undertaken so that the labour force is prepared in time to operate the plant.

It is a common failing to pay a great deal of attention to formulation and evaluation of projects, but to leave their implementation to inadequately trained and inexperienced personnel. The successful operation of industrial projects depends on the quality of management, but good managers are extremely scarce in developing countries which lack an industrial tradition. The problems typically encountered are: poor comprehension of the functions of management, particularly at the higher levels; failure to delineate clear lines of authority and responsibility; lack of experience, which shows up in the way plant and equipment are maintained and emergency situations handled; reluctance to exercise proper leadership or to delegate authority to subordinates; emphasis on production techniques to the neglect of the cost elements; lack of familiarity with basic accounting procedures; unsuitable personnel relations; and a failure to appreciate the importance of marketing.

Labour and managerial aspects

One may conclude that the ability to use less sophisticated technology or perhaps more second-hand machinery depends on the development of a skilled labour force. Industrial progress and the growing stock of technical knowledge cannot be harnessed without an educational system at all levels up to university, industrial research laboratories and scientific institutes. The economic development plan must include educational planning with correct time-phasing for the production of professional and technical skills has a long gestation period; an engineer, for example, requires at least sixteen years of schooling. On-the-job training is also an important way of developing skilled workers, though the ability to assimilate such training is enhanced by formal education and the inculcation of work attitudes appropriate to industrial employment.

Despite its crucial nature, the manpower aspect of industrial development is often neglected in planning and implementation. If an industrial project is to be operated successfully, the planners should have forecast the total number and the types of employees needed, according to grade and skill, and at which stages of construction of the project they should be recruited. Since there is a shortage of skilled workers, manpower planning must be done in advance. It may be possible to recruit skilled workers from other areas of the country. When skilled workers have to be trained from scratch, it may be necessary to establish local training centres to provide instruction in the skills required for particular industrial projects. Construction plans, therefore, should include temporary buildings for training facilities. In order to capitalize the training costs, an estimate should be made in the early planning stage of training requirements, including the number and types of instructors needed.

The recruitment and training of managerial cadres can be undertaken by drawing on the services of consultants employed in a national productivity bureau, by hiring foreign consultants or by using experts obtained from international agencies as technical assistance. The effectiveness of the local managerial talent can be improved by adopting good management practices in formulating and implementing industrial projects. The objectives of the project should be defined consistently, clearly and in quantitative terms and management should then be held responsible for achieving them. Managers can be motivated to perform more efficiently through the use of incentive techniques, such as payment of bonuses if they meet the time, cost and quality schedules. Such practices have been widely and successfully used in the industrially advanced countries, both in the centrally planned and the market economies.

Government-owned businesses tend to show a poor performance record in many developing countries and encounter the most difficult managerial problems. Often, their problems are due to the selection of managers on the basis of personal or political considerations rather than capability; this practice can only hinder development and work counter to the basic interests of a country. But even when managers are chosen by merit, difficulties tend to arise because central government agencies are reluctant to delegate sufficient authority to project managers. Successful implementation of an industrial project calls for operational autonomy. This can be achieved in government-owned businesses only by removing the managers from the regular civil service structure and making them subject to the requirements of the project and to periodic scrutiny by the public authorities generally responsible for implementing the industrial programme.

In an attempt to overcome these managerial problems, India, which has a large public sector, has begun to hire top managers from private companies and to introduce into the state-run enterprises such basic business principles as the profit motive, management accounting and market research.[41] According to published reports, the Government of India is also considering compensating managers of public projects on the basis of the profits earned by the enterprises. Since this new programme was inaugurated the boards of two public enterprises were reorganized to include functional directors with specific responsibilities. Furthermore, special schools to train future managers have been established, such as the Indian Institute of Management at Calcutta and the Institute of Management at Ahmedabad.

The experience of a number of developing countries shows that a national productivity bureau can play a significant role in training managers. In conjunction with local universities and technical institutes, the bureau can run short-term training courses for industrial managers, from both the public and private sectors. Indeed, such follow-on education for managers is most popular in the United States where many colleges and universities conduct such courses. The national productivity bureau can offer fellowships for longer periods (six months or a year) for more ambitious courses with the understanding that the manager will then return to his plant. It can also operate an extension service, by which its personnel would be available to assist local plant management and to set up in-plant advanced training programmes in management practices.

Foreign participation in industrial projects can help to strengthen project management, for the foreign partner can supply the types of managerial and technical manpower needed. It is unwise, however, to rely on the foreign partner indefinitely; part of the assignment of expatriate managers should be to train local personnel to take over their jobs. Some of the understandable reluctance of developing countries to accept foreign participation stems from fear of the possible political implications of associating with companies from the major world powers; the fact should not be overlooked, however, that many of the smaller industrial countries are also capable of extending assistance in this field. The United Nations and its agencies also offer technical assistance for industrial project implementation.

[41] "India Hires Pro Managers", *Business Week*, New York: McGraw-Hill, August 30, 1969, p. 92.

Organization of the planning agency

The organizational structure of the industrial planning agency crucially determines its ability to implement as well as to formulate its programmes. The administrative structure must enable the agency to do both. It is of primary importance to ensure proper co-ordination among the various offices and agencies responsible for the different phases of development, from planning formulation to implementation. There is no single structure that can be recommended to all developing countries; each must devise one that is in line with its own needs, avoiding excessive centralization and decentralization.

In establishing an organizational structure, emphasis must be placed on a clear delineation of the functions of each department, its responsibilities and authority, and its relationships with other departments. Ultimate responsibility for industrial planning should be located preferably at ministerial level, where the power exists to enforce inter-departmental co-ordination. No perfect organizational structure has ever been proposed; the findings of the behavioral sciences show that the functioning of an organization depends, to a considerable extent, upon the particular individuals who fill the administrative and executive positions. It is obvious that personnel engaged in industrial planning and implementation should possess the necessary competence, knowledge and experience. Unfortunately, the very status of underdevelopment implies that a country has a dearth of such personnel. Frequently, the talent that a country does possess is poorly used. Appointments to posts should be based primarily on merit and not on personal and political considerations.

The old cliché that "time is money" should be kept to the fore when implementing an industrial programme. An integrated, time-phased plan of action is essential; this requires a balancing of time and cost considerations. Continuous programming in greater detail is needed as the programme progresses, together with periodic reporting and evaluation, at all levels, of the progress that has been achieved compared with schedules and cost estimates. Current and potential bottlenecks must be identified and corrective measures taken in good time to overcome them. The programme and implementation procedures must be regularly updated. Networking is an important technique to be utilized in the implementation of industrial programmes and projects.[42] Its procedures show what must be done before each particular phase of

[42] See, for example, "Procedures for Programming and Control of Implementation of Industrial Projects in Developing Countries", UNIDO, IPPD/3; to be published as ID/SER.L/1 in 1970.

the programme can be started, what can be done concurrently, and what follows in sequence.

Control and evaluation

An essential function of the administrative agency is control and evaluation, i.e., monitoring the execution of the programme. Control and evaluation require feedback from the implementation process to the formulation of the short-term programmes as well as continuous two-way communication between the implementation and the formulation organs. Since industrialization is a dynamic process, it will be necessary to make modifications in short-term programmes to conform with changed circumstances during the course of plan execution. Thus, when one part of the programme is essential to the operation of another part and cannot be implemented on schedule, the organizational structure should provide for the planning agency to be informed immediately so that the latter part of the programme may also be delayed or resources transferred from another less essential part of the programme, to enable the first part to be completed in time. The structure must also ensure that the planners, in turn, keep the implementers informed of any changes in the programmes that would affect their actions.

In order to control and evaluate its programme, the planning organization must pay close attention to follow-up action. This may be facilitated by creating within the agency responsible for project formulation and evaluation a separate department for this purpose. Follow-up action should begin the moment a project is authorized and should continue throughout the construction period and early stages of operation.

The responsibility for follow-up often falls to the agency that provides financial support to a project. The Industrial Credit and Investment Corporation (ICIC) of India, for example, requires that projects which it is supporting submit reports every three months during the construction phase, every month in the initial stages of production and every three months thereafter. The reports must cover physical and financial progress so that comparisons may be made with the estimates which formed the basis of project approval and the situation analysed in detail. In this way, the supporting agency may be able to anticipate problems that will require special attention. The periodic reports, if they are to serve a useful purpose, must be systematically evaluated in relation to the progress achieved in the over-all development plan.

The identification of potential trouble spots through analysis of the periodic reports by project management enables the supervising agency—development bank, central planning bureau, Ministry of Industry to proffer aid in overcoming the difficulties. The main obstacle may be a shortage of funds, in which case additional financing may be arranged before construction of the project comes to a halt. The problem may be a failure to secure government permission for some necessary action, such as licences to import critical materials, and the supervising agency may be in a position to expedite the granting of such permission. The difficulty may be technical, in which case the supervising agency may be able to provide experts to handle the problem or may suggest private consultants.

Follow-up, however, consists of more than making sure that periodic reports are submitted. Experience indicates that project managers are often loath to report problems lest their mere existence be interpreted as a reflection upon the competence of management. Even when this is not the case, they may not report problems simply because they are unaware of their existence. It is therefore essential that the supervising agency itself conduct periodical inspections by sending its personnel to visit projects in preparation and operation. During such visits, their personnel may discover incipient problems and may be able to provide immediate advice and assistance. This requires, however, that the follow-up staff should include people in such professional disciplines as accounting, economics and engineering. As far as possible, the members of the follow-up staff should be given experience of many different industrial situations in order to widen their background. This is particularly important because implementation problems are rarely standardized but cover a broad range of diverse elements. If the follow-up staff were composed of experts in a narrow field, it would be incapable of taking the necessary broad view of problems and of suggesting solutions to them. By being exposed to a wide variety of projects, the follow-up staff gains a fuller experience than the manager of an individual project can hope to obtain, and, consequently, it can provide insights into his problems that the manager himself has overlooked.

Industrial programming data

The collection of industrial programming data is another aspect of organizing industrial planning. One of the characteristics of economic underdevelopment is the insufficiency of the informational basis in which development planning must be grounded. In theory, planners should have access to each and every piece of information concerning development, but in practice, this is impossible. The extent in practice of the data gap facing a country depends essentially on the planning methodology being used and the planning targets set. Cost-benefit criteria can be applied to proposals for gathering new data, i.e. the cost of collecting additional economic and technical information in order that more advanced planning methodology may be used can be compared with the additional benefits expected from applying the more advanced methods.

Since planning is oriented towards the future, past patterns are at best only indicative. In fact, much of the information that would be required for truly effective development planning is non-existent, not so much in the sense that it has not been collected, but because it would relate to events that have not yet taken place and are qualitatively different from past developments. This is especially the case with industrial planning and programming: since it starts with a very small industrial base, a developing country inevitably finds it most difficult to plan future industrial growth on the basis of its limited past experience. To some degree, the paucity of domestic statistical information can be relieved by using similar information derived from the experience of other countries, but this presents two problems. First, planners must take account of the specialized nature of data originating from different sources and attempt to reconcile or synthesize them. Secondly, the degree of applicability of other countries' data to the conditions prevailing in a particular developing country must be carefully assessed. Thus, it is unrealistic to expect that all problems concerning availability of data can be solved or that planning must await their solution; on the contrary, planning must proceed with whatever information is available.[43]

The data necessary for planning and programming include engineering and economic statistics, as well as information on policy instruments, the social environment and financial and commercial aspects. They range from the general economic and social statistics about a given geographical area that are necessary for macroeconomic problems to specific data required for implementation of a particular industrial project, such as technological data on alternative production processes and the specific production equipment most suited to local conditions. The planners also need data on current conditions in, and prospects for, the industrial sectors they plan to develop. The weight to be given to each set of data will vary, depending on the outlook and objectives of the institution concerned with a particular stage of planning. From a practical point of view, the industrial programming data should include information that is generally useful for a wide variety of planning and programming purposes, can be efficiently collected and distributed by a single or limited number of sources, and is justified in terms of the cost-benefit analysis of its collection and use.

The formulation and evaluation of industrial plans and projects require information at each of the three main levels of programming: the economy-wide level, the sectoral level and the project level. Economy-wide plans can be formulated according to three types of constituent elements: the major components of national income, the principal industrial sectors and the resources of economy-wide importance; there is also planning by mathematical programming models. Projects may be defined and specified on the basis of: *(a)* market, cost and the findings of institutional studies; *(b)* analysis of their social impact; and *(c)* techno-economic studies aimed at translating sectoral plans into the formulation of a specific project plan. The data requirements for sectoral plans depend on the level of sectoral planning which is adopted: by process analysis; feasibility or location studies; or industrial complex analysis.

The advantage of collecting and analysing industrial planning and programming data on an international basis lies in the broad perspective that can be gained by dealing with the entire range of data problems in many countries and in the expertise acquired through dealing with such large masses of data. While most industrial planning information should be collected systematically, it is usually necessary to conduct special surveys in order to obtain complementary information so that the regular flow of data can be most effectively applied to specific industrial programmes. Unfortunately, there has not generally been an efficient balance between continuing programming work and *ad hoc* surveys. Normal cataloguing activity should be complemented by an attempt to identify the information that will prove useful for various phases of industrial programming. There is a reciprocal relationship between data availability and project design. The level of aggregation and specification adopted in project formulation depends on the amount and nature of the information available. Such information should therefore be collected and classified with the practical needs of plan and project formulation in mind. However, the reverse is also partly true: as far as possible, the design of a project (and to some extent, the mode of formulation of a programme) should be such as to simplify the task of collecting the information necessary for its evaluation and implementation. To the extent that planners can do this, they will both simplify problems of data collection and strengthen their programming approach.

[43] For an illustration of this, see W. F. Stolper, *Planning without Facts*, Harvard University Press, Cambridge, 1966.

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Industrial development strategy

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Development strategy

The term development strategy is now commonly used to denote the fundamentals underlying the operational approach to the process of long-term development. Emphasis is on rationale rather than on operational details. Thus, the strategy is more general than a long-term plan or programme in two senses: *(a)* it outlines the system to be set up in order to obtain the development objectives and hence logically precedes the plan; *(b)* it leaves aside the quantitative details, concentrating on fundamental ratios and sequences. Even so, to be practically useful, the development strategy will indicate, at least roughly, the pace and the path (the broad commodity pattern scheduled over time) of the desired process of development.

Since, in an absolutely free-market, there is practically no strategy to promote the process of growth other than recognizing profit as the major aim and regulator of economic activity, it follows logically that the emphasis in the strategy should be put on governmental policies.[1] All governmental policies must be tested for their consistency (coherence, completeness and beneficial effect), allowing for the actual environmental conditions, society's desired objectives and how bold the government is willing to be in intervening in economic affairs. Such tests will at times show the need for policy changes.

The framing of a strategy is an exercise almost identical in its structure to long-term planning. First, it is necessary to identify the conditions for economic development, particularly the weak spots and bottlenecks on the one hand and under-utilized resources on the other. Then, the general objectives of society must be clarified, for later they should be the criteria by which alternative programmes of action, i.e. sets of goals, are compared. Finally, ways of relating means to objectives, i.e. new policies, must be conceived. At the strategy framing stage, we are primarily interested in: evolving a framework or system to be used for solving the developmental problem; identifying areas for decision and action; and identifying means for such action.

The strategist, therefore, has more freedom to use imagination than the planner. He is less bound by figures, as the quantitative details will be worked out during the later planning stage. Lacking precise quantitative targets, the strategist cannot produce optimal solutions but endeavours to provide the planner with a global framework within which he can work out sectoral optimizations to incorporate in the plan.[2] Briefly, strategy-framing is to long-term planning what systems analysis is to operational research.

If the above view is accepted, it follows that strategy and planning are complementary. Strategy-framing cannot replace planning, for a strategy without a plan, or at least a general programme, is meaningless. Nor can planning be thought of solely as a detailed quantification by the planner of a previously worked out strategy. Nevertheless, to be most effective, planning should proceed within a carefully evolved strategic framework.

The choice of a strategy is as much an exercise in "variant thinking" as planning itself, and meaningful variants of strategy can be conceived only on the basis of extensive information of the kind required by planners. The strategist must be

[1] Assisting the free-market forces by means of various Government policies is admittedly a strategy, though a weak one because it gives little guarantee of achieving definite objectives in a given time-span.

[2] Strict optimization of development plans does not appear to be practical, since plans are, by definition, multipurpose, while mathematical methods of optimization are based either on a single goal function or on a strict hierarchy of goals. Theoretically, it is always possible to optimize by assigning different weights to different goals, but the choice of weights is itself an arbitrary procedure. Sectoral optimizations, however, appear to be quite practical and useful.

continually fed with information by the planner. On the other hand, he should keep the planner informed on the general direction of his thought, long before the best strategy takes final shape. As a matter of fact, the feedbacks between strategy-framing and plan-making are so many, particularly when both are considered as a continuous process, that perhaps the best solution would be to provide a single team with the hats of both strategists and long-term planners. The planners would put on their strategist hats when they discussed the inner logic of their approach to fundamental decisions likely to commit several generations[3] or of their approach to the invariants (mostly of an institutional nature) which they may wish to build into the social economic structure during a period spanning several normal plan periods.[4]

The development strategy should be continuously reviewed to the extent possible, i.e. to the extent to which the processes set out by previous action can be modified by new, more appropriate action. Strategists and planners will always be, to some extent, prisoners of prior strategy and plans, but this dependence should not be overstated.

OVER-ALL DEVELOPMENT AND INDUSTRIAL DEVELOPMENT STRATEGY

The place of industrialization in the over-all development strategy of a country should be carefully examined.

Neither a development strategy nor a development plan is an arithmetical sum of sectoral strategies or plans. It is impossible to frame a sectoral strategy without referring to the economy as a whole, but it would be meaningless to try to set out the intersectoral relations, as embodied in the over-all strategy of development, without an intimate knowledge of the problems and possibilities of each sector. Indeed, the pace and pattern of growth of the industrial sector are likely to influence heavily the whole development strategy of a developing country, even though the sector may account for only a small part of the national product for many years to come. The relative share of manufacturing industries in GNP is not a good index to use to illustrate their role in a country's economic development. Using as criteria the rates of growth, levels of and changes in productivity, diversification of the output mix, introduction of new techniques and new forms of management, the industrial sector appears to be leading the process of economic development in nearly every case. This is why most developing countries want rapid industrialization.

How rapid should this industrial growth be? Should priority be given to it over all other goals? In the past, the reply to these questions was often formulated in excessively simple and extreme terms, according to whether the speaker was a partisan of industry or agriculture in the debate over their rival claims. The advocates of structural change were all for industrialization. Meanwhile, development through agriculture was being defended with two arguments: the common-sense observation that industrial workers had to eat and the expected comparative advantage of many developing countries if they specialized further in export-oriented crop agriculture. It was easy to object that this expectation was based on two questionable assumptions: *(a)* the inflexibility of the international division of labour; and *(b)* the high elasticity of export markets for agricultural crops produced by developing countries. Thus, both sides were sometimes right and sometimes wrong. Simplified one-pronged strategies rarely suit actual cases; at best they serve to illustrate the limits within which economic development will fall. All of the reasonably good strategies—except for a few exceptionally short-lived ones—fall in between. The dichotomic formulation "either... or" must be discarded in favour of a changing mix of proportions, varying from country to country and over time. The creation of dogmas that favour one economic sector or another is ill-advised, although there is agreement that manufacturing industries are likely to be one of the prime forces of economic growth in the great majority of developing countries.

The same reservations apply to all such dichotomic discussions on lower levels of strategy-framing and planning, including export promotion *versus* import substitution, cash crop *versus* subsistence agriculture, and heavy *versus* light industries. In all of these instances, the need is to vary proportions intelligently rather than to proceed by exclusions. Of course, some sectors (or subsectors or single industries) will be given priority and may accordingly receive the lion's share of investment. These will then be the dynamic industries, which is tantamount to saying that, in a given context and time span, they will develop at a quicker rate than the rest of the economy. But this priority cannot be derived from the character of an in-

[3] Such as the opening of virgin lands, the building of new towns, or the development of industries requiring large capital investment.

[4] In mixed economies, where the public and the private sectors co-exist, the government may wish to commit itself for a period of several years with respect to the areas which are to be left to private initiative and those which are to become government's responsibility in order to create a suitable climate for private investment.

dustry nor from a regression analysis of the development pattern of a number of countries, though such an analysis may be useful as one element among many in the discussion on relative size of various sectors and subsectors. The priority must instead be established for each individual country on the basis of an extensive analysis of all the relevant information and an examination of various alternatives. In some cases, these may conform to the actual experience of other countries, but as a rule they will differ in a number of significant features.

To summarize, no *a priori* assumptions can be made about the exact place of industrialization in the over-all development strategy of developing countries. This is a matter of crucial importance indeed, and one which must be treated in the context of each country's actual experience. Nor is it profitable to discuss whether growth should be balanced or unbalanced as these alternatives are actually only two different ways of looking at the shape of things, rather than two distinct approaches. To the extent that growth is a discrete process, proceeding by leaps, there are bound to be certain generators of growth, possibly different for each country and period—sectors which not only grow at a quicker rate than other sectors of the economy but also have the germinative property of creating external effects conducive to accelerated growth in other parts of the economy. Paying special attention to them is likely to result in unbalanced growth. However, as the main purpose of planning is to avoid waste of resources owing to underutilization of existing and newly created facilities, a planner always looks for a balanced growth path, even when he includes in his plan some growth generators. His plan will be good only to the extent to which he correctly evaluates the working of his growth generators and provides for a distribution of resources that will not tend to waste the germinative power they inject into the economy.

