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INDUSTRIALIZATION AND PRODUCTIVITY

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BULLETIN

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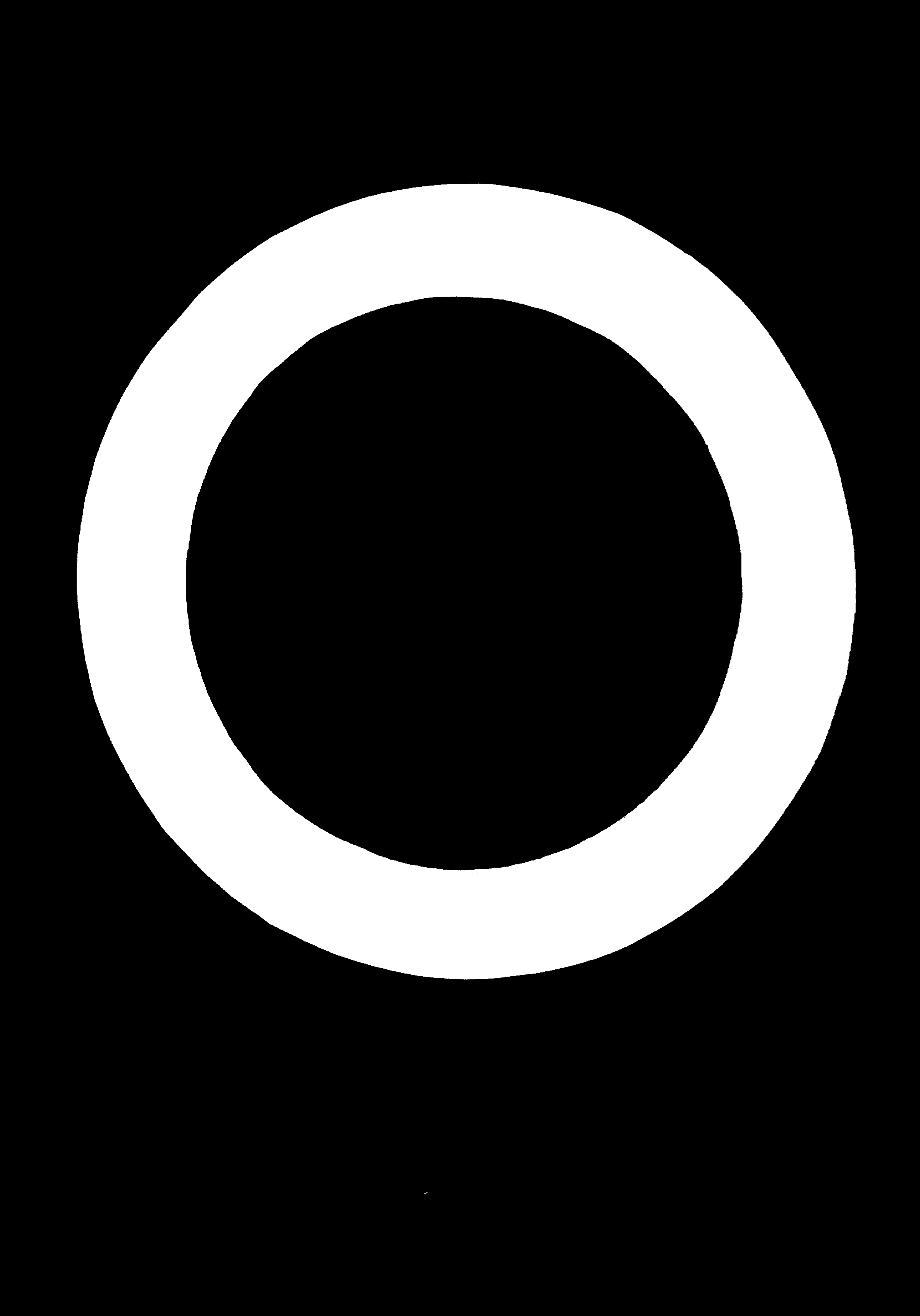

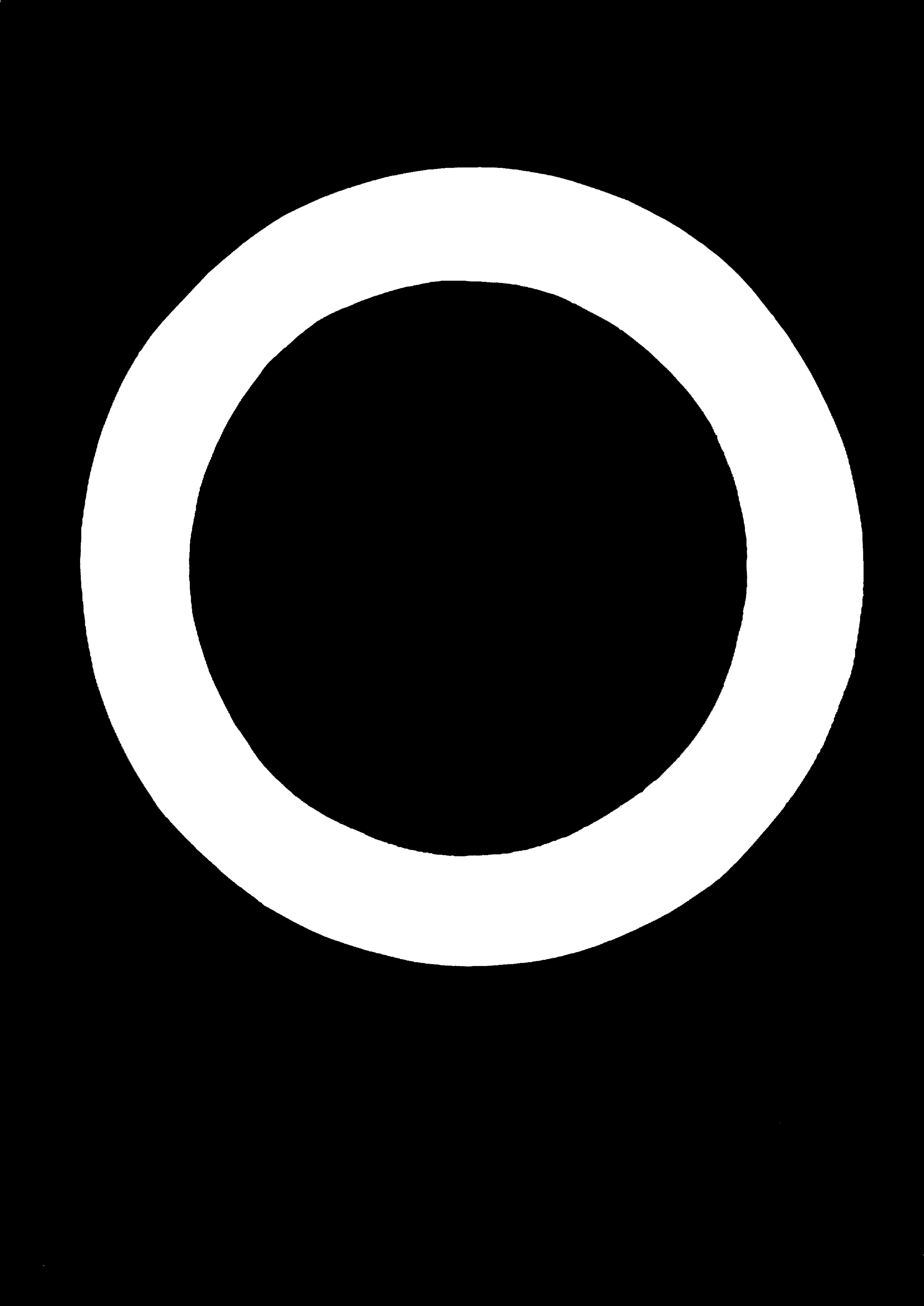

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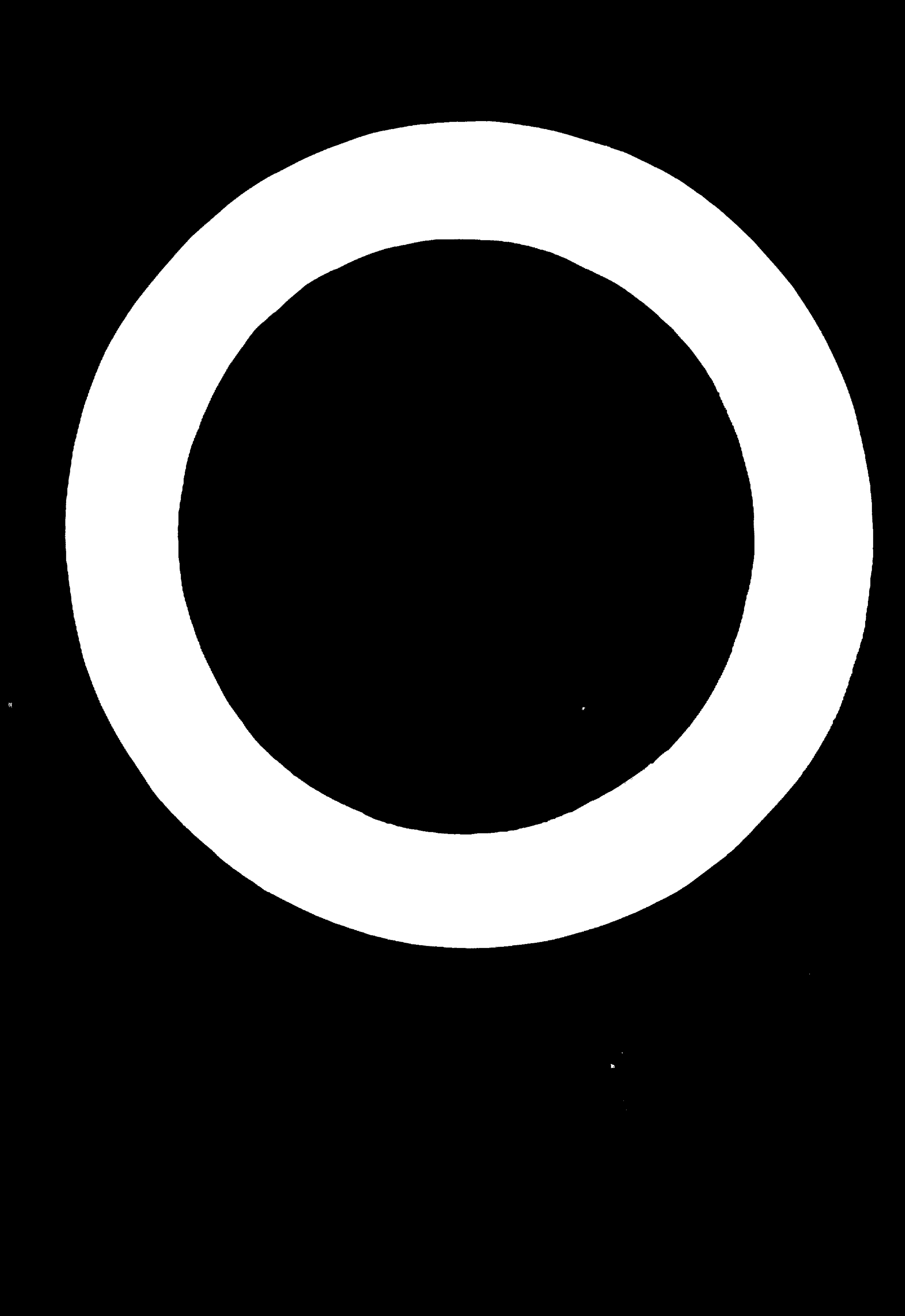

In this issue

Cover illustration: Maintenance man adjusting a direct current generator. An article in this issue discusses the use of industrial equipment in under-developed countries with special reference to maintenance and repairs

INDUSTRIALIZATION AND PRODUCTIVITY

BULLETIN 4

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Preface

In this issue of the *Bulletin on Industrialization and Productivity*, as in the preceding issues, the Secretariat of the United Nations presents a number of studies pertaining to its work programme on industrialization. In recent decisions, the Economic and Social Council and the General Assembly have requested the Secretary-General to place special emphasis, in the further development and implementation of the work programme, on "studies on economic programming techniques as applicable to industrialization" and the "most effective application of modern industrial methods of production and management techniques to the establishment and operation of industries in the under-developed countries". The present issue reflects to some extent this orientation of the programme.

The subject of programming techniques is dealt with in the first two articles—"Use of Models in Programming" and "Programming Techniques for Economic Development". The first article reviews representative types of development models which have been proposed for and—in some cases—applied in the elaboration of national plans for economic and industrial development, and attempts to evaluate the applicability of such models to countries at different stages of economic development in the light of the experience gained under the United Nations technical assistance programme. The second summarizes a report prepared by a group of experts with a view to providing guidance to countries in Asia and the Far East in programming their economic development.

The third article, "Choice of Techniques: the Experience of Japan and its Implications for Under-developed Countries", by Mr. S. Okita, is a further contribution to a matter of considerable importance in planning economic development, namely, that of the appropriate combination of factors of production in relation to their endowment, a problem generally referred to as that of capital intensity. Mr. Okita's article is a continuation of the series of studies on the subject published in the first three issues of the *Bulletin*.

The next article, "Use of Industrial Equipment in Under-developed Countries: Problems of Maintenance, Repairs, Replacement and Obsolescence", deals with the problem of how to ensure the most effective utilization of capital equipment in industry, so as to reduce the rate of consumption of available capital. The study discusses the principles and practices followed in the developed countries to achieve optimum performance of industrial equipment, including replacement practices, and appraises their applicability under the conditions obtaining in the less developed economies.

Engineering and technical skill is another resource whose scarcity hinders not only the operation, but also the establishment of industry in under-developed countries. A means of increasing and improving its supply is studied in "In-plant Training of Graduate Engineers", by Mr. Yap Kie Han. The article reviews the experience gained in industrial countries and underlines the possibilities which in-plant training of engineers offers to the less developed ones.

The need for services to protect the health and safety of industrial workers is discussed in an article on "Health Problems of Industrialization" by Professor R. S. F. Schilling, a consultant in this field to the World Health Organization. The article stresses, in particular, the need for integrating medical care and health protection in planning industrialization projects.

The last article reviews recent United Nations activities in industrialization. It provides information on the developments in the Secretariat's work programme on industrialization and the decisions of the Economic and Social Council and the General Assembly, mentioned above. It is concerned, in particular, with the decisions pertaining to the establishment of a Committee for Industrial Development, one of whose main functions is to examine the work programme and to make recommendations concerning its further development.

Use of Models in Programming

Prepared by the Division of Industrial Development of the United Nations Department of Economic and Social Affairs on the basis of reports by United Nations Technical Assistance Experts

INTRODUCTION

In the preparation of this study, the Division has had the co-operation of Professor Hollis B. Chenery of the Research Center in Economic Growth of Stanford University.

PROGRAMMING IS WIDELY used in formulating industrial development policies in the less developed countries. The United Nations has contributed to the work in this field through various studies undertaken by the Secretariat at Headquarters and by the secretariats of the regional economic commissions, and through direct assistance to Governments under its technical assistance programme.

The elaboration of development programmes relies on the existence of a certain number of interrelationships in the economy. Whether a system of such relationships, which constitutes an "economic model", is explicitly formulated or implicitly assumed is not important. The soundness of a programme will depend largely on whether and to what extent the relevant relationships have been taken into account in formulating it. The purpose of this article is to examine representative types of models that are now being used in some countries for national economic and industrial planning purposes, and to attempt a preliminary evaluation in the light of the available experience under the United Nations technical assistance programme and elsewhere. Emphasis must be laid on the preliminary character of any findings or judgements expressed in this study.

Work in the use of development models, including the application of inter-industry models, has been carried out by the secretariat of the Economic Commission for Latin America (ECLA), and a report by a working party on programming techniques sponsored by the secretariat of the Economic Commission for Asia and the Far East (ECAFE)[1] contains a description of various types of models and mathematical examples of the types described; it also examines data requirements and other problems arising in the use of such models in the countries of the region. More recently, the secretariat of the Economic Commission for Africa (ECA) has investigated problems of applying programming techniques to African economies.[2] Much work in this field has also been done outside the United Nations by academic and governmental research institutions. The present study examines the uses made of some of these models and may be considered as a complement to previous United Nations studies on this subject, in particular to the ECAFE report.

An economic model is an organized set of relationships that describes the functioning of an economic entity, whether it be a household, a single industry or a national economy, under a set of simplifying assumptions. As mentioned above, all economic reasoning is based implicitly or explicitly on models, but this study is concerned only with those models, or explicit relationships within a model, that can be expressed in quantitative terms and for which data can be assembled. The data and relationships required for constructing a model are usually either based on the *past* experience of the economy concerned or "borrowed" from economies considered to be sufficiently similar. Before using such models for planning purposes it is necessary either to adopt certain specific assumptions with respect to the country's future or to adjust the historical relationships to allow for prospective changes. The extent to which the quantitative value and the direction of the changes in the relationships are correctly anticipated determines the reliability of the model for planning purposes.

[1] A brief note on this report will be found elsewhere in the present issue.

[2] *See* documents of the United Nations Economic Commission for Latin America, the Economic Commission for Asia and the Far East and the Economic Commission for Africa listed in parts II and III of the bibliography appended to this article. An extensive bibliography is contained in the ECAFE document. Among the books on economic programming techniques, *see* J. Tinbergen, *Economic Policy: Principles and Design* (North-Holland Publishing Company, Amsterdam, 1956); H. B. Chenery and P. G. Clark, *Inter-industry Economics* (John Wiley and Sons, Inc., New York, 1959), and P. J. Bjerve, *Planning in Norway, 1947-1956* (North-Holland Publishing Company, Amsterdam, 1959), which present thorough discussions of this subject, with applications.

Models can be applied to the determination of economic policies in two different ways. In the first and simpler case, it may be desired to determine the effects of a particular set of economic measures, for example, of investment in certain sectors. The measures and other data are taken as given, and the model is used to trace their effects throughout the economy.[3] In the second case, a certain set of objectives is specified, such as a given rise in income or employment or a given reduction of a balance of payments deficit, and the model is used to determine the most appropriate policy measures to achieve these objectives. Although both types of analysis are valuable for programming purposes, the second will be given particular attention. In the first place, underdeveloped economies are more likely to think of programming in terms of choice of policy measures; in the second place, the use of models has its greatest advantage over more intuitive methods precisely for this type of analysis.

A policy model of the second type consists of the following elements:

(1) A specified set of *objectives*—such as maximum income, full employment, reduced balance of payments deficit—which defines the objectives of the development programme;

(2) A set of *instrument variables* related to the policy measures that a government intends to use to achieve its objectives. Examples of instrument variables are levels of savings, production and investment by sector, exports, or other magnitudes that it is intended to influence in some way. The instrument variables are affected by measures such as subsidies, taxes, or direct public investment to achieve a given level of output;[4]

(3) *Other variables*, not directly affected by government action, but which are necessary for an adequate analysis of the economy, such as consumption of individual commodities, and prices of commodities and of productive factors;

(4) *Economic relationships* in the form of equations containing the variables mentioned above. Such equations may (*a*) describe the behaviour of an economic entity in terms of a response of one economic variable to a change in another variable (for example, a consumption function); (*b*) express a technological relationship (for example, a production function), or (*c*) take the form of accounting identities that must hold true in any economy, such as the equality of total supply and demand. These last equations impose constraints upon the values of the component variables that must be simultaneously satisfied in order to obtain a programme that is at all feasible.

A solution of a model consists of a set of values for the instrument variables that satisfies all the equations in the model. As a rule, values of some of the variables are fixed by prior analysis and the model itself determines the values for only as many variables as there are equations. The same basic model may be solved for different dependent variables. For example, the Harrod-Domar model in its simplest form states that the rate of growth of income depends on the proportion of income saved and the capital-output ratio. According to the circumstances, different combinations of two variables will be taken as given and the equation solved for the third. The model may thus serve to determine either the rate of growth that can be achieved with a given economic structure, the savings rate required to attain a given rate of growth, or the upper limit of the capital-output ratio if both growth and savings rates are fixed.