CONDITIONS FOR INDUSTRIAL DEVELOPMENT

The urgency of problems faced by the developing countries stems, in large part, from the fact that, due to unusual demographic pressures, they need to industrialize at a much quicker pace than that achieved in the past by more advanced countries. The developing countries are confronted with additional difficulties, among which are the considerably higher capital-labour ratios now prevailing in most industries, the growing complexity of modern techniques and the unfavourable impact on them of the international division of labour. These disadvantages more than offset the possible benefits reserved to latecomers who supposedly can omit some stages of technological development. As matters now stand, even after a considerable leap forward in industrialization, a developing country can hardly expect to enter world markets for industrial goods, although the lack of access to these markets does not solely come from a lack of competitiveness. If this were the only obstacle, it could probably be overcome by a policy of subsidies for exports. In the long run, however, there is no reason to believe that developing countries will suffer from a comparative disadvantage in industrial production as long as such activity is well planned, i.e. adapted to the local conditions and availability of resources. The more a particular type of production depends on human skills, the less reason there is to believe that people living in one particular country are more fit for it than those in another; they may be better trained or better equipped, but such differences can be overcome. The last century provides many historical examples in support of this proposition.

This optimism about the long run (which boils down to a reaffirmation of the basic equality of all groups of human beings with respect to their potentialities) should not be understood, however, as an invitation to indulge in adventurous planning that is out of touch with the hard realities of the present day. The quest for industrial development strategy should start with a sober assessment of the available resources and their limitations.

Natural resources

As manufacturing consists of making articles from raw materials extracted from nature or grown by man, the possession of plentiful supplies of such materials constitutes an invitation to enter the field of processing industries, particularly where these raw materials are bulky as well as cheap, thus making transport costs high in relation to their value. In practice, however, we see many exceptions to this rule of thumb. Oil producers export the bulk of their output in the form of raw petroleum, while Japan manages to produce steel at competitive prices, even though it is compelled to import the necessary raw materials over great distances. If the case of the oil-producing countries can be explained by the pressure of vested foreign interests, solidly entrenched and backed by big powers, no such reason can be invoked to explain why Sweden, for example, finds it profitable to export iron ore.

These examples are used to emphasize the need to undertake a careful economic analysis whenever the apparently obvious case for exploiting a country's natural resources arises. Mineral riches do not necessarily make a country rich; access to them may require costly investment, characterized by a "lumpiness" of the capital expenditure involved and long gestation periods. As for processing industries based on locally-produced raw material, they may not enjoy an internal market of reasonable size. Furthermore, access to foreign markets often depends not so much on the competitiveness of the articles produced as on the policies followed by the major industrial countries and powerful oligopolies. Briefly, no easy optimism can be derived from the mere identification of large mineral deposits, forestry resources or similar natural resources.

In spite of the need to guard against early over-optimism, there will normally be plenty of opportunities to start or expand industries based on locally produced raw materials and to specialize eventually in some of them. This calls for a careful surveying of domestic resources and a concentration of scientific and technological research on the best way to utilize them. Whenever possible, the strategy for industrial development should specify one or more industries that are expected to become leaders in the economy. All forward and backward linkages of such industries should be carefully investigated, as it may prove rewarding to pursue the idea of an industrial complex organized around each of them.

As for export-oriented industries based on exportable raw material, their development should normally be rewarding; it should pay a country to increase the value-added incorporated in its exports. But two qualifications must be noted. One is the problem of access to foreign markets. This problem can often be solved by developing an appropriate foreign trade strategy, consisting of long-term export agreements. It may be possible to negotiate such agreements in return for granting similar import contracts. The developing countries have hardly started to explore such fields of mutual co-operation. The second problem is that of vertical integration. An investigation should always be made whether it is more profitable to enter all stages of production, from extraction to the distribution of the final product, or to enter only certain areas. The time scheduling of the whole operation is an important matter.

Human resources

Only the broad outlines of an inquiry into this complex subject can be indicated here. A full treatment comprises an assessment of the impact of the socio-political organization on the working of the economy and studies of the social stratification, the demography and some more specific questions dealing with the labour force and manpower availability. In other words, it calls for a global institutional approach.

Perhaps the most delicate task in framing development strategy is dealing with wholesale changes in the economic behaviour of the various strata of the population. How can social change, commonly called modernization, be brought about? To what extent does it constitute a prerequisite to, or an outcome of, industrialization? Under what circumstances is the implementation of industrial development programmes most likely to catch the popular imagination and so gain active support? What place should be assigned to the national government? What institutions should be created, or supported or discriminated against? The strategist must have an intimate knowledge, based on extensive interdisciplinary research, of what goes on at the grass roots. It is permissible to doubt whether he is always aware of this important dimension of his task.

The labour force and manpower situation are more commonly reviewed. Broadly speaking, an investigation is likely to highlight the following aspects:

(a) An over-abundance of unskilled labour, coupled with acute shortages of qualified manpower, aggravated by a wasteful distribution of skills (too many lawyers and holders of diplomas in the humanities, but very few scientists, engineers, or technicians and hardly any intermediate-level skilled manpower);

(b) Urbanization without sufficient accompanying industrialization, owing to the migration from outlying villages, where living conditions are miserable, of people attracted by the mirage of job opportunities in towns;[5]

(c) Social stratification very different from past experience in Europe and the United States, with relatively few industrial workers enjoying a privileged position compared to the large but poor rural population and those urban wage earners who have not managed to get stable employment in the modern sector of the economy.

Taken as a whole, the human resources situation imposes severe constraints on the strategy of development. Some economists and politicians tend to argue that an over-abundant supply of unskilled labour is a boon, as it can be used for labour-intensive investment projects. Unfortunately, there are limitations to such operations; even workers who perform the very simplest of tasks must be fed, clothed and housed, and therefore, the ability to satisfy these essential needs sets an upper limit

[5] In some towns of the Third World, the construction of each new plant adds to the host of unemployed as the newcomers from villages, attracted by the possibility of employment, far exceed the number of jobs created.

on mass mobilization of labour. One should also be aware of the very difficult organizational problems involved, as well as of the relatively restricted scope of investment activity of the pick-and-shovel type. Thus, investment schemes based on labour-intensive methods will continue to find a place in industrial development strategy, but they will seldom, by themselves, provide the possibility for a big leap forward.

Supply of technology

The supply of technology is a severely limiting factor. As a rule, developing countries live by direct transfers of techniques used in more advanced countries, and often they are not equipped even to adapt such techniques. Original local research is scarce and its results are seldom developed into workable production techniques. This dependent condition makes the developing countries vulnerable to all sorts of pressures. They must buy on a seller's market, mitigated to some extent by international competition. Many transfers of technology are ill conceived or simply redundant, not necessarily through the action of a vested interest; often it is due to lack of imagination on the part of foreign technicians from developed countries who are used to completely different environmental conditions and factor ratios and so are naturally inclined simply to duplicate solutions already existing in their own countries. Thus, mimicry of modern techniques takes the place of invention. On the other hand, developing countries must rely for years on a dual industrial structure, owing to the employment implications if their cottage industries were destroyed. For this reason, the traditional techniques should definitely be improved wherever it is even marginally feasible to do so, i.e. whenever they do not result in a level of productivity below the acceptable minimum having regard to the postulated level of real wages.

Markets

The size of the market is of paramount importance in making decisions about the introduction of new industries. The indivisibilities and economies of scale affect especially modern steel, petrochemical and automobile industries. However, for many industries the minimum viable size of plant continues to be relatively small and, in those countries where transport costs are high, local industries enjoy a kind of protection on this account.

The size of the market depends roughly on the country's total population and its *per capita* income. This approach can be misleading, however, to the extent that it does not take into account the distribution of income by social or economic classes. If, in a country of 100 million people, 1 per cent of the population enjoys an average annual income of about \$ 6,500, 9 per cent about \$ 800, 40 per cent about \$ 300 and 50 per cent about \$ 125,[6] the average *per capita* income of more than \$ 300 indicates little about the demand for different kinds of commodities. In fact, the top 1 per cent can afford many luxuries, the next 9 per cent have already crossed the income threshold which permits them to purchase durables, but the poorer half of the population can hardly spend more than a few dollars a year on very simple manufactured goods. Thus, there is a very differentiated picture of the demand for various types of goods. There is a relatively small market of relatively well-to-do people for luxuries, a larger market for less expensive durables (easy to overestimate, owing to the existence of deferred demand arising from import difficulties) and a deceptively small market for mass consumption industrial goods, including those produced by traditional techniques. Expansion of this last market depends on bold policies of support for peasant agriculture which, at the same time, would increase the food supply for additional industrial workers.

An industrial development strategy should not be based wholly on market considerations. In the interests of long-term social and economic development, the rate of expansion of industries turning out luxuries has to be restricted in order to permit the allocation of scarce resources, such as capital goods, foreign exchange and skills, to other projects with higher social priority. The application of this social policy on the supply side needs to be co-ordinated with an income and fiscal policy directed toward a corresponding restraint of the growth of demand for luxuries.

The opposite approach is required for essentials. The income policy should aim at increasing the demand for them, and the income elasticities of demand should be carefully respected.

Thus far, only the domestic market has been considered. But whenever the minimum viable size of production exceeds the domestic demand, the question of access to foreign markets arises. Here the basic problem is not usually competitive prices, for it is often possible to subsidize exports if this is the only obstacle;[7] rather, it is a problem of organi-

[6] This is roughly the estimated income distribution in Brazil; many other developing countries have a similarly uneven distribution of incomes.

[7] The case for such subsidies can be argued along the following lines: In an import-sensitive economy, what matters most is to obtain additional foreign currency, even if the real marginal domestic cost of a unit of foreign currency earned is higher than the exchange rate. How far this line should be pursued is a matter for political decision. Of course, there will be no problem as long as the average domestic cost of a unit of foreign currency does not exceed the official exchange rate or if export subsidies on some goods are paid out of export duties imposed on other goods which enjoy a comparative advantage in the world market.

zational and political obstacles. Whenever the world market has an oligopolistic structure and big vested interests are involved, a newcomer has little chance to break through. This problem can be dealt with only through imaginative trade policies and active entry into markets that are not entirely dominated by such interests.

When comparing the prospective demand with the production possibilities, it may be useful to divide all industries into two groups:

(a) So-called supply-determined industries, where rates of growth are limited by the availability of natural resources or by technical or organizational ceilings;

(b) Demand-determined industries, where it should be possible to expand output as the markets grow.

When rates of growth become sufficiently high, all industries are supply-determined, and therefore the concept has only a relative meaning in the context of a given rate of growth. It does help to clarify, however, the importance of the market size for each industry considered and to identify potential export surpluses and supply shortages to be covered by imports.

Capacity to import and foreign aid

All deficits in supply – whether of raw materials, intermediate goods, capital equipment, consumer goods, management know-how or skilled manpower – can be made up by imports, as long as the country has sufficient import capacity. Thus, there is a fundamental need for the strategist to make a sober and realistic assessment of the country's present and future position in the international division of labour, as well as of the foreign resources available on conditions considered acceptable in the country's long-term interest. His conclusions drawn from such an assessment may weigh heavily on the rate of industrial development he proposes, depending on whether or not the country can except a sizable yearly expansion of its traditional exports at reasonable prices.

It may be desirable to resort to foreign resources when an irreducible trade gap appears likely. On the other hand, a savings gap may be taken care of by proper fiscal and income policies.[•] But the strategist should make sure that the growing indebtedness and the non-economic obligations which often accompany foreign aid do not restrict still more his freedom of choosing a development strategy. The policies regarding the inflow of foreign resources should be geared to the implementation of the chosen strategy, but in practice the strategy quite often is made to conform with projects that are offered as a package within the framework of foreign assistance.

When considering resort to foreign resources, it is necessary to take into account all inflows and outflows of resources. The inflow of foreign capital must be weighed against payments to be made abroad in order to service foreign debt and foreign direct investment. Technical assistance received from outside should be weighed against the brain drain of young talents to other countries.

Evaluation criteria

In order to ensure that a strategy of industrial development will make the fullest possible use of available resources, it is necessary to clarify the objectives of society. Industrialization is not an aim in itself, but a means to achieve economic progress and social welfare.

It is a matter for philosophical reflection whether all societies have the same concept of progress. Nevertheless, it appears likely that the same concept of material well-being permeates the ideas pursued by the overwhelming majority of men. Thus, common consent is assumed with regard to the desirability of achieving more output per worker, more jobs, higher productivity, higher wages,[•] a greater variety of goods available at economical prices to the common man and a fairly equal distribution of wealth geographically. Furthermore, it is assumed that people like to feel that the economy is continuously on the move, and that they can expect a steady and continuous improvement in their standard of living. They derive less satisfaction from occasional forward leaps followed by stagnation. This means that resources must be husbanded so as not to exhaust them. In particular, the most precious resource, foreign exchange, should be continuously replenished and therefore industrialization should promote exports and import substitution.

The development objectives that are chosen will evidently differ in the degree to which they can be measured. Gross output and value added per worker can be measured fairly well. The number of jobs created is a definite figure, and it should be possible to define adequately the ultimate goal in this respect. Full employment, based on an

[•] Looked at *ex post*, the two gaps are equal.

[•] Economic well-being cannot be measured exactly, but the least imperfect quantitative approximation to such a measurement is consumption *per capita* for different income brackets. Higher [illegible]ut without increases in consumption and higher prod[illegible] without increases in real wages may help to build a better future (if they do not simply add to the wealth of the rich), but they do not increase the current living standards of the majority.

average minimum productivity, can be calculated from demographic and sociological data about the labour force. Output-mix can be described in detail as can the rate of exhaustion of natural resources (corrected for possible new discoveries). The impact of new industries on the balance of payments can be estimated, and it is even possible to work out balance of payments criteria to aid in the selection of new projects. The export or import-substitution oriented industries will be chosen that are rated most desirable in terms of net domestic cost per unit of foreign exchange earned or saved.[10] It is more difficult to work out a dynamic picture of interindustry relations and to find ways of taking into consideration the complementary nature of certain industries. Moreover, germinative power and the modernization effect are phenomena that undoubtedly exist and must be taken into account, but they defy the imagination when it comes to finding suitable quantitative indices for them.

Unfortunately, the various objectives involved are not all consistent. Pareto-optimal situations (in which it is possible to maximize each goal up to a certain point without negatively affecting the pursuit of the other goals) seldom occur when the goals consist of reasonably high over-all rates of growth. For lower rates of development, a strategy is not necessary. In many aspects, the objectives are even contradictory. For instance, with a limited amount of investment resources it is impossible to maximize employment and productivity per worker simultaneously. Whenever the desire for a better geographical balance in the distribution of industries results in the selection of an underdeveloped site for a new plant, the decision must be paid for in terms of added construction costs and additional operating costs resulting from the lack of supporting external facilities available in more developed parts of the country.

There is usually constant opposition between short- and long-term objectives. A strategist must decide whether, to use Joan Robinson's expression, he prefers more jam today or more jam tomorrow. More investment today means less current consumption but higher levels of future consumption as well as higher long-term rates of growth. In contrast, allowing more consumption in the short-run means slowing down the long-term rate of growth. This is, of course, a political decision to be taken when framing the over-all development strategy. But at the level of industrial development strategy, decisions must also be made about problems of a similar nature. For example, the import substitution opportunities yielding the best results in the short-run are likely to be exhausted after some time, and the long-term interest requires that the more difficult import-substitution industries manufacturing intermediate and capital goods should also be developed at an early stage. Investment in industrial infrastructure, because of its indivisibilities and long gestation periods, must be planned with a much longer time horizon than industrial projects themselves. But how long should this time horizon be and how much capital should be immobilized in infrastructure? The anticipated modernization effect may prompt the strategist to advocate the early implantation of some industries, which even though their operation is non-economic, will be judged useful because they disseminate technological knowledge in a population hitherto completely innocent of modern technology.

The foregoing examples highlight the fundamental importance of time-scheduling in strategy-making and point to the need to make compromises between different objectives. This is the Achilles' heel of economics—a fundamental inability to add different sorts of utilities and hence to pass from vectorial to scaler calculus when dealing with a multiplicity of objectives. It is possible formally to give weights to each objective and then to maximize their sum, discounting future utilities at their present value. But there is such a considerable degree of arbitrariness involved in using one particular set of weights and discount rates rather than another that less formal and more direct ways of arbitrating between the different objectives are to be preferred. Such an approach may look pedestrian, but it has the advantage of not concealing the political decisions and the arbitrary choices involved. Regardless of the particular method used, deliberate varying of the objectives-mix and of its distribution over time gives rise to alternative strategies, one of which will be chosen.

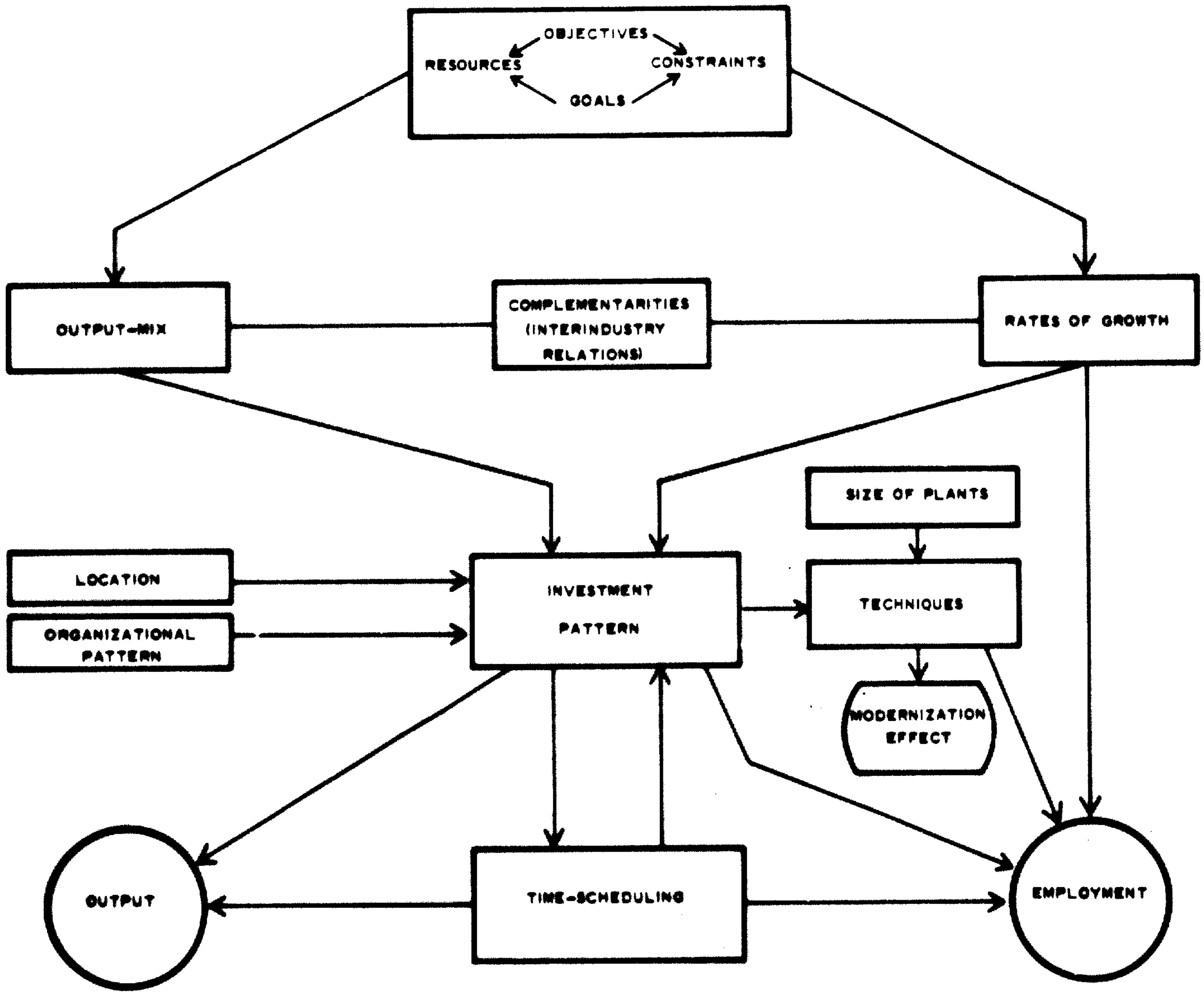
SETTING STRATEGIC GOALS

Once the general economic objectives are established, they must be translated into specific strategic goals, capable of being realized with the country's existing resources and the proposed policies. For convenience, the policies proper will be discussed later. It should be made clear, however, that the choice of policies will definitely affect the setting of goals and, for all practical purposes, the two operations—goal setting and matching of goals with policies—should be conducted simultaneously, allowing for feedbacks in both directions.

[10] It should again be emphasized that no sharp conflict should arise between export-promotion and import-substitution.

Figure 1

PROCEDURE FOR SETTING STRATEGIC GOALS



One procedure for setting strategic goals, which particularly emphasizes the areas for decision making, is graphically summarized in figure 1. Here objectives are translated into goals by setting them against the resources and constraints that are objectively imposed upon the process of growth. The consideration of different policies, which will ultimately determine how many resources are effectively mobilized, will be discussed later.

The goals will normally take the form of an output-mix, varying over time in conformity with the approximate growth rates foreseen for each industry.[11] The relative rates of growth of different industries will have to be chosen, taking into consideration the interindustry relations and the postulated complementarities. Strategies may vary in this respect between the following two extremes:

(a) The implantation of integrated industrial complexes, self-sufficient from the extraction of raw material to the production of final goods, including the manufacture of the necessary machinery. This autarkical industrialization pattern is particularly tempting for huge, almost continent-wide, countries with severe balance of payments difficulties;

(b) Geographically scattered construction of selected industries which are well served by the country's natural endowments or potential markets. This is a frequent industrialization pattern for countries that have no difficulties with their balance of payments.

[11] The output-mix becomes more and more diversified through the addition of new industries.

The output-mix will reflect the strategist's expectations about the prospective demand and certain of the goals he chooses to be built into his scheme. It will be a compromise involving a rather extensive and laborious exercise of allocating the available resources to the production of goods that fit into the assumed pattern of demand and can be produced at a reasonable cost. In other words, the strategist will try to identify those industries which are likely to yield the highest returns in terms of satisfaction of some of the goals pursued. This exercise requires many rounds or repetitions as good results can be reached only by trial and error, on account of the multiplicity of objectives pursued. Partial optimization should be possible, however, as already mentioned, by selecting the export-oriented and import-substituting industries that earn or save a unit of foreign exchange at a reasonable net domstic cost. Other considerations which affect in one way or another the output-mix include the complementarities between industries and external facilities, germinative power and modernization effect.

Given the output-mix and rates of growth on the one hand and the existing capacities on the other, it is possible to visualize the pattern of investments and arrive at a first approximation of their time-scheduling. However, this time-scheduling should be submitted to an additional rigorous analysis as it is of paramount importance for the whole strategy. In fact, it constitutes a major part of any industrial development strategy and will be described in more detail later on.

At this point, it is possible to enrich the strategy with three additional elements. First of all, decisions about the location of new projects will introduce into the strategy measures to fulfil the objective of reducing regional inequalities.

Secondly, it is possible at this stage to choose an organizational pattern for the industries and, in particular, to decide how the responsibilities will be distributed between the public, private and mixed sectors. It should also be possible, through the organizational pattern, to implement some of the social objectives of the over-all development strategy, such as a new pattern of income distribution.

Finally, there is a very important element in strategy framing—selection of techniques. Given the volume of the investment, the number of jobs created will depend on the capital intensity of the techniques employed. In many cases, the only available technique is capital-intensive. Hence the importance of not making unnecessary use of capital-intensive techniques in those areas where a wide spectrum of techniques exists, as, for example, in construction. This criterion also applies when deciding the size of new plants and, more particularly, the place accorded in the industrial development strategy to small-scale industries which may be necessary to preserve and protect the employment potential of cottage industries. As for modern small-scale industries, they may offer various advantages that will offset their higher production costs, as compared with big plants where full economies of scale are achieved. Moreover, they may offer more scope for regional decentralization and stand a better chance of attracting small and medium-sized savings and managerial talents, which cannot cope with big, modern industries but are good enough for smaller units such as family businesses. A special case is that of modern production units which are quite small in terms of capital and labour employed, but are so narrowly specialized that they reap all the economies of scale; they often make ancillary engineering products. Of course, such plants represent an ideal solution, except for the knotty organizational problems they create at the level of interindustry co-operation. Large industries can rely on such ancillary units only if they are sure that they will not be compelled to slow down production owing to the lack of some part ordered from an ancillary unit. This problem can be solved by keeping large stocks, but this usually involves a serious increase in the capital-output ratios, owing to the increase in working capital requirements.

The pressure of unemployment, both overt and disguised, is likely to be so great that the strategist will be tempted to bias his output-mix toward labour-intensive industries, chiefly the modern labour-intensive industries like electronics. A note of warning should be sounded here. Though there should be feed-backs between the selection of techniques and that of an output-mix, one should be aware of the existence of important limitations, such as the size and accessibility of the market. As a rule, considerations of the output-mix should take priority over those of the selection of techniques.

TIME-SCHEDULING

As previously mentioned, time-scheduling provides a new dimension to the framing of industrial development strategy. In fact, the same goals can be pursued by different time solutions, based on different sequences for the implantation of new industries and expansion of existing ones. Freedom of decision is restricted, of course, by considerations of crude complementarity. There is no point in setting up a steel mill, meant to use local inputs, five years before opening the local iron ore and coal mines intended to supply the mill, or five years prior to linking the mines to the steel mill by appropriate transport facilities. But many more considerations are involved, particularly in the initial stages of industrialization, when external facilities, production capacities and investment possibilities are relatively restricted.

Should one start by concentrating on the infrastructure, hoping (as many experts did in the late forties, and as some partisans of the theory of growth poles still do) that investment in manufacturing industries will automatically follow? Or should the strategist start, instead, by concentrating on import-substituting consumer goods industries, contenting himself with a more modest investment in infrastructure?

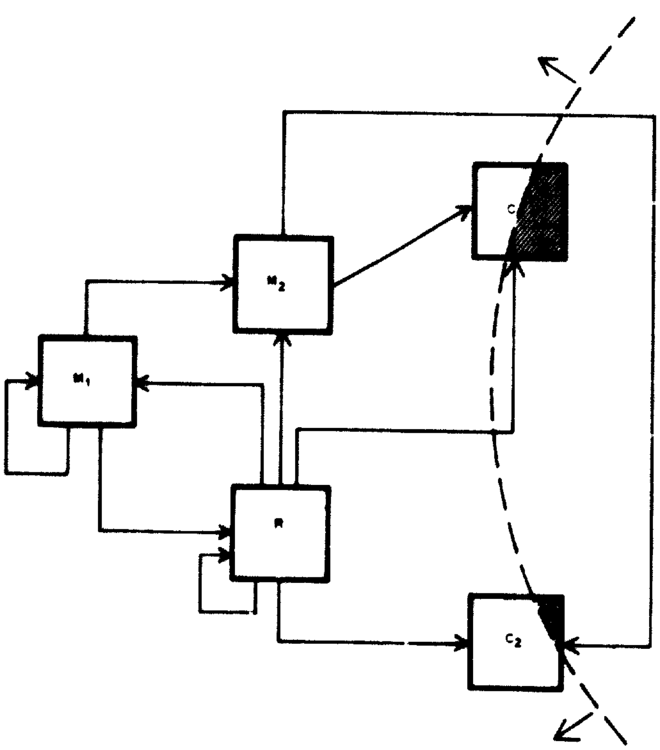
In figures 2 to 5, interindustry relations are shown schematically in the simplest terms. Industry is subdivided into five sectors as follows:

M_1 = Sector of machines to produce machines and intermediate goods,
M_2 = Sector of machines to produce consumer goods,
R = Sector of raw materials and intermediate goods,
C_1 = Sector of essential consumer goods,
C_2 = Sector of non-essential consumer goods.

The results of concentrating on import-substitution investments are likely to be spectacular in the beginning, but the possibility will be exhausted after some time (see figure 2 below). Industrialization starts in this case in C_1 and C_2 industries. A hypertrophy of C_2 may retard the development of the remaining sectors (the case of perverse growth).

Figure 2

DEVELOPMENT THROUGH IMPORT SUBSTITUTION: EMPHASIS ON SECTORS YIELDING RAPID RESULTS

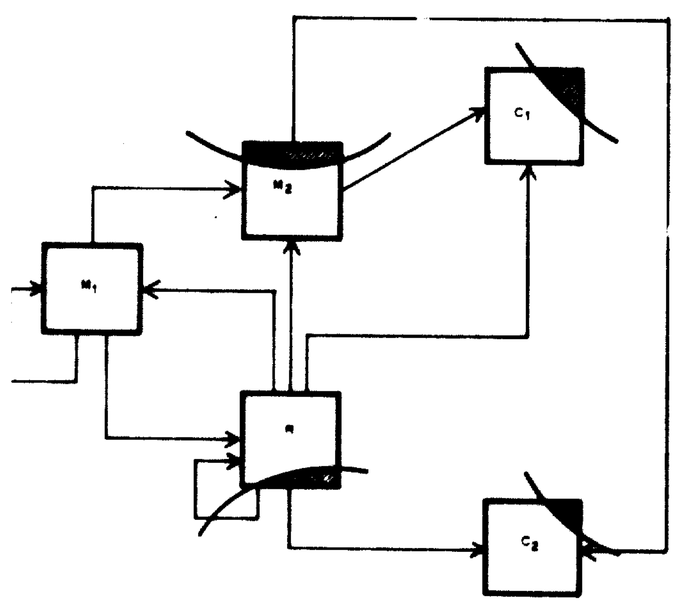


Furthermore, the real net import substitution may be much less than the apparent gross substitution, especially if we take into account the additional imports in the form of equipment and material inputs and the additional payments abroad incurred by the industries in the form of royalties, technical services and dividends to foreign capital.

In addition to import substitution of consumer goods, import substitution can also be undertaken with respect to industry inputs and equipment, but the gestation periods in these branches of production are long (or at least longer than in consumer industries), considerable knowledge is required and, in many cases, the minimum necessary investment is very high. Thus, a long-term investment strategy oriented towards import substitution should contain an element of early preparation of this more difficult import-substitution phase (see figure 3 below). The future advantages of such an approach will have to be paid for by an initial period of aggravated balance-of-trade difficulties during which some essential consumer goods will have to be imported, since some of the investment is to be diverted towards those projects which do not produce consumer goods and which have longer gestation periods.

Figure 3

DEVELOPMENT THROUGH IMPORT SUBSTITUTION: MIXED STRATEGY INVOLVING SECTORS YIELDING BOTH RAPID AND LONG-TERM RESULTS

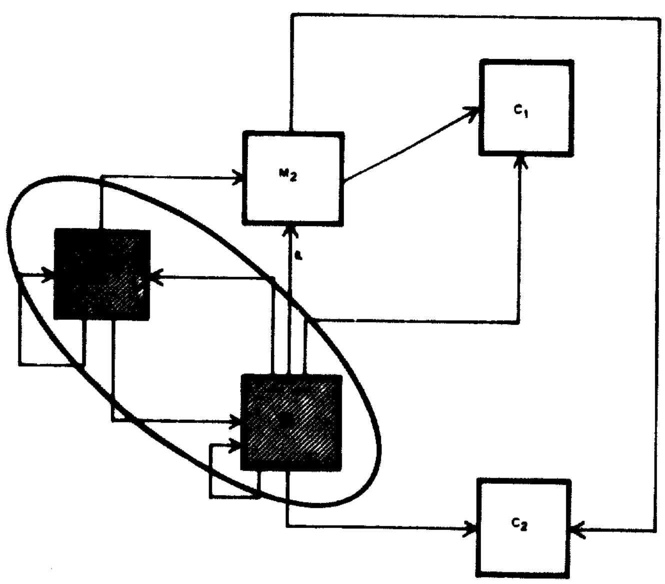


Obviously, the balance between the immediate and the long-term import-substitution effects requires careful consideration. Some strategists believe that under such circumstances it pays to go through an initial period of hardships in order to implant complete production complexes, from raw materials to final goods. These complexes would be established in mining, steel and other basic metals, as well as in capital goods industries. But such a short-cut toward self-sufficiency in capital goods and inputs can at most be taken only by exceptionally large countries which are richly endowed with natural resources and which are prepared to undergo whatever self-imposed austerity in consumption may result from adverse conditions in foreign trade or in their political or military affairs.

A complete industrial complex may, however, still prove to be desirable in certain specific industrial fields in a particular developing country (see figure 4). It may often constitute a suitable approach to an integrated industrial development programme, based on complementarities on a regional, national or multi-national scale. Such a

Figure 4

DEVELOPMENT BY ESTABLISHING A SELF-SUFFICIENT HEAVY INDUSTRY COMPLEX

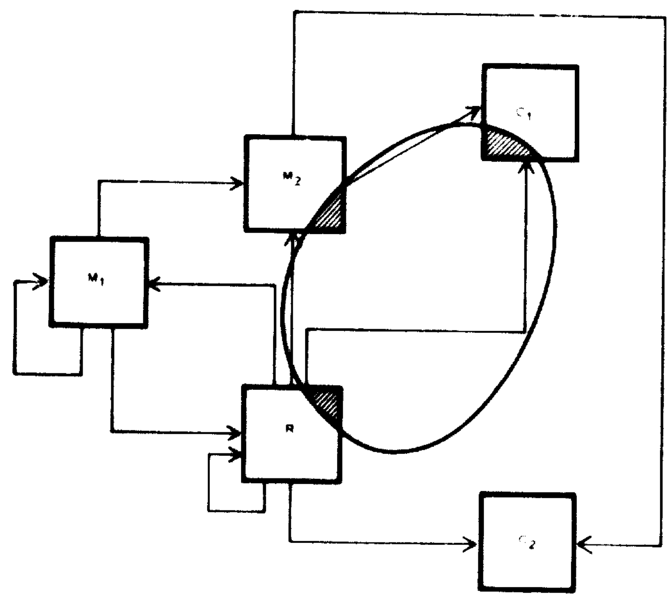


programme may not exhaust all the industrial possibilities of the country, but may well give a definite purpose to a particular sector. For example, a country with abundant resources of marine life may well consider an integrated industrial programme which would exploit all the backward and forward linkages of fishing—from canning, food processing and chemical factories at one end to the construction of boats and boat engines at the other (see figure 5).

The degree of technological complexity of the different industries involved may offer one primary criterion for determining the sequence of implementation. The impact of an industry on the foreign exchange position may offer another important criterion; it may be used to determine the industries for import substitution and the delicate question of the right moment to start the right export-oriented industries. The choice and the timing will depend on the country's natural endowments, available skills and foreign market prospects. The risks involved may be greatly reduced through an imaginative foreign trade

Figure 5

DEVELOPMENT BY EXPLOITING FORWARD AND BACKWARD INDUSTRIAL LINKAGES



policy seeking, whenever possible, long-term arrangements and contracts with other countries[12] and sectoral division of labour on an international basis.

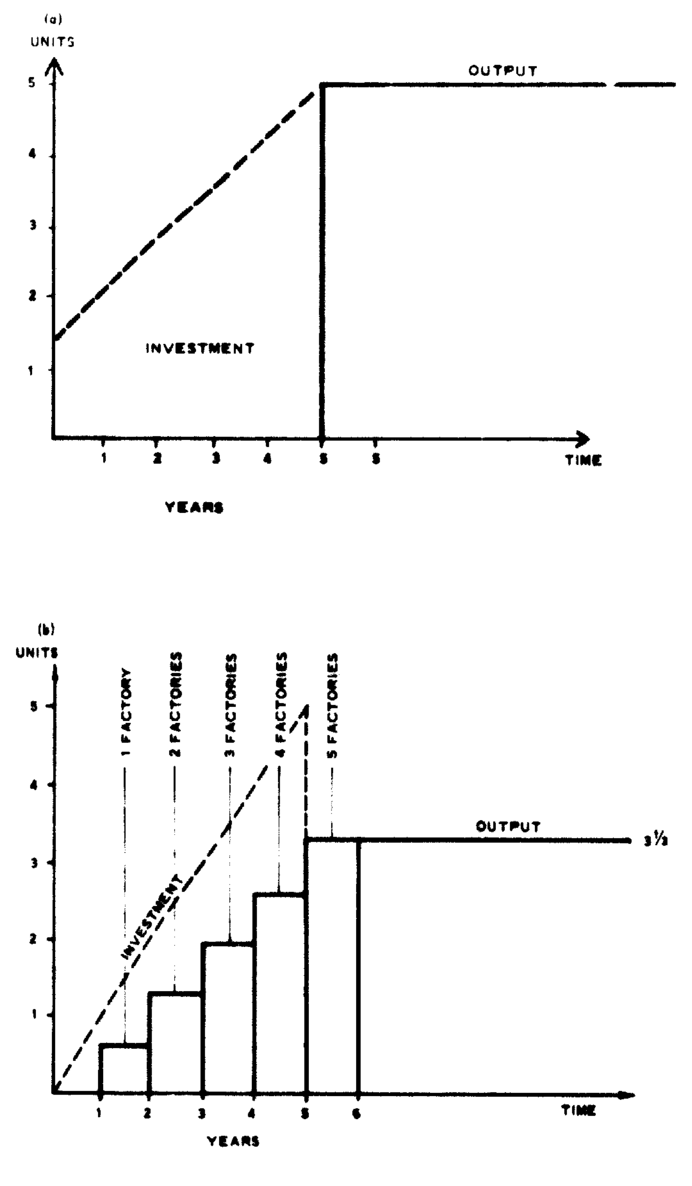
One final aspect of time-scheduling needs to be explored. Suppose a decision is made to invest a certain amount in a given industry over five years. It may happen that there would be a choice between investing in one large project, with a relatively long gestation period, or five smaller ones, which have higher capital-output ratios but shorter gestation periods. The total investment over time would be the same, the capacities installed in the first case bigger than in the second, but the productive effects of the second alternative would be felt earlier (not considering the added possible advantage of locating the five factories in five different regions). It may prove advisable to adopt the second alternative in certain cases. The two solutions are compared in figure 6. In the first case, investment would go on for five years before production starts. The total investment would be five units and the output also five units per year, starting from the sixth year. In the

[12] A practical solution might be to enter into bilateral long-term contracts so as to guarantee to each partner outlets for some newly manufactured products in a given branch of industry.

second case, total investment outlays would be also five, but production would start in the second year. Maximum yearly output, from the sixth year, would be only $3\frac{1}{3}$ but, between year 2 and 5, the factories would produce cumulatively $6\frac{2}{3}$, which might be of considerable importance in the context of balance of payments or other difficulties.

Figure 6

BALANCING THE LENGTH OF PROJECT GESTATION PERIOD WITH THE CAPITAL-OUTPUT RATIO: *(a)* SINGLE-FACTORY PROJECT OVER 5 YEARS WITH CAPITAL-OUTPUT RATIO OF 1.0; *(b)* FIVE SMALLER FACTORIES BUILT AT ANNUAL INTERVALS, EACH WITH CAPITAL-OUTPUT RATIO OF 1.5.



It should be noted that none of the foregoing considerations are intended to substitute for the detailed time-scheduling needed at the implementation stage, when some type of network analysis may be needed.

MATCHING GOALS WITH POLICIES

The setting of goals and the time-scheduling are now complete. The strategy will essentially take the shape of an investment pattern scheduled over time. The following areas for decision-making have been considered: choice of output-mix, choice of relative and absolute rates of growth, geographical location, choice of an organizational pattern, selection of techniques and the size-mix of industries. The expected results will materialize in increases in output, in new jobs and in the social change brought about by the modernization effect which, for the sake of simplicity, was represented as arising mainly from the introduction of new production and management techniques. To achieve these results, however, effective policies must be evolved and used to mobilize the country's resources and use them rationally.

It should be made clear from the very outset that a whole spectrum of policies is usually possible. These may vary significantly in their degree of boldness, as well as in their effectiveness. Their effectiveness in a mixed economy should normally increase with the participation of the public sector, which can be specifically geared to the implementation of the strategy, whereas the private sector can, at best, be induced and persuaded to join in a given programme. On the other hand, policies are likely to become relatively ineffective when over-ambitious goals are set. Similarly, policies, like programmes, must be continuously revised and adjusted; therefore, at the strategy-framing level, there should be more emphasis on identifying which instruments will be used than on trying to give them their final shape. Of course, over-all development policies will influence to a great extent the policy choices for industrial development. This is particularly true of measures aimed at the mobilization of resources and of the kind of relationship envisaged between the public and the private sectors.

In considering the mobilization of resources, several distinct problems arise. First, it is necessary to find ways of financing investment at large, and industrial investment in particular. Secondly, physical resources must be provided in a suitable mix and at the proper time. As for the financing problem, it comprises the whole set of fiscal and income policies, as well as the price policy followed by the public sector. Such policies will normally pursue several aims which are more or less contradictory. For example, in order to increase the financial resources of the public sector, it is necessary to increase taxes. In contrast, one way of inducing private investors to invest consists of giving them special tax reductions, coupled with special credit facilities for projects of high social priority. In such cases, arbitration and compromise solutions are necessary.

As to the mobilization of physical resources, it seems advisable not to leave the matter entirely to the free interplay of market forces. As a rule, a reasonably speedy industrialization process will require the imposition of some type of controls on foreign trade in order to ensure that the best use is made of the available foreign exchange. The direct physical allocation of certain scarce capital goods should not be completely ruled out, though rationing, in general, is not believed to be a viable measure in mixed economies.

Thirdly, there is the problem of mobilizing human resources, in particular the problem of promoting labour-intensive investment and public works within the narrow limits imposed by the availability of food, by organizational difficulties and by the restricted scope of projects of the pick-and-shovel variety. In addition, there is the problem of releasing the dormant initiative of the people and of creating a mood of participation and interest in the strategy and in the subsequent plans. Unfortunately, however, a precise knowledge of social engineering methods conducive to arousing such an attitude is lacking, and experience to date is of a rather negative nature. Mere propaganda will not do.

Specific policies supporting industrialization may include:

(a) A statement setting out the spheres of influence of the public and private sectors. This is desirable in order to avoid uncertainties which often paralyse the initiative of private entrepreneurs;

(b) The organization of special financial institutions to give selective support to investors who take up projects falling within the programme priorities;

(c) The provision of technical assistance to industries;

(d) Schemes combining fiscal advantages, credit availability and technical facilities in order to attract industrial investment to a given region or area;

(e) The granting of protection to infant industries by means of tariffs, import restrictions and, if necessary, subsidies to exporters;

(f) The protection of cottage industries through tax concessions and, if need be, subsidies.

In the selection of techniques, there is little byance of influencing private entrepreneurs except ndcontrol,ling the introduction of manufacturing acnd trying whenever possible, to build into fiscal ah credit policies incentives to save on equipment.[13] This illustrates the importance of making proper choices in the public sector on the one hand, and, on the other, of co-ordinating industrial development strategy with policies of research and development on manufacturing techniques. The latter aspect has often been neglected. A vigorous, government-supported programme of research, centred on the specific problems of the country concerned and ultimately leading to the invention of new, original techniques better suited to local factors, factor-ratios and social environment, should be capable of making a significant contribution to the effectiveness of future investment in industry. A carefully framed educational programme, paying special attention to vocational and technical training, should have a similar effect.