All of the models used in development programming are basically similar because they describe the same set of economic phenomena, except that in the various models some relationships are selected as being of greater relative importance for a given situation. The choice among the various relationships will be determined by the economist according to the terms of reference of his task, including the general political and economic goals which have been set up by the authorities. It is true that the terms of reference may be very general and vague; or the goals which are pre-set by the authorities—such as "raising per capita income", "providing full employment" and "reducing the gap in the balance of payments"—may be competing ones or mutually inconsistent. In such cases, the economist will have to decide for himself which key variables are to be considered for the construction of his first preliminary model. Whether the initial choice of the relationships is based on economic intuition or is given beforehand, this first model could be checked subsequently by constructing a more complex model through the addition of other elements. The ultimate test of a model is that it should make the best use of the available information and analytical resources within the time available for its construction.

A few general observations may be added on the relationship between models, programming and the type of economy of a country. A model provides a systematic framework for economic programming; the purpose of programming, in turn, is to provide for an effective government economic policy which is consistent with the goals pursued. The nature of the development programme, and consequently the type of model, will differ in accordance with the nature and extent of government intervention and the type of instruments used. In principle, the effectiveness of economic programming based on the use of models is not necessarily related to any particular type of economic structure. Thus, programming can be usefully applied in economies ranging from those based predominantly on private enterprise

[3] These models are sometimes called "projection" models, in contrast to the second type of "decision" models.

[4] In some cases, the model is devised to determine the measures directly—the percentage increase in direct taxes, tariffs, or the amount of government investment and so forth—that will be necessary and sufficient to achieve the objectives. This type of "decision model" in the strict sense necessitates that the economic parameters of the model be known with a degree of accuracy which is generally achieved only in highly developed economies. For this reason such models are not discussed in the present study. For a detailed discussion of these, *see* J. Tinbergen, *On the Theory of Economic Policy* (North-Holland Publishing Company, Amsterdam, 1952).

to centrally planned economies where the government is fully in control of directing national economic activities. This study is primarily concerned with use of models in economies of the former type; among countries of this group, government intervention in the economy varies within a fairly wide range (for example, as in the Netherlands, Puerto Rico, India and Israel), yet programming and planning techniques have been applied with considerable success in some of them.

There are three types of models used in development programming:[5]

(1) *Aggregate models*, which apply to the entire economy and deal with production, consumption, investment and the like as single aggregates;

(2) *Sector models*, which apply to individual sectors;

(3) *Inter-industry models*, which are concerned with the relationships of the productive sectors of an economy with each other, and of each of these sectors with other entities of the economy.

[5] The present study is not concerned with short-term models used for year-to-year analysis.

It may be helpful to indicate some of the uses of each of these types. *Aggregate models* are used to determine possible growth rates in national income; the division of the national product among consumption (public and private), investment and exports; the required volume of domestic savings, imports and foreign financial assistance to carry out a given programme. *Sector models* are used to determine levels of production and consumption by economic sectors and to explore alternative production possibilities within individual productive branches. *Inter-industry models* serve to determine the demand for intermediate products and capital goods (including imports), and their solution provides for a mutually consistent set of production levels by economic sectors, and imports for the whole economy. It will be clear, however, from the following discussion that this subdivision is to some extent arbitrary, since, in practice, the dividing lines are not always so clear cut.

EXAMPLES OF MODELS USED IN DEVELOPMENT PROGRAMMING

AGGREGATE MODELS

THE RELATIONS MOST commonly included in an aggregate model are the following:

(1) A consumption-income (or savings-income) relation;

(2) A production function, relating national product to the input of capital and labour;

(3) An import function, relating import requirements to the level of national income or its components;

(4) The definition of domestic product on the expenditure side as the sum of consumption plus investment plus government expenditure on goods and services plus net exports of goods and services or—on the income disposal side—as the sum of consumption outlay plus net taxes plus savings;

(5) A certain number of "constraints" or limitations on resource use, such as: (*a*) the demand for labour cannot exceed the supply; (*b*) investment cannot exceed domestic savings plus net import of capital; (*c*) imports cannot exceed foreign exchange earnings plus net receipts from foreign loans and grants.

In most cases, not all these relations are used in the construction of the initial model. It is customary to focus on one or two of the resources considered to be of strategic importance in a given situation and on the relevant behaviour equations.

Capital-centred growth

When capital is felt to be the main bottleneck in economic growth, as is the case in many of the under-developed countries, the typical equations of the aggregate model can be consolidated into the Harrod-Domar equation. This simplification ignores or treats as given data—at least initially—the labour factor and the import requirements and determines the maximum growth achievable from the rate of investment and its "productivity" as measured by a capital-output ratio. Further refinements may be introduced into this simplified model to allow for other variables or objectives other than income growth.

In the case of Morocco and in the Greek five-year plan, the Harrod-Domar model was applied on an aggregate basis with no distinction among sectors. A capital-output ratio was applied to the over-all income target to estimate an aggregate investment figure. In the Algerian ten-year plan, and the plan frame for the Indian second five-year plan, capital requirements were calculated on a sectoral basis. In both plans the income targets and investment requirements were set initially on an aggregate basis; the over-all projections were then broken down by sectors. In the case of India, four main sectors were singled out: investment goods; factory-produced consumer goods; small-scale industry and agriculture, and services. The total investment figure was allocated among these sectors on the basis of priorities and the resulting rise in sectoral income and employment was projected consistently with the assumed priorities and over-all targets. In the case of Algeria, the economy was divided into nine sectors. Sectoral capital-output ratios were then applied, and the resulting rates of growth and investment requirements by sectors were reconciled with the first aggregate estimates by a process of successive approximations. A twenty-seven sector input-output table was used for that purpose. The capital requirements were then compared with the available supply of capital, the internal capital formation being estimated on the basis of the marginal propensity to save. The difference between investment requirements and internal savings (both public and private) provides a measure of the required foreign financial aid, unless the investment programme is scaled down. The process of adjusting investment requirements to capital availabilities in a capital-short economy is a process of successive approximations; it involves repeated evaluation and re-evaluation of the projects making up the investment plan by a process of successive eliminations and substitutions so as to achieve a balance between the demand for, and supply of, capital.[6]

Although a Harrod-Domar model is principally centred on the capital factor, it can also be used to indicate the extent to which it would be possible to achieve full employment of labour. The increase in employment which may be expected to result from the investment programme can be estimated by using either a labour-capital or a labour-output ratio. The former method was used in India; the latter in Algeria. It may then be found that significant gaps exist between the resulting direct increase in employment and the desired employment targets. In such a case, unless the employment target is abandoned as unachievable, certain other labour using activities, which are unrelated to the planned investment, may be suggested by the planner to fill the gap.

Employment-centred models

If labour is taken as a starting point in planning, national product will be projected, as a first approximation, on the basis of the available labour supply and the labour-output ratio. The implications of the resulting growth in output can then be ascertained from the remaining conditions. Compliance with constraints 5 (*b*) and 5 (*c*) mentioned above will determine the amount, if any, of requirements in foreign capital. If the latter is not available, a different pattern of national growth based on lower investment requirements and lower imports will have to be devised, unless the initially stated employment targets are reduced.

In Ceylon, a model was used in which the prime objective was to provide employment for the unemployed and under-employed labour force, taking into account the anticipated natural increase in the labour force by the end of the ten-year plan period. On the basis of the projected labour force and an assumed level of labour productivity, an estimate was made of the national product at the end of the period and during the intervening years. The distribution of this aggregate product among the various sectors was made as follows. In the case of consumption, it was done by introducing an assumption of a slight rise in per capita consumption, in conjunction with appropriate income-demand elasticities. Production for export demand was projected as an exogenous variable, and an aggregate gross investment figure was estimated. The estimates of domestic consumption, exports and investment provided the basis for a projection of import requirements and of the balance of payments. This first round of estimates showed a significant balance of payments gap which led to the next step, namely, an estimate of the required expansion of exports and development of import-substitute industries. Employment in the various sectors was then projected on the basis of the production levels thus obtained, and the aggregate labour requirements compared with the estimated labour supply. In this case, there appeared a wide gap between the two. Only a limited amount of additional direct employment could be accounted for by the proposed investment. The residual unemployment was assumed to be taken care of by increases in employment in small-scale industry and services on which, however, no quantitative conclusions could be reached because of lack of data.

Foreign exchange-centred models

In the projections made by the Economic Commission for Latin America, the balance of payments deficit is considered to be a major limitation to growth, at least in the short run. Foreign exchange availabilities determine the possible imports of raw materials and investment goods, and the achievable increase in national product. An aggregate model is constructed which projects national product on the basis of the supply of foreign exchange. The latter is, in turn, determined by estimates of prospective exports, terms of trade and capital inflow. In a formal sense, this model is analogous to the previous two, and is usually combined with one or the other of them.

More complex models

The model approach is most valuable when several constraints have to be taken into account simultaneously. Instead of starting with one of the simplified versions indicated above, all the limitations to growth are specified from the start, and a solution of the set of simultaneous equations is arrived at which determines the rate of growth compatible with all of them. Thus, in the projections of the economy of the Netherlands for the period from 1950 to 1970, a series of limitations was introduced with respect to the supply of capital, the supply of labour and the volume of imports over that period. The problem was to determine the maximum rise in per capita income compatible with these limitations. Such a solution was derived, and by adding additional "instruments" relationships it was possible to present certain alternatives to a "single optimum" plan.[7]

As mentioned above, this model makes the various restrictions explicit at the start of the analysis. The solution of the models described in the preceding sections is reached by a process of successive approximations. Attention is centred first on one restriction—that of the assumed key factor; the other restrictions are then brought into the picture, by a trial-and-error procedure, in a second or subsequent round of calculations.

The technique of successive approximations, which has been used in a great many countries, is well brought

[6] Various methods of project evaluation are described in part II of United Nations, *Manual on Economic Development Projects* (Sales No.: 58.II.G.5), prepared by the Economic Commission for Latin America.

[7] *See* Netherlands Central Planning Bureau, *Scope and Methods of the Central Planning Bureau* (The Hague, August 1956), pages 37 to 46 and appendix V A.

out in the planning for Tunisia, which was carried out with United Nations technical assistance. The planning began by constructing a series of aggregate investment-income projections for the period from 1957 to 1971, which were based on a set of alternative assumptions of capital-output ratios and the share of capital formation in gross domestic product. In the computation of these parameters, the past performance of the economy, among other things, was taken into account. A parallel projection was made of aggregate consumption—both public and private—which assumed different rates of increase by major groups of consumers, including government. This projection was based on the expected changes in the demographic structure of the economy and in the structure of employment. These two sets of projections provided the basis for calculations of the required import surpluses. Among the series of alternative projections thus obtained, one plan frame was selected as most realistic in the light of the restrictions on investment and foreign exchange resources. The plan outline for the final year of the planning period was then elaborated in more detail by estimating the availability of and uses for a certain number of major products (approximately 160) in the consumer goods, investment goods and intermediate goods categories. The demand for consumer and investment goods was calculated by an appropriate breakdown of the projected aggregate figures of consumption and investment. Domestic output was then estimated on the basis of the present production plus the prospective output from new investments, taking into account domestic demand and the potential export possibilities. These estimates were, in turn, used to determine the demand for intermediate products. By equating the domestic supply of these major products with the demand, it was possible to project import requirements and export availabilities.

These data for the major products were then used as the basis for a twenty-two-sector input-output matrix, in order to arrive at a more complete projection for the entire economy. The gaps in the outputs and inputs, as well as the projections of the distributive shares of the domestic product, by sectors, were filled by using coefficients from the input-output table of 1957. This process was carried out through successive approximations until a balanced matrix was reached. Finally, estimates were made for employment on the basis of the projected growth in output in major sectors of the economy, partly by calculating demand for labour force to achieve the required growth, and partly by assuming certain changes in labour productivity.

SECTORAL MODELS

The first attempts to establish a development programme usually start from an assessment of the prospects in individual sectors of the economy. Such a procedure is followed when data for an over-all model are lacking although information may exist with respect to individual projects. The drawback of this approach is that the development programme tends to become a collection of assorted projects which are not part of an integrated total. It is not possible either to evaluate these projects on a consistent basis or to check the total inputs against the over-all availability of resources. This section will assess the experience of various countries in formulating national programmes in this way, which may be designated as a "from the bottom up" approach.

The project approach

Although the project approach apparently dispenses with the use of models, some implicit, if not explicit, general economic relationships are inherent in the criteria used to evaluate the projects. It is common, for example, to give priority to those that earn or save foreign exchange and also to favour those that employ local labour.[5] The weights to be given to these and other criteria can only be adequately determined from some sort of over-all analysis. If no such over-all analytical framework exists, there is a danger that individual projects will be evaluated under different assumptions and different criteria.

The project approach to planning has been particularly used in countries where the industrial sector is relatively little developed, such as Ghana (five-year plan, July 1959-June 1964), Cambodia (five-year plan, 1960-1964), Jamaica (ten-year plan, 1957/58-1966/67) and, to some extent, in the first five-year plans of India (1951/52-1955/56) and Pakistan (1955/56-1959/60).

The procedure followed in Pakistan provides a good illustration of the way in which a set of projects is made consistent with an over-all analytical framework covering the availability of resources and an assumed rate of income growth. Lists of projects were first drawn up, by sector, on the basis of technical feasibility and market demand. Since the total of the resulting claims on government financial resources and foreign exchange supplies greatly exceeded their availability, priorities were allocated to the various sectors and to individual projects within each sector, in order to arrive at a feasible over-all programme. The criteria used in allocating such priorities were the contribution of the project to the national income and its impact on the balance of payments. Further adjustments were required to make the planning of different sectors consistent with one another, and to avoid bottlenecks in the production of power, and of cement or other critical materials. This called essentially for projections of the demand for and supply of these key commodities, and the establishment of physical balance-sheets.

The Ceylon ten-year plan also proceeded initially from programmes for selected key sectors, based on certain assumptions concerning the contribution of these sectors to the economy as a whole, and, to the extent possible,

[5] The Philippine Planning Board uses an elaborate priority system of this sort with weights assigned to each factor. Most countries apply priority criteria in a less formal manner. This weighting procedure is discussed at great length in the ECAFE document on programming, op. cit., chapter IV, where the concept of "accounting prices" is presented.

upon analyses of the demand and supply factors for each of these sectors. The resulting sectoral data were then aggregated by successive approximations, taking into account the over-all plan targets and the specific assumptions which were made concerning the movement of the main aggregates of the economy, such as investment and consumption. In this way a consistent set of macro-economic and micro-economic projections was achieved.

The problem of integrating sector projections into a consistent plan is discussed in the reports of several United Nations experts. An expert advising Israel noted that planning had previously been done on a sector basis, and that no need had been felt for an organized and integrated plan. The effect of this piecemeal approach was that the price structure had become distorted on account of numerous taxes and subsidies which, however, did not achieve the desired reduction in the country's balance of payments deficit. Since a significant reduction of this deficit was considered to be imperative, the adviser's task consisted in preparing an aggregate plan which would provide a general framework for an effective co-ordination of sectoral plans and policies.

In Viet-Nam, an adviser discussing the consistency of the national plan and the sectoral plans made by individual ministries noted that, in that country, the cumulative effect of sectoral plans led to over-ambitious and unrealistic targets. In such a case, there may be a lack of balance between resource requirements and availabilities which may lead to a failure to complete the projects.

Demand projections

Planning techniques involve estimates of the demand for particular commodities. Such demand projections can be carried out by various methods: extrapolation of past trends; experience of other countries in similar fields, and an analysis and projection of the economic variables determining the demand. In the case of intermediate demand, a detailed analysis involves the use of an input-output model, to be discussed below, but in many cases simpler models may serve the purpose.

The simplest model for the analysis of consumer demand relates the consumption of each commodity to the total consumer demand—or the total disposable income—in the economy. This relationship can be estimated either from cross-section studies of consumer budgets at a particular time or from an analysis of changes in consumption over time as income has varied. The two methods were combined in the ECLA studies of Colombia and Argentina, in which consumption was first projected on the basis of demand elasticities from household budget studies. The results were then adjusted in the light of recent trends to take account of price changes, population shifts and other factors.

As was pointed out previously, sector projections were used in all countries before the input-output techniques came into existence; they are also used widely even where the latter do exist. They have the advantage of economy in time and effort since they can be made without constructing elaborate input-output matrices. Where the data for an input-output table are of poor quality, or there is little interdependence between the economic sectors, such partial projection techniques may yield results as accurate as those provided by input-output models. However, they do have the weakness that indirect and secondary consequences may be frequently forgotten or ignored. Care should be taken when using these projections to make their limitations explicit, and to make some allowance also for indirect and secondary effects if these are considered to be of significant magnitude.

Industry-agriculture models

In these models the economy is divided into two major sectors, and it is assumed that the development of other sectors may be derived from these. While industry-agriculture or similar two-sector models have seldom been used in actual planning, they are sometimes referred to in the economic literature (for example, in the report of the ECAFE working party referred to above). One such model has been used in the general literature to project India's economic growth.[9] These models seem to be potentially usable to make projections of "balanced" agriculture-industry growth; to project employment shifts from agriculture to industry in relation to given increases in per capita income, and to estimate the required increases in output in both sectors necessary to sustain a long-term economic growth.

INTER-INDUSTRY MODELS

Inter-industry models range from simple input-output matrices to more complicated linear programming models. This article is mainly concerned with the simpler types, which are widely used in programming; a brief discussion will be presented of the applications of linear programming techniques.

Input-output models

Input-output models analyse explicitly the relationships among different sectors of the economy. In the applications for development programming, the economy is generally subdivided into from fifteen to thirty or more production sectors and from three to five or six sectors of final use. The variables in the model are the levels of final use, production, and imports of each group of commodities. The levels of final use are usually determined outside the model and the demands for intermediate products and imports are determined from the solution of the model.

The input-output model may be considered as a breakdown of the aggregate models considered above. Instead of a single equation for total supply of goods

[9] *See* A. J. Coale and E. M. Hoover, *Population Growth and Economic Development in Low Income Countries* (Princeton, 1958).

and services and their use, there is an equation for each sector of production. Similarly, the use of capital, labour and imported materials is estimated separately for each using sector instead of on an aggregate basis. Input-output models therefore take into account the effects of changes in the composition of demand and output in estimating the requirements of such entities as capital, foreign currency and skilled labour, in contrast to aggregate models, which assume, for instance, in the projection of capital requirements, a single over-all capital-output ratio.

In its usual form the input-output model assumes a linear relationship between the output of a sector and its input requirement. From this assumption it is possible to estimate the effect on other sectors of an increase in output in one industry. When technological changes or economies or diseconomies of scale are anticipated, an allowance can be made for changes in input-output coefficients.[10]

Inter-industry models are primarily applicable in economies that have achieved a certain degree of industrial development and hence have a substantial volume of inter-industry transactions. As a rule of thumb, it may be suggested that this is the case in countries having at least 15 per cent of the gross national product originating in industry or having a per capita national income of $150 or more.

Input-output models have several uses in development programming.

(1) They provide for individual branches of the economy estimates of production and import levels that are consistent with each other and with the estimates of final demand.

(2) The solution to the model aids in the allocation of the investment required to achieve the production levels in the programme and it provides a more accurate test of the adequacy of available investment resources.

(3) The requirements for skilled labour can be evaluated in the same way.

(4) The analysis of import requirements and substitution possibilities is facilitated by the knowledge of the use of domestic and imported materials in different branches of the economy.

(5) In addition to direct requirements of capital, labour and imports, the indirect requirements in other sectors of the economy can be estimated.

(6) Regional input-output models can also be constructed for planning purposes to explore the implications of development programmes for the particular region concerned, as well as for the economy as a whole. Such regional tables have been constructed and used for planning purposes in Italy, where there is a clear regional distinction between the North and the South, and where a large programme for the development of the South has been under way for some time. Various tables have also been constructed for specific states, regions and industries in the United States.

[10] A more complete exposition of the input-output method and its application to development programmes is given in H. B. Chenery and P. G. Clark, op. cit.

Some early uses of input-output models to analyse long-term development prospects were made in projections for Italy (1951-1956) and the Netherlands (1950-1970). The method has since been applied in development studies of Colombia, Argentina and Peru by the Economic Commission for Latin America, and in five-year to ten-year projections for Mexico, Tunisia, Algeria and other countries or areas. In most cases, models containing twenty to thirty sectors are used for analytical convenience.

The main problem in applying input-output analysis to developing countries is to allow for structural changes that may be taking place. These consist of substitutions of domestic productions for imports, of changes in technology and other shifts in the structure of intermediate demand. The following examples illustrate the methods of handling these problems.