CONCLUSION

In this article, two major ways of building alternative strategies have been presented. The first is by varying the goals-mix; the second, by varying the intensity of the policies adopted. A third implicit way is by comparing different paths or, more specifically, different sequences of obtaining approximately the same results after a given time-span. The framing of strategy is thus typically an exercise in "variant thinking". The purpose of the exercise is to acquire a better knowledge of the particularly sensitive decision areas and of possible means of intervention.

Under these circumstances, the number of possible viable strategies of industrialization is so large and depends to such an extent on the particular conditions of each country that a rigid typology of strategies cannot be established which would be meaningful for the strategist. Nevertheless, his ability to frame useful strategy can be improved considerably by a deep comparative analysis of the actual experience of different countries. After all, economics is the study of economies.

Such an analysis would seem to constitute a valuable task to be performed with the assistance of international organizations, not for the purpose of undertaking yet another academic exercise, but rather to assist planners and development strategists. It would give them a sober, critical ap-

[13] No case is yet known in which such a policy has actually been used. But, in contrast, many existing schemes of support to industrialization which are intended to create jobs have proved to be self-defeating because the opportunity cost of capital for the entrepreneur fortunate enough to get government support becomes so low that it encourages him instead to import the most capital-intensive techniques, particularly as this helps him avoid the troubles that occasionally arise with a large labour force.

praisal of the industrialization path followed by selected countries, chosen in such a way as to vary the initial conditions as well as the policies followed. In the opinion of the authors of this article, such a procedure would constitute the least imperfect approximation obtainable through an empirical investigation such as natural scientists conduct in their laboratories.

D02561

Planning aspects of replacement, repair and maintenance

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THE SPECIFIC AIM of this study is to provide planners in developing countries with a set of methodological instruments for assessing the nature and volume of replacement, repair and maintenance needs, and for identifying the resources—labour, materials and machinery—required to meet these needs. At the same time, the study reviews the main technical and organizational procedures used in this important area of economic activity. The main emphasis is placed on methodological instruments for analysis and projections.

An attempt is made to analyse the problems at the enterprise, sectoral, national and international levels. Admittedly, the bulk of technical and organizational problems must be solved at the level of the enterprise, either as an integral part of the process of utilizing the installed equipment, or through the use of specialized maintenance and repair units.

Special attention has been given to an analysis at the sectoral level since, by applying a sectoral approach, it is possible to assess the demand for replacement and repair and, consequently, the needs for specific economic resources, in the various sectors. In the process, important conclusions usually emerge, which are relevant to the formulation of over-all economic strategy and economic policies. At the same time, the sectoral approach helps to bridge the gap between the micro- and macro-economic levels of analysis in solving problems in industrial development. Some aspects of the problem area under discussion are undoubtedly of a macro-economic nature, e.g. the balance of payments impact of different replacement and repair policies. Certain problems can be successfully solved by the Government through co-ordinating and indicative measures.

Problems related to replacement, repair and maintenance are of great importance from the very start of the industrialization process. Sound policy in this field is a necessary condition for rational investment outlays and capital utilization, and this is particularly true in developing countries where scarcity of investment resources is often the main limitation to economic growth. Efficient and safe operation of the expanding industrial capacity requires highly qualified personnel, various material supplies and an appropriate organizational framework which, in the industrially developed countries, are taken for granted but which are often lacking in developing countries.

It is not the aim of this study to put forward uniform or normative solutions but, by suggesting alternative solutions, to enable the optimum approach to be chosen, taking into account the given conditions of individual sectors and countries. Even the basic concepts of replacement, repair and maintenance are defined in alternative ways.

This study deals only with fixed capital assets in the industrial sector, and attention is devoted primarily to plant equipment.

BASIC CONCEPTS

Wear and Obsolescence

At the same time that buildings, machinery and other equipment wear out physically, they also lose their value due to the effects of continuous economic and technical progress. Thus, there are two types of depreciation with entirely different causes. A classification of causes of depreciation is given in table 1.

Physical wear

Physical wear is a process that changes the original qualities—physical, chemical, mechanical etc.—of plants and equipment. The rate of physical wear of plants and equipment is determined by the rate of utilization and load characteristics of the equipment; the environment in which the equip-

Table 1

CLASSIFICATION OF CAUSES OF DEPRECIATION

Physical causes:
- By gradual wear
  - Through operation
  - Due to environment
- By break-down

Economic causes:
- Obsolescence
  - Due to the development of new, more efficient types of equipment
  - Due to changes in production technology
  - Due to changes in market conditions
- Reduction in purchase price of replacement equipment

ment is utilized; and the care exercised in operation and maintenance.

In contrast to the wear that occurs with operation, the wear caused by adverse effects of environment is not related to the degree of equipment utilization. On the contrary, the adverse effects of environment are often greater when equipment is partially utilized or completely unutilized. Figure 1 illustrates a factor that can determine the degree of physical wear. The amount of ferrous matter deposited in engine lubricating oil is an indirect measure of wear. The figure shows how this depends on the grade of oil used and the engine running time.

Two basic apparent forms of physical wear can be distinguished: mechanical wear, resulting in surface damage to the parts (components) of plant and equipment, in changes of dimensions, distortion and loss of precision and performance generally; and chemical wear, resulting in corrosion of material, deterioration of mechanical qualities and functional failure.

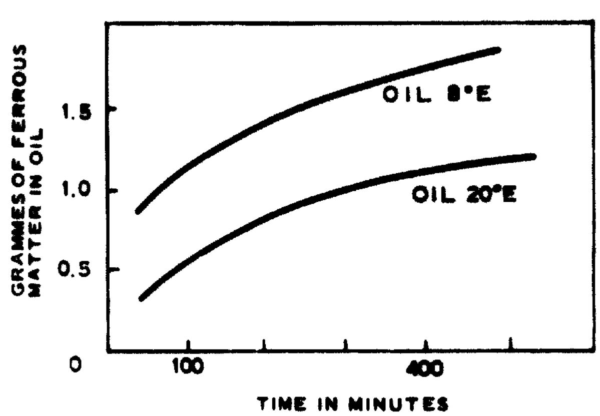
An example of the mechanical wear of simple parts of a machine (e.g. bearing, pin) is given in figure 2. In the initial, rather short period, the running-in period after the equipment has been put into operation, wear is very marked. In the subsequent long period of normal operation, wear tends to level off, but it again increases very steeply if use of the machine is extended unduly.

An example of chemical wear is that of a steel pipe-line, due to gradual loss of carbon by the steel (see figure 3).

Some components of plants and equipment lose their functional qualities suddenly (e.g. light bulbs, certain components of measuring devices). It is, of course, not possible to make a reliable and exact prediction of such functional failure.

Figure 1

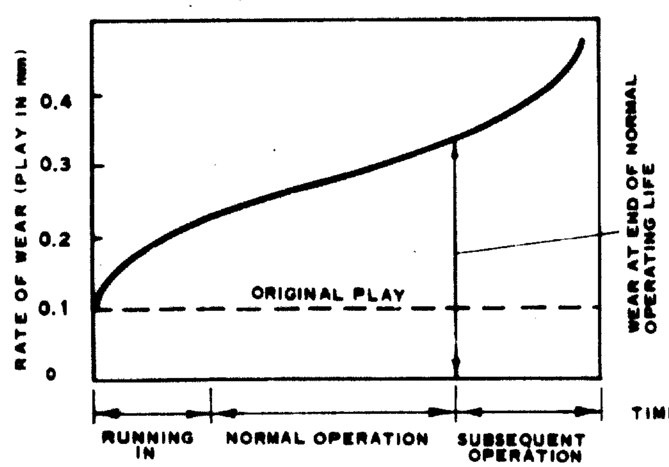
DEPENDENCE OF ENGINE WEAR ON GRADE OF OIL AND OPERATING TIME



SOURCE: Voinov H. R., Issledovanie obkladki dvigateley trenija, Sbornik IV, Moscow, 1949.

Figure 2

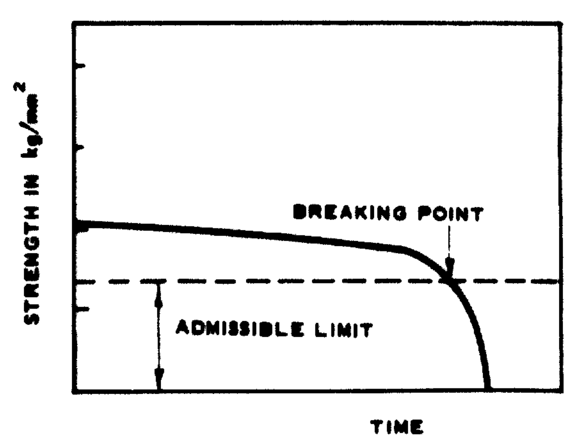
COURSE OF WEAR OF A SIMPLE PART



SOURCE: Zelenkov G. I., Technologija remonta dorozhnyhk mashin, Dorizdat 1951, Moscow.

Figure 3

PIPE-LINE WEAR DUE TO GRADUAL CARBON LOSS



SOURCE: Vybrané kapitoly z ekonomiky chemického prumyslu. Selected chapters of the economics of chemical industry, Pedagogic Publishing, Prague, 1966.

Two specific cases of the physical wear may be cited: *(a)* "infant illnesses", usually caused by unexpected defects or errors in production, assembly, methods of installation etc.; and *(b)* accidental depreciation or break-down, in which case wear does not occur gradually but suddenly owing to external or internal factors such as fire, explosion, flood, typhoon and other disasters.

Economic depreciation

In a dynamic economic system, the bulk of plant and equipment depreciates and is scrapped as a result of obsolescence, rather than of physical wear. Economic depreciation is a process through which plants and equipment lose their value owing to technical innovations and changes in the economic conditions.

Generally, three different types of economic depreciation through obsolescence can be distinguished. First, there is the appearance of a "challenger", i.e. a new, more efficient machine, which can replace the installed machine. This is the case of obsolescence due to technical progress. The use of the new, more efficient machine causes a reduction in production cost, an improvement in product quality, safety and/or labour conditions.

The rate of depreciation is determined above all by the economic parameters of new machines capable of replacing existing machines in their functions. The pace of technical progress and, consequently, the rate of depreciation of equipment already in use in factories vary substantially according to the branch of industry and the kinds of equipment. In general, it can be said that the most rapid changes in design take place in equipment used in the most progressive industries from the point of view of technology and market requirements.

Secondly, changes in the technology and organization of production affect depreciation. These changes can be caused by innovations that involve substantial changes in material inputs; changes in product design; and the transition from small to large-scale production.

In the engineering industry, for instance, a shift from metal-cutting to metal-forming tends to accelerate the depreciation of currently used metal-cutting machine tools. The transition to large-scale production leads to accelerated scrapping of universal machine tools and to their replacement by specialized equipment.

Thirdly, changes in market conditions can cause a decline in demand for products produced on the given equipment. Thus extensive replacement of classical electronic tubes by transistors accelerated the depreciation and scrapping of many types of vacuum equipment.

Finally, economic depreciation (or, exceptionally, appreciation) occurs when there is a decline (or increase) in the purchase price of identical equipment to replace that in use.

It is thus necessary to consider the changes in value of installed plant and equipment, from the point of view of both their physical state and their efficiency of operation, within the context of overall economic conditions.

Service life

Depreciation of an individual item of equipment usually proceeds gradually. The final stage of this process is scrapping. The time during which the equipment can fulfil its technical and economic functions is the period of its service life. A quantitative analysis of the service life is usually the starting point for an estimation of renewal needs.

The following different concepts of service life are of practical significance:

"Total" service life, which is the period after which a machine is scrapped;

"Primary" service life, which is that part of the total service life, in which a machine operates at its highest efficiency;

"Economically useful" or "optimal" service life.

The service life of plant and equipment can be physically extended almost without limit through repair and careful maintenance, but in practice scrapping takes place as soon as their operation fails to meet certain economic requirements.

Estimates of the length of service life can vary between 10 and 30 years for the same type of machine. The number of years a particular machine can be "active" depends on the conditions and method of utilization, as regards physical wear and susceptibility to economic depreciation. The illustrative examples of service life in table 2 give only a very rough guide.

Table 2

ESTIMATES OF SERVICE LIFE AND COST OF OVERHAUL OF PLANT AND EQUIPMENT

	Service life (years)	*Average yearly cost of overhaul (per cent of purchase price)*
Buildings		
Industrial	60–80	0.6–1.7
Office and residential	100	0.5
Structures		
Bridges, reinforced concrete	200	0.3
Railway roadbeds and superstructures	120	1.5
Dams	80–120	0.5–1.0
Conditioning systems	30–50	1.6–1.0
Sewer pipes, cement	20	1.4

Table 2 (cont'd)

	Service life (years)	Average yearly cost of overhaul (per cent of purchase price)
Structures (cont'd)		
Concrete cooling towers ...	50	2.0
Steel drilling derricks......	12	8.7
Machinery and equipment		
Power and propulsion equipment		
Mobile compressors	10	8.0
Mine ventilators	40	2.0
Transformers...........	30	1.0
Steam turbo-generators ..	30	2.0
Hydraulic turbo-generators	40	1.8
Mobile combustion engines	15	4.0
Transmission networks, 200 kV and 100 kV ...	40	0.5
Switchgear 200 kV and 100 kV	30	1.0
Mining industry equipment		
Mining equipment	35—40	1.5—3.2
Stripping shovels	10—25	2.4—30.0
Drilling sets	4—12	4.0—20.0
Mills and crushers	15—20	5.0—20.0
Food industry equipment		
Grinding and crushing mills	15—30	1.2—5.0
Sifting/screening machines	15—40	1.5—5.0
Oven/bakery equipment .	20	2.5
Bottle-washing machines	10	3.0
Milk and canned food evaporators	20	2.2—4.0
Woodworking equipment		
Wood drilling machines .	15	0.2
Knot borers............	15	3.2
Woodworking lathes	15	6.6
Sanders	15	3.8
Paper industry equipment		
Diffusers	20	5.0
Paper-making machines .	30	5.0
Cutting machines	20	5.0
Printing industry equipment		
Composing machines ...	20	4.0
Rotary printing machines	20	2.0
Gravure printing presses	8	3.2
Cutting machines	30	0.2
Chemical and rubber industry equipment		
Homogenizers	20	4.0
Absorption towers for sulphuric acid production...........	15	5.3
Machinery and equipment (cont'd)		
Storage tanks for gasoline, oil	40	2.0
Reactors for sulphuric acid production	12	5.5
Roasting furnaces for pyrites	30	6.7
Non-metallic minerals industry equipment		
Building materials equipment	10	7.0
Cement furnaces........	25	2.8
Baking ovens for ceramics.............	40	2.5
Drying and annealing kilns	20	7.0
Metallurgical industries equipment		
Blast furnaces	30	5.3
Coke ovens	18	2.0
Steel melting furnaces ...	24	10.0
Moulding machines	12	3.3
Casting machines and equipment	20	3.3
Rolling mills	20—30	2.5—3.3
Metal-working industry		
Reheating furnaces	20	4.0
Power presses	20	5.6
Centre lathes...........	12—25	3.8—7.1
Automatic lathes	12	5.2
Horizontal boring machines	15—20	3.5
Planning machines	20—25	3.1—4.0
Grinders	12—15	5.8—9.0
Welding equipment	12—15	5.5—7.1
Coil-winding machines ..	15	4.5
Construction industry		
Concrete and mortar mixers	10	8.0
Dozers, scrapers, graders	5—6	10—35
Building cranes	8—12	9—12
Transport and communications		
Trunk cables	30—35	0.7
Gas mains	30	0.5
Telephone exchanges ...	25	1.0
Diesel-electric locomotives	10	8.0
Covered goods wagons ..	45	0.7
Cargo boats............	40	1.8
Airplanes	5—12	2.7—16.2

SOURCE: Ministry of Finance (CSSR), Laws and Orders, 1954.

These estimates of service life and cost of overhauls were originally designed for financing replacement and overhauls out of a special fund. The following data were used: estimates of average service life, standards for a cycle of major overhauls (according to the system of planned preventive repairs), overhaul costs and purchase prices of machines.

Estimates of service life are often quite different from the service life actually achieved. For metal cutting and forming machine tools, estimates of service life generally range around 15 years. But, in any country where an inventory has been made of installed machine tools according to their age, a large number of machines older than 20 years has been found still in operation.

From the inventories of machinery in metal-working industry in USA, carried out by the *American Machinist* in 1949 and 1958, we can conclude that only 14.5 per cent of metal-forming machines and 26 per cent of metal-cutting machines were scrapped between their 10th and 20th year of age. A very detailed analysis by the Research Institute for Engineering Technology and Economics in Prague has shown that in the Czechoslovak engineering industry, machine tools are kept in operation on average for 25 to 30 years. Even after this period, however, most of them are not scrapped. More than 70 per cent of discarded machines are resold or transferred to plants, shops and schools outside the engineering industry.

Table 3

AGE-COMPOSITION OF MACHINE TOOLS IN THE INDUSTRIALIZED COUNTRIES

Country	*Year*	*Percentage of machine tools older than*	
		10 years	*20 years*
USA	1958	60	18
United Kingdom[a]	1955	52	12
	1961	59	22
Western Germany	1953	62	21
	1961	55	20
France	1955	62	43
	1961	59	..
Italy[a]	1958	59	33
	1961	56	..
Canada	1958	58	18
Czechoslovakia	1962	61	23

SOURCE: V. Nesvera (1963) Rozvoj technické základny strojírenství [The development of the technical basis in engineering], Prague.

[a] Machine tools in metal-working industries only.

Not all the causes of depreciation have a direct bearing on service life. Thus, physical wear may have no impact on the length of service time, if the consequences of physical wear can be made good by repairs. Physical wear plays a decisive role only where repair would be more costly than the purchase of a new machine or would not be technically feasible at all. Therefore, most machinery and equipment and also buildings and structures are scrapped (discarded) due to economic depreciation, caused by the appearance of new, more efficient machines and equipment, by changes in the technology of production and by market conditions for the products.

In the scrap-yards, however, we can see that the machines brought there are usually both physically worn out and technically obsolete. The question —which of the two basic causes of depreciation determines the service life—cannot be answered without qualification. Technical obsolescence is generally the basic cause, whereas the technical condition of a given machine, i.e. the degree of its physical wear is often the direct (immediate) cause of scrapping. The technical condition depends to a certain extent on economic factors, since machines which cannot meet certain economic criteria do not receive proper maintenance and repair.

Machines which are prematurely scrapped due to their technical obsolescence are considered to cause a loss, amounting to the portion of balance sheet value not written off. However, it is hardly a loss in the case of really obsolete machines. The loss actually occurred at the time the investment was made in an obsolete machine and should therefore be charged to the past period in which the machine was purchased. Otherwise there is the danger that obsolescent equipment will be kept in operation.

Where service life is dependent on the intensity of physical wear, some of the factors can be quantified or estimated on the basis of past experience. Examples of these estimates are presented in table 4. The physical wear of a lathe utilized in two shifts (coefficient 0.7), operated in dusty environment (coefficient 0.7), exposed to shocks and vibration (coffiecient 0.7) and operating under difficult cutting conditions (coefficient 0.8) would be so high compared to the normal conditions of lathe utilization in one shift, that the service life would be reduced to little more than one third. The calculation is $0.7 \times 0.7 \times 0.7 \times 0.8 \times 1.25 = 0.343$.

If the same lathe is usèd as a piece of ancillary equipment 8.25 hours a day in an assembly shop under good conditions, its service life might be extended by about 50 per cent over the normal service time. The calculation in this case $1.4 \times (8/8.25) \times 1.1 = 1.493$.

The rather complex process of depreciation and scrapping plant and equipment means that only exceptionally can a direct link be established between the time at which scrapping takes place, the service life and the replacement date of a particular item. Individual machines are replaced without it being possible to follow and quantify this process. Therefore it is appropriate to set the subject of replacement in the context of the whole stock of capital equipment installed in an industry or in the economy (see appendix 2). Furthermore replacement must not be considered in isolation from the modernization of equipment, buildings and structures, depending on or conditioned by the development of technology, production, demand, etc.

Table 4

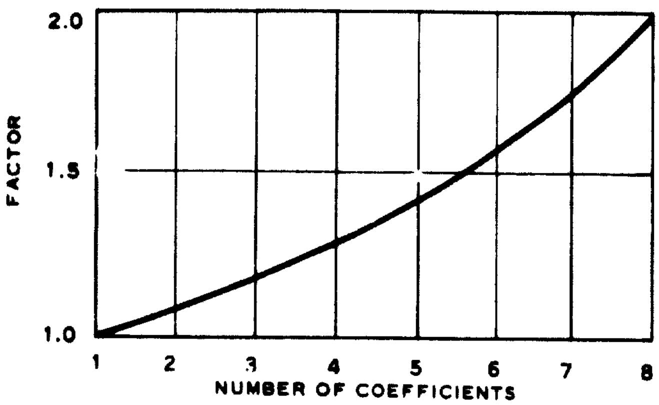
COEFFICIENTS FOR CALCULATING SERVICE LIFE OF MACHINERY AS A PROPORTION OF SERVICE LIFE UNDER NORMAL CONDITIONS WITH A SINGLE 8-HOUR SHIFT

Conditions of utilization	*Coefficient*
Normal operation	
In two shifts	0.6–0.8
In three shifts	0.4–0.6
For x hours a day	8/x
In laboratories or research units (shops)	1.2–1.3
In assembly shops	1.4–1.4
Incidental usage	0.6–0.8
In humid shops	0.6–0.8
In excessively dusty rooms	0.6–0.8
In shops with adverse chemical environment	0.4–0.8
In shops without heating	0.7–0.9
In shops exposed to intensive shocks or vibration	0.6–0.8
Usage without adequate footings (foundations)	0.7–0.9
Work in wet conditions	0.7–0.9
Machining work with continuous mesh	0.8–0.9
Work under difficult cutting conditions	0.7–0.9
Cast iron machining	0.8–0.9
Plastic material machining	0.8–0.9
Incidental usage of grinding preparations on cutting machine tools	0.7–0.8
Deficient operation (vocational training shops)	0.6–0.8

NOTE: The product of all the applicable coefficients must be multiplied by a correction factor which is shown graphically in figure 4.