The Italian input-output projections[11] dealt with both technological changes and import substitutes. An important change in technology was expected to result from the increasingly widespread replacement of imported coal by domestic natural gas and certain other potential energy sources. These potential fuel replacements were estimated in a fuel balance sheet; the input-output calculations were then adjusted to the new fuel pattern by a method of successive approximations. The fuel balance sheet, which estimated the total demands for fuel in standard units of heat, was based on the expansion of fuel-consuming industries, on the economic and technological feasibility of meeting the demands of these industries with alternative fuels and on the special conditions affecting fuel supplies. The results of these estimates were then fed back into the input and output projections in order to trace their repercussions throughout the economy.

With regard to import substitutes, a set of marginal import figures was estimated for each of the two hundred product classes, namely, the fraction of additional requirements expected to be covered by imports rather than by domestic production. These import coefficients, each of which was an independent estimate of import substitution possibilities, were based partly on the average import proportions of the base year, partly on those of more recent years, and the rest on marginal trends in imports from one year to the next.

The ECLA input-output studies for Colombia, Argentina and Peru also focus upon the problem of import substitution. Projections were first made with existing ratios of imports to domestic production in order to determine the required amount of import substitution. In each sector, an assessment of production possibilities on technological and economic grounds was then undertaken. The study of Peru, in particular, illustrates the usefulness of the input-output technique in bringing together in a consistent way engineering and economic estimates in a country where statistical data are not entirely adequate.

The Mexican input-output projections, in which a United Nations adviser participated, provide another

[11] H. B. Chenery and P. G. Clark, op. cit., pages 253 to 254.

example of a procedure sufficiently flexible to allow for structural changes. A projection was first made for the period from 1955 to 1965, using the input coefficients of 1950 corrected for intervening price changes. The direct effects of changes, such as import substitution, increased consumption of electric power and other structural changes in consumption patterns, were then studied in independent projections and the indirect effects of these changes throughout the economy were estimated by feeding them into the model.

An important use of the input-output studies made so far is in checking the over-all requirements of a development programme or of an important specific project against the availabilities of such factors as capital, foreign currency and manpower. The indirect repercussions of the contemplated developments throughout the economy are often of equal or greater importance than the direct effects, and it may be difficult to evaluate them adequately if the traditional instruments of analysis are used. Thus, for instance, the checking of a preliminary investment programme in detail through the input-output method has made it possible in several cases, for example, in Argentina and Israel, to detect inconsistencies in the original formulation, and has led to adjustments of investment allocations in certain sectors.

Experiments with input-output analysis in some countries where industry plays a relatively minor role have not yet led to practical applications, presumably because of lack of data. Even where this is the case, however, the preparation of a rough input-output table is often a useful way to organize the data that do exist and to indicate areas where inconsistencies and other deficiencies obtain and further investigation is needed. A number of unpublished tables are known to have been prepared for this purpose for various countries. A related use of the input-output table is to serve as an intermediate step in the construction of a system of national accounts.

Linear programming models

In order to overcome some of the technical limitations arising from the assumptions of the input-output models indicated above, inter-industry relations may be formulated in the more general framework of linear programming. This technique takes into account imports and alternative techniques of production as separate variables, or "activities". It can also take account more effectively of such factors as shortages of capital, foreign exchange limitations and availabilities of specific natural resources.

A linear programming model describes economic functions, such as production, consumption, transportation, exporting and importing, as "activities". The levels at which these activities are carried on are the variables in the model. Several alternative techniques of producing the same commodity can be included, as can alternative uses of the same resources. In this way the model constitutes a formalized description of the alternative ways of using existing resources to satisfy specified needs. The input-output model can be thought of as a simplified linear programming model in which the choice of production activities and of imports and exports is specified in advance, thereby reducing the number of variables in the model.

The solution to a linear programming model consists in finding the most economical way of achieving a given set of objectives. In one formulation, targets for the expansion of national income and limitations on its composition are specified; the minimum amount of foreign borrowing consistent with these objectives is then taken as the test of efficiency. In another case, resources (including foreign investment) are given and the national income is to be maximized. The solutions also provide sets of equilibrium prices that help to determine the efficiency of alternative programmes.

Two applications of linear programming to India illustrate its potential usefulness for development analysis. A United Nations planning expert constructed a fourteen-sector model designed to determine the optimum allocation of investment for a hypothetical ten-year programme. He was able, for example, to show the interrelationships among investments in such sectors as steel, coal and machinery and to compare costs and results of alternative investment expenditure in various industries.[12] Although his results were intended—because of the limitations in the data—to be merely illustrative, they suggest a number of possible applications in other under-developed countries. The main value of this study seems to be in making apparent the interrelationships among policies adopted in different sectors of the economy.

Another study of Indian planning used a linear programming formulation to check the efficiency of investment and prices implicit in the plan frame four-sector model.[13] The analysis did not support the conclusions that had been reached in the Indian plan frame as to the relative efficiency of investment in different sectors of the economy. It pointed out inconsistencies between the implicit factor prices assumed in the model and the actual factor price relationships in India. Thus, it indicated the need for revisions in the model or in its interpretation, which had not been apparent when the plan was originally formulated.

The main practical obstacle to the use of linear programming models lies in their greater demand for statistical information. The technology of industries that do not yet exist may be described on the basis of engineering projects or of coefficients "imported" from other countries, but care must be taken to use comparable classifications of products and to correct for price differ-

[12] J. Sandee, "A Long-term Planning Model for India", 1959 (United Nations mimeographed document TAO/IND/22 Rev.1). A similar application was suggested in the report of a United Nations adviser to Egypt.

[13] R. Komiya, "A Note on Professor Mahalanobis' Model of Indian Economic Planning", *Review of Economics and Statistics*, vol. 40, No. 1, February 1959 (Harvard University Press, Cambridge, Massachusetts), pages 29 to 35.

ences.[14] Furthermore, a comparison of the efficiency of alternative techniques is feasible only when production is broken down into smaller, more homogeneous classifications than have so far been used for input-output analysis, since the latter assumes parallel variations among the activities that are aggregated in a given sector.

[14] Although input coefficients are interpreted in input-output and linear programming as being ratios in physical terms, they are normally measured in value terms.

For these and other reasons, it is likely that the use of linear programming models for formulating development programmes will not be of wide spread use in the near future. These models do, however, have a considerable value in exploring the consistency of development alternatives, even when some of the parameters used in the analysis are no better than reasonable approximations. Such a preliminary exploration of alternatives by means of linear programming has been recommended in the reports of United Nations advisers in India and Israel.

EVALUATION OF USE OF MODELS IN PROGRAMMING

Although there have been a few evaluations of the results of economic projections in the more advanced countries, relatively little work has been done on evaluation of such projections in the less developed countries. Certain tentative and preliminary conclusions as to the usefulness and limitations of models may be derived from the present study of the experience gained through the United Nations technical assistance programme and other work in this field.

The first question to be raised is whether the use of models is likely to improve the formulation of economic policies by governments. Here the weight of opinion strongly favours the use of some sort of planning model although the possible drawbacks are not being ignored. The advantages most often cited are:

(1) The avoidance of overly-ambitious investment programmes that would cause inflation and balance of payment difficulties, and may even prove to be altogether unmanageable;

(2) Provision of a better basis for an economic evaluation of individual projects;

(3) Achieving a balance in the growth of different sectors and thus avoiding bottlenecks.

A second question is the extent to which the use of a formal model improves the making of projections and the assessment of policy alternatives. A minimum logical structure for making projections is provided by the requirement that supply be at least equal to demand for all commodities and factors of production. The remaining relationships among economic variables can either be formulated as mathematical functions or determined by the use of judgement.[15] The main arguments for specifying these relations as explicitly as possible are that in this way it is easier to determine the range of possible solutions and that important restrictions will not be overlooked.

A third general question is the degree of detail that should be aimed at in an over-all model, given the typical limitations on statistical data in under-developed countries. As a general proposition, it can be stated that, the less complete the model, the more it tends to overstate the development possibilities of an economy because it ignores the composition of output and the shifts in resources that may be required to achieve a given increase in total output. In other words, it fails to take into account the possibility of development of sectoral bottlenecks which may slow down considerably the over-all rate of growth. A detailed model of the input-output type may err in the other direction by underestimating the flexibility of the economy when it omits the possible substitutions that may take place among commodities as prices change and new technologies are introduced. The degree of detail that is useful in any particular case depends largely on the complexity of the economy and the data available.

Some of the objections that have been raised to the use of models in under-developed countries are the following:

(1) The model may be more elaborate than the data warrant;

(2) Assumptions may be made at the start of the analysis which are not re-examined later (for example, the assumption of given exports in certain models, or the initial allocation of investment in the Indian four sector model);

(3) The use of models favours mechanistic types of projections and may tend to overlook less tangible though important factors;

(4) The results of aggregate models are of little operational significance since the government policy is more concerned with the requirements of individual sectors of the economy.

These objections are not properly criticisms of the use of models *per se*, but rather of the abilities of the people who use them. All these objections can be met by use of sound economic judgement as well as of statistical analysis and by subjecting the results of the models to various kinds of tests. This may be put differently by stating that, working without an aggregate model, an expert planning body may make some minor mistakes while an incompetent planning office working even with perfect models may cause an

[15] The latter procedure is followed to a large extent in the projections of the National Planning Association for the United States economy. Whether their procedure involves the use of a formal model is largely a semantic question; it requires the estimation of a number of ratios among the components of national income and product in much the same way as these ratios are determined by a combination of statistical analysis and judgement in the less developed countries.

economic disaster. The use of models does not in any way eliminate or diminish the importance of competence and sound judgement. On the contrary, a model being generally a complex system, any projection or plan based on it is strongly affected by the values of the technical and economic coefficients used. The proper estimate and use of these coefficients is a key problem in programming. They cannot be determined or used in an automatic fashion.

The following general conclusions as to the use of models in planning development may be suggested.

(1) An aggregate model, however crude, is likely to be of value in any country in the first phase of planning. Its main uses are:

(*a*) To provide initial assumptions as to the values of national product and other aggregates that are needed in the analysis of individual sectors;

(*b*) To provide a basis for initial allocation of total investment resources, and more specifically of those available to the government;

(*c*) To provide a basis for the evaluation of investment projects (see conclusion (3) below).

(2) Sectoral output projections are needed for the major sectors of the economy whatever type of development policy is to be followed. In the less industrialized countries, these projections can be made separately for each sector and co-ordinated by the use of common assumptions as to income growth and total use of resources. However, in countries which have reached a certain level of industrial development, particularly as regards production of intermediate products, an input-output analysis is useful in order to ensure the consistency of the sector projections with each other and with the changing pattern of domestic demand and exports. A number of countries have found it convenient, for the application of input-output analysis, to use a breakdown of the economy into between twenty and thirty sectors of production. In particular, all the "instrument variables" mentioned earlier refer to individual sectors and it is important in that respect to have sectoral models which can project the behaviour of each sector in response to changes in policies or final demand.

(3) The establishment of priorities for investment can be improved by the use of aggregate and sector models.[16] The various methods of assessing priorities require the estimation of the future value to the economy as determined by aggregate demand and total availability of labour and foreign exchange and the prospective demands for individual commodities. These magnitudes can best be derived from aggregate and sector projections.

(4) Economic models have considerable value in the exploration of alternative development policies. They make it possible to determine the effects of changes in the planning assumptions or objectives, such as a rise in foreign investment, a change in the rate of growth, or a larger labour force. They can also serve to identify critical variables or relationships in the development process, which helps to focus empirical research and policy formulation on the most important problems.

(5) The development of economic models must be paralleled by an improvement, both in quality and quantity, of the body of statistical information on which they are based. There is a two-way interaction here. Not only are better statistics required for the construction of models and the implementation of policies based on them, but the existence of models helps to point up weaknesses in the available statistics and thus guides the authorities in improving them. The requirements for the construction of planning models have thus had a beneficial effect upon the basic statistical information in countries where they have been used.

[16] This topic is not discussed in detail in the present article because it is proposed to make it the subject of a separate United Nations study. Investment priorities in relation to over-all planning have been studied by both the Economic Commission for Latin America and the Economic Commission for Asia and the Far East.

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[17] The country studies mentioned under this heading were carried out by ECLA in collaboration with the Governments concerned.

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Programming Techniques for Economic Development

IN JULY 1959, the Economic Commission for Asia and the Far East (ECAFE) convened the First Group of Experts on Programming Techniques[1] to "prepare a report outlining the most efficient and practical approach to economic development programming techniques, with special reference to growth models as a tool of development programming in countries of the ECAFE region". The group's conclusions are embodied in a report entitled *Programming Techniques for Economic Development with Special Reference to Asia and the Far East.*[2] This report is briefly summarized below.

The report examines various types of growth models, indicates the data required for each of them, and presents recommendations on their construction and use. While the report is aimed at providing guidance to countries of the region in programming their economic development, the techniques which it describes and the conclusions and recommendations which it formulates are of much broader applicability. The main body of the report is presented in literary form, with simple arithmetical illustrations. The mathematical treatment of the models is given in appendices to certain chapters. The report also contains a selected bibliography on programming techniques.

The growth models are presented in order of increasing complexity, an arrangement motivated not only by didactic considerations, but also by the fact that the availability of data and degree of advancement of planning techniques vary considerably from one country to another in the region.

Aggregate models, aimed at projecting the general rate of economic development which a country seeks to attain, are discussed first. In these models, the measures of economic development are expressed in terms of national income, consumption, savings, investment and employment; in a simplified model, the basic target for development programming is the achievement of the highest possible rate of capital accumulation.

Models to determine the rate of development in major economic sectors are examined next. Inter-sector growth relationships are considered in models limited to two main sectors: consumption goods-investment goods; export goods-products for the home market; agricultural production-industrial production.

The report then proceeds to what is perhaps the key problem of planning—the integration of programmes of specific projects into sectoral and national investment plans. Various quantitative methods for appraising the effects of projects and establishing priorities among them are reviewed. The report examines models with different combinations of aims and factors, taking into consideration, among other things, the role of "accounting" or "shadow" prices in project valuation. This leads to a discussion of input-output and linear programming techniques for detailed multisectoral planning and, as a further step, to an examination of multiregional development programmes.

The report deals with the question of short-term external disturbances arising during the plan period, and proposes that certain models be used to make the necessary adjustments. It concludes with a brief review of the problems involved in planning the supply and distribution of manpower, and the establishment of educational and training facilities to meet the needs of the economic programme.

The nature of the data required for constructing the models varies with their type. The relatively simple aggregate models require recent data on national income, savings, investment, exports, imports, capital coefficients, population and labour force. The sectoral models need, in addition, statistics on output, income and employment, price indices and wage rates, and data on income and price elasticities of demand, labour productivity and capital coefficients for each main sector. The use of the more complex input-output and linear programming techniques further involves the availability of a large number of data on current transactions, technological characteristics of projects, including possible alternative techniques, import contents of expenditures by industrial consumers and producers, and so on. The construction of regional models requires most of the above data, by sector and by region. Finally, to evaluate projects effectively, it is desirable to have a large amount of information on investment requirements, costs and technological alterna-

[1] The group was composed of the following experts who attended in their personal capacities: Jan Tinbergen, Professor, Netherlands School of Economics, Rotterdam (Chairman); Dwarkanath Ghosh, Chairman, Programmes Evaluation Organization, Planning Commission, Government of India (Vice-Chairman); Gamani Corea, Secretary, National Planning Council and Director, Planning Secretariat, Government of Ceylon; Benjamin Higgins, Professor of Economics and Chairman, Department of Economics, University of Texas, and Shinichi Ichimura, Assistant Professor, Institute of Social and Economic Research, Osaka University, Japan.

[2] United Nations publication (Sales No.: 60.II.F.3). The report represents the unanimous views of its authors.

tives. The group of experts suggested that aggregate models might be used in most countries of the region and sectoral models in a few of these. It felt that only in Japan and India would it be possible to apply the more complex input-output or linear programming techniques.

The group recommended that knowledge of programming techniques be more widely disseminated through such methods as the preparation of a handbook on development programming for the use of planning agencies and the organization of a series of training courses in countries of the region. It also recommended that programming data and techniques be improved through increased efforts in collection and research by national and international organizations and by further meetings of expert groups; particular emphasis was put on the collection and analysis of data on costs, capital and input coefficients, consumption and investment functions, labour productivity, shadow prices and the related question of choice of technology.

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"Transport makes it possible for the village economy to cast off its age-old shell of self-sufficiency . . ."

A train runs slowly through paddy fields dotted with rows of stands for drying

Choice of Techniques

The experience of Japan and its implications for under-developed countries

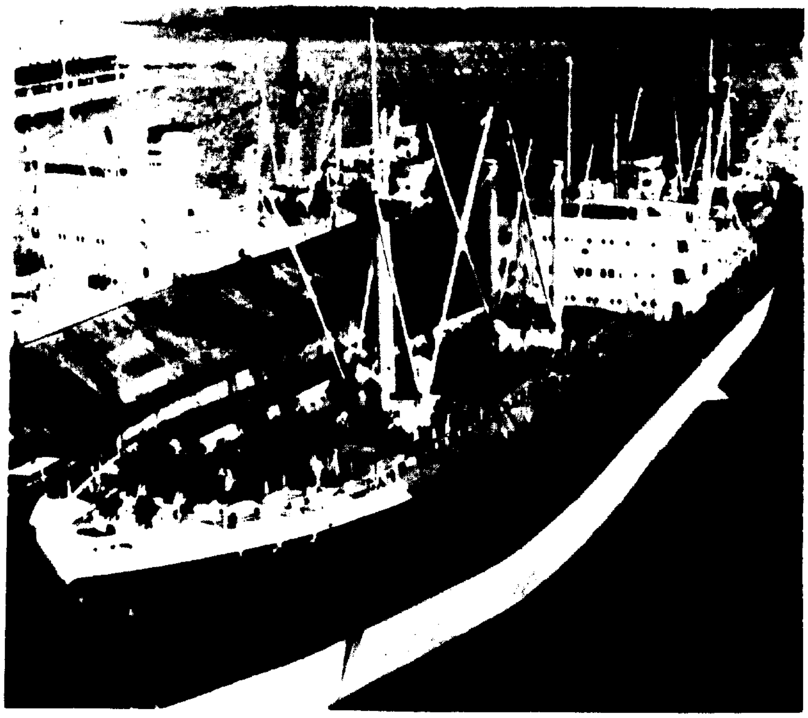
BY SABURO OKITA

THE FOLLOWING ARTICLE *is a part of a series of studies on capital intensity published in earlier issues of the* Bulletin. *In these studies, the problem was dealt with on a macro-economic or over-all national planning level, and a micro-economic or industry and plant level.*

An article in the first issue, entitled "Capital Intensity in Industry in Under-developed Countries", served as an introduction to the series and envisaged the problem under both aspects. It reviewed and assessed recommendations made to Governments by technical assistance experts on general industrialization policies, selection of industries and degree of mechanization in individual industries, with a view to providing guidance both to authorities in charge of industrial development and to experts supplying technical assistance. In another article in the same issue, "Choice of Technology in Industrial Planning", Mr. Jan Tinbergen, Professor at the Netherlands School of Economics, discussed capital intensity in the context of the establishment of national development plans, and presented practical suggestions for a systematic micro-economic approach in carrying out research in this field. The problem of capital intensity in planning was also one of the subjects discussed at a conference of the Economic Commission for Asia and the Far East (ECAFE) on industrialization in the region, an account of which was published in the second issue of the Bulletin.

On the micro-economic level, the problem has been explored in a number of articles. One of them, entitled "Capital Intensity in Heavy Engineering Construction", published in the first issue, examined the economics of alternative techniques of varying capital intensity in a specific industry offering a wide range of technological possibilities in that respect. It was followed up by a study on "Capital Intensity and Costs in Earth-moving Operations", which appeared in the third issue. This article was accompanied by a note on the meeting of a working party on earth-moving operations in the ECAFE region which dealt with various aspects of the technology of earth-moving using manual labour, mechanized equipment and combined operations of both. Another industry was analysed from that standpoint in an article by Mr. G. K. Boon of the Netherlands Economic Institute. This study, entitled "Choice of Industrial Technology: The Case of Wood-working", which was published in the same issue, dealt with alternative production processes in a simple industrial operation, the manufacture of wooden window frames and furniture. Finally, a study published in the second issue of the Bulletin *on problems of size of plant in under-developed countries, which dealt with the economies of size in the fertilizer and glass-container industries, examined the problem of capital intensity in connexion with certain aspects of the subject, namely, the choice of technologies and the lifetime of equipment.*

The article by Mr. Saburo Okita of the Economic Planning Agency of Japan, presented below, examines again the problem of capital intensity on a macro-economic level, in the context of historical developments in Japan. It analyses the approach which has been adopted in Japan in order to make the best use of its endowment in capital and labour in developing agriculture, transportation and manufacturing.



"If there are good port facilities, coastal transportation is an effective means of saving capital..."

Merchant ships in the harbour of Kobe

SOME OF THE decisions which under-developed countries have to make to bring about the transformation of their economy from a state of stagnation to a process of dynamic development are in the nature of a choice between techniques. A proper choice may achieve the double purpose of carrying out this transformation with the least pain and sacrifice and attaining a state of autonomous development within the shortest period of time.

In a narrow sense, choice of techniques means selecting the most adequate and effective means or processes to achieve a given target in production, transportation or other economic activities. In a broader sense, choosing techniques is tantamount to setting up investment priorities. In this article, the problem will be examined under the latter aspect.

The problem under consideration is to find the optimum combination of factors of production—labour, capital and natural resources, including land—under given basic conditions. The factors should be combined so as to make the fullest use of all existing available resources, and to maximize the surplus of product over current consumption. The resources thus generated will be available for new capital formation, which is the precondition for the further development and cumulative expansion of the economy. Economic development should proceed without having to resort to coercive means to mobilize capital or labour, or to impose excessively austere living conditions.

CHOICE OF TECHNIQUES AND ENDOWMENT IN RESOURCES

In combining the factors of production, account will be taken of their relative scarcity. The following criteria regarding utilization of resources apply to all under-developed countries in eastern Asia; they would also be valid in many under-developed countries in other regions.

(*1*) Capital resources should be saved and used with maximum effectiveness. Where factor substitution is possible, capital-saving techniques should be adopted, provided a reasonable level of efficiency is achieved.

(*2*) Foreign exchange resources should also be saved and used with maximum effectiveness. In general, economic development will raise the demand for imports of both consumer and capital goods, while exports will not increase proportionately. In under-developed countries, especially in those depending upon export of primary products, a substantial increase in the surplus available for export is often precluded by natural factors; sometimes, the surplus may be diminished by an increase in domestic demand induced by the process of development. For these reasons, developing countries often experience a strain on their balance of payments. Factor combinations permitting saving of foreign exchange should therefore be preferred.

(*3*) Full use should be made of the labour force. To leave manpower idle is to waste a major resource, and, to be used effectively, it should be trained. The starting point in a programme of economic development should therefore be to provide training and education to the labour force.

The development of Japan was largely guided by these principles. Before examining the case of Japan in more detail, a few remarks will be made concerning another case in which development was achieved along different lines—that of the Soviet Union. In that country, development efforts were from the beginning, and still are, focused on the promotion of heavy industry; the development of consumer goods industries was to follow gradually.

There were a number of reasons for which the Soviet Union chose to give special priority to heavy industry. The first was that, in order to realize socialism in a state surrounded by capitalist countries, the Soviet Union found it necessary to strengthen its national defence, which involved development of heavy industries.

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The second was that the Soviet Union had vast uncultivated agricultural regions that were thinly populated; to increase agricultural production, it was decided to resort, on a large scale, to tractors, combines and other mechanized implements, the supply of which also required the development of heavy industry. At the same time, labour was to be released from the agricultural to the industrial sector.

In eastern Asia, where population density in agricultural areas is relatively high, it is considered far more important to raise agricultural production per unit of land than to economize human labour, and farm mechanization does not have the same urgency. Also, national defence requirements in Asian countries today are certainly not comparable to what they were in the Soviet Union after the revolution. The difference in historical and structural conditions—in particular, the relative scarcity of capital and land and the relative abundance of labour—will normally involve in the under-developed countries of Asia and the Far East a different type of economic development.

THE EXPERIENCE OF JAPAN

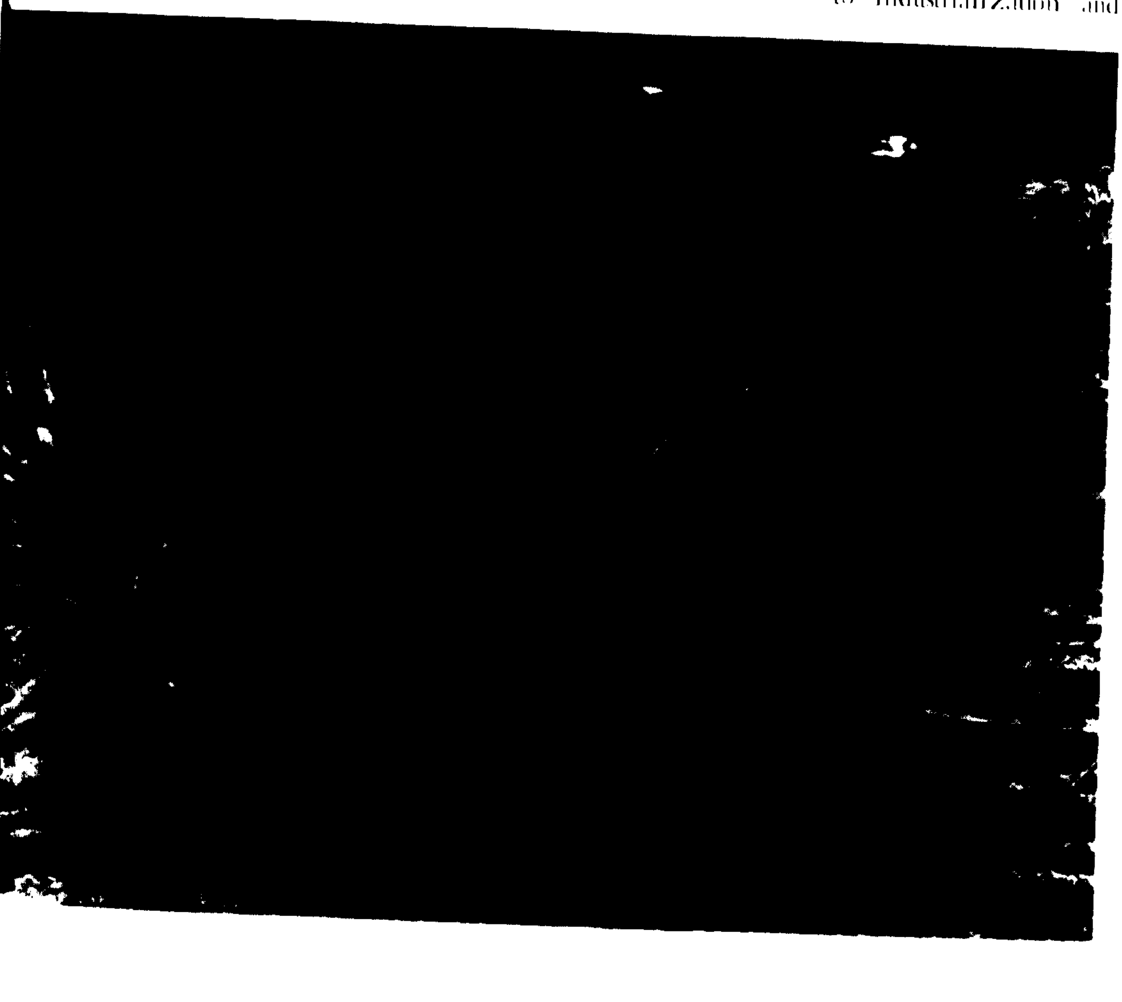
Japan provides the example of a country with high population density which, starting as an agricultural country, has rapidly developed into a modern industrial economy. In this process, several economic sectors, including that of agriculture, have played an important role.

Agriculture

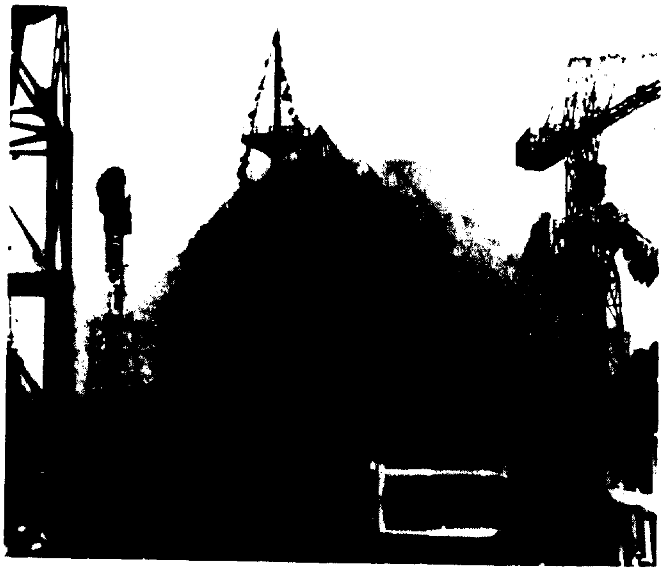
The techniques applied in developing agricultural production in Japan have consisted of increased use of manure, improved plant breeding, weeding, and construction, mostly by hand, of drainage and irrigation works. These techniques aimed at economizing capital, increasing yield per unit of land and utilizing labour extensively. Large-scale use of cultivators or other modern equipment began only recently, when, owing to the increasing claims on the labour force on the part of industry, it became imperative for agricultural enterprises to save on labour input and increase labour productivity.

In under-developed countries where the economy is based on agriculture, a surplus should be created in agriculture if capital investment is to take place in industry. At the same time, the agricultural sector should offer markets for the products turned out by the newly established industries. Thus, the agricultural sector would play a double role in the industrialization of these countries. In the eighteen seventies, when Japan had just started to modernize, 90 per cent of the central government revenue was derived from land tax; within forty years the proportion had been reduced to 40 per cent. A large part of the rental income of land-owners came to be invested in industry, banks, shipping and other modern sectors of the economy. At the same time, agricultural production increased and the living conditions of the farmers gradually improved.

In countries where development policies give priority to industrialization and neglect agriculture, inflation



"Before Japan's modernization, resort was principally made to human shoulders . . ."



"The expansion in shipbuilding involved the development of the iron and steel industry..."

and difficulties in the balance of payments may develop, living standards may remain low, and the smooth process of economic development may be impaired. Promoting the growth and improvement of agricultural production is thus the most important prerequisite to industrialization. The choice of techniques in agriculture should, in general, be such as to save on capital resources and make the fullest possible use of the available labour force.

Transportation

The development of an efficient transportation system is another prerequisite to economic development. Transport makes it possible for the village economy to cast off its age-old shell of self-sufficiency, enlarge the market for its products and increase the gains due to the division of labour. In this sector, too, the choice of techniques should be made from the viewpoint of saving capital and foreign exchange and employing labour effectively.

For a long time in Japan, railroads and maritime coastal shipping provided the chief means of transportation; it is only recently that construction of a modern road network was begun. If there are good port facilities, coastal transportation is an effective means of saving capital. On the whole, railroads have been more economical than roads in Japan, because of the topographical configuration of this mountainous country and its high population density. In a recent study, it was found that construction of a railroad between Tokyo and Osaka (554 kilometres) would cost about half as much as that of a modern high-speed highway. The Japanese network includes many single-track railways; these are now becoming bottlenecks, but they have played their part in economizing capital. Full use should evidently be made of the rolling-stock, and time schedules should be strictly observed if traffic capacity is to be maximized. Freight costs are generally lower for rail than for road transport, except for short-distance haulage or carrying perishable or high-value commodities, for which door-to-door transport is more economical. Rail transport in Japan also has a distinct advantage over road traffic as regards consumption of energy, as it can use indigenous coal and hydroelectricity; road transport requires oil products, the domestic output of which can satisfy only a small part of the demand. Railroads are also more suitable than motor-cars for passenger traffic in a country with a high population density and a relatively low income level.

There are a number of reasons, some of them historical, for which roads have not been developed extensively in Japan. One is that, before Japan's modernization, resort was principally made to human shoulders. Draft animals were not much used in rice cultivation and, consequently, played no important role in transportation. In Europe, where animals were widely used in agriculture, they could also be employed for transportation, which, in turn, necessitated the development of good roads. A second reason is that the costs of building and maintaining roads are high in Japan because of its topography; a third is that, paralleling the expansion of sea transport, almost all important industrial cities have developed along the coast.

As its population increases and it advances into higher stages of industrialization and urbanization, Japan feels the need for expanding its road network, the inadequacy of which is becoming a bottleneck hindering the country's economic activity. In recent years, investment in road construction and improvement has been increasing. Looking back, it can be said that, on the whole, in developing its transportation system, Japan has followed a course that was in line with the need to save capital and foreign exchange.

Manufacturing

It is generally recognized that industrialization is a dynamic factor in economic development. The choice of industrial techniques should aim at inducing a cumulative expansion. Industrialization policies fulfilling the basic criteria of saving capital and foreign exchange and making effective use of the labour force would normally give priority, at least in the early stages, to producing substitutes for imported goods, especially those requiring relatively little capital and a fair amount of labour. Such import substitution policies will generally involve adoption of measures to protect the market for the new products against the competition of foreign goods.

As mentioned earlier, there is a fundamentally different approach in which priority is given from the earliest stages of industrialization to the development of capital-intensive industries. This course is sometimes followed for reasons of national defence, or sometimes of prestige; in such cases a judgement based on economic criteria would not be relevant. However, it would be legitimate to examine from an economic standpoint the opportunity of following a process of development in which industries manufacturing comparatively simple consumer goods would be established first; in the course of time, more capital-intensive industries would be set up as a result of the increase in numbers of experienced entrepreneurs and trained workers, and in accumulated capital. This is the course that European countries have spontaneously followed in the past. In under-developed countries, on the other hand, such a process of industrialization should be planned deliberately so as to maximize progress in as short a period as possible. In this way, economic development would be achieved with less sacrifice in terms of employment and living standards than if priority were given to the establishment of heavy industry. Such a policy would be particularly effective in small countries with limited markets.

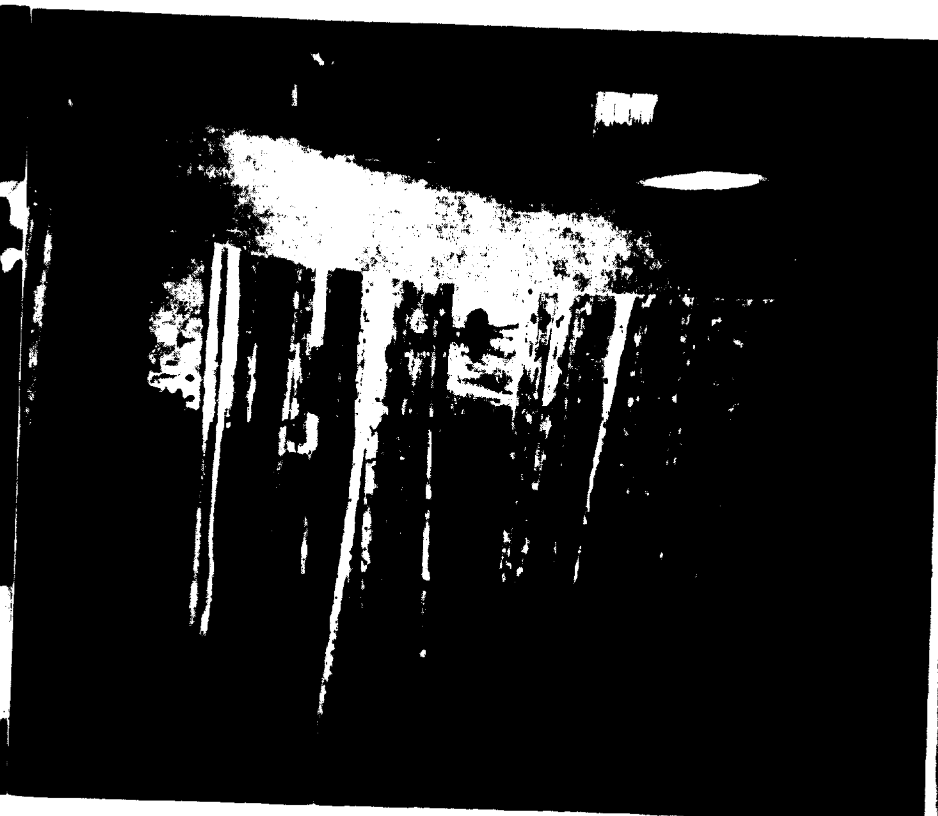
The following statement by a working party on industrialization of the Economic Commission for Asia and the Far East may be quoted in this connexion:

"The Working Party discussed at some length the various aspects of the question of choice of techniques in industrial development. Relative scarcity of capital and relative abundance of manpower were features common to the economies of the countries in the region. If the policies and programmes of development aimed at the best utilization of this factor combination, the choice of labour-intensive techniques appeared to some countries to be the preferable course in several fields, at any rate in the early stage of development. ***From the standpoint of rapid economic growth, however, capital-intensive techniques offered distinct advantages. The higher levels of productivity which could be achieved with these techniques made possible a higher rate of capital accumulation, larger output and, in the longer period, creation of larger employment.*** Some capital-intensive activities might have a more immediate effect in the indirect promotion of employment in other fields."[1]

The industrialization of Japan is characterized by a combination of hasty construction of heavy industries for military needs and spontaneous growth in response to consumers' demand. The building up of the Japanese Navy brought about an expansion in shipbuilding which in turn involved the development of the iron and steel industry. Military arsenals were literally the birth-place of the civilian machine-building industry, since, in the early stages, machines and goods for civilian use were often produced there. Operation of the iron and steel industry was not commercially profitable in the early stages and, until the nineteen thirties, a major part of this industry was operated by the Government with little emphasis on profit-making. It was only after the Sino-Japanese war that iron and steel became a profitable industry. The fact that Japan was seeking raw materials for its iron and steel industry may be considered as one of the causes for the policy of territorial expansion followed at that time.

On the other hand, Japan's textile industry developed in response to consumers' demand. At first, raw cotton was produced in the country. At the beginning of this century, import of cotton was made free, and

[1] United Nations, *Economic Bulletin for Asia and the Far East*, vol. IX, No. 3 (December 1958), page 63. Italics supplied by the author.



"There was a rapid expansion of the spinning, weaving and sericulture industries . . ."

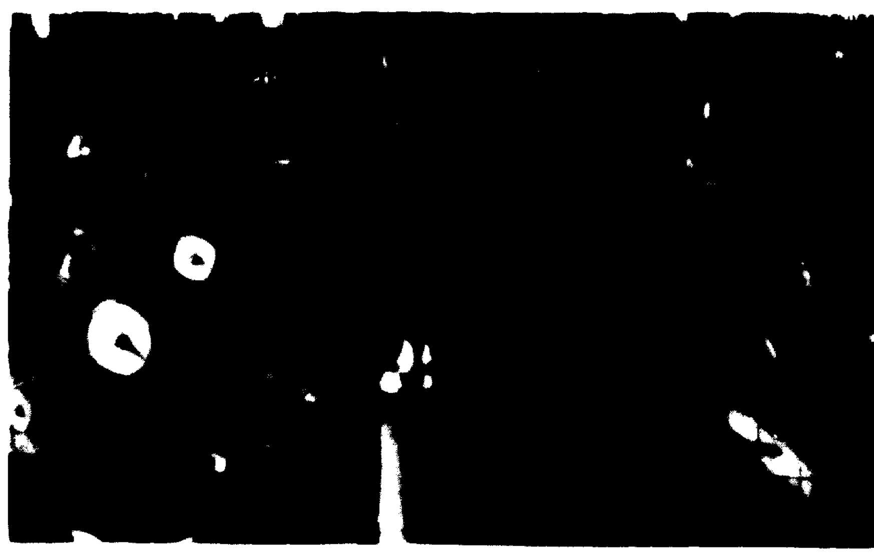
Collecting filled spools in a spinning mill

Drying silk fabrics near Kyoto

the lower price of imported raw cotton led to a rapid expansion of the spinning and weaving industries. Mulberry plantations took the place of cotton in the fields and the sericulture industry developed. Export of raw silk became one of the most important sources of the foreign exchange which paid for the imports needed for industrialization.

In the nineteen thirties, the capital accumulated by the cotton and silk industries laid the groundwork for the establishment of the rayon industry, and, after the Second World War, made possible the rapid development of the synthetic fibre industry. The spinning and fibre-producing plants are generally of large size; weaving and other textile operations are predominantly carried out in medium-sized and small-scale enterprises. The latter are still playing an important role in providing employment opportunities.