Figure 4

CORRECTION FACTOR WHEN SERVAL COEFFICIENTS FROM TABLE 4 ARE EMPLOYED



SOURCE: Simonis, F. W.: "Die Bewertung von gebrauchten Werkzeugmaschinen und maschinellen Anlagen", VDI No. 18/1956.

Replacement, repair and maintenance

Replacement

Replacement during a given period is defined here as the volume of investment needed to replace plant and equipment which has deteriorated in that period beyond the point where repair and maintenance are justifiable on economic grounds.

A broader definition might cover not only actual replacement but also repairs of worn-out parts of machinery, equipment, buildings etc. In this case repair of machinery particularly so-called general repairs (overhauls) would fall under the heading of replacement.

Usually, however, the term replacement is applied to complete machines or complete production lines.

In the context of the whole national economy the construction of new capacity can be considered as replacement, even if there is no visible connexion with the old capacity being liquidated.

The commonest interpretation of replacement is the physical replacement of worn out machinery, equipment, building etc. within a given production unit by new items. This is the interpretation applied in this study.

When renewing production equipment, the purpose in practice is not merely to replace physically worn out items, but also to modernize the whole system, according to the needs of modern technology and the requirements of the market. An active renewal policy means investing according to a consistent and economically rational plan. Above all it takes into account the aspect of modernization and transfer of machines within the factory. For estimating the investment resources required for replacements, it is also necessary to consider the timelag between replacement in the existing use and the actual scrapping of the replaced item. Frequently, used machines are transferred within a plant, i.e. the location and/or the function of the machine is changed to better meet the over-all requirements of the plant. Trade statistics of industrialized countries show that there is also a considerable transfer of used machines between plants.

Replacement and modernization cannot be considered as two separate phenomena. Replacement usually expresses quantitative, and modernization qualitative, aspects of the same process.

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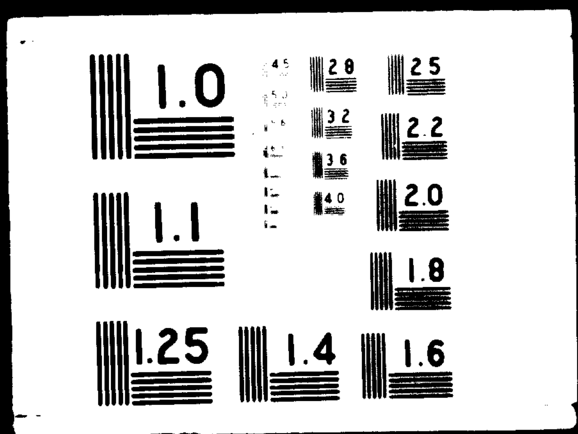


Modernization can sometimes be carried out by modifying existing machinery to increase the performance, minimize losses from breakdowns, lower the labour cost, improve the safety of operation, etc. The largest effects, however, can usually be achieved only by a systematic total modernization of the whole production unit.

Modernization in a narrower sense is limited to the modification of individual units of equipment already installed. Two basic approaches may be distinguished:

(a) Adaptation to a different use of machines, equipment, buildings or construction, e.g. reconstruction of a lathe into a machine tool for centrifugal casting;

(b) Standard modernization to improve the qualities of older models of machines. Promotion of such modernization is usually undertaken by producers of the machines.

The best occasion for modernization is usually a major overhaul. Thus, major overhaul and repair are together to be considered as not only a way of removing the deterioration in a machine, but also of increasing its adaptability to new conditions of utilization.

Reconstruction—a functional adaptation of machinery, equipment and/or buildings through changes in technical design—and modernization are not identical concepts, but reconstruction is usually undertaken with the object of modernizing the capital assets.

Repair

As has been already mentioned, the distinction between replacement and repair is far from being clear-cut. However, replacement normally means total replacement of worn out or obsolete machinery, equipment, buildings, etc., while repairs consist of the replacement of certain parts or their renovation.

Two basic categories of repairs can be distinguished:

(a) Routine (small) repairs, consisting usually in replacement or repair of individual parts and elements of the machine, i.e. those which have a shorter service life;

(b) Overhaul (rather extensive repair of the whole machine, building, etc.) of all worn and damaged parts, in order to restore the original technical condition and operational efficiency. As a rule, the cycle of major overhauls is longer than one year.

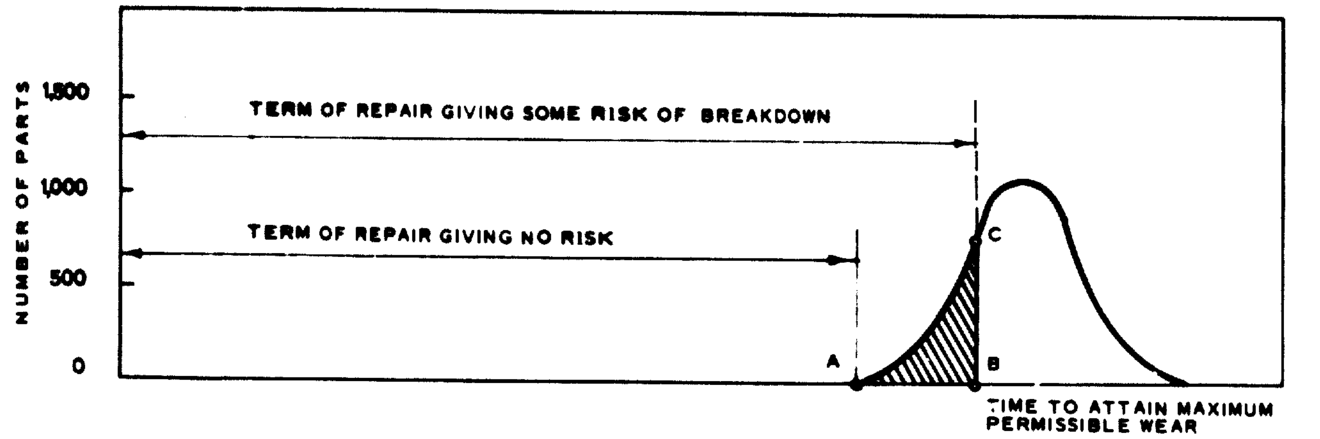
The causes of physical wear vary for individual parts of plants and equipment. Individual parts therefore have different service lives. The prevailing working conditions affect the wear of individual parts and of the whole machine, equipment, building or structure and can give an accidental character to the course of physical wear. The distribution of the times in which maximum permissible wear is suffered by the individual parts determines the risk of failure of the whole machine.

From figure 5 it can be seen that if the repair is carried out at point *A*, the risk of failure is almost nil since none of the parts of the machine will yet have reached the maximum permissible wear. However, if the date for repair is fixed at point *B*, a risk is being taken that some parts wear out before the repair is undertaken. The curve shows the spread of physical wear periods of individual parts, according to expert estimates.

The course of wear of individual parts and the cost of their repair or replacement determine the

Figure 5

TIMING OF REPAIR AND RISK OF BREAKDOWN



SOURCE: Vybrene kapiboly z ekonomiky chemickeho prumyslu slatni pedagogicke nakladatelstri, Prague 1966, p. 111 (collective work of several authors).

volume and timing of repairs during the repair cycle.

The graph in figure 6 has been worked out according to the norms of preventive repair applied in the Czechoslovak engineering industry. In the period between two overhauls, two "medium" repairs, six small repairs, and a number of inspections are to be carried out. Before and after each "medium" repair and overhaul, the work is controlled by precision measuring.

There is no standard repair system which can be generally applied. The obvious reasons for this are the different rates of wear of individual machines, the different requirements in regard to reliability of operation of equipment and differences in working conditions of the equipment in individual countries. The repair system to be used therefore should be based on an objective evaluation of the actual situation in regard to the equipment, plant, industry, and country. A classification of repair systems is set out in table 5.

Figure 6

CYBLE OF REPAIRS ACCORDING TO THE STANDARDS FOR PREVENTIVE PERIODICAL REPAIR OF A LATHE (TWO-SHIFT OPERATION)

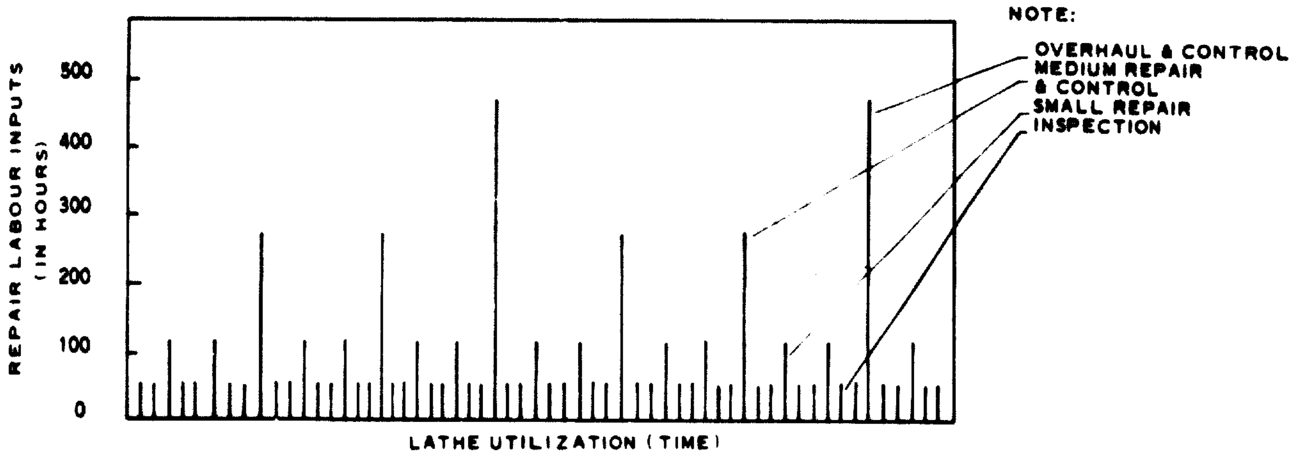


Table 5 CLASSIFICATION

	Complex repair	*Standard repair*
Characteristics	Complex repair planned and prepared long time ahead	Rigid repair cycle, replacement of all parts according to the prescribed standards[a]
Advisable for	Electrical power plants, metallurgical, chemical and food industry equipment[c]	Equipment involving great safety risk[e] or operating losses in event of breakdown; equipment with low-cost spare parts
Basic requirements	Repair activities co-ordinated with production programme	Discipline and regularity of the repair process, scientifically elaborated system of standards
Effects	Minimal losses in output; minimal time needed for repairs	Lower requirement for qualifications and flexibility on part of repair personnel; repair activities can be planned

[a] Repairs are timed according to the rate of wear of the component with the shortest service life.
[b] Repairs planned with certain degree of flexibility as compared to standard repairs.

The need for overhauls and the need for other repairs are interdependent. Careful and regular carrying out of small repairs can reduce the need for overhauls. This interrelationship has been confirmed by a sample inquiry in the Czechoslovak engineering industry: whereas in individual plants the cost of overhauls and the cost of small repairs (as a proportion of the purchase cost of machinery) fluctuate widely, on average, for the economy as a whole, the small repair costs were 50 per cent higher than the overhaul costs.

Maintenance

According to generally accepted terminology, maintenance means the whole set of measures employed to keep the plant in good operating condition. This concept of maintenance would thus include repairs and sometimes even replacement. In this article, however, a narrower concept will be used, covering only routine care, such as:

- Cleaning;
- Painting, anticorrosion protection;
- Lubrication;
- Inspection control.

Some other functions are usually organized in close relationship with maintenance, namely:

- Stock keeping;
- Power generation and distribution and other utilities;
- Plant protection, including fire protection;
- Pollution control and noise abatement.

These activities, however, fall outside the scope of this article.

Special importance should be attached to anticorrosion protection, lubrication and inspection control, since these activities require specific resources and skills.

Anticorrosion protection ensures the surface protection of machinery, equipment, buildings and structures against attack by the environment. It mainly consists of protective coatings and conservation, is quite labour-intensive and requires a wide variety of special materials.

Losses caused annually by corrosion are estimated at $ 6.5 billion in USA, £ 195 million in U.K. and DM 2 billion to 3 billion (steel corrosion only) in the Federal Republic of Germany.

In a number of industries corrosion is the main reason for repair. Increasing attention is therefore being paid to coating and painting. The cost of anticorrosion measures in US chemical industry represents 20 per cent of investment outlay and 80 per cent of repair and maintenance cost.

Lubrication must be regulated by exact rules stipulating the kind of lubricants, their quantity and the timing and method of their use. Proper

OF REPAIR SYSTEMS

Planned preventive (periodical) repair	*Repair scheduled after checking*	*Breakdown repair*
Repairs planned on the basis of standards[b], definite decisions about timing taken after checking	Repairs planned on the basis of regular inspections	Repairs carried out in case of imminent danger of a breakdown or after actual breakdown
Large number of identical machines; large-scale production; production requiring high accuracy	Where the service life periods of individual parts differ widely or the rate of wear is hard to predict[d]	Auxiliary equipment, equipment with a completely unpredictable rate of wear
System of scientifically worked out standards for the cycles, the volume, and the duration of repairs	Qualified and experienced personnel checking the equipment; measuring devices and laboratory facilities, advanced operational planning of repair activities, adequate stock of spare parts	Reserves of equipment, large stocks of spare parts, high flexibility of repair capacities
High utilization of repair capacities	Repairs are planned and carried out at most appropriate points of time	Timing of repairs fortuitous; difficult to plan repair activities

[c] Individual components are functionally interdependent.
[d] Equipment exposed to intensive corrosion, buildings and structures.

lubrication, accordingly, demands specific qualification of personnel (lubrication technicians), materials and organized measures.

It can be assumed that on average one lubrication specialist is required for each thousand employees in an engineering plant.

The various pieces of equipment and their components have specific requirements as to the quality of the lubricant. Therefore a large variety of lubricants is needed, requiring specific purchases and large stocks.

The organization and control of lubrication in a plant is handled by the chief maintenance engineer. The lubrication technicians are usually organized in maintenance crews. A proper organization of lubrication requires:

- Equipment records;
- Lubrication prescriptions, lubrication plans;
- Indications of lubrication points;
- Organization of deliveries, stocks and distribution of lubricants;
- System of disposal of used lubricants.

Inspection means checking the condition and functioning of plant and equipment. This involves a variety of activities including the rectification of minor defects. These activities are carried out by the operating personnel and special "inspection repair men", largely without stopping operations. The allocation of the various functions between these two categories of personnel depends on the specific conditions as well as the safety requirements of the plant.

Professional supervision of plant and equipment is usually undertaken by a special group of maintenance workers, some of whom are always on duty, especially in the case of continuous production.

Underutilization of the specialized inspection maintenance workers and the difficulty of controlling their work are the main staff problems.

Prerequisites for repair and maintenance

Labour (maintenance workers)

It is not possible to draw a clear-cut line between maintenance workers and workers who operate machinery and other equipment. In statistics of industrial establishments repair workers usually fall within the category of auxiliary personnel. The broader term "maintenance workers" often includes not only workers carrying out maintenance and repair but also those producing spare parts and even complete pieces of equipment. In addition, firemen and members of the factory guard are sometimes included under this term.

The main factors determining the ratio of the number of maintenance workers to the total manpower in a plant are:

(a) The capital intensity of production: maintenance manpower requirements tend to be high in capital-intensive industries (e.g. power generation, metalworking and chemical industry) and low in textile, garment, tanning, and woodworking industries;

(b) The type of capital equipment to be maintained: machinery and equipment naturally have a different demand for repair from buildings and structures;

(c) The design, material characteristics and degree of standardization of plant and equipment: manpower requirements thus depend to a great extent on the choice and method of manufacture of equipment;

(d) The factors determining the physical deterioration of plant and equipment (discussed above); and

(e) The efficiency of the system of maintenance applied.

The data in tables 6 and 7 illustrate the differences in intensity of repair activities in various industries.

Table 6

INDICATORS OF REPAIR ACTIVITY IN VARIOUS INDUSTRIES

Industry	*Total number of personnel*	*Installed HP* per repair worker	*Plant area in m²* per repair worker	*Area of repair shops in m²*	*Repair workers as percentage of total personnel*	*Area of repair shops as percentage of total plant area*
Oil refineries	3	41	—	6.6	33.3	—
Chemicals	8	59	720	13.8	12.5	1.92
Metallurgy	9	153	970	17.3	11.1	1.78
Rubber	13	94	475	7.7	7.7	1.62
Textiles	20	68	725	20.3	5.0	2.8
Electrical engineering	27	105	660	12.8	3.7	1.94
Mechanical engineering	28	92	740	12.8	3.6	1.73
Precision tools	37	60	495	9.2	2.7	1.86

SOURCE: FACTORY 110/1958/No. 8, pp. 52 — 63.

Table 7

Labour standards for preventive repairs of a bench drilling machine

Type of repair	*Norm of labour intensity in hours*
Inspection	0.75
Control	1.0
Minor Repair	10
Medium Repair	27
Overhaul	54

Equipment requires 4 to 5 times more expenditure on repair labour per unit of capital cost than do buildings and structures. Furthermore, within the category of equipment there are substantial differences in the repair work requirements of technically specialized equipment, power plants, and instruments. In the more complex repair systems the requirements of repair workers are determined on the basis of standards of repair intensity for individual kinds of capital equipment. The data in table 7, based on standards for Czechoslovak machinery, serve to illustrate this approach.

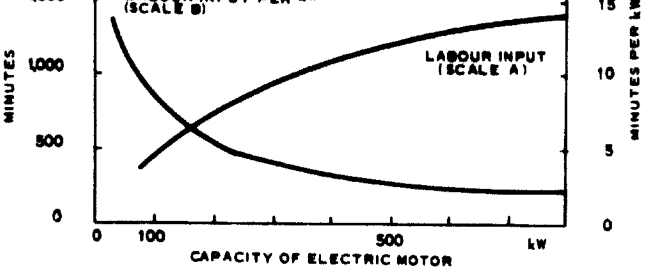
Figure 7 shows how the number of maintenance workers depends on the technical capacity of the equipment. Thus the repair of a 10 kW electric motor takes about 15 minutes per kW, whereas the repair of a 100 kW motor takes about 7 minutes per kW.

As technical development progresses, the ratio of repair workers to the total number of personnel tends to increase. In particular, automation increases the complexity of equipment and its repair requirements.

Thus, for instance, in the chemical concern Du Pont de Nemours over the years 1940—1955

Figure 7

Repair labour inputs (minutes) in relation to capacity of electric motors



Source: Zigmund J., Informace o udribe, No. 6050/1966, VUTECHP, Prague.

the number of production workers was increased by 50 per cent while the number of repair workers grew by 250 per cent.

Repair and maintenance make special demands on the skills of labour. In some industries the skill requirements for maintenance workers are higher than for production workers. In the case of automatic or programme-controlled machines, for instance, the production worker need have only the ability to repeat relatively simple tasks (manual skills for fixing and handling the products) and to switch the machine on and off. The maintenance worker, on the other hand, should have in addition to these manual skills a deep professional knowledge of basic mechanical, electric and hydraulic principles. These skill requirements obviously make the specialization and division of labour within a plant necessary, but opinion is divided on specialization within the maintenance profession. Generally, two basic professions are recommended: maintenance workers for mechanical systems and maintenance workers for electrical systems.

Maintenance and repair personnel need special training which should aim at broadening their general knowledge and giving them a mastery of specific technical problems.

In addition to formal education at the appropriate level (vocational schools, technical high schools, technical universities), the qualified technician requires specialized practical knowledge of maintenance. An example of a basic training programme for repair workers is given in table 8.

Table 8

Repair worker training programme

General Millwrights Assignment	*Hours*
Assembling and erecting and general maintenance of machines and shop equipment	2,920
Construction of special equipment	1,000
Installation and maintenance of hydraulic and pneumatic equipment	1,000
Fitting bearings and scraping ways	500
Lubrication of machines	500
Arc and acetylene welding and cutting	1,000
Operation of various machines	500
Related classroom instruction	580
Total	8,000

Source: Morrow L. C., *Maintenance Engineering Handbook*, McGraw-Hill, N. Y., 1957, pp. 2 – 19.

Spare parts and materials for maintenance

Spare parts are used to replace those parts of a machine which wear out faster than the machine as a whole. A spare part can be defined as a part of a machine or equipment that can be substituted individually for an identical, worn or damaged part of the machine. A self-contained functional unit can also be considered as a spare part, e.g. an electric motor or pump. On the other hand, clamping and cutting tools for a lathe are not regarded as spare parts and are not depreciated as part of the lathe; they are treated instead as material inputs.

Requirements of spare parts and materials for maintenance are estimated similarly to requirements of maintenance workers. However, there is a wide range of different parts generally needed. Special importance, therefore, attaches to the purchase and stocking of spare parts.

In various industries the annual consumption of spare parts amounts to 1 — 4 per cent of the purchase price of installed machines and equipment. Stocks represent 1 to 2 years' consumption of spare parts.

In an average-sized chemical plant there are about 10,000 items on the list of spare parts and about 15,000 items on the list of repair materials.

The need for spare parts is especially influenced by the degree of standardization of equipment. For 100 identical machines it is necessary to keep in stock only about one third of the spare parts needed for 100 machines of five different models.

Equipment in repair shops

Only certain repair and maintenance activities require a separate shop and special equipment. By their nature repair and maintenance work are mainly ambulatory. A large part of repairs and the predominant part of maintenance are carried out at the installation point without moving the machine or equipment.

Capital requirements for repair and maintenance have to cover the technical outfitting (machinery and equipment) and working area of repair shops; mechanical implements (tools) and instruments (e.g. for measuring); and stocks of spare parts and materials.

Repair shops contain a large proportion of universal machine tools (general purpose lathes, drilling, grinding and milling machines of normal sizes) and expensive and complex measuring devices. Technical data on the machine tools in repair shops in USSR are contained in table 9.

Table 9

DISTRIBUTION OF MACHINE TOOLS IN REPAIR SHOPS IN ENGINEERING INDUSTRY

	Proportion (per cent) of total number of machines in repair shops
Centre and turret lathes	40—50
Vertical and chucking lathes	2—3
Boring machines	3—4
Vertical drilling machines	7—8
Radial drilling machines	2—3
Milling machines	7—9
Planing machines	7—8
Shaping (slotting) machines	2—3
Grinders	10—12
Gear milling machines	6—7
Other machines	3—4

SOURCE: Jakobson M. C.: Jedinaja sistema planovopredupreditelnovo remonta masinostroitelnych predprijatij, Masinostrojenije, Moskva 1967.

Repair shops in big plants outside the engineering industry (e.g. metallurgical, chemical works) are generally more complex and costly. There are special anticorrosion shops, usually linked to the material testing department, boiler shops, pipe shops, stainless steel welding shops, etc. Shops for the repair of electrical items and, in particular, measuring and regulating devices, are relatively larger and more elaborately equipped.

The working area of repair shops is, as a rule, relatively larger than the area devoted to production activities in machine tool works. In repair shops the working area is about 30—35 m^2 per worker, which is three times the average area per worker in process shops in the machine tool industry.

The investment cost of building and equipping repair shops depends on the technical needs of the shops, the working area required and the cost of the initial stocking with tools, spare parts and repair materials. The fixed investment costs in repair shops generally represent 1—3 per cent of total fixed investment in a factory, even more for small factories.

The value of the stock of spare parts is at approximately the same level, i.e. 1 — 3 per cent of total fixed investment.

Down time of equipment

One of the specific implications of repair activities is that the down time during which the machinery is taken out of production causes production losses.

To minimize production losses, the plant manager can take specific organizational and technical measures to shorten the down time for repair work and he can take advantage of periods when equipment is normally idle, or he can utilize reserve capacity. All activities mentioned above to reduce deterioration of equipment and the risk of break down naturally play an important role in this context. The choice of repair system is largely determined by the estimated risk for down time of the machines.

The length of machine down time depends on the magnitude of the repair and therefore can be reduced by rationalizing the repairs and planning them well in advance. Technically, repairs can be prepared beforehand mainly by assembling the necessary technical documentation, by securing the availability of spare parts needed and by calculating the repair time and scheduling the repair work sequence. In many cases it is possible to prepare the scheduled repair by dismantling the equipment in advance for a short time and making a diagnosis of the repair spare part needs.

Finally, the losses due to down time of machinery, through failures and repairs can be minimized by installing reserve equipment, in the production units or in the repair shops (system of repair through exchange).

The feasibility of keeping such reserves is determined by the relation between the investment cost of such a solution and the value of the probable production losses thereby avoided. It is usually not feasible to keep reserves of costly and complex machinery. One can also regard the possibility of using other machines of the same kind more intensively in the case of breakdown, as one kind of spare capacity. In the engineering industry a universal machine tool could be used in this way.

Specialized repair and maintenance shops

In order to rationalize repair services at the sectoral and national levels specialized repair shops can be established. Generally three types of such repair shops can be distinguished:

- sectoral shops,
- repair shops for specific kinds and brands of machines,
- regional repair shops.

It should be added that the commonest specialized repair and maintenance service is that provided by the producers of the equipment.

Sectoral repair shops repair and maintain special equipment of a given industry such as oil refining, electric power generation or the construction industry.

A sectoral repair shop can be organized as a separate establishment, or as a repair shop attached to some factory within the specific industrial sector. The personnel of this repair shop may be sent out to carry out service at the production units or the machines and equipment may be sent to the repair shop.

Repair shops dealing with specific kinds and brands of machines are a progressive form of organization. They mainly perform overhauls. This kind of specialization makes it feasible to introduce methods of large-scale production into repair activities and overhauls can be carried out at much lower cost than if done individually by the factories. As a result of specialization of overhauls in the Czechoslovak engineering industry the time needed for overhauls of certain types of machines was reduced by 75 per cent and the labour costs by 50 per cent. Experience shows that in order to achieve such substantial savings the number of machines of a given type to be repaired must reach 35 pieces annually.

Some experiments in USSR and in Czechoslovakia show that it is possible to reduce the down time of equipment through the system of "repairs through exchange", whereby the specialized repair shop delivers another machine of the same type in good working condition as a permanent replacement at the time it removes the machine for overhaul. This system can only function if the repairs are of high quality and if repaired machines have the same technical parameters as new machines. Another precondition for the rational use of this system is the existence of a sufficiently large industrial sector and a sufficient number of machines.

Regional repair shops are advisable where there is a large concentration of industrial, mainly small-sized, establishments with the same repair requirements. The main items repaired on a regional basis are buildings, electric motors, pipes, electrical distribution systems and air conditioning equipment.

POLICY AND STRATEGY FOR REPLACEMENT, REPAIR AND MAINTENANCE

The economic and organizational aspects of replacement, repair and maintenance need to be examined at the level of the enterprise and also nationally. Emphasis is placed mainly on explaining the organization, management and control, the book-keeping and recording system and the analysis of replacement, repair and maintenance at the enterprise. The aggregation of these problems will then be discussed, i.e. the national planning of these activities and the strategy required for industrial development.

At the enterprise level

Organization and management

The specific problems of organization and management of repair and maintenance are to decide upon:

(a) The degree of specialization of repair shops and repair teams in the factory—sectoral and regional repair shops have already been discussed;
(b) The centralization or decentralization of repair capacity; and
(c) The management structure for repair activities.

(In this section, the term 'repair' is used for brevity to denote both repair and maintenance.)

The choice of the appropriate degree of specialization depends mainly on the size of the enterprise. The larger the factory, the more the repair facilities can be specialized. In smaller enterprises all the repair activities are concentrated in one department, while overhauls and special servicing are carried out by external shops. In large factories specialization may take the form of a system of internal repair units, comprising the following:

(a) Machines and equipment repair section to undertake:
   (i) Machining (machine shops),
   (ii) Welding (pipe shops, tinsmith shops, boiler shops, etc.);
(b) Transportation equipment repair section;
(c) Electrical repair section (shops for electric motors, etc.);
(d) Section for repair of electronic measuring and regulating devices;
(e) Woodworking repair section;
(f) Construction repair section (bricklayer crews, scaffolding crews, etc.).

The degree of specialization depends, however, not only on the size of the plant, but also on the technology and organization of the main production activity. Thus, in the chemical industry, in electric power generation and in metallurgical and engineering industries using high precision machine-tools, the specialization generally is rather far reaching.

In choosing between centralized and decentralized repair facilities, the following alternatives are possible:

(a) Centralized facilities, organized as:
   (i) An independent repair plant of the enterprise (or group of enterprises),
   (ii) A central workshop within the factory, or
   (iii) Several workshops, one for each major section of the factory;
(b) Decentralized workshops within the production sections;
(c) A combination of *(a)* and *(b)* consisting of several smaller, detached shops combined with the central workshop. This can be organized either as:
   (i) Decentralized workshops, with the planning, spare parts stocking and inspection centralized in the central shop, or
   (ii) Decentralized workshops in the large production sections and centralized repair for smaller sections, and also for certain kinds of equipment which have special repair requirements.

The choice of the appropriate degree of specialization depends on the actual costs, the quality and the quantity of activities as well as the actual down time of machines in repair.

Finally, a decision must be taken on the degree of centralization of management and on the integration of repair activities within the organizational structure of the enterprise. Two alternative solutions are possible:

(a) All repair personnel are subordinated to the chief of the whole repair section (there are usually sections for repairing electrical items, measuring devices and buildings); or
(b) Repair personnel are subordinated partly to the chiefs of various production sections, and to the repair chief only in regard to methodology and professional aspects of repair.

The repair chief may be subordinated to the production manager, the technical manager or the production director.

Subordination to the production director is often of doubtful wisdom, since repair may conflict in the short term with the aim of maximizing output and there may be a tendency to postpone or neglect repairs. This risk can be avoided or reduced if the technical manager is in charge. The direct subordination of the repair manager to the production director is particularly suitable in large factories with complex equipment and a great number of repair workers.

As can be seen, there are no fixed criteria for choosing one of these alternatives. The choice depends on the actual conditions in the enterprise and its past experience.

The recording system

The analysis and planning of repair and replacement necessarily requires systematic collection of information on the existing capital equipment and its development. This information usually serves as a basis not only for managing repair and maintenance activities, but also for making tax calculations, capacity planning, etc. The two basic kinds of records are financial book-keeping and technical recording of operations.

The financial book-keeping deals with the value of installed plant and equipment, depreciation, maintenance and repair costs, etc. It requires an inventory of plant and equipment and the method of valuation presents a problem. In general, there are three ways of valuing existing capital equipment:

- in terms of the original purchase cost,
- in terms of current replacement cost,
- in terms of balance-sheet value (net, after depreciation).

Generally, however, the method to be used for valuing installed plant and equipment is determined by governmental regulations. The value must include, in addition to the purchase cost, transportation cost and the costs of assembling, mounting and installation at the factory.

The technical recording of operations is the primary source of information for the control of replacement, repair and maintenance activities The inventory list and the inventory card are the basic elements of the system.

The inventory list summarizes the installation of plant and equipment in chronological order, while the inventory card gives detailed basic information on a single item of plant or equipment. The inventory card usually serves for financial accounting and technical decisions. The content and form of such a card naturally depend upon the kind of plant and equipment and the maintenance system.

Usually, the necessary details and records concerning maintenance, lubrication and spare parts are noted on the card. Records of the cost of individual pieces of equipment on the other hand are only kept for valuable equipment and if highly developed systems of accounting are used. These records serve as a basis for a systematic evaluation of replacement alternatives.[1]

To make rational decisions on replacement, repair and maintenance it is important to have a constant flow of up-to-date information on innovations, i.e. new technologies and new machines, which offer possible alternatives to those currently in use.

The establishment of a rational information system on plant and equipment requires various methodological and organizational preconditions, such as:

(a) The definition of an inventory item;
(b) The determination of its code number;
(c) The classification of plants and equipment;
(d) The introduction of the new plant and equipment in the control records;
(e) Regulations concerning periodical inventories.

[1] The inventory card is discussed, with an illustrative example, in Morrow, L. C., *Maintenance Engineering Handbook*, McGraw-Hill, New York, 1957.

An inventory item is the smallest separate unit of plant or equipment. The concept inventory item is usually defined in tax laws which lay down its minimum value or the minimum period of its service life. In this way a dividing line is drawn between investment items and other, minor or short-lived items. In the case of buildings, each separate building is an inventory item, irrespective of whether it actually stands alone or is located within a block of buildings. Each structure or structural part of a plant that fulfils a distinct technical or economic function and is complete with accessories forms an inventory item. The definition of an inventory item is more complicated for equipment having a large number of components and various accessories. The telephone system of an enterprise, for instance, can be considered as one item including connecting lines and telephone sets. In the case of a boiler house it is, however, convenient to treat the boiler with the supporting frame, gallery and foundation as one inventory item, and the economizer, the ventilator, pipes, stack, fly ash handling equipment, etc. each as separate inventory items.

Code numbering of inventory items provides a permanent, uniform and unambiguous identification of plant and equipment by a symbol, usually a number. Code numbering is the best solution also for mechanized recording. Since the number of inventory items generally runs into thousands, it is usually not possible to make a separate coding for the technical characteristics of each item.

As a rule, the items are numbered in chronological order of acquisition. Sometimes it is useful to combine the identification number with a classification number, as shown in table 10.

Table 10

A SYSTEM OF CODE NUMBERING FOR PLANT AND EQUIPMENT

Classification number	*Plant and equipment group*	*Inventory numbers*	*Number of items*
1	Buildings	101–199	99
2	Structures	201–299	99
3	Power equipment	3001–3999	999
4	Production machinery and equipment	40001–49999	9999
5	Power distribution equipment	5001–5999	999
6	Transportation equipment	6001–6999	999
7	Instruments etc.	7001–7999	999
8	Animals	801–899	99
9	Land, land improvements	901–999	99

Classification is a basic step to introducing an information system. The simplest and most general way of classifying capital equipment is to divide it into buildings and machinery. These two groups can be divided further in a more detailed classification. The machinery component, for instance, can be sub-divided into: production machinery and equipment, power equipment, driving and transmission equipment, means of transportation, instruments, etc. However, even this type of classification is usually too rough to serve as an operational technical information system. A more detailed decimal classification system used in the Czechoslovak engineering industry is illustrated in table 11. In this classification number stands for a rather detailed technical characteristic.

Table 11

EXAMPLE OF DECIMAL CLASSIFICATION SYSTEM USED IN CZECHOSLOVAKIA

Classification code	*Description*
4	Machines
402	Machines in engineering industry
4024	Metal-cutting machines
40241	Centre lathes
402412	Centre lathes with 250–315 mm turning diameter
4024122	Centre lathes with 250–315 mm turning diameter and 750–1,000 mm bed length

The noting of new plant and equipment in the control records is an important part of the information system. Obviously, the starting point for keeping records is the moment of installation, when the following actions should be taken:

(*a*) The item is given an inventory number;

(*b*) The item is registered in an inventory list;

(*c*) A permanent equipment record (inventory card) is established;

(*d*) The technical documentation is registered.

Periodical inventories are revisions of the records which are necessary from time to time. They compare the records with the real state of plant and equipment.

The inventory of plant and equipment is usually combined with the inventory of other capital assets, such as uncompleted investments, work in process, stocks of material and finished products, etc. The inventory of plant and equipment can be carried out in the course of a technical inspection. A special case of inventorying is a general census, organized to cover the whole industry or all industries in the country.

Analysis of economic efficiency

The analysis of needs and resources for replacement, repair, etc. is explicitly or implicitly an optimization analysis. The repair needs of a machine are not determined exclusively by technical circumstances, i.e. by its physical wear and technical functions. Ultimately, criteria of economic efficiency also play a decisive role, since a decision to carry out a repair means an extension of the life of the item repaired. Such a decision is necessarily the outcome of economic rather than purely technological considerations.

The methodology of assessing economic efficiency in order to decide on new investment as well as repair and replacement has given rise to complicated theoretical discussions in the literature. It should be noted, however, that evaluation should not consist merely of applying simple or even complex formulas involving a series of indicators. It must also include drawing on relevant broader experience and qualified prognoses.

The logical basis of the efficiency evaluation consists in confronting the target utility function with the restrictions inherent in the situation. The first task therefore is to establish a utility function. Usually, the maximization of profit is taken to be the principle utility function. In choosing between repair and replacement, the maximization of profit is identical with the minimization of production costs. Thus, the first step in efficiency evaluation is the calculation of operating costs.

It is usually rather complicated to calculate how the operating costs of a repaired machine compare with the costs of a new machine. The calculation can and should be limited to those items which are specifically subject to change in the event of replacement, such as basic wages, depreciation charges, material cost, cost of instruments, repair and maintenance cost, electric power, and technical preparation for production.

The main restriction on achieving the given utility function is the size of the investment funds or the investment costs, including the costs of introducing the new technology, the costs of installing new and dismantling old equipment, etc.

An example of the calculation of production and investment costs is given in table 12. It is assumed that two universal centre lathes are in operation, one of which is now due for an overhaul, while the other will be due for an overhaul in two years time. The choice has to be evaluated between carrying out these overhauls and replacing the two lathes by one semi-automatic lathe.

If the replacement is carried out instead of the two overhauls, the wage costs will be reduced. On the other hand, the costs of electricity, maintenance and routine repairs, instruments and tech-

Table 12

EVALUATION OF THE ECONOMIC EFFICIENCY OF AN OVERHAUL VERSUS REPLACEMENT AND MODERNIZATION

I. CHARACTERISTICS

Subject of analysis:	Replacement of two universal lathes by a semi-automatic profiling lathe	
Product-mix and volume of output:	No changes	
Description of alternative solutions:	*Alternative A:*	Maintaining the old technology; production on two universal lathes utilized for more than two shifts a day; lathes require major overhaul
	Alternative B:	Introduction of a new technology; usage of one new semi-automatic lathe

II. PRODUCTION COST (in US dollars)

	Alternative		*Differences between alternatives*
	A	*B*	*(A–B)*
Wages	3,030	1,310	1,720
Materials (basic)	—	—	
Materials (overhead)	—	—	
Energy	1,030	1,200	–170
Instruments	330	350	–20
Routine repairs and maintenance	500	400	100
Depreciation charges	690	1,300	–610
Rejects	200	30	170
Technical preparation for production	—	80	–80
Total savings in case of alternative B			1,110

III. RESOURCE REQUIREMENTS (in US dollars)

	Alternative		*Differences between alternatives*
	A	*B*	*(B–A)*
Investment outlays	—	8,750	8,750
Overhaul cost	5,430	—	–5,430
Balance-sheet (resale) value of scrapped lathes		–2,000	–2,000
Start-up costs associated with new machine		250	250
Difference in outlays			1,570

IV. RESULTS

(a)	Annual savings in production cost	1,110 $
(b)	Difference (once for all) in investment outlays	1,570 $

nical preparation for production will increase. The costs of overhaul of a universal lathe are estimated at US $ 3,000. The present value of the second overhaul is naturally less, since it occurs in two years' time. The cost of a new semi-automatic lathe is estimated at US $ 10,000 and introducing the new technology will cost about US $ 300. The replacement of two universal lathes by one semi-automatic lathe will reduce the floor area occupied by 10 m². It is appropriate to include the value of the reduction in floor area in the calculations, since all rationalization measures within a given plant should also economize on floor area, thereby reducing the requirements for new factory construction to expand production.

There are various methods for evaluating the efficiency of replacement and repair. The simplest of them are based on minimizing the length of the pay-off time, maximizing the rate of return and minimizing the average cost. Each of these methods can be applied in a variety of forms, the simplest of which are discussed here.

The method based on the length of the pay-off time is applied as follows: the annual cost savings resulting from the use of the new machine instead of the old machine are compared with the amount of investment according to the formula:

$$k = \frac{I_2 - I_1}{C_1 - C_2}$$

where k is the coefficient of economic efficiency of the replacement (2) as compared with the overhaul (1);

I_1, I_2 are the costs of overhaul and replacement, respectively;

C_1, C_2 are the annual production costs using the old repaired machine and the new machine, respectively.

The results of the calculation are then set against a normative pay-off period, which is the decisive factor in evaluating the results of an efficiency analysis of this kind.

In the case shown in table 12, the coefficient of economic efficiency is

$$k = \frac{1{,}570}{1{,}110} = 1.4$$

This result is usually interpreted by saying that the new machine pays for itself in 1.4 years. If the minimum pay-off period has been determined at, for instance, 2 years,[2] the replacement is acceptable.

In its simplest version the 'rate of return' method is very similar to the above pay-off method. Its basic coefficient is the reciprocal of the previous formula, *viz.*:

$$k = \frac{C_1 - C_2}{I_2 - I_1}$$

The empirical value of k is compared with the required rate of return. In the case presented in table 12, the value of the coefficient is

$$k = \frac{1{,}110}{1{,}570} = 0.71$$

This value is compared with a rate of return set by the enterprise, for instance, 20 per cent. The replacement gives a rate of return of 71 per cent in this case and would therefore be recommended.

In the "minimum average cost" method the capital cost of a machine is divided by the number of years of service life and added to the average of annual operating costs. If this sum in respect of a new machine is smaller than the corresponding sum for the old machine assuming it is kept in service, then the time has arrived for replacement.

According to the hypothetical figures given in table 13, the average annual cost of a new machine is at a minimum ($ 4,386) when the service life is seven years. The replacement carried out when using the old, repaired machine will cause a minimum average cost which is higher than this figure.

A problem common to each form of efficiency analysis is how to adjust capital costs and operating costs overtime. A time adjustment is carried out to discount receipts and expenditures spread unevenly over time. Theoretically, the rate of return used by the enterprise in deciding on replacement should be higher than (or equal to) the rate of return obtainable from alternative investments with comparable risk and tax status; and lower than (or equal to) the cost of obtaining outside finance.

Table 13 also shows the same example calculated with time adjustment, the interest rate being 10 per cent. In this case, the replacement is efficient if in the future the average annual costs of the old machine will be higher than US $ 4,173, time-adjusted, since this is the minimum attainable with a new machine, on a time-advised basis, occurring after 12 years.

Planning

Planning of replacement and repair can be defined as the explicit co-ordination of future requirements and supplies. A material balance must be drawn up between the requirements for replacement, repair and maintenance in physical and/or value terms and the available repair and maintenance capacities, allowing for external services and supplies. Two different kinds of plans can be distinguished, general and operational plans.