The Japanese machine-building industry includes large, medium-sized and small establishments. Many small enterprises have subcontracting relationships with the large ones.[2] Repair shops have played their part in the development of this sector. Not only do they improve the rate of operation of existing plants and constitute a source of supply of trained technicians,[3] but they also have opportunities of growing into large and profitable enterprises. An example is provided by the Hitachi Manufacturing Company, the largest machine-building concern in Japan, which had its origin in the repair shop of the Hitachi copper mine.



"The Japanese machine-building industry includes large, medium-sized and small establishments ..."

A large textile machinery factory

SCALE OF INDUSTRY AND CAPITAL INTENSITY

In 1956, the total number of workers in the Japanese manufacturing industry was about 7 million, of which about 4 million were employed in medium-sized and small enterprises (less than 300 employees) and more than 3 million in very small enterprises (less than 30 employees).

Generally speaking, the larger the scale of the enterprise in Japan, the higher the degree of capital intensity. Where industrialization policies emphasize the establishment of capital-intensive industries, wide differentials in wages and living standards are likely to develop between the employees of the large-scale factories and the majority of the labour force, the former becoming a sort of labour aristocracy. In view of the scarcity of capital, the number of capital-intensive industries likely to be established in under-developed countries will in general be small, and these industries will be able to absorb only a fraction of the labour population. In Japan, a large part of the labour force is employed in medium-sized and small enterprises in which the degree of capital intensity is relatively low. So also, of course, are the levels of productivity and wages in such enterprises. An illustration of this pattern is given in table 1, which shows capital intensity and wage level in industry by size of enterprise. Table 2 shows capital intensity in industry and other economic sectors.

Where large wage and living standard differentials exist, it is not advisable, in general, to correct the situation too hastily by artificial measures which may involve a risk of increasing substantially the numbers of unemployed. It is preferable to remedy the discrepancies gradually, keeping pace with economic growth and capital accumulation. As employment opportunities increase, the surplus population in farm districts may be absorbed into other occupations, which would contribute to improving productivity and raising levels in agriculture. In Japan, it is anticipated that the recently observed slowdown in the rate of increase of population and the high rate of economic growth will continue in the foreseeable future, which is likely to bring about, within some ten to twenty years, a gradual elimination of the dual structure of the labour market described above and move Japan's economy closer to the full-employment

[2] *See* United Nations, "Interrelations Between Large and Small Industrial Enterprises in Japan", by Toyoroku Ando, *Bulletin on Industrialization and Productivity*, No. 2 (Sales No.: 59.II.B.1).

[3] *See also* "Use of Industrial Equipment in Under-developed Countries" in the present issue.

Table 1

JAPAN: CAPITAL INTENSITY AND WAGE LEVEL IN INDUSTRY, BY SIZE OF ENTERPRISE, 1957

Size of enterprise (number of employees) (1)	*Ratio of gross output to fixed capital* (2)	*Fixed capital per worker (capital intensity)* (thousands of yen) (3)	*Labour productivity* (thousands of yen) (2) × (3) (4)	*Ratio of gross profit to fixed capital* (5)	*Gross profit per worker* (thousands of yen) (3) × (5) (6)	*Wage per worker* (thousands of yen) (4) − (6) (7)
1-3	0.139	93	13	0.043	4	9
4-9	0.186	97	18	0.082	8	10
10-19	0.256	90	23	0.133	12	11
20-29	0.269	97	26	0.144	14	12
30-49	0.284	102	29	0.167	17	12
50-99	0.258	136	35	0.162	22	13
100-199	0.221	186	41	0.145	27	14
200-299	0.202	233	47	0.133	31	16
300-499	0.168	345	58	0.119	41	17
500-999	0.146	447	65	0.103	46	19
1,000 and over	0.100	769	77	0.068	52	25
Total	0.133	324	43	0.083	27	16

Source: Ministry of International Trade and Industry, *Analysis of Current Japanese Industry, 1959* (Tokyo), page 183.

Table 2

JAPAN: CAPITAL INTENSITY IN INDUSTRY AND OTHER ECONOMIC SECTORS: VALUE OF FIXED CAPITAL ASSETS PER WORKER, 1955
(At 1951 prices)

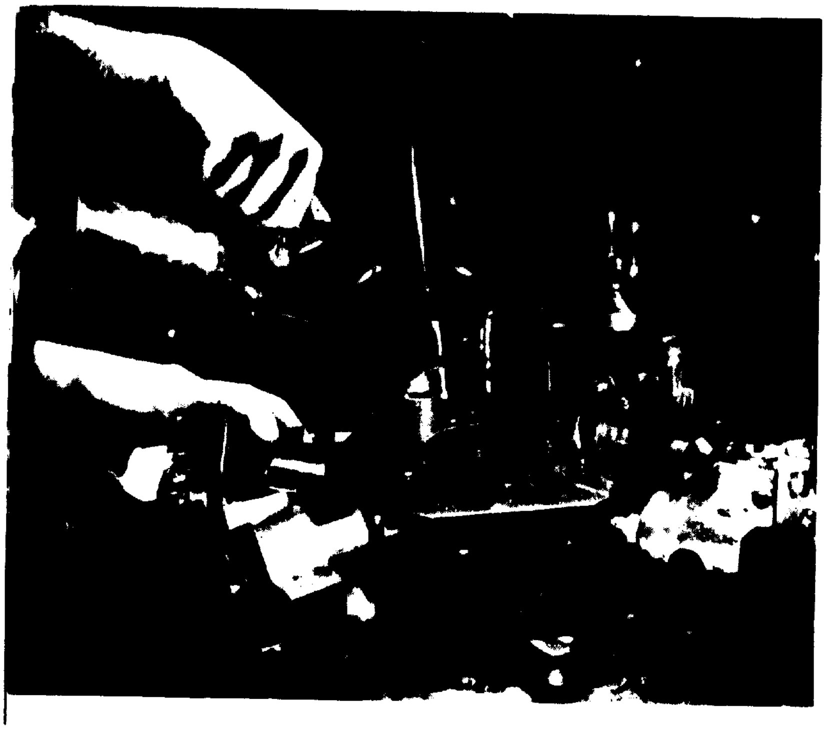
Industry	*Thousands of yen*	*Industry*	*Thousands of yen*
Agriculture, forestry and fisheries	77	Rubber products	97
Mining	239	Cotton spinning	481
Coal	231	Textile products	171
Gas	2,676	Basic chemicals	509
Coal products	482	Chemical products	396
Petroleum products	3,459	Ceramics	196
Foodstuffs	191	Other manufacturing industries	102
Iron and steel	921	Electric power	5,964
Iron and steel products	75	Commerce	121
Non ferrous metals	546	Communications	756
Machinery	172	Construction	22
Vehicles and shipbuilding	254	Banking and insurance	82
Paper and paper products	183	Services, miscellaneous and unclassified	980
Wood products	134		
Leather products	152		

Source: Ministry of International Trade and Industry, *Analysis of Current Japanese Industry, 1959*, page 167. The table is based on information obtained by the Economic Planning Agency in its "National Wealth Survey" for 1955.

conditions now prevailing in Europe. It may be expected that a vital role will be played in this process by medium-sized and small-scale enterprises offering numerous employment opportunities while requiring relatively small capital investments.

CONCLUDING REMARKS

The question of choice of techniques has been examined above with reference to the conditions obtaining in under-developed countries of Asia characterized not only by scarcity of capital and foreign exchange, but also by high population density. The conditions favouring rapid industrialization without entailing major sacrifices in living standards appear to be the following: techniques maximizing the effectiveness of investment and employment should be preferred; simple techniques should be used first, and more complex ones introduced gradually; planning and leadership by the government are necessary if progress is to be accelerated.



Use of Industrial Equipment in Under-developed Countries

PROBLEMS OF MAINTENANCE, REPAIRS, REPLACEMENT AND OBSOLESCENCE

Prepared by the Division of Industrial Development of the United Nations Department of Economic and Social Affairs

INTRODUCTION

THE DIVISION OF Industrial Development of the United Nations Secretariat is concentrating a considerable part of its research activities on problems of utilization of capital resources in under-developed countries where the efficient use of such scarce resources particularly in the industrial sector—is a key problem. A number of studies in previous issues of this publication have been devoted to this subject. The present study, which deals with the problems of maintenance, repair and replacement of industrial equipment in under-developed countries, forms part of this series.

In the course of the next decades the scope and importance of these problems are bound to increase rapidly. At first, maintenance and repair requirements will grow at approximately the same rate as the stock of industrial fixed assets. In the absence of quantitative indications as to the magnitude of this stock in the under-developed areas, the rate of growth in maintenance requirements may be estimated on the basis of the annual average increase of production volume. In the past twenty years, in spite of war-time destruction in some areas and lack of investment funds, the rate of growth of industrial production in those areas has been impressive (table 1).

If the rates of growth in the last reported five-year period continue, by 1975 industrial output will reach 300 per cent of the 1958 level in Latin America, 600 per cent of the 1958 level in East and South-East Asia and 550 per cent of the 1953 level in Africa and the Middle East. If, as a first approximation, the capital-output ratio is assumed to be constant and the volume of maintenance is assumed to be a linear function of the stock of capital, the volume of maintenance by 1975 will be three to six times greater than that in 1958, or, for Africa and the Middle East, than that in 1953.

At the same time, maintenance will change qualitatively, that is, it will become more intensive; more efficient methods are likely to be introduced. On the other hand, investment in modern equipment requires more careful upkeep, based upon scientific control of wear and tear.

The actual performance of equipment depends on a variety of factors: skill of the operating personnel; adequacy of design and capacity in relation to the required quality and quantity of production; rate of utilization; adequate flow of raw materials and supplies; uninterrupted operation of the entire production line of which the particular piece of equipment is part, and so forth. Deficiencies in any of these links will be reflected in a drop in the over-all performance. Effective industrial operation depends on a sustained and integrated effort in the technological, managerial and economic fields.

The present study is confined to the part played by equipment in achieving optimum performance. It deals, in particular, with three topics: maintenance and repairs, optimum lifetime, and replacement.

Although the three topics are clearly interrelated, it is convenient to make these distinctions for the purposes of this study. For each topic, the discussion consists of a summary of the principles and practices in the industrialized countries, followed by an appraisal of their applicability under the conditions obtaining in the less developed countries.

MAINTENANCE AND REPAIRS

POLICIES AND PRACTICES IN THE INDUSTRIALIZED COUNTRIES

IN RECENT YEARS, especially since the Second World War, the importance of maintenance of industrial equipment has been increasingly recognized in the developed economies, western[1] and centrally planned[2] ones alike. Two reasons seem to be responsible for this interest:

(*a*) Progressive management in the industrialized countries is more aware now than in the past of the fact that maintenance must be as closely controlled as production, if maximum efficiency is to be achieved.

(*b*) There have been considerable changes in the nature of industrial processes and organization. Instead of individual machines, modern industry increasingly uses integrated production processes—for example, production lines, automated processes which are planned according to the latest, highly efficient process and organization layouts. A breakdown of a piece of equipment which is part of an integrated production line is liable to cause far greater disruption than that of a machine operating separately. Conversely, increases in maintenance and repair costs are justified if they obviate or reduce the chances of stoppages of very expensive equipment.

The basic objectives of maintenance and repair policies in modern industry are:[3]

1. To keep plant and equipment production and service in proper condition to perform continuously the functions for which they were originally designed;
2. To keep costs to a minimum;
3. To increase the efficiency of maintenance work and so increase the availability of plant for production. This means not only reducing the time taken from maintenance jobs, but also using improved methods to reduce their frequency;
4. To improve the operation of the plant while in production;
5. To improve working conditions in the plant.

Types of maintenance

A variety of types of maintenance has been developed, suitable for diverse technical and economic conditions. A short summary of these types, with an evaluation of their respective advantages and disadvantages, is included in appendix I to this article. Under the older plant practice, maintenance is controlled and carried out by the production supervisor: skilled craftsmen operating machine tools or similar equipment take care of their own machinery as they judge necessary. Special maintenance men—either responsible to a production foreman or organized as a small group under a special maintenance foreman responsible to the production manager of the area—are called in by operatives or production supervisors whenever repairs are needed.

Under another, older system known as the "system of breakdown maintenance", a separate unit is organized whose services are called upon by the production department when mechanical, structural or other failure reduces the desired rate of production. Maintenance proper is generally confined to periodic lubrication and to such inspections and minor adjustments as are requested from time to time by the production department. Otherwise equipment is worked until a breakdown makes repair necessary.

[1] *See* among others, Anglo-American Council on Productivity, *Plant Maintenance* (London, December 1952) and *Maintenance Engineering Handbook* (McGraw Hill, New York, 1957).

[2] A. Dodonow, *Planirovanye, finansirovanye, uchet i analiz zatrat na remont osnovnykh sredstv* (Planning, financing, accounting and economic analysis of fixed assets maintenance), Gosfinizdat (Moscow, 1954); A. P. Wladievsky and M. O. Yakobson, "O edinoi sisteme planovo-predupreditelnovo remonta tekhnologicheskovo oborudovania mashinostroitelnykh predpriyatye" (On the unified system of planned and preventive maintenance of the technical equipment in machine-building industries), *Vestnik Mashinostroenia* (Machine-building Bulletin), No. 12, 1954 (Moscow).

[3] *See* Wladievsky and Yakobson, op. cit. and *Plant Maintenance*, op. cit., page 3.

Table 1

AVERAGE ANNUAL RATE OF GROWTH OF INDUSTRIAL OUTPUT, BY GEOGRAPHICAL REGION
(Percentage)

Region and period	*Total manufacturing*	*Heavy manufacturing component*
Latin America		
1938—1958	5.4	7.2
1938—1948	5.8	7.0
1948—1953	3.7	5.9
1953—1958	6.2	9.0
East and South-East Asia		
1938—1958	3.9	5.4
1938—1948	−2.7	−4.7
1948—1953	9.6	16.1
1953—1958	11.5	15.0
Africa and the Middle East		
1938—1958	...	...
1938—1948	5.3	6.1
1948—1953	10.5	13.1
1953—1958	...	...

Source: United Nations, *Patterns of Industrial Growth, 1938-1958* (Sales No.: 59.XVII.6), page 76.

A more modern method is to organize maintenance as a process to a certain extent separate from production. Under such an arrangement, maintenance includes inspections and overhauls at regular, scheduled intervals, including systematic checks of parts exposed to wear and tear; thus, repairs decrease in frequency and importance. This system has become standard practice in many industries where preventing breakdowns and lengthening the lifetime of equipment is of major importance.

Maintenance comprises inspections of various degrees of intensity, from a routine check of parts exposed to severe wear and tear and particularly liable to develop defects, to a general overhaul. Normally, for a given type of equipment, the scheme would include several types of inspections which are scheduled according to stated time periods or hours of operation.[4] A maintenance plan is established which indicates the periodicity of the various types of inspection, the parts to be inspected, and the wear tolerance for each part, beyond which it is to be replaced. Such specifications are normally given in the instructions of the producer of the equipment; they are subsequently revised in the plant in the light of experience, taking into account such factors as the importance attached by management to the prevention of breakdowns.[5] All serviceable equipment in well-organized industrial enterprises is generally provided with a minimum maintenance programme based upon technical safety requirements. Regular lubrication, inspection, adjustments and repairs become routine. Special maintenance units are generally in charge of such operations.

Workers in industrial countries have been familiar with technical equipment for generations and have developed a certain "feel" for the care of such equipment. No enterprise considers itself prosperous enough to neglect maintenance and repair, and each one will establish an optimum programme which generally exceeds the required technical minimum for ensuring safe operation during the expected useful life of the equipment and which is often based upon considerations of possible and economically justified substitutions of scarce factors.

In modern practice there is some possibility of choice among "scheduled", "planned" and "preventive" maintenance schemes. Each successive scheme involves an increase in clerical and engineering work, but is more efficient in lengthening the period of serviceability of the equipment and its reliability of performance.

Under the "scheduled" maintenance scheme, the staff draws up an inventory of the major plant items and submits to the production department an estimate of those likely to need repairs during the next operation period. In general, the production programme influences the fixing of the times at which individual items are taken out of production for repairs.

"Preventive" maintenance utilizes a systematic comparative analysis of performance which greatly improves the budgeting for inspection, maintenance, replacement and modification to be carried out during the lifetime of each item. Its purpose is to prevent excessive wear and tear and reduce to a minimum breakdown repair by substituting for it upkeep, preplanned replacement of parts and their modification.[6]

Importance of maintenance operations in modern industry

A recent survey[7] conducted in the United States clearly indicates the importance of maintenance in modern industry. It also reveals the variety of maintenance practices and requirements in individual industrial branches. The following table shows the importance of maintenance in various industries based upon the proportion of maintenance workers to production workers employed.

Industry	*Number of maintenance employees per 100 production employees*
Chemicals, oils	50
Stone, clay, glass	16
Food	14
Primary metals and metal fabrication	13
Transportation	12
Electrical machinery	10
Machinery (excluding electrical machinery)	9
Pulp, paper, allied industries	9
Electronics, instruments	6
Rubber	6

[4] The lightest inspection, type "A", may, for instance, be scheduled at three-month intervals, or after 500 hours of operation; the schedule would further indicate that after three type "A" inspections, there is an inspection of medium type "B"; and that each "B" inspection is followed by a type "C" inspection, which includes an intensive overhaul.

[5] As mentioned earlier, the latter factor will be of special importance if the breakdown of the given piece of equipment brings an entire production line to a standstill. The maintenance schedule should then indicate a lower wear tolerance for replacement of vital parts and, occasionally, also shorter intervals between inspections.

In the United States, the former procedure has, in some instances, been pursued to the point of automatic replacement of certain parts under a fixed schedule based on past experience. This practice of replacing parts on the basis of probability, that is, irrespective of evidenced need, is being adopted when high wages make the checking of parts more costly than automatic replacement, or when particular importance is attached to uninterrupted operation between overhaul inspections. Except for very special cases—for example, aircraft—this practice is not likely to be justified in under-developed countries where wage levels are normally considerably lower and the cost of spare parts considerably higher.

[6] The practice of "modernization" of existing equipment, especially machine tools, has recently been introduced in many countries. The basic idea is to bring old equipment up to the standards of the latest development. A number of different methods are used, for example, rebuilding certain parts of the machine during overhauls. This practice has been particularly developed in centrally planned economies. *See* J. M. Kucher and A. M. Kucher, *Modernizatsia i avtomatizatsia stankov* (Modernization and automation of machine tools) (Mashgiz, Moscow, 1958).

[7] "Maintenance Management Practices Today", *Factory Management and Maintenance* (McGraw-Hill, New York, October 1958), page 138.

Owing, among other factors, to improved maintenance, the lifetime of industrial equipment in the developed countries is generally long,[8] much longer than the so-called "useful life" employed for purposes of assessing depreciation. There is generally a discrepancy between the "real" life of equipment and its "accounting" life. Depreciation policy aims at formulating convenient methods of assessing depreciation and at shortening "useful lives", the latter for two main reasons: the high rate of obsolescence of capital items caused by technological progress, and the need for financial resources not only to replace but also to enlarge industrial capacity. On the other hand, industry is obviously interested in extending the actual lifetime of equipment. Unless excessive operating and repair costs clearly call for replacement, completely "depreciated" and even "obsolete" equipment is generally kept in use on secondary lines of production along with modern equipment. Thus, some equipment—for example, machine tools—often undergoes a process of functional downgrading, that is, it is shifted from jobs on primary production lines to jobs of lower intensity or quality, in which the superiority of new and better equipment is less important. An obsolescent machine tool may be put on operations where precision requirements are less exacting, either in the same plant or elsewhere.[9]

Policies and measures suggested for the under-developed countries

There is hardly need to stress the importance of maintenance and repair in under-developed countries where scarcity of capital is a major obstacle to industrialization. Investment in a piece of equipment—especially imported equipment—represents a considerably greater social cost in terms of resource input than is the case in developed countries. Under these conditions, waste of equipment which could be avoided by good maintenance practices or adequate repair is extremely poor industry practice; in fact, even more care is called for to ensure optimum performance of each piece of equipment.