General plans aim at balancing requirements and resources on a long-term basis within the framework of the system of plans of the enterprises. In the case of long and medium-term plans, ranging from about 4 to 10 years, great attention has to be paid to the choice between replacement and overhaul as alternative strategies. Another crucial point of long-term planning is the assessment of future capacity resources for repair and maintenance.

While the long-term plan consists of a system of aggregated indicators, the annual plan for re-

[2] According to the *Journal of Manufacturing Industries*, Vol. XV, No. 1, p. 27, about 60 per cent of US companies require a pay-off period in the range of between 1.5 and 3 years.

Table 13

CALCULATION OF MINIMUM AVERAGE COST OF A NEW MACHINE

(US dollars)

Years of service	*Annual average for period ending with year indicated*					
	Without time adjustment			*With time adjustment*		
	Operating cost	*Capital cost*	*Total cost*	*Operating cost*	*Capital cost*	*Total cost*
1	3,000	5,500	8,500	3,000	5,500	8,500
2	3,100	2,750	5,850	3,048	2,881	5,929
3	3,200	1,833	5,033	3,094	2,011	5,104
4	3,300	1,375	4,675	3,138	1,577	4,716
5	3,400	1,100	4,500	3,181	1,319	4,500
6	3,500	917	4,417	3,222	1,148	4,371
7	3,600	786	4,386	3,262	1,027	4,289
8	3,700	688	4,388	3,300	937	4,238
9	3,800	611	4,411	3,337	868	4,205
10	3,900	550	4,450	3,373	814	4,186
11	4,000	500	4,500	3,406	770	4,176
12	4,100	458	4,558	3,439	734	4,173
13	4,200	423	4,623	3,470	704	4,174
14	4,300	393	4,693	3,500	679	4,178
15	4,400	367	4,767	3,528	657	4,185

(Figures do not always add, because of rounding.)

SOURCE: G. Terborgh, *Dynamic Equipment Policy*, McGraw-Hill, New York, 1949.

newal, repair and maintenance is more detailed. The example given in appendix 1 can be regarded as an illustration of a system of indicators suitable for annual planning of repair.

The concrete programming of repair and maintenance activities is a matter of operational plans. Their character and form depend on the type of maintenance system adopted (see table 5). Two basic kinds of operational plans for maintenance can be distinguished: *(a)* plans based on inspection regulations, *viz.* repair scheduled after checking, and *(b)* plans based on fixed maintenance and repair standards.

The former (*a*) requires qualified and experienced personnel (inspectors) advanced operational planning in repair shops and a relatively large stock of spare parts. It is primarily suitable for buildings and structures and for equipment with a rate of wear hard to predict. The results of inspection may be summarized for each factory department on a daily inspection sheet. Here, an inspector reports for each equipment item his remarks and the reason for whatever repairs he considers necessary. A separate sheet is compiled for each type of inspection (mechanical, electrical etc.) during each factory shift. These inspection sheets are complemented by the maintenance inspection log sheet, which registers what kind of repairs are done each day during a period of, for example, 28 days. The log sheet of a factory department will indicate the type of repair (e.g. emergency, routine, minor) arising from each type of inspection (mechanical, electrical etc.) of each item of equipment. Maintenance inspection does not always take place once in 24 hours. The time cycle may range from every 8 hours to every 28 days and need not be the same for all types of inspection of a given equipment item. The time cycle is recorded on the long sheet, which will be marked up only on those days when an inspection takes place.[3]

The latter (*b*) is characteristic of standard repair and planned preventive (periodical) repair systems. Its basic precondition is an elaborated system of standards. It is suitable for equipment involving a great safety risk or where a large number of identical machines is used in large-scale production. An example of a standard for this kind of operational planning was given in figure 6 and further examples appear in tables 14, 15 and 16.

The basic distinction between the two kinds of operational planning is the degree of flexibility of plans. Since in reality the demand for replacement and repair is determined partly by accidental factors, operational planning must always be flexible to some extent. Even in the most elaborate systems of maintenance, certain decisions remain to be made from day to day.

At the national level

There are a number of problems connected with a rational planning of maintenance, repair

[3] For a fuller discussion of this kind of operational planning, see Morrow, L. C., *op. cit.*

and replacement which it is beyond the technical and economic capacities of an enterprise to solve. The multi-plant, sectoral and or national level is where a solution must then be sought.

The definition of these problems and the methodology for solving them depend on the over-all economic policy. They will obviously be different in a market economy and a centrally planned economy.

Analysis and planning

The analysis and planning at a macro level of repair and replacement of plant and equipment, in order to co-ordinate future requirements and supplies, require different methods and objectives from those used at the enterprise level.

In sectoral and macro-economic studies relating to the process of industrialization, the assessment of requirements and resources for replacement, repair and maintenance is obviously based on highly aggregated indicators.

(a) Demand

We have so far discussed repair and maintenance of individual machines, pieces of equipment, buildings and structures. The planning and analysis of a national aggregate such as a machine tool park must describe the process of depreciation, replacement, modernization, etc. with the use of quite different methods, as illustrated in the model in appendix 2.

The aggregate demand for replacement, repair and maintenance depends on the volume, the age characteristics and the service life of the country's installed capital equipment structure. It is obvious that an increase in the stock of capital equipment in a given sector or country, increases the demand for replacement, repair and maintenance services as well. It is, however, difficult to make generalizations about the ratio of this increased demand to the increase in stock. On the one hand, the demand tends to increase not only in absolute terms but also in relative terms due to the continuous process of mechanization and automation. On the other hand, the demand can be reduced by pursuing a policy of rationalizing designs of machinery and, just as importantly, the repair and maintenance activities.

In general, it can be assumed that the extent of wear and the need for replacement, repair and maintenance are functions of the age of the stock of plant and equipment. Repair and maintenance requirements grow with increasing age, mostly at an accelerating rate. But this rule is not without exceptions; old equipment and buildings are often used for auxiliary purposes only, where the precision and performance required are usually less strict and hence the need for replacement, repair and maintenance decreases.

The various categories of capital equipment differ in regard to their need for replacement, repair and maintenance, the simplest example of this being the differences between the needs of buildings and machines. Thus, depending on these structural characteristics, capital equipment of similar value can be associated with entirely different repair needs. A larger proportion of machinery and equipment obviously results in relatively higher requirements.

In table 17 data are given showing the value of machinery and equipment as a per cent of the

Table 14

Repair standards

EQUIPMENT: COMPRESSOR

Kind of repair	Repair cycle (hours)	Repair time (hours)	Repair labour input (hours)	Average number of repairs per year	Cost of one repair in thousand Kcs				
					Materials	Wages	Overhead	External services	Total
O	17,520	300	1,600	½	30	16	20	5	71
M	4,380	60	250	1½	4	2.5	2.5	-	9
R	1,460	15	50	2	1	0.5	0.5	-	2
Yearly average		270	1,265	x	23	12.7	14.7	2.5	53

STRUCTURE OF A REPAIR CYCLE

R R M R R M R R M R R O

Months → 6 12

NOTE: *O*—Overhaul
M—Medium repair
R—Routine repair

Table 15

STRUCTURE OF A REPAIR CYCLE

Production unit: Annual plan of repairs for 19..

Equipment number	Month 1	2	3	4	5	6	7	8	9	10	11	12
1	15 a/ / 50 R	R	60 / 250 M	R	R	M	R	R	M	R	R	300 / 1,600 O
2		M			70 / 300 M			M			M	
3		10 / 80 R		R			200 / 3,000 O		R		R	
Repair time (duration of R) (hours)	15	70	60	15	70	60	200	70	60	15	70	300
Repair labour input (hours)	50	430	250	130	350	250	3,050	350	330	50	430	1,600
Repair cost: M plus R plus other minor repairs												
Repair outlays	x	x	x	x	x	x	120	x	x	x	x	71

Annual data for financial plan — 240 plus 191 thousand Kcs

Annual data for planning repair labour — 7,270 hours of labour inputs

Annual data for production (output) planning (equipment utilization) — 1,035 hours = 11.8 per cent of 8,760 hours

a/ 15 ...... Duration of repair in hours
50 ...... Repair labour inputs in hours

Table 16

STANDARDS FOR REPAIR IN THE CHEMICAL INDUSTRY (USSR)

Equipment: Vertical centrifugal pump, 10–25 m³/hr, 70 m, 2,900 r.p.m. 8 kW
Type of repair cycle: 7 B-25-60

Kind of repair	*Cycle of first overhaul (hours)*	*Repair cycles (hours)*	*Duration of one repair (hours)*	*Number of repairs in one cycle*	*Volume of one repair*		*Cost (roubles)*	
					total hours	*machinery hours*	*materials*	*spare parts*
Overhaul	3,640	8,200	168	1	68	27	200	300
Medium repair .		2,880	48	2	34	13	100	150
Routine repair ..		720	8	7	10	4	50	80
Total in one cycle				10	206	81	750	1,160

Table 17

CAPITAL OUTPUT RATIOS IN MANUFACTURING INDUSTRIES IN THE UNITED STATES[a]

Industry branches	*Total ratio*	*Machinery (including electrical and transportation equipment)*	
		Ratio	*Per cent of total ratio*
Food, beverages and tobacco	0.81	0.41	51
Textiles	0.91	0.51	45
Wood and wood products	0.78	0.39	50
Pulp and paper	1.13	0.65	58
Printing and publishing	0.66	0.42	64
Rubber	0.70	0.44	63
Leather	0.43	0.19	44
Clothing	0.38	0.18	53
Non-metallic minerals	1.18	0.67	43
Chemicals	0.89	0.35	61
Petroleum	5.64	0.94	17
Base metals	2.34	0.92	39
Metal products	0.83	0.51	62

SOURCE: Based on unpublished material supplied by Harvard Economic Research Project.

[a] Dollar capital investment per dollar value added in annual production, at 1953 prices.

total fixed capital assets, for various manufacturing industries in the USA. From these data, it may be inferred that the demand for replacement, repair and maintenance is higher in metal-working industries, printing and publishing, chemicals and rubber, than, for example, in the petroleum industry.

Table 2 indicated the wide variation in requirements for renewal and repair for different kinds of buildings, structures and equipment. Equipment in the construction industry, for instance, has much greater repair requirements than machine tools in the metal-working industry (the costs of an overhaul represent on average more than 10 per cent annually of the purchase price in the first case and about 5 per cent in the second case).

There is a fairly clear relationship between the cost of machines and the cost of their overhaul. As a rule, the cost of overhaul of expensive machines is a lower proportion of their purchase price than in the case of cheaper machines. This applies, for instance, to machine tools. The most important reason for this relationship is probably the fact that low-cost machines are mainly produced in large series, whereas their overhauls are carried out individually. The difference in labour productivity between repair shops and production units making new machines is therefore more pronounced for low-cost than for complex machines which are often produced on a one-off basis.

Repair and replacement requirements are, generally, interdependent: machinery and equipment with high replacement requirements also need more repair. However, in some cases the accelerated replacement of equipment (shortening of service life) can result in the reduction of repair needs. In such a situation, the replacement and repair needs are mutually exclusive.

(b) Supply

From the national or sectoral point of view the resources required for replacement, repair and maintenance consist of specialized labour, capital, material supplies and specific imports of goods (equipment and spare parts).

Repair activities are characterized by large labour inputs both as regards the quantity and the quality of the labour required. This is partly due to the fact that manual work predominates in the actual productive hours and partly to the relatively low proportion of productive hours (35 to 50 per cent) in the total working time of repair personnel. Even with a good organization, the bulk of the working time of repair workers is spent on preparatory activities.

In the framework of the economy as a whole, the resources of labour engaged in repair activities are usually large. Out of a total population of 14 million, Czechoslovakia, for instance, has about 500,000 workers engaged in repair work.

Compared to the labour inputs the capital inputs are generally not large. Thus, in Czechoslovak repair shops there is an average of only 28,000 Kcs (US $2,000) worth of fixed assets per worker, whereas in the chemical industry the figure is 220,000 Kcs (US $16,000).

Material inputs are likewise not large in volume. The variety of materials required in repair shops, on the other hand, is generally large. Keeping adequate stocks of spare parts and materials therefore requires relatively large amounts of working capital.

The national demand for maintenance can normally be met only in part from domestic resources. The degree of self-sufficiency in maintenance services, supplies of spare parts, etc. depends primarily on the size of the national economy and the level of industrial development achieved. Developing countries are to a large extent dependent on imports of capital goods, especially machinery. This is reflected in the high rate of imports of spare parts and components for replacement, and of imports of maintenance services.

(c) Techniques of planning

A country's plans at the aggregate level for replacement, repair and maintenance are generally not prepared in detail and only exceptionally take the form of material balance sheets. This is true even in the centrally planned economies, where in most cases only partial analysis and planning are done, with a view to applying specific policy measures.

Such a partial analysis can aim, for instance, at assessing replacement needs. Sectoral studies would then be the most suitable method of analysis, to examine the existing state of installed capital equipment and to evaluate it from the viewpoint of replacement by new machines in the light of the over-all investment climate, and the technological level of the existing machines compared with that of the most modern ones.

The analysis of replacement needs based on the examination of the economic efficiency of replacement investment, usually requires plenty of data and large inputs of highly qualified labour. Where these prerequisites are not available, a different, less demanding method of comparative analysis is used. The technological level and structure, the age and kinds of machinery and equipment in a given industrial sector are compared with the corresponding situation in another country in which this sector is more developed. The volume of resources needed can then be approximately calculated from this comparison.

Policy measures

Governmental action to solve replacement, repair and maintenance problems consists of technical, organizational and financial measures. Technical measures include promoting or in some cases establishing specialized repair shops and servicing facilities, central stocks of spare parts, design and technical bureaux, research institutes and state inspection bodies, educational and training facilities, etc. These actions must be based on a systematic analysis of their economic and technical feasibility from the national point of view.

Specialized repair shops as the rational technical basis for supplies and services have already been discussed. Their advantages are the savings resulting from higher productivity and the improved quality and shorter repair time. The main disadvantages are increased transport costs, reduced flexibility and speed in coping with breakdowns and the lack of knowledge of the precise conditions under which the equipment operates.

It is not possible to determine a general ratio between the volume of repair and maintenance which should be carried out at factories and that which should be performed by external suppliers. The ratio would vary substantially according to the industry and the type of capital equipment in use. Large differences exist between different countries, which cannot be explained solely by the different levels of industrial development, but also depend on habits, traditions and the institutional set-up. In the United States, for instance, about 80 per cent of all plants use external repair services, but the external suppliers perform on average only 7.6 per cent of the total volume of repair work. In the Federal Republic of Germany and in the German Democratic Republic, on the other hand, chemical plants use external services to a very little extent. In Japan, repairs are usually performed by external firms, particularly by the suppliers of the equipment.

Decisions regarding the creation of central stocks of spare parts at the national, sectoral or regional level are based on similar considerations. Specialized repair shops also form a natural basis for storing and distributing the spare parts.

Design and technical bureaux, research institutes and state inspection bodies have the following functions:

To provide consultative services in regard to the rational repair and maintenance of equipment;

To develop standards for the techniques and organization of repair and maintenance;

To adapt the design of imported machinery and equipment to local conditions;

To develop a system of technical standards for plant and equipment;

To establish a system of state inspection for crucial parts of plant and equipment, especially in cases where major safety risks are involved.

The government plays an important role in promoting or establishing these institutions. Many developing countries lack this necessary institutional set-up.

In the field of education and training governmental policy comprises the following measures:

Promotion of the education of skilled labour by establishing training centres and vocational schools;

Encouragement of closer contacts between industries and educational institutions;

Inclusion of the problems of maintenance, repair and proper operation of equipment in the curricula of vocational schools;

Organization of the exchange of experience among repair and maintenance personnel.

In addition to these various direct actions, the government can apply indirect measures of promotion such as the following:

(a) A rational depreciation policy conducive to the modernization of installed plant and equipment;

(b) Tax and credit policy measures, subsidies

and or state capital participation to help create specialized repair shops, spare parts, stores and specialized factories for producing spare parts;

(c) Foreign exchange and tariff regulations that permit adequate imports of spare parts, technical services and replacement of machines not produced domestically.

In view of the adverse balance of payments and scarcity of foreign exchange in most developing countries, policy decisions that may call for imports of replacement parts and maintenance services require special attention. In short, it can be said that the policymaker in a developing country has a two-fold task: he must minimize foreign exchange outlays on these imports, but he also has to assure a continuous and adequate supply of these items to all public and private enterprises.

There are several measures that the Government can adopt to achieve these aims. It should endeavour to increase efficiency of maintenance and economy in spare parts utilization, by improving the skills of the maintenance and repair personnel who investigate the causes of breakdowns, specify services required and order spare parts. A flexible policy is needed in regard to administrative restrictions and tariffs on imports of spare parts in order to speed up the delivery of spare parts. Spare parts should be given special treatment in customs procedures and import tariff policies. Finally, the Government should initiate a rigorous import substitution policy to build up repair shops and workshops producing spare parts within the country.

Such a policy cannot consist merely in levying high tariffs on imports of spare parts to protect the local producers from foreign competition. Tariff barriers have to be temporary and be accompanied by additional, positive measures on the part of the Government. Thus, local production can be stimulated by technical services, credits, training facilities, etc. The introduction of administrative or tariff restrictions on imports of spare parts and maintenance services may bring some foreign exchange savings in the short run, but will inevitably lead to underutilization of imported equipment on which large amounts of foreign exchange were spent previously. There will therefore be no saving in the long run.

In the case of export industries, if achieving foreign exchange savings by reducing imports of spare parts and maintenance services has an adverse effect on output, the value of the savings could easily be outweighed by the subsequent losses in export proceeds. In domestic market oriented industries the corresponding cost-benefit calculation compares output losses with foreign exchange savings. (Here a shadow price for foreign exchange might have to be used to value losses in supplies to the domestic market.) In addition, the demand for other imported goods may increase, due to the fact that some domestic industries are forced to operate below capacity through lack of spare parts, etc. and cannot fully meet the domestic demand.

Data requirements

The governmental bodies and other relevant institutions require information on existing plants and their equipment, in order to carry out these policy measures.

The method of collecting the data as well as the type of data asked for are obviously related to the economic system. In market economies capital equipment is subject only rarely to centralized stock-taking, whereas in centrally planned economies usually very detailed information on the national capital stock is collected and used by ministries, planning agencies, etc.

In market economies it is customary to employ indirect methods of estimation, using balance sheets of individual companies, retrospective data on investment, data on output, imports and exports of capital goods and inquiries, mainly by sample.[4]

In centrally planned economies the fixed capital stock and its development are normally the subject of very detailed reporting. In Czechoslovakia, for instance, a centralized system was introduced to obtain information annually on the current state of all machinery in the engineering industry, of railway wagons, main machines in coal mining, etc.

Data are collected not only in value terms but also in technical terms. The whole system is based on a rational computing technique (punch cards). The content of the system can be seen from the example of a punch card in table 18.

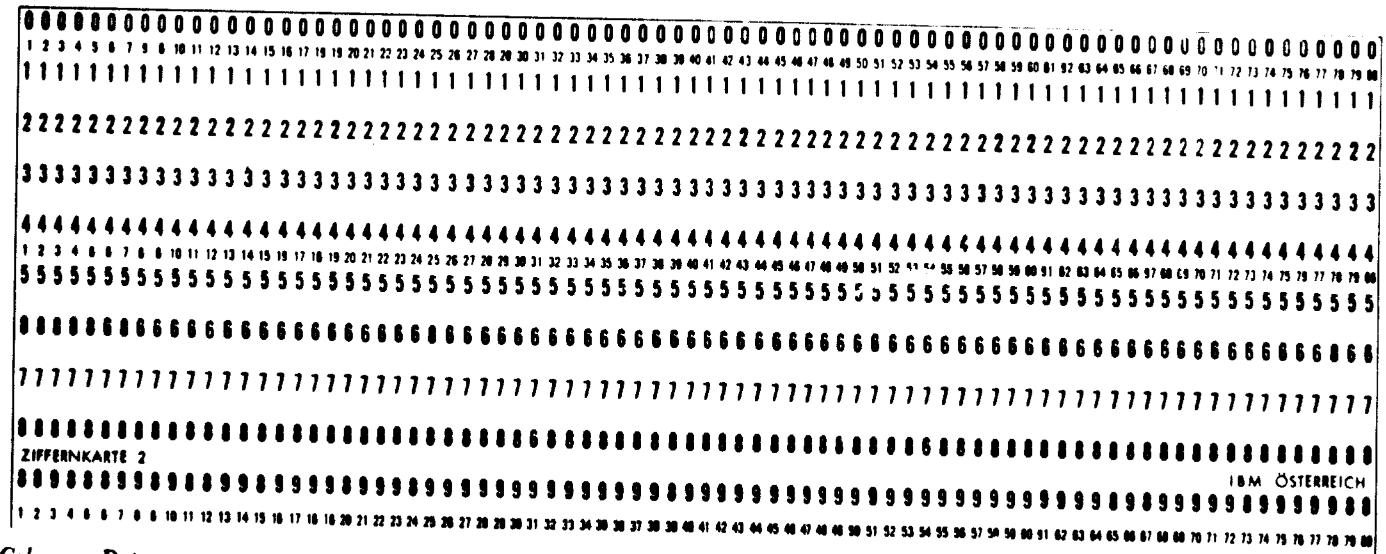
Such a detailed, centralized information system requires a whole complex of organizational prescriptions, normative definitions, classifications and code numbers. This is necessary to identify each machine and to get information about the extent and composition of the machine park in different enterprises, industries, regions, etc. The system is based on primary records provided by the factories on a standard form. It also serves as an efficient means of rationalizing the information system within individual enterprises.