Actual practice in under-developed countries often fails, however, to bear out this simple logic. United Nations technical assistance experts in industry have noted on a number of occasions that, because of neglect, valuable equipment operated at only a fraction of capacity, was out of production for prolonged periods of time and, in some cases, had been damaged beyond repair. Lack of skilled operators as well as inadequate care are generally the main causes. In many cases, however, lack of attention to maintenance is due to indifference on the part of management.[10] There is often reluctance to engage in expense which may not yield immediate returns; a maintenance department is considered an unnecessary burden on the enterprise. Paradoxically enough, management may be inclined—even more so than in industrialized countries—to consider aged equipment obsolete and valueless; this aversion to old equipment and techniques may even sometimes take the form, especially in public enterprises and services, of deliberate neglect in cases where a policy of replacement of old equipment is favoured by the management.[11]

Maintenance in the modern sense requires a high level of organization. It is not directly related to the manufacturing procedure and its timing and periodicity are set by predetermined arrangements rather than by following "signals" sent out by the production process.[12] Where modern methods of maintenance are not spontaneously initiated by industry, Governments of under-developed countries should undertake corrective action as an essential element of their policy of industrial development. In the public sector, such action can be direct; in the other sector, indirect measures are called for. Of the utmost importance is an extensive training programme, emphasizing methods and techniques of improving the utilization of equipment. Another measure is the granting of premiums to production workers for proper care of equipment. Financial and fiscal incentives should also be provided by the Government, particularly where management and engineers tend to underestimate the importance of extending the life of equipment by proper maintenance. The use of fully-depreciated equipment beyond its "accounting" life should be encouraged.

[8] In 1958, 60 per cent of the machine tools in the United States were at least ten years of age; in the United Kingdom and the Federal Republic of Germany 50 and 44 per cent, respectively, of all machinery were estimated to be over ten years of age. The lower age of equipment in the last two countries is explained by the war-time destruction and subsequent renewal and replacement policies. That year, in Poland, over 47 per cent of machine tools were at least ten years old and about one-fourth were over twenty years old. *American Machinist*, 17 November 1958 (New York); R. Krengel, "Das Industriepotential der vier Grössten Industrieländer der Welt" (The industrial potentialities of the four largest industrial countries of the world), *Konjunkturpolitik*, 1958 (Berlin); *Rocznik Statystyczny* (Statistical Yearbook), 1959 (Warsaw), page 131.

[9] *See* United Nations, "Problems of Size of Plant in Industry in Under-developed Countries", *Bulletin on Industrialization and Productivity*, No. 2 (Sales No.: 59.II.B.1), page 22, footnote *26*.

[10] The seriousness of this factor may be illustrated by the difficulties encountered by an expert in an Asian country in issuing maintenance instructions because the local language did not even have a word for the concept of maintenance. *See*, in addition, United Nations, *Management of Industrial Enterprises in Under-developed Countries* (Sales No.: 58.II.B.5), pages 22 to 24; "Some Problems of Industrial Management Reported by Technical Assistance Experts", *Bulletin on Industrialization and Productivity*, No. 2, pages 55 and 56.

[11] At the same time, purchase of second-hand equipment, particularly by the smaller enterprises, is done on a large scale in under-developed countries.

[12] In order to ensure a high level of maintenance, it has been suggested that modern, capital-intensive technology be used in under-developed countries. Capital-intensive processes are usually organized in a very strict and rigorous way: aware of the high value of equipment, operators, as well as management, are supposed to pay the utmost attention to each process requirement in the production and maintenance fields. (Albert O. Hirschman, *The Strategy of Economic Development* (Yale University Press, New Haven, 1958), pages 138 to 143). This measure, possibly efficient in theory, is generally too expensive in terms of capital and skilled labour to be introduced on a mass scale.

Spare parts

An important problem in under-developed countries is that of spare parts, which are often scarce and expensive. In many cases, management is not aware of the necessity of carrying adequate inventories of parts; in other cases, equipment is so heterogeneous as regards age, type and country of origin that procurement of parts is a complex and, in the case of some rapidly obsolescing equipment, an impossible task. These difficulties are often compounded when exchange authorities, because of their lack of appreciation of the spare parts problem, are reluctant to allow exchange for adequate imports. This problem has been discussed in an earlier report.[13] The alternative of local production of spare parts is briefly discussed in appendix II.

Greasing a turret lathe in a Michigan factory

In the following section, some aspects of possible substitution of labour for spare parts in maintenance and repairs will be considered.

In the industrial countries, as a consequence of rising wage levels relative to material costs, the trend has been towards decreasing the use of labour in maintenance. The automatic replacement of spare parts, mentioned above, is an extreme illustration of this tendency. In less developed countries—where labour is cheaper and spare parts are more expensive—it appears questionable whether the same trend should be followed or whether, on the contrary, greater use should be made of labour in order to save on spare parts. The extent to which the latter substitution is justified will be determined by two factors: the price relationship between labour and spare parts and the elasticity of substitution between the two.[14] For a given country, the former is fairly constant over relatively short periods of time. Elasticity of substitution, on the other hand, varies with the type of equipment and the type of maintenance or repair, but, given the latter, is roughly the same regardless of location.

While no direct data are available, approximate values for the elasticity of substitution can be derived from relative outlays in maintenance and repairs for wages and material costs. Thus, a fifty-fifty ratio would indicate a substitution elasticity value of one; a ratio of 60 per cent labour costs and 40 per cent material costs an elasticity value of 1.5.[15]

A simple example will illustrate the impact of a change in the price relationship of labour and spare parts on the optimum relative input of both components. It will be assumed that elasticity of substitution is equal to unity. This means that the product of outlays for labour and spare parts is constant, irrespective of the proportions in which they are used; under these conditions the optimum proportion would obtain when the *outlays* for both factors are equal. It is further assumed that for a given volume of maintenance and repairs the outlay in the United States equals $100 for each component, or $200 for the total. Finally, it is assumed that the price of labour in a given under-developed country, as compared with the United States, is in the ratio of 0.40 to 1 and the price of spare parts in the ratio of 1.60 to 1. If the relative *physical* input of both factors is unchanged, the outlay for labour is equivalent to 0.40 × $100 = $40, and that for spare parts to 1.60 × $100 = $160, which gives an unchanged total outlay of $200. However, because of the low cost of labour compared to that of spare parts, it will be profitable to change the proportions of physical input in favour of the former. A minimum of total costs will be reached when, on the basis of the assumed elasticity coefficient of one, substitution of labour for spare parts is pushed up to the point at which the outlays for both factors are again equal, assuming this to be technologically feasible.[16] This will imply doubling the physical input of labour combined with a saving of one-half on spare parts; the combined outlay will then be 2 × $40 + 0.5 × $160 = $160. An adaptation of the relative use of labour and spare parts to the different price relationship would thus result in a saving of 20 per cent.[17]

[13] United Nations, *Management of Industrial Enterprises in Under-developed Countries*, pages 22 to 29.

[14] This elasticity may be defined as the percentage saving on spare parts resulting from a one per cent increase in labour input.

[15] For the mathematical deduction of these statements, see appendix III.

[16] *See* appendix III. It is interesting to note that the affirmation that the optimum relative outlays for production factors will remain constant under different relative factor prices (under the proviso of substitution possibility and a constant coefficient of substitution) is not limited to maintenance operations but holds true for all production processes.

[17] An interesting example of international co-operation in maintenance based upon marked differences in labour costs is the practice of American, British and other airlines of sending their airplanes to Israel for major repairs, heavy maintenance overhauls, crash damage repairs and similar jobs. The competitive advantage of Israel in this field stems mainly from the low cost of its skilled labour. (*The New York Times*, 7 July 1960.)

OPTIMUM LIFETIME

The problem of optimum lifetime has two aspects: one relates to measures for extending the useful life of a given piece of equipment. This poses, as will be seen later, an "optimum" problem. The second aspect relates to the more general question of replacement, in which physical lifetime is only one of the elements to be considered. This section is concerned with the first aspect; the following section deals with the second.

Table 2

ANNUITY VALUES OF INTEREST AND DEPRECIATION AT INTEREST RATES OF 6 AND 12 PER CENT, AT END OF YEARS

(Percentage of cost of equipment)

Lifetime of equipment (number of years)	Annuity values at end of lifetime: At 6 per cent interest	At 12 per cent interest
8	16.10	20.13
9	14.70	18.77
10	13.59	17.70
11	12.68	16.84
12	11.93	16.14
13	11.30	15.57
14	10.76	15.09
15	10.30	14.68
16	9.90	14.34
17	9.54	14.05
18	9.24	13.79
19	8.96	13.58
20	8.72	13.39

RELATION OF MAINTENANCE AND REPAIR TO LIFETIME

The problem is to determine the optimum physical lifetime of the equipment in relation to the required volume of maintenance and repairs. For the sake of simplicity, it will be assumed that obsolescence can be left out of account. The useful lifetime will then be determined by physical wear and tear and it is assumed that it could be extended, through more intensive maintenance and repair, over the working life of the equipment. Thus, moving parts can be kept in good working order longer through more frequent lubrication, inspection, adjustment and replacement of worn out parts; untimely deterioration of the basic frame can be prevented by periodic derusting, repainting, repairs and the like. The problem referred to above may be formulated as follows: given the increase in the annual volume of maintenance and repair corresponding to an increase in the lifetime of the equipment, what is the optimum lifetime and the corresponding annual outlay for maintenance and repair? The solution to this problem is simple. Since the extension of lifetime will correspond to a decrease in annual cost of interest and "accounting" depreciation, the optimum lifetime will be the point at which this decrease equals the increase in annual cost of maintenance and repairs.[18]

A numerical example may be given as an illustration. It will be assumed that with an increase in the annual cost of maintenance and repair equal to one half of one per cent of the cost of the equipment, a one-year extension of lifetime can be obtained. It is further assumed that the annual interest rate is 6 per cent. The annuity values for this rate are given in the appropriate column of table 2.

It can be seen from table 2 that the optimum lifetime is about fourteen years; an extension from thirteen to fourteen years will result in a saving of 0.54 per cent on the annual cost of interest and depreciation

Electricians examining the windings of a large motor before repairing it

which is more than the assumed one half of one per cent additionally required for annual maintenance and repairs—and will thus be profitable. An extension from fourteen to fifteen years would result in an annual saving in the cost of interest and depreciation of only 0.46 per cent and, therefore, would not be profitable.

The effect on optimum lifetime of the different factor-price relationships normally obtaining in under developed countries will now be examined, the as

[18] Throughout this section it is assumed that equipment of comparable performance is available at the time of replacement at the same cost as the equipment in use.

Maintenance crew checking pipelines in a DDT production plant in New Delhi

sumptions made in the preceding section in connexion with the relative use of labour and spare parts being retained. Under these assumptions, the cost of labour[19] in the under-developed areas is 60 per cent lower than that in the United States, and the cost of imported spare parts—which is being taken to be that of equipment in general—is 60 per cent higher. In maintenance and repairs, labour and spare parts may be substituted for one another in inverse ratios. It was found that under such conditions the cost of a given volume of maintenance and repairs, assuming that the physical input mix of labour and spare parts is adapted to the price relation between these factors, will be 20 per cent lower in the under-developed countries than in the United States. The ratio of the cost of maintenance to the cost of equipment in the under-developed area is thus one-half of what it is in the United States.[20] If this figure is applied to the case cited above it will be found that, for the under-developed areas, an extension of the lifetime of the equipment by one year requires an increase of only one-fourth of one per cent in the annual costs of maintenance and repairs instead of one-half of one per cent. This corresponds, according to table 2, to an optimum lifetime of approximately nineteen years. The decrease in annuity resulting from an extension of lifetime from eighteen to nineteen years is 0.28 per cent, and from nineteen to twenty years, 0.24 per cent.[21]

It will be noted that for the calculations of optimum lifetime only the corresponding *change* in annual cost of maintenance and repairs of the lifetime is relevant, and not the actual *level* of it.[22]

Relaxation of the simple assumptions discussed above

It was assumed in the example used above that the same interest rate obtains in the under-developed area and in the United States. The introduction of different interest rates will not raise any additional problems: it will involve the use of different annuity tables. Thus, for an interest rate of 12 per cent, the annuity values in the appropriate column in table 2 indicate a slightly lower optimum lifetime of about eighteen years.

Also in the example above the maintenance and repairs were assumed to be spread evenly over the whole life of the equipment. However, in what we may label "the first case", part of the maintenance and repairs is normally in the form of periodic inspections and overhauls (see chart 1, graphs 1a and 1b). Moreover, maintenance and repairs may increase with the age of the equipment (graph 3a); this we call "the second case". In the first case, in order to extend the life of the equipment, more frequent and more intensive inspections and overhauls (graph 2a) are required; the corresponding increase in annual maintenance and repairs can then be estimated by averaging[23] the additional costs (graph 2b).[24] In the second case, extension of lifetime requires relatively more intensive maintenance and repairs during the "extra" lifetime which is reflected in substantially higher averaged cost (graphs 3a and 3b). The procedure for determining the optimum lifetime in the first case will not differ basically from that in the simple example given above; the profitability of such an extension in the second case requires further investigation.

The following example may be offered as an illustration. It will be assumed that, in the United States, the cost of maintenance and repairs increases each year after the first five years of operation by one-half of

[19] The ratio of the cost of labour should clearly be calculated as the ratio of the wage level multiplied by the ratio of labour productivity.

[20] The ratio is indeed 80 per cent 160 per cent ½.

[21] The optimum lifetime can be determined with greater accuracy by a graphical procedure.

[22] To determine the total volume of maintenance and repairs that is required for the physical lifetime to be optimum, the latter datum, of course, has to be known.

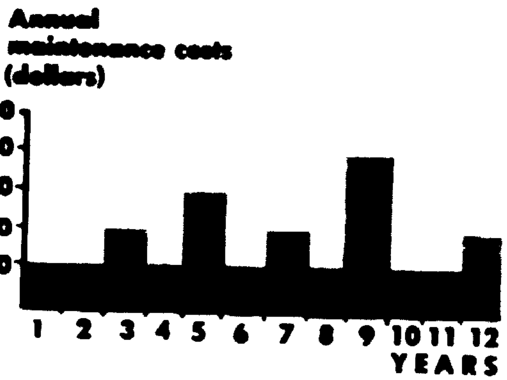
[23] The averages in the graphs refer to averages for alternative lifetimes.

[24] The decision regarding actual replacement may, in this case, be advanced or deferred depending on whether or not a major overhaul is impending. This, however, can rarely be foreseen with sufficient accuracy at the time the equipment is put into operation. Thus, it will not influence the decision regarding the appropriate periodicity and intensity of the general overhauls in view of the initial estimate of the optimum lifetime.

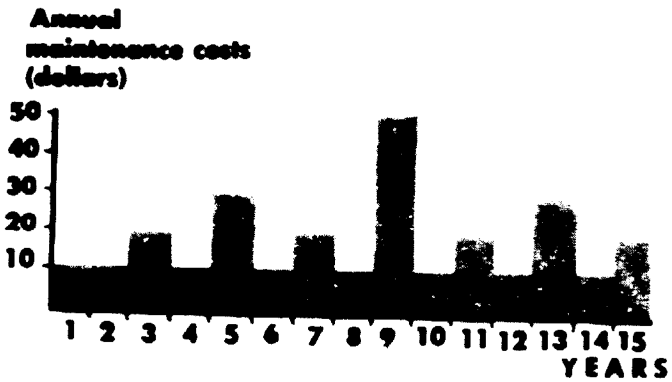
Chart 1

PATTERNS OF MAINTENANCE

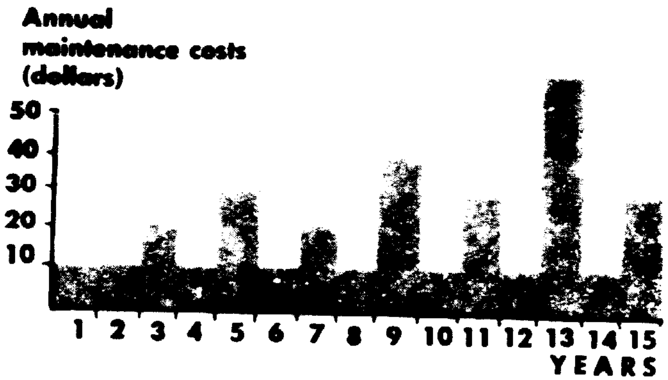
Graph 1a



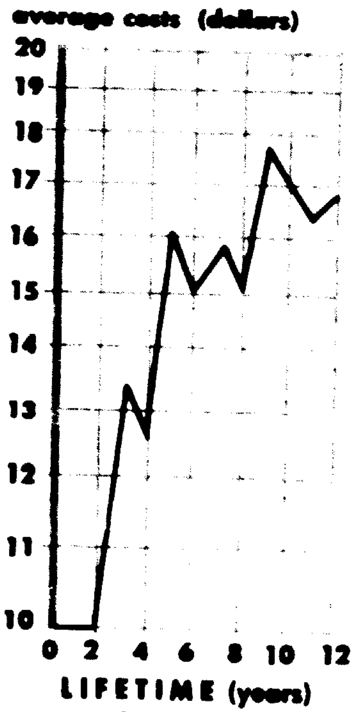
Graph 2a



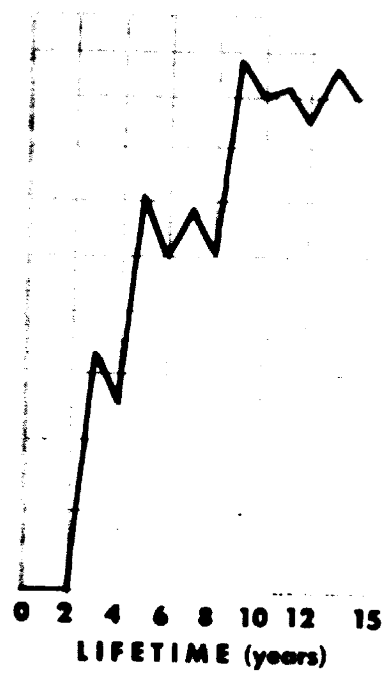
Graph 3a



AVERAGE MAINTENANCE COSTS FOR ALTERNATIVE LIFETIME PERIODS
(*Semilogarithmic scale*)



Graph 1b



Graph 2b

Graph 3b

one per cent of the cost of the equipment;[25] and that, as in the earlier example, by increasing the annual cost of maintenance and repairs over the whole working life by one-half of one per cent of the cost of the equipment, a one-year extension of the lifetime will be achieved. The procedure will consist of calculating the annual average of the variable component of the cost of maintenance and repairs for alternative lifetimes, and comparing the increase in this average with each additional year of lifetime against the decrease in costs of interest and depreciation. The optimum lifetime will correspond to the point at which the two are equal.

The calculation[26] shows that for a 6 per cent rate of interest the "aging" factor in maintenance would reduce, under assumed conditions, the optimum lifetime in the United States from fourteen to twelve years, and in the under-developed areas from nineteen to sixteen years; for a 12 per cent interest rate, the corresponding figures for under-developed areas would be eighteen and fifteen years.

[25] The absolute level of the cost of maintenance and repairs is, again, irrelevant to this problem.

[26] This is given in appendix IV. Anticipated obsolescence can be taken into account in the same way, by raising the figure of expected increase in annual costs of maintenance and repairs with growing age by a factor for the expected disadvantage in annual operating costs (other than maintenance and repairs) of the existing equipment is compared with the new.

A more accurate procedure would be to calculate the annual equivalents of the variable maintenance and repair costs on an annuity basis, as has been done for interest and depreciation.[27] This, however, would introduce a considerable complication into the computations that does not seem justified if the margin of uncertainty in the underlying data themselves is taken into account.[28]

[27] By simply averaging, the interest factor is not taken into account, which means that a cost item towards the end of the lifetime is given the same weight as a cost item at the beginning. Under the indicated alternative method, maintenance costs for each year would be discounted at the given interest rate; the cumulative discounted values for each alternative lifetime would then be converted into the equivalent annuity.

[28] In the given example the optimum lifetime values calculated by the two methods would be as follows (rounded at full years):

	United States	Under-developed areas: At 6 per cent interest	Under-developed areas: At 12 per cent interest
Equivalent constant annual cost of maintenance and repairs:			
By the simple averaging method	12	16	15
By the annuity method	12	16	16

Only in one case is there a divergence—of one year—in the result obtained by the more refined method.

REPLACEMENT OF EQUIPMENT

POLICIES AND PRACTICES DEVELOPED IN INDUSTRIALIZED COUNTRIES

THE DECISION TO replace an old equipment item with a new and "better" one is usually based on a number of considerations. Economic factors, important as they are, will not always be decisive: old equipment may be replaced because of social legislation—for example, new equipment may be safer or more healthful to operate; replacement may also be justified on the grounds of technological improvements of the production process. However, economic viewpoints, if not decisive, are taken into account as subsidiary factors whenever a decision to replace equipment is being considered. The issue involves two aspects: first, the decision whether to retain old equipment or to replace it; and second, assuming that a replacement decision is made, the selection of the appropriate capacity, type and make of new equipment.

The two aspects are clearly interrelated: the decision to replace old equipment will be influenced by a comparison of the performance expected from the replacement equipment with that of the old. For this reason, a systematic approach requires an analysis of the two problems in inverse order; that is, to make, first, a comparative study of the prospective performance of the potential "challengers" in view of the requirements, and next, to compare the most successful "challenger" with the "defender".[29]

Performance is taken net, that is, gross earnings minus costs, the difference in performance being related to net investment—the installed cost of the new less the salvage value of the old equipment.[30]

Each of the above factors can be quantified with more or less precision; several methods—described below—have been devised to measure their combined effect. Once a method has been adopted, the computations are generally made by the technical department which in turn relies on the sales, production and maintenance departments for data on such items as the anticipated development of the market, performance, and maintenance and repair costs.

For the final decision, a few more factors will generally be taken into account. As the funds available for investment in a given company are necessarily limited, a given replacement proposal will be ap-

[29] The terms "challenger" and "defender", which represent the new or second-hand and the present equipment, respectively, are taken from George Terborgh, *Dynamic Equipment Policy* (McGraw Hill, New York, 1948).

[30] Tax regulations—for example, temporary tax exemptions or accelerated depreciation periods for new equipment—which sometimes play an important role in the calculations of performance, will not be considered here.

praised not exclusively on its own merit, but in relation to other competing investment needs, such as replacement of other equipment, expansion of capacity or stocking up on raw materials or supplies (when price rises or shortages are anticipated). On the other hand, there may be various financing considerations, such as present and anticipated liquidity, possibility of loan financing or required return and interest rates. Other factors also play a role, such as the expectation of an impending technological "breakthrough" in the type of equipment under consideration which would favour postponing immediate replacement, expectations of shifts in demand which would tend to make new equipment economically obsolete and so forth.

Information regarding these and similar factors are provided in well-managed enterprises by "intelligence services" in the respective departments. The final decision on replacement would be based on a careful consideration of all the factors involved, but would take particularly into account a systematic profitability appraisal of the replacement on the basis of a comparison of costs and earnings of the "challenger" equipment with those of the "defender". However, no rigid formula can be devised; the final decision will involve a comparative weighing of a complex of factors, several of them intangible ones. For this reason, important decisions on equipment replacement are, as a general rule, not left to one or another department of the enterprise, but are made by top management, which is in a position to have an over all view.

In the following paragraphs, some procedures are discussed which aim at determining the combined effect of the "objective" or measurable factors on the profitability and urgency of considered replacements. First, a few rule-of-thumb approaches are briefly examined. Then follows a description of some of the methods for more systematic evaluation which have been developed in the economically advanced countries. Finally, an analysis is made of the latter procedures in the light of conditions in industry in under-developed countries.

Rule-of-thumb approaches

Rule-of-thumb approaches—although they are rather crude—are mentioned because of their wide-spread use in industry in both developed and under-developed countries.

(*a*) One such practice is based on the criterion that a piece of equipment should not be replaced until it has "earned its worth", or has been "written off". This criterion is clearly incorrect. In decisions regarding replacement of equipment—as in all economic decisions—it is only the present and the future that should play a role.[31] Thus, replacement of even a recently purchased machine can be justified if it was bought because of wrong judgement, or if it became obsolete because of new developments in technology or market demand that could not have been foreseen at the time of the purchase; conversely, further retention of equipment that has been operating far in excess of its anticipated lifetime and has earned its worth several times over may be justified.

(*b*) "*Postponability*" is a somewhat more acceptable criterion for replacement. Under this test, proposals for replacement are appraised according to their "urgency" taking into consideration impending major repairs or breakdown of the old equipment, and any replacements that can be postponed are deferred almost automatically. The drawback of this practice is that it is based on emergency situations and fails to provide guidance for decisions on replacements that would, in themselves, be highly profitable.

(*c*) *Pay-back time*, a somewhat less crude criterion, is the number of years required to earn back the cost of the equipment; it is obtained by dividing the cost of the new equipment by annual savings or additional earnings or both. Thus, the pay-back time of a machine costing $15,000 and yielding an annual return of $3,000 will be five years. Refinements are introduced by adjusting the profits for taxes, depreciation and similar items, by taking the cost of the new equipment net of the salvage value of the old equipment and by introducing the annuity factor into the calculations.

The pay-back time test may to a certain extent be justified, especially when capital for replacement is extremely limited and will continue to be so for a number of years. Under such conditions, it is of the utmost importance that an investment for replacement should be recovered in the shortest possible time, thereby releasing funds for other desirable purposes. The weakness of the practice is that the situation obtaining after the pay-back period is left out of account; yet, it is precisely after this period that the investment may start yielding substantial profits. This may be illustrated by a simple example: two alternative replacements are being considered with pay-back periods of three and four years, respectively. Assuming that the lifetime of the new equipment is five years in the first case and ten years in the second, a strict application of the pay-back time criterion would give priority to the first replacement. On the other hand, assuming stable yearly profits, the second replacement would earn 150 per cent in excess of its cost, against 67 per cent for the first one.

More refined methods

The more refined methods used in appraising replacement proposals involve a systematic comparison of present outlays with future outlays and of the earnings and savings of the existing equipment with those of the proposed new equipment. The *accounting method*, also called the *present worth method*, is a "traditional" method based upon normal accounting principles. The new equipment will require a capital outlay at the time of purchase and probably additional outlays in the course of its lifetime. The latter are discounted

[31] Past developments may play an indirect role in providing an indication of expected future developments.

at a given interest rate, and the sum of the immediate outlay and the discounted future expenditures, less the salvage value of the old equipment, constitutes the net investment involved in the replacement. On the other hand, the new equipment may permit savings on operational costs and on maintenance and repairs, as compared with the old. It may, moreover, yield greater earnings as a result of increased capacity or better quality of product, or because the number and duration of breakdowns are expected to be smaller. All these elements are estimated on a year-to-year basis and again discounted at the same interest rate. If the total of the discounted advantages exceeds the cost of investment, the replacement is profitable, and will be considered; in the reverse case, it will be rejected.

The cost of future replacement will be taken into account as an item implied in the alternative of "no replacement now". On the other hand, the equipment to be acquired in, say, three or five years may be expected to be better than the immediately available replacement as far as operational costs, maintenance and repairs and other factors—for example, quality—are concerned. All these items, at their discounted values and with their appropriate signs, will, of course, again be included in the comparison.[32]

It follows that the accounting method, although simple in principle, is rather complicated in practice. This is one of its major weaknesses, not only because of the computations involved, but much more because it requires estimates of costs and benefits extending into the far future. These forecasts may easily take the form of more or less educated guesses, thus making the apparent precision of the method rather illusory.

Another drawback is that future costs and benefits are discounted at a predetermined interest rate. This would be justified if it were certain that the required capital for the purchase of the replacement could be obtained at that rate. There is an implicit assumption that either the replacement is the only investment under consideration, or enough capital can be obtained at the same rate for the financing of this and all other investments of comparable and greater profitability. These conditions may, exceptionally, be fulfilled in the case of some larger publicly-financed projects—power plants, bridges, highways; they will rarely apply in the case of private or even public industrial enterprises.

The "discounted cash-flow method"

The problem of replacement normally involves the choice among a number of proposals competing for scarce capital; consequently, priorities have to be applied to the various proposals, rather than the profitability of each proposal being analysed individually. If these priorities are set according to the excess of discounted profits over discounted costs, the procedure is not unexceptionable, because the calculations are made on the basis of a predetermined interest rate, which, as mentioned above, is not always applicable.

An approach which aims at avoiding this drawback is the "discounted cash-flow method",[33] under which the rate of return on the proposed investment is defined as the discount rate that will make the sum of the present value of the flow of future savings and the earnings resulting from a proposed replacement equal to the cost of the replacement. The discount rates thus obtained for alternative replacements are then used to determine the order of priority.

As a simple illustration, consider a cost-reducing replacement for which data are presented in table 3. It is assumed that the replacement requires a net investment of $10,000; that the new equipment, as compared with the old, is expected to produce savings and extra earnings over its anticipated lifetime of ten years, as indicated in the table; and that neither the old nor the new machine has a salvage value. As the table shows, the rate of return on the investment in replacement would, in this case, be 20 per cent.

This method has a decisive advantage over the accounting method; however, it still retains the drawback of the latter in that the reliability of the results depends on the accuracy of estimates for far-off years. It involves a considerable amount of work, not only in making the predictions in connexion with a number of items over the lifetime of the new equipment, but also in the computations of the equity return rate.

The MAPI formula

A method developed in the United States by the Machinery and Allied Products Institute (MAPI) aims at presenting a short-cut formula that avoids the drawbacks referred to in the preceding paragraphs. First introduced in 1948, the formula was substantially modified in 1958.[34] The following discussion is based on the later version.

To derive the "MAPI urgency rating", which is an order of priority for prospective investment, a detailed comparison is made of projected costs and revenue under two assumptions: (*a*) that the present equipment is kept, and (*b*) that it is replaced. Then a calculation is made of next-year capital consumption of the replaced item; this is considered below in some detail. Next-year "advantages" of the new over the old equipment will, in general, comprise the following components, some of which are negative: (*i*) lower operating costs of the new equipment in terms of direct labour, maintenance and repairs, power and the

[32] The comparison, at least in theory, should not be confined to the expected life of the new equipment, because the decision as to whether or not to replace now will, in principle, influence the dates of all future replacements.

[33] This method is also referred to as the "cash-flow method", "investor's method", or "profitability index method". *See* Joel Dean, "Better Management of Capital Expenditures Through Research", *The Journal of Finance*, May 1953 (Chicago), pages 121 to 124; Ray I. Reul, "Profitability Index for Investments", *Harvard Business Review*, July-August 1957 (Cambridge, Massachusetts).

[34] Compare George Terborgh, *Dynamic Equipment Policy*, op. cit., and *Business Investment Policy* (Machinery and Allied Products Institute, Washington, D.C., 1958).

Table 8

ILLUSTRATION OF DISCOUNTED CASH FLOW METHOD FOR DETERMINATION OF RATE OF RETURN ON AN INVESTMENT FOR REPLACEMENT
(United States dollars)

Net investment required for replacement: $10,000
Anticipated lifetime of new equipment: 10 years
No salvage value of old or new equipment

		Discounted value of earnings[a] at various interest rates				
Number of years	*Earnings of new equipment[b]*	*15 per cent*	*18 per cent*	*20 per cent*	*22 per cent*	*25 per cent*
1	1,200	1,119	1,105	1,095	1,086	1,073
2	1,500	1,216	1,170	1,141	1,112	1,073
3	1,900	1,340	1,252	1,204	1,156	1,088
4	2,400	1,472	1,345	1,268	1,197	1,099
5	3,000	1,599	1,424	1,321	1,226	1,099
6	3,400	1,576	1,368	1,247	1,139	997
7	3,400	1,371	1,159	1,039	934	797
8	3,400	1,192	983	866	762	638
9	2,500	756	612	531	461	375
10	1,600	424	332	283	242	192
TOTAL	24,300	12,065	10,754	9,995	9,315	8,431

Note. The table illustrates one variation of the discounted cash flow method. Other variations might be based upon different assumptions, for example, earnings gross of depreciation, or a different timing of earnings, or taking into account "savings" which are not the internal project earnings but rather the difference between having the project and not having it.

[a] Annual earnings are assumed to accrue at mid-points of years.

[b] Earnings are taken as gross earnings minus costs and net of depreciation. They are assumed, first, to increase with a growing market from $1,200 annually in the first year to $3,400 in the sixth year, to remain at that level for three years, and finally to decrease during the last two years as a consequence of deterioration of the equipment.

ake; fringe benefits; adverse elements, such as higher insurance premiums; (*ii*) additional revenue, if any, obtained from the new equipment as a result of better quality—for example, better conformity to specifications—or higher output due to greater capacity and fewer or shorter breakdowns; (*iii*) savings, in the case of replacement, on next-year capital consumption of the old equipment; this is estimated as the difference between the salvage value now and what it would be in a year's time; (*iv*) next-year capital consumption of the replaced item calculated on the basis of the estimated lifetime of the new equipment, taking into account several other factors; when any additional capital outlays are foreseen in connexion with the new equipment in the course of its lifetime, an annual *pro rata* of such outlays will be added to this item; (*v*) in business practice all these factors would, of course, be adjusted for their tax incidence.

The net investment involved is calculated as the installed cost of the new equipment minus the amount of capital recovered or saved through the replacement; the latter may comprise the salvage value of the old equipment or capital outlays in connexion with the old equipment required in the absence of replacement, or both.[35]

Most of the items above can be directly estimated by a technical department in the enterprise on the basis of available data from the production, maintenance and sales departments, and those supplied by the producer of the new equipment.[36] In the calculation of the next-year capital consumption of the new equipment (item (*iv*)), a number of factors are taken into account, such as the assumed pattern of decline in earnings of the equipment over its lifetime; the depreciation method applied; the terminal salvage value; the income-tax rate; the ratio between loan capital and total investment; the interest rate on borrowed capital; the after-tax return on equity capital.[37]

In evaluating the MAPI formula, the following considerations must be taken into account. First, there is an implicit assumption that next year advantages are representative of all future years, which is not tenable in theory. In practice, however, cases of substantial variations in these magnitudes over the years of operation are rather exceptional; if necessary, such variations can be taken into account on an *ad hoc* basis. Projections over long periods, such as were described in connexion with the methods previously discussed, may often tend to be subjectively biased; a definite advantage of including only next-year estimates is that they are less liable to estimating errors.

The second consideration relates to the use of a

[35] The procedure is illustrated by an example in appendix IV, table 4.

[36] Standard forms for these calculations have been prepared by MAPI.

[37] MAPI has published a set of charts that permit, for various combinations of assumptions with regard to these factors, the immediate reading of the percentage rating for any lifetime between five and forty years and salvage values of up to 50 per cent.

predetermined interest rate. As mentioned earlier, this is one of the reasons why the discounted cash-flow method is considered more suitable than the accounting method. It will be noted, however, that the interest rate is used here only for the calculation of a relatively unimportant component relating to next-year capital consumption. On the other hand, the MAPI rating is essentially similar to the rate of return under the discounted cash-flow method.

The third consideration relates to the estimate of next-year capital consumption of the new equipment. The formula for the calculation of this component is very complicated and it is practically out of the question to apply it in each individual case. For some combinations of factors the capital consumption can be read off as a percentage of the installed cost of the equipment from the charts referred to earlier. However, even for the United States, for which the charts were calculated, they provide only approximate values inasmuch as conditions in each enterprise will diverge from the standard assumptions of the formula as regards some of the determining factors.[38]

THE PROBLEM OF REPLACEMENT OF EQUIPMENT IN UNDER-DEVELOPED COUNTRIES

The practices used in the developed countries are to a certain extent applicable also in under-developed countries.

(*a*) In many under-developed countries foreign enterprises comprise a substantial part of the industrial sector. These enterprises are set up on lines basically similar to those in their home countries; their capital supplies and even their demand for skilled labour are determined essentially by factor endowments in the home country, even if some allowances are made for possible substitution of labour for capital.

(*b*) Decisions on replacement are normally made by top management, which is frequently well versed in the practices of developed countries.

(*c*) The decisions are taken on the basis of objective evaluation reports prepared according to a standard procedure, taking into account such factors as the present liquidity position of the enterprise and its anticipated development in the near future, prospective changes in technology, the market situation and so on.

On the other hand, other considerations operate against the application of policies and methods used in the developed countries. In the developed countries based on private enterprise, replacement decisions are made essentially in terms of market prices. In under-developed countries—especially those with "mixed" economies—it is generally more appropriate to base decisions on "economic" prices—called also "shadow" or "accounting" prices—reflecting the prevailing factor endowments.[39]

In view of the scarcity of investment resources, Governments in under-developed countries are generally taking a more active role in plant utilization as well as in investment allocation. Optimum maintenance, minimum replacement and maximum efficiency of new investment are among the targets of such policies. Clearly, from the point of view of optimum distribution of investment, replacement may be considered as one investment alternative. If this approach is taken, apart from comparing the respective merits of the "challengers" and "defenders", as discussed above, some new considerations should be brought into the picture.

In the developed countries, from 20 to 40 per cent of gross investment in industry is usually for replacement purposes. It is supposed to add little, if anything, to plant capacity, its purpose being mainly a reduction in operating costs or an improvement in quality of output.

In the under-developed countries a somewhat smaller share in investment plans is normally allocated to replacement because rates of new investment generally exceed those of replacement needs. Resources are devoted as much as possible to new investment and new capacity in order to accelerate the growth of national income. Therefore, Governments should seek to reduce replacement volume as much as possible and encourage installation of new capacity.

Thus, in under-developed countries, there may frequently be a divergence between the private and social points of view in replacement policy. From the private economic point of view reduction of costs is equally satisfactory whether it applies to labour, material or capital costs. From the national economic point of view, since labour is generally the abundant factor, its replacement by capital in order to achieve a reduction in labour cost may not be justified. Replacement should take place, on the other hand, if the new equipment provides substantial reduction in materials costs, especially those of imported materials, or investment costs elsewhere in the production process. To a certain extent, the same holds true of depreciation charges, in so far as these reflect not physical but accounting depreciation.[40] If these considerations are not sufficiently reflected in the replacement policies of the private sector, which is often the case, the government should take special measures for ensuring appropriate policies. Such measures might consist, for example, of elaborating suitable methods for economic justification of replacement in mixed and publicly financed or government-assisted private enterprises; these methods could take

[38] Nevertheless, varying the MAPI chart factors ("debt ratio", "debt interest rate" and "after-tax equity return") within a considerable range above and below their "frozen" values ordinarily causes only negligible errors. (*Business Investment Policy*, op. cit., page 234.)

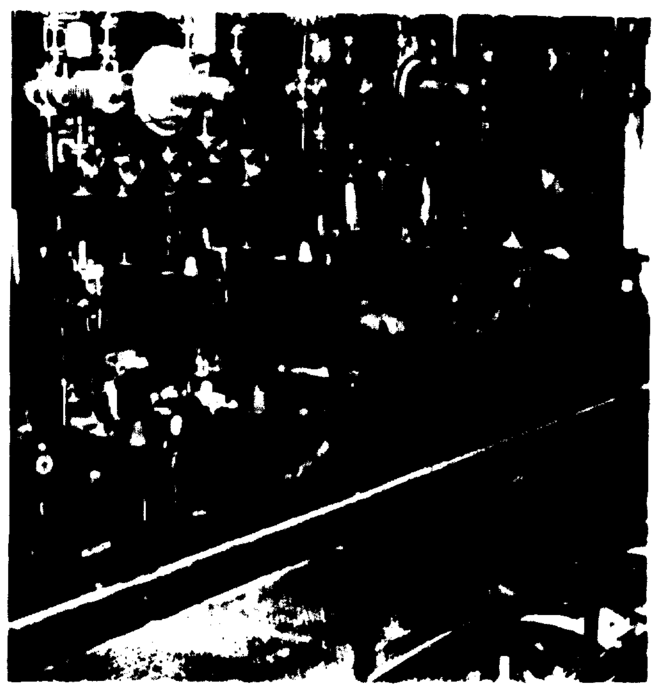
[39] Reference is made to the discussion of this problem in *The Design of Development* by Jan Tinbergen (Baltimore, 1958), pages [illegible] to 41.

[40] This difference, especially important in growing economies, is discussed in detail in "Depreciation, Replacement and Growth", by E. D. Domar, *Economic Journal*, vol. LXIII, March 1953 (London). *See also* "Capital Intensity in Heavy Engineering Construction", United Nations, *Bulletin on Industrialization and Productivity*, No. 1 (Sales No.: 58.II.B.2).

Repairing the return bends on one of the low pressure cracking coils in a Louisiana refinery

Maintenance crew inspecting a large rotary press in a Japanese printing plant

Bringing a diesel engine into the shop of a West Virginia construction company for repair



Checking burners for sulphite waste liquor in a Finnish sulphite mill

the form of a detailed classification and evaluation of costs (labour, imported and domestic materials, fuel, depreciation) and the use of a "social" rate of interest for computing capital costs, or a "social" rate of exchange of foreign currency. In the case of other private enterprises, government action might be taken through tax legislation, import policy, credit policy, and provision of training facilities. Where public enterprises do not already take social costs into account, some of the above measures should, of course, also be applied.

The problem of choice and application of the "social" rate of interest in evaluation of investment projects is extremely complex and many planning agencies in the private enterprise and centrally planned economies, which recognize the importance of its use, are working on this problem. For example, the Commissariat général du Plan in France uses 7 to 8 per cent as the "economic" rate of interest. In centrally planned economies these rates recently were ranging from 15 to 30 per cent for different branches of industry, which correspond respectively to from seven to three years for recoupment of the invested capital.[41]

Detailed discussion of how to determine the "proper" rate of interest while evaluating projects in under-developed countries is beyond the scope of this article.[42] It is useful, however, to mention here one important point, namely, that the same rate should be used in replacement calculations as in evaluation of projects.

In the light of the above-mentioned considerations, the applicability of different techniques of evaluation will now be discussed. Among the cruder yardsticks, the one based on past performance of the old equipment is, as stated, inapplicable; so also is the simple "postponability" criterion, which tends to lead to decisions based on emergency situations. However, a somewhat more refined "postponability" method connected with the pay-back time criterion may sometimes be considered, for instance in the following form.

The problem of replacement seldom arises as long as a general overhaul is not required. The cost of new equipment is usually very considerable and savings on operating costs should be very substantial in order to justify retirement of serviceable plant. The situation changes completely, however, when an overhaul becomes necessary in order that the equipment may continue to be used. General overhauls occur at intervals governed by the technical nature of the equipment and are usually very expensive—generally not less than 20 per cent and sometimes up to 70 per cent of the original or replacement cost. When one becomes necessary, the problem is whether to retain the old equipment with its high—and sometimes increasing—operating costs and undertake another overhaul, or to replace it with new equipment which, while less expensive in operation, will entail a larger capital expenditure.

The basic method of computation is to compare the net cost of new equipment (that is, gross outlay minus cost of overhaul and possible salvage value of the old) with the annual saving in operating costs. This is expressed in the number of years or months in which the "additional" capital cost would be "paid back" through savings in operating costs. If the period is substantially less than the estimated interval until the next overhaul, the equipment should be replaced.

This method might be used in a variety of ways; for example, savings in material costs—the importance of which was noted earlier—might be compared, a "social" rate of interest might be introduced and so on.

Among the more refined procedures, the accounting method appears suitable for appraising the profitability of large single projects in public works and public utilities, provided that a proper rate of interest is used. The discounted cash-flow method is more logical for comparison purposes, but requires—as does the accounting method—estimates of costs and performances over the lifetime of the new equipment, the accuracy of which will, in general, be questionable; moreover, this method necessitates extensive and intricate computations. The MAPI procedure provides a reasonably sound indicator, the determination of which requires relatively little work, on condition that the method of evaluating next-year capital consumption relating to the new equipment is simplified so as to be workable under conditions in under-developed countries. Appendix V contains a more detailed discussion of this problem.

[41] Akademia Nauk SSSR (Academy of Science of the USSR), *Tipovaia metodika opredeleniia ekonomicheskoi effektivnosti kapitalnykh vlozheny i novoi tekhniki v narodnom khozyaistve SSSR* (Standard method of evaluation of economic efficiency of investments and innovations in the Soviet national economy) (Gosplanizdat, Moscow, 1960). *See also* Komisja Planowania przy Radzie Ministrów (Council of Ministers, Planning Commission), *Instrukcja w sprawie badania efektywności inwestycji* (Directives concerning evaluation of economic efficiency of investment) (Warsaw, 1960).

[42] Studies on evaluation of projects in predominantly private enterprise economies and centrally planned economies, respectively, will be published in forthcoming issues of the *Bulletin*.

SUMMARY AND RECOMMENDATIONS

A SUMMARY OF the major points raised in this study and a number of concluding remarks are presented below.

1. Industrial equipment in developed countries is generally well maintained. The effective lives of equipment items are relatively long—much longer than the accounting useful lives allowed for depreciation purposes. Older and sometimes even obsolete equipment is utilized along with the most advanced equipment. Maintenance of equipment in industrially under-developed countries is in many cases far less satisfactory.

2. In order to meet increasing requirements for maintenance and repairs, Governments of under-developed countries should develop, encourage and facilitate the implementation of maintenance and replacement programmes. These would include direct action as well as indirect measures in the form of financial, fiscal and other incentives, which would induce a rational maintenance policy on the part of the private industrial sector. A maintenance and replacement programme in rapidly developing economies should be closely connected with the national investment programme.

3. More efficient and modern methods of maintenance should be adopted, for example, by using "scheduled", "planned", or "preventive" types of maintenance, as set out in appendix I. Governments and managements should, subject to point 4 below, adopt successively improved systems; they should be aware, how-

ever, of the considerable amount of engineering and clerical work involved, particularly in the "preventive" maintenance.

4. It appears certain that research is needed in this field in the following areas.

(*a*) In the abstract—and perhaps also as a goal to strive for—a substantial substitution of labour for spare parts is possible in maintenance. In terms of practical implementation, as a number of United Nations technical experts have pointed out, wide-spread substitution is often not feasible in under-developed countries because of a lack of skilled help. If it is to be practicable, a basic prerequisite would be training of both maintenance workers and operators. Equipment must be more carefully operated and kept up in order to extend the lives of the parts and thereby use relatively fewer imported and scarce spare parts.

(*b*) Technical assistance experts report that some factories have large numbers of maintenance help; yet these plants are poorly maintained because the workers are not skilled. In addition, except for certain outstanding exceptions, it would be extremely difficult at present to implement in under-developed countries the advanced maintenance methods discussed above. This is so not only because there is a shortage of skilled maintenance workers, but also because there is a scarcity of well-trained clerical staff to keep the records, and engineering staff to elaborate the instructions needed for the introduction of more advanced methods. Thus, if the heavy investment in fixed assets is to be carefully maintained, training of clerical and engineering personnel is essential. It would also be necessary to make a study of the costs of the more advanced methods of maintenance as compared with their advantages.

(*c*) The most important field of research relates to the economic instruments of maintenance and replacement policy. A set of economic indicators is required to guide both management and government agencies in improving maintenance programmes. These instruments should include, for example, economically justified prices of replacement equipment, reasonable rates of interest for use in evaluating the alternatives of replacement or new investment, and various approaches to different possibilities of reducing operating costs. Other areas of research relate to appropriate government depreciation policies for encouraging enterprises to use better maintenance and replacement procedures; the effectiveness of incentives and bonus systems for operators, supervisors and maintenance staff, especially in public and mixed enterprises, and the use of financial incentives and import licences to induce adoption of improved maintenance and replacement policies.

(*d*) Research is needed to improve the organization of maintenance and its implementation. This would include studies of means to improve the supply of imported spare parts, their local production, establishment of centralized maintenance shops for mass-scale maintenance processes, and standardization of equipment imported into under-developed countries.

5. The modern practice of using centralized repair shops and spare parts inventories is recommended, whenever appropriate. Reference is made in this connexion to appendix II, which also deals with the question of spare parts.

6. From the discussion of the "optimum lifetime", it appears that in the case of costly, long-lived equipment, that is, equipment having a lifetime of at least twenty to thirty years, such as steel mills, blast furnaces, hydroelectric plants, railroads and ships, the actuarial equivalents must be taken into account. In actual practice, actuarial equivalents may often be ignored in the case of inexpensive equipment which is not expected to have a life longer than from five to ten years. Nevertheless, when large amounts of such items are imported, the equivalents should be applied.

7. Optimum lifetimes should be considerably longer in under-developed countries, in part because of the potentially lower maintenance costs and lower operating labour costs and in part because of higher replacement costs. More detailed research, conducted with reference to specific conditions prevailing in particular countries, should convince both government and management of the importance and consequences of this basic consideration.

8. In developed countries decisions concerning replacement are dependent upon practices which are generally based on market prices and availability of equipment. In under-developed countries, market prices reflect existing factor endowments far less satisfactorily. Because of the scarcity of capital resources and in particular of imported equipment, the replacement practices followed in developed countries are only to a certain extent applicable in under-developed countries.

It is important, therefore, for governments and enterprises to develop methods on decision models applicable to conditions in the under-developed countries. As a simple and practicable method of replacement evaluation, the improved method of pay back period is tentatively recommended.

9. Governments should encourage postponement of replacement decisions, if advisable from the "social" point of view, by use of both direct measures—in state-owned and mixed enterprises—and indirect measures in the private sector. Such measures could include advice on classifying the costs, tax legislation, training facilities, and the others mentioned on page 41.

10. In a number of countries there already exist United Nations technical assistance missions dealing with maintenance and repair problems; certain other countries could usefully request such assistance.

Appendix I

TYPES OF MAINTENANCE

	Controlled by production supervision	*Breakdown*	*Scheduled*	*Planned*	*Preventive*
1 *Methods of control*	(*a*) Skilled craftsmen operating machine tools or similar engineering equipment carry out their own maintenance. (*b*) The production department has skilled craftsmen specifically allocated to machine maintenance; these men are called to machines by operatives or production supervisors as necessary. (*c*) A small maintenance gang is carried in each plant or area, under the supervision of a skilled foreman responsible to the production manager of the area.	Maintenance is organized as a separate section, but regarded merely as a service to be brought in by the production department when failures impede, limit or prevent the desired rate of production.	The maintenance staff produce an inventory of major items of plant and suggest to the production department items likely to require attention during the following year. In general, the production programme determines the approximate times at which individual items will be made available for maintenance. Scheduled maintenance is the first step, both in time and principle, towards preventive maintenance and is the natural system to use where plant does not run continuously or is subject to periods of idleness, due to change of product or completion of orders. It is usually readily applicable to service plant, such as boilers, compressed air stations and the like.	This system presupposes the establishment of scheduling for at least the major items of plant, the schedule forming the framework of a more detailed analysis leading to the planning of the work to be done on those items. From records of the conditions found and work done under scheduled maintenance, tentative estimates are made of the work content of jobs, and labour and material are provisionally allocated. Analysis of performance against estimate, and strict application of the lessons learned, improve forecasting to an extent which experience has shown to be unexpectedly large, indirect advantages being considerable.	This system is a development of planned maintenance, the prior establishment of which it presumes. At this stage previous records become inadequate by themselves, and scheduling and planning are extended to more detailed items of production and service plants. Work of an inspection, maintenance, replacement or modification nature, which it will be necessary to carry out during the lifetime of the items, is broken down into elements, and these are studied to improve methods and to obtain more accurate work contents. Maintenance policy is aiming at the abolition of "repair" as generally understood and is concerned with upkeep, replacement and modification.
2 *System may be suitable*	Where: (*a*) The production staff are qualified engineers; (*b*) The operating personnel are skilled craftsmen; (*c*) The corrosion factor is negligible; (*d*) The machinery employed in production is straightforward in its engineering aspect; (*e*) Production is to satisfy specific orders, which can be programmed individually.	Where: (*a*) There is temporary urgency for a limited and definable period; (*b*) Plant capacity exceeds the current market demand; (*c*) Storage capacity for the final product is large; (*d*) The process is obsolescent and more modern equipment is under consideration; (*e*) Many standardized and interchangeable units are concerned, a short life is economically justified and replacement is easy.	Where: (*a*) Plant does not operate continuously on three shifts, seven days a week, and maintenance in the idle periods does not necessitate excessive overtime; (*b*) Continuously operating plant has either fixed idle periods in the year, such as an annual holiday, re-tooling or revising of layout for new product, seasonal falling off in demand or statutory examination, for example, of boiler plant; (*c*) Plant is operating at or below its capacity.	Where scheduled maintenance is said to be inadequate, that is, where: (*a*) Demand exceeds the rated capacity of continuously operating plant; (*b*) There is no general annual holiday or other accepted break in production.	Where: (*a*) Continuity of production is essential because of inadequate storage for finished product or of perishable nature of the product; (*b*) Building space for extension is restricted or excessively costly; (*c*) There is a shortage of labour either for production or for maintenance; (*d*) Limitations are imposed on capital expenditure; (*e*) Delivery of materials is slow; (*f*) Maintenance costs form a high proportion of the indirect charges against production.

3. *Advantages*	(*a*) The absence of any clerical or paper work; (*b*) No need to employ highly qualified maintenance staff who might be more directly used on production; (*c*) The unity of control obtained by a single vertical organization; (*d*) Economy of labour in small plants.	(*a*) The absence of any clerical or paper work; (*b*) No need to employ highly qualified maintenance staff; (*c*) The cheaper initial capital cost of plant, if the system is combined with a capital replacement policy.	(*a*) It enables the maintenance staff to make better long-term forecasts of labour requirements; (*b*) A large measure of flexibility in the use of any item is retained until a date close to the scheduled date; (*c*) The approximate date at which particular replacement items may be required is known.	(*a*) Better utilization of maintenance labour and material; (*b*) Provision of data whereby alternative production programmes can be compared from the maintenance aspect; (*c*) More reliable and consistent production during normal running period.	(*a*) Flexibility arising from accurate advance knowledge in easily interpreted form; (*b*) Accuracy of production forecasts not only as to quantity but as to time; (*c*) The lowest possible depreciation for a given installation; (*d*) Low capital charges for installed spares and storage; (*e*) Better working conditions for all employees; (*f*) Lowest costs for a satisfactory standard of plant condition.
4. *Disadvantages*	(*a*) The inability to obtain separate maintenance costs and records; (*b*) The lack of continuity in maintenance techniques as operating personnel change; (*c*) The difficulty of organizing an adequately trained squad for a major emergency, or a complete overhaul; (*d*) The risk of neglecting essential maintenance due to concentration on immediate production.	(*a*) Heavy depreciation; (*b*) Increased cost of plant spares, particularly installed spares, due to the need for greater "insurance" cover; (*c*) Lower machine availability and therefore incomplete utilization; (*d*) Lower labour utilization in both production and maintenance, and erratic nature of demand; (*e*) Unreliable production forecasts, with unheralded repercussions on associated departments; (*f*) Wide fluctuations in cost over standard reference periods; (*g*) Poor working conditions for maintenance labour and probably for operating labour, due to less reliable nature of plant; (*h*) Greater losses in production, at breakdown, due to lack of warning of failure.	(*a*) The idle production period may be inadequate for the work found desirable on a particular item; (*b*) The maintenance staff, owing to lack of data, cannot make an accurate forecast of maintenance work and can therefore make little contribution to that aspect of the original production programme; (*c*) Some clerical work is necessary in preparing and following up the programmes; (*d*) There is a tendency for production staff to release items at short notice; this mainly arises from (*b*) above.	(*a*) There may be some loss of flexibility in production programmes as last-minute alterations to planned shut-down work become too expensive; (*b*) Clerical work may be increased—it will at least have to be rationalized; (*c*) High-quality supervision is essential if the benefits are to be obtained.	(*a*) The main potential disadvantage is a tendency towards keeping in production plant which is technically out of date, but which is in such good condition that there is reluctance to spend money on known technical improvements; (*b*) A substantial amount of clerical and additional engineers' paper work is necessary.
5. *Conclusion*	This method is an elementary type of maintenance of strictly limited application and one which may put a heavy and divided responsibility on the production staff. They must be able to give equal weight to arguments for and against short term overloading of plant at the eventual expense of efficiency or total annual output. The method also tends to disguise from top management the real size of the maintenance problem with which it may be faced.	Maintenance of this type appears to involve the acceptance of a lower state of mechanical efficiency, which may not result in a very high percentage of lost production time, but will continuously restrict production below that obtainable from the same machinery and plant, maintained at a higher (and attainable) level.	Where the normal idle time of production plant is adequate for total necessary maintenance, scheduling increases the efficient use of that idle time. With continuously operating plant, it is a very necessary first step towards reduction in "down time" due to mechanical failures of running plant and equipment.	Planned maintenance sets a standard which may be economically justified only in plants operating continuously at high rates of output. In these conditions, experience indicates that it will reduce both maintenance and production costs and the incidence of emergencies.	There is no generally applicable formula for preventive maintenance. It can be applied successfully only through the efforts of efficient maintenance staff who have that outlook. Its administration must be at a sufficiently high level to ensure integration with production policy. Technical methods for both production and maintenance must be under constant (and related) review and allocation of functions must be clearly defined, so that a simple mechanism exists for applying policy at the operating level in both departments.

Source: Anglo-American Council on Productivity, *Plant Maintenance* (London, 1952), pages 18 to 23.

Appendix II

LOCAL PRODUCTION OF SPARE PARTS

Production of spare parts is occasionally carried out in the firm's own workshop.[a] In the under-developed countries, this is done with a twofold purpose—to save on foreign exchange and to reduce delays in obtaining the parts from abroad. When the first purpose is decisive, the practice constitutes a special type of substitution of labour for material costs in maintenance and repairs, the general principles of which have been discussed elsewhere in the present article. The second purpose deserves further consideration.[b]

The problem of availability of essential parts may be of particularly critical importance in under-developed countries. Equipment of a given type and make is frequently used in single pieces or in small series only, which makes the stocking of adequate inventories of parts an extremely costly operation. The alternative to keeping such stocks is the risk of even more costly breakdowns and stoppages due to lengthy delays in obtaining government permits for the import of parts, in shipping time and clearance through customs. The problem is aggravated when the equipment is no longer produced in the exporting countries so that spare parts are difficult, if not impossible, to obtain.

A well-equipped workshop has a very flexible range of output and makes it possible to reduce considerably the stock of parts to be carried, many of which may not, in fact, ever be needed. Emergency repairs can be carried out at once without waiting for long periods for the arrival of parts. These advantages outweigh in many cases the drawback of possibly higher costs of the parts; in the longer run the cost situation is likely to improve.

A good arrangement seems to be to order an initial set of spares when any new equipment is purchased. These parts are studied and their reproduction is planned in the factory's workshop, the actual production being tied in with use so as to keep the stock at the desired level.[c]

Where the requirements of an individual firm do not justify the establishment of an adequately equipped workshop, one can be set up on a co-operative basis or as a separate enterprise. There are a number of interesting examples of such schemes in under-developed countries which show the benefits obtainable from such arrangements. An additional important advantage of local production of parts is that the skills thus acquired will benefit the maintenance and repairs operations proper, and may even lay the foundation—as has occurred—for domestic production of machinery.

Where parts are not produced locally, it seems advisable for Governments to provide efficient arrangements for the allocation of import licences and foreign exchange, and for the rapid clearance through customs of such parts; the same holds true for the initial stock of parts when the equipment is bought. It has been stressed that Governments may well go one step further and insist that a sufficient stock of parts be maintained by industrial entrepreneurs, equipment dealers, or importers as a condition for obtaining the permit to import the equipment itself.[d]

Attention has been given to the possibility of reducing the level of inventories of imported spare parts (and consequently of saving foreign exchange) through the elimination of excessive diversification of equipment and component parts. As an example, a committee of the Government of India which was concerned with construction of plant and equipment has made recommendations for action in this respect[e] and formal arrangements for putting them into practice are being considered.

[a] Even in the United States, some factories produce their own parts. The firms claim they can produce them for less than the purchase price; the parts are also said to be better adapted to the firm's requirements.

[b] *See also* United Nations, *Management of Industrial Enterprises in Under-developed Countries*.

[c] Due attention will, of course, be given to patent rights.

[d] This, clearly, also facilitates local production of parts.

[e] See *Report of the Government of India Construction Plant and Machinery Committee* (New Delhi, 1954), page 67.

Appendix III

THE RELATION BETWEEN THE ELASTICITY COEFFICIENT OF SUBSTITUTION OF LABOUR FOR SPARE PARTS AND THE OPTIMUM RELATIVE USE OF THESE FACTORS IN MAINTENANCE AND REPAIRS

(1) Let l be the outlay for labour and s the outlay for spare parts for a given volume of maintenance and repairs.

An elasticity coefficient of one corresponds with the condition:

$$l \cdot s = C, \text{ where } C \text{ is a constant.}$$

The minimum value of $l + s = l + \frac{C}{l}$ will then occur for:

$$1 - \frac{C}{l_0^2} = 0 \text{ or, } l_0 = \sqrt{C}.$$

This gives $s_0 = \frac{C}{l_0} = \sqrt{C}$,

and thus $l_0 = s_0$.

(2) The