In all economic systems tax policy requires some basic standardization of the recording of installed capital equipment. Special regulations usually define the methods of book-keeping for plant and

[4] For example, the US journal *American Machinist* sent out questionnaires to ascertain the state of machinery in the metalworking industry.

Table 18

DESCRIPTION OF A PUNCH CARD FOR THE STATISTICS OF INSTALLED MACHINES



Column	Data
0– 5	Classification Code
6– 7	Country of origin
8–20	Producer, model
21–25	Purchase price
26–30	Weight in kg
31–40	Technical characteristics
41–45	Maintenance characteristics
46–47	Year of production
48–50	Central organ (industry)
51–52	Industry sector
53–54	Enterprise
55–56	Plant
57–58	Shop
59–	Free columns

equipment, the definition and valuation as well as the periodical inventories of these assets.

Most problems connected with such regulations at the plant level have already been discussed. The revaluation of installed plant and equipment, when the nominal value differs widely from the present real value is a special problem. The process is a very expensive and complicated one. The aim in standardizing valuations is to create a more reliable basis for the calculation of depreciation charges. The valuation is based either on price indices or on price lists. A new valuation can be combined with the so-called general censns (inventory of existing plants and equipment in the country, region or industry), such as occurred in 1954 in Czechoslovakia and in 1960 in the USSR.

Development strategy

Developing countries have to carry out their industrialization programmes under much more capital-intensive investment conditions in almost every industrial sector than today's industrialized countries faced in the nineteenth century. In addition, a rather clear division of labour has arisen between the operation and maintenance of plant and equipment. That is the reason why repair and maintenance have gained such importance and become an inherent part of any sound development policy.

Some developing countries find themselves unable to adopt new technologies, because they lack facilities to provide maintenance and repairs on an adequate scale. In such a situation even equipment provided through grants can become a burden to the receiving country.

A number of aspects of replacement, repair and maintenance are relevant to formulation of the fundamental principles underlying the setting of long-term aims for economic development. The replacement, repair and maintenance of existing plant and equipment is one of the essential conditions for economic development. Replacement and, to a certain extent, repairs represent alternatives to building new capacity.

Replacement, repair and maintenance requirements place specific demands on economic resources and consequently represent an important limitation to economic development in an optimalization exercise.

The demand for replacement, repair and maintenance forms an appreciable part of the demand structure for commodities. We can therefore regard it as a structural limitation of the process of economic development.

A certain similarity can be found between the supply of services, spare parts and replacement machines on the one hand and the supplies of intermediates on the other hand. Problems of repair and replacement are treated accordingly. All supplies mentioned are described in the matrix of inter-industry relationships (technical coefficients). Furthermore, replacement, repair and maintenance place specific demands on qualified labour and material supplies. The availability of these resources constitutes a limiting factor of economic development.

Maintenance, repair and replacement require production factors of the same technological nature as new investments, drawn mainly from the engineering industries and construction. They therefore form a competing demand. Moreover, they need a great number of skilled personnel at intermediate levels which is the scarcest factor in developing countries.

Where investment resources are extremely limited, repair can be considered an alternative to development. In order to concentrate investment on important development projects, the replacement of existing plant and equipment can be delayed by prolonging their service life. Developing countries do not usually need to economize on labour costs through innovations and modernization of equipment as do the highly industrialized countries; on the contrary, investment is often motivated by the aim to create additional employment opportunities. Thus abundance of labour logically favours extension of the service life of capital equipment.

In developing countries the proportion of machinery older than ten or even twenty years is rather large. This is an inevitable consequence of delaying the replacement of equipment in order to invest instead in additional production capacity and to increase industrial employment.

To a certain extent it is also possible to delay major overhauls. There are, of course, certain technological and economic limits to postponing replacement or repair, overstepping which results in the misallocation of resources. The introduction of measures limiting investment outlays on replacement may lead to a situation in which the cost of overhauls becomes higher than the cost of buying new equipment.

The modernization and rational utilization of older machinery acquire strategic importance in implementing an industrialization programme since in this way existing equipment in many industries can be adapted to the requirements of modern technology. Modernization is usually less costly (in terms of investment funds) than replacement and it facilitates the adaptation of machinery to the conditions of production.

Another important way of reducing investment outlays for industrial development is the purchase of second-hand machines and equipment. It is obvious that the use of older machines can be justified only if the cost of their repair and modernization is less than the cost of new machines. It is therefore absolutely necessary to check this by an efficiency analysis. Although the installation of second-hand equipment reduces the purchasing cost, it usually increases the repair and maintenance costs. Furthermore, the use of second-hand equipment is generally a hindrance to the standardization of installed equipment. Considerations of technical efficiency must be kept in mind even in cases of very favourable purchasing conditions.

The various material and organizational prerequisites for adequate maintenance, repair and replacement form an important part of the industrial infrastructure. The construction of specialized repair shops, factories for production of spare parts and stores to stock them are a specific problem for the policy maker. Among the institutional conditions for smooth operation of plant and equipment, the whole set-up of training, consulting and research institutions play an important role.

The problem of maintenance and repair has an impact on the time-scheduling in economic programming. The conditions for assuring these services must be created from the very outset of the execution of the investment programme. The need for overhaul and replacement usually arises several years after the plant and equipment have been put into operation and is of a stochastic character. Most of the requirements appear after a period corresponding approximately to the average service life of a given item of equipment and its parts. The necessity to install maintenance and repair capacities from the beginning stems, however, from the frequent incidence of initial troubles during the running-in period.

The time-scheduling must include advance training of an adequate number of repair and maintenance workers and lubrication specialists. Approximately half of these workers must be available during the running-in period of equipment. For the same reasons, the main stock of spare parts and maintenance materials must be available from the very beginning.

Lastly, the comment should be made that maintenance and repair activities form a logical basis for the development of local engineering industries.

APPENDIX 1

A SYSTEM OF INDICATORS FOR PLANNING REPAIR

This simplified example of a repair plan (see table 19) consists of a set of the most important indicators of the interrelationships between needs and resources for repair activities. The data are obtained from empirical studies undertaken in the Czechoslovak chemical industry.

Repair needs are calculated here for four groups of plant and equipment, which differ in their needs for repair and in the labour and material required:

(a) Machinery;
(b) Electrical equipment;
(c) Measuring devices;
(d) Buildings and structures.

The necessary resources are classified as follows:

(a) Labour inputs:
  repair workers
  technical and administrative personnel;
(b) Material inputs:
  spare parts
  — produced in own workshops
  — delivered from outside
  other materials;
(c) External repairs (services delivered from outside).

The final balance of requirements against resources for repair is struck on the basis of cost calculations.

By prerequisites, we understand here a system of standards that form the basis of a repair plan and define:

(a) The relative need for repair of the various categories of fixed assets;
(b) The corresponding inputs of labour and material;
(c) The related volume of spare parts and materials to be stocked; and
(d) The degree of self-sufficiency of the enterprise or industry in repair services and production of spare parts.

These standards are based on thorough analyses which precede the actual planning process.

The example is meant to cover a period of up to five years on an average annual basis. It can be applied both for an individual enterprise and for more aggregated units. According to the length of the plan period and the level of planning, the needs and resources for repair can be disaggregated. Thus, the needs can be divided according to different kinds of machines, different kinds of repairs, etc. The classification of spare parts and material inputs can be made according to technological, organizational or other criteria.

Table 19

AN EXAMPLE OF A REPAIR PLAN

Item	*Indicator*	*Unit*	*Total*	*Machinery*	*Electrical equipment*	*Measuring devices*	*Buildings and structures*
	I. PREREQUISITE DATA						
A	Value of fixed assets	Thousand dollars	50,000	24,500	5,000	3,000	17,500
B	Ratio of repair costs to value of fixed assets	Per cent	...	8.0	7.0	12.0	1.3
C	Degree of self-sufficiency in repairs	Per cent	...	70.0	70.0	60.0	20
D	Degree of self-sufficiency in production of spare parts ...	Per cent	...	25.0	20.0	15.0	...
E	Annual repair output per repair worker...........	Thousand dollars	...	8.0	7.0	8.3	5.5
E'	Fixed assets per repair worker	Thousand dollars	...	100.0	100.0	70.0	440.0
F	Ratio of annual consumption of spare parts to value of fixed assets	Per cent	...	1.43	1.04	1.62	...
G	Ratio of annual consumption of materials to value of fixed assets..................	Per cent	...	0.41	0.56	0.70	0.09

... Not available.

Table 19 (cont'd)

Item	*Indicator*	*Unit*	*Total*	*Machinery*	*Electrical equipment*	*Measuring devices*	*Buildings and structures*
	I. PREREQUISITE DATA (cont'd)						
H	Ratio of spare parts stock value to value of fixed assets	Per cent	...	2.15	1.87	2.60	...
H'	Stock of spare parts in relation to annual consumption. . . .	Years	...	1.5	1.8	1.6	...
I	Ratio of materials stock value to value of fixed assets	Per cent	...	0.41	0.56	0.70	0.60
I'	Stock of materials in relation to annual consumption	Years	...	1.0	1.0	1.0	0.7
J	Average annual wage of repair workers	Dollars	...	2,680	2,490	3,080	2,000
K	Ratio of overhead costs to wage costs	Per cent	...	100	90	80	70
L	Technical and administrative staff in relation to number of workers	Per cent	...	18.0	16.0	17.0	12.0
	II. CALCULATION OF THE VOLUME OF REPAIR ACTIVITIES						
a	Total annual cost of repairs $\left(A \frac{B}{100}\right)$	Thousand dollars	2,900	1,960	350	360	230
b	Cost of repairs effected with own facilities $\left(a \frac{C}{100}\right)$	Thousand dollars	1,875	1,370	245	215	45
c	Value of repairs effected externally $\left(a - b = a \frac{100-C}{100}\right)$	Thousand dollars	1,025	590	105	145	185
	III. CACULATION OF NUMBER OF REPAIR PERSONNEL						
d	Repair workers $\left(\frac{b}{E} = \frac{A}{E} \frac{C}{100}\right)$	Persons	241	172	35	26	8
e	Technical and administrative personnel $\left(d \frac{L}{100}\right)$	Persons	42	31	6	4	1
f	Total repair personnel $(d + e)$	Persons	283	203	41	30	9
	IV. CALCULATION OF SPARE PARTS AND MATERIALS						
g	Annual consumption of spare parts $\left(A \frac{F}{1{,}000}\right)$	Thousand dollars	451	350	52	49	—
h	Annual consumption of materials $\left(A \frac{G}{1{,}000}\right)$	Thousand dollars	164	100	28	21	15

. . . Not available.

Table 19 (cont'd)

Item	*Indicator*	*Unit*	*Total*	*Machinery*	*Electrical equipment*	*Measuring devices*	*Buildings and structures*
	IV. CALCULATION OF SPARE PARTS AND MATERIALS (cont'd)						
i	Annual consumption of spare parts and materials $(g + h)$ . . .	Thousand dollars	615	450	80	70	15
j	Own production of spare parts $\left(g \frac{D}{100}\right)$	Thousand dollars	105	88	10	7	–
k	External purchases of spare parts $(g - j)$	Thousand dollars	346	262	42	42	–
l	Stock of spare parts $\left(A \frac{H}{1,000} = g H'\right)$	Thousand dollars	698	527	93	78	–
m	Stock of materials $\left(A \frac{I}{1,000} \frac{C}{100} = h I'\right)$	Thousand dollars	159	100	28	21	10
n	Stock of spare parts and materials $(l + m)$	Thousand dollars	857	627	121	99	10
	V. COST CALCULATIONS						
o	Labour costs per year $(d J)$ . . .	Thousand dollars	643	460	87	80	16
p	Materials and spare parts costs (i)	Thousand dollars	615	450	80	70	15
q	Overhead costs $\left(o \frac{K}{100}\right)$	Thousand dollars	614	460	78	65	11
r	Total costs $(o + p + q = b)$ . . .	Thousand dollars	1,872	1,370	245	215	42

. . . Not available.

APPENDIX 2

A MODEL FOR THE ANALYSIS AND PLANNING OF REPLACEMENT

The analysis of replacement requirements needs to be made at the sectoral and national levels when assessing long-term prospects. The following model will serve to throw light on this problem. The data used are drawn from empirical studies in the metalworking industry[5] and therefore the model is not only a methodological instrument, but also an actual illustration of the development of a system of plant and equipment.

The aim of the model is to provide a quantitative analysis of the volume of replacement of such a system, for example, the machine tools or looms in use or the fleet of vehicles. This national stock of plant and equipment is usually far from homogeneous. Therefore, special attention is paid to analysing the structure of plant and equipment and the impact of changes in structure on the volume and composition of replacement demand, which are examined in physical and money value terms.

Requirements in physical terms

The volume of requirements expressed in physical units, e.g. the number of machines, depends on the time period under consideration, the size of the system, its growth rate, age composition and service life.

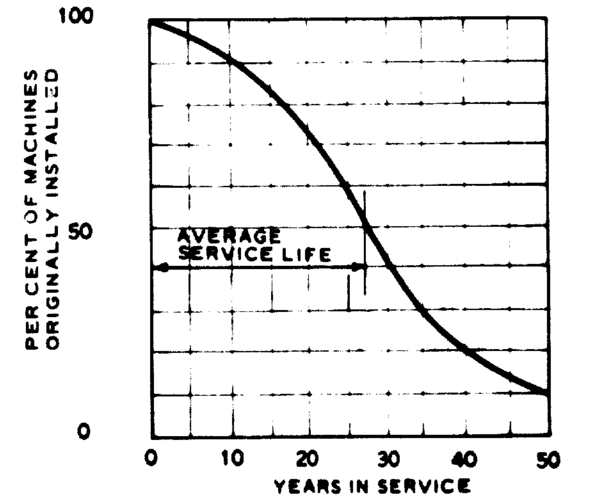
The availability of data on the volume, rate of growth, age and service life of plant and equipment is thus the precondition for an analysis of replacement requirements. The model describes the interrelationships of these data and their use for analysis (see table 20).

Special attention must be paid to the characteristics of the service life. Information on the average service life is not sufficient. Empirical analyses show that the service life of individual items can differ substantially from the average, because of the stochastic nature of the process of renewal. The calculations must therefore be based not only on the average service life, but on the survival curve as well.

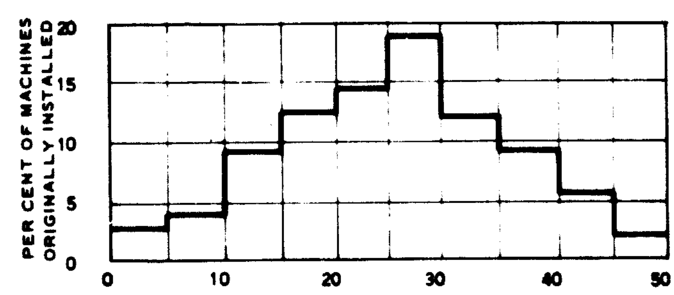
The survival curve describes the rate of scrappage over future years of machines installed at a given time. From this curve the number of machines of various age groups to be scrapped during the plan period can be estimated. The survival curve is used for the calculations in table 20. There are substantial differences in the scrappage rate of machines in the various age groups. In the illustrated case (see figure 8) the median service life of the machines—the age at which 50 per cent

Figure 8

SURVIVAL CURVES



PROGRESSIVE DECREASE IN THE NUMBER OF INSTALLED MACHINES AND THEIR AVERAGE SERVICE LIFE (SURVIVAL CURVE)



PERCENTAGE OF MACHINES SCRAPPED IN VARIOUS PERIODS OF UTILIZATION

of the original number has been scrapped—is 27.5 years, while about 10 per cent survive the age of 50 years.

According to table 20, the requirements for replacement during the years 1961—1965 total 1,378 machines. If the planning of future needs had been based simply on the age composition and an estimated "normal" service life of 27.5 years, it would have led to a completely unrealistic conclusion.

In this scheme the analysis and projection of the survival curve is the basis on which the number of machines scrapped and the volume of replacement necessary is determined (the number of machines and their age composition being given).

The model enables the planner to follow up the effects of structural changes and he can then take them into consideration in analysing the replacement needs.

Replacement, as part of a rational investment policy, contributes to the process of technical innovation. In the example given in table 20, an

[5] V. Nesvera (1963), Rozvoj technické základny strojírenství, Prag.

Table 20

AN ILLUSTRATIVE MODEL FOR THE ANALYSIS OF RENEWAL IN PHYSICAL TERMS

		Age of capital equipment in years						
	Total	*up to 5*	*6–10*	*11–15*	*16–20*	*21–25*	*26–30*	*over 30*
Number of machine tools, 1.1.1961	10,000	2,200	1,900	1,300	2,300	1,200	500	600
Rate of scrappage in next 5 years . . .	13.8	3.8	6.4	11.6	17.0	25.8	31.4	27.7
Number of machines scrapped, 1961–1965	1,378	83	122	151	390	309	157	166
Gross increment – new machines, 1961–1965	2,248							
Number of machine tools, 31.12.1965	10,870	2,248	2,117	1,778	1,149	1,910	891	777
Number of grinding machines, 1.1.1961	2,000	770	510	310	210	110	50	40
Rate of scrappage in next 5 years . . .	22.5	13.0	28.0	27.4	27.1	27.3	28.0	27.5
Number of machines scrapped, 1961–1965	440	100	143	85	57	30	14	11
Gross increment – new machines, 1961–1965	930							
Number of grinding machines, 31.12.1965	2,470	930	670	357	215	153	80	65
Percentage of grinding machines								
in total number of machine tools, 1.1.1961	20.0							
in total number of machine tools, 31.12.1965	22.7							
in gross increment, 1961–1965 . .	41.4							

important trend in the use of machines is shown. Grinding machines represent an increasing proportion of the total installed machine tools (20.0 per cent in 1961, 22.8 per cent in 1965) and have a relatively short service life, as shown by their higher scrap rates.

Consequently, the share of these machines in the number of new machine tools was about twice as high as their share in the total number of installed machines.

Requirements in money value terms

The requirements for replacement of plant and equipment are more often calculated in value terms, based on investment outlays. Two alternatives are possible: one can adopt gross values (purchase cost) or net values (purchase cost less depreciation charges).

When the calculations are based on the gross value of installed plant and equipment, they must take into account the length of the plan period, the volume of fixed assets and their age and service life. In addition, changes in the purchase cost of individual items must be included in the calculations. Empirical analyses show that generally the money value of plant and equipment increases faster than their physical volume (expressed in terms of the number of machines, floor area, etc.). This is due to improvements in technical performance and changes in composition of the machinery. Thus, in table 21, the number of installed machine tools increased in a 5 year period by about 9 per cent, whereas their value increased by 25 to 30 per cent.

Under these circumstances, if the value of replacement demand is simply calculated by reference to the volume of scrapped machines, it will be understated. The average value of scrapped machines is related to the level of prices a number of years previously, corresponding roughly to the average service life of those machines.

In the case of the installed machine tools, the machines scrapped yearly represented 2.5 to 3 per cent by number and about 2 per cent by value. This example confirms another rule: the service life of the more expensive machines is on average longer.

If the replacement requirements are calculated on the basis of the net value of plant and equipment, they are traced through the depreciation charges and therefore depend on the method of depreciation and, of course, the length of the plan period. The depreciation charges usually exceed the real value of renewal requirements because they are included from the very beginning of the functioning of plant and equipment, whereas the real requirements for replacement follow with a

Table 21

AN ILLUSTRATIVE MODEL FOR THE ANALYSIS OF RENEWAL IN TERMS OF VALUE

		Age of capital equipment in years						
	Total	*Up to 5*	*6–10*	*11–15*	*16–20*	*21–25*	*26–30*	*over 30*
Number of machine tools, 1.1.1961	10,000	2,200	1,900	1,300	2,300	1,200	500	600
Their purchase cost in million dollars	42.61	13.20	9.12	5.55	8.95	3.25	1.15	1.39
Average purchase cost per machine in thousand dollars	4.26	6.00	4.80	4.27	3.89	2.71	2.30	2.32
Number of machine tools scrapped in next 5 years	1,378	83	122	151	390	309	157	166
Their purchase cost in million dollars	4.36	0.25	0.47	0.60	1.48	0.82	0.36	0.38
Average purchase cost per machine in thousand dollars	4.00	2.97	3.83	3.97	3.80	2.66	2.27	2.30
Number of new machine tools, 1961–1965	2,248							
Their purchase cost in million dollars	16.03							
Average purchase cost value per machine in thousand dollars	7.13							
Number of machine tools, 31.12.1965	10,870	2,248	2,117	1,778	1,149	1,910	891	777
Their purchase cost in million dollars	54.29	16.03	12.95	8.65	4.95	7.47	2.44	1.80
Average purchase cost in thousand dollars	4.99	7.13	6.09	4.86	4.31	3.91	2.74	2.32
Age distribution of machines, according to number, 1961	100.0	22.0	19.0	13.0	23.0	12.0	5.0	6.0
value, 1961	100.0	31.0	21.4	13.0	21.0	7.6	2.7	3.3
number, 1965	100.0	20.7	19.5	16.4	10.6	17.6	8.2	7.0
value, 1965	100.0	29.6	23.9	15.9	9.1	13.7	4.5	3.3

considerable time-lag. The effect of this lag is considerable, especially when there is a high rate of growth of the fixed assets. It must also be mentioned that tax legislation generally dictates the depreciation rates and that the use of depreciation charges or net value of fixed assets as the basis for calculating the service life and replacement requirements is of dubious validity.

The different concepts that may be adopted for calculating the requirements for replacement lead to different results. It is recommended that calculations in physical terms should be used to establish a realistic policy. The indicators obtained by these means make it possible to weigh the existing state of plant and equipment against the technical innovations and changes on the market. After all, innovation is the primary motive and impulse for replacement.

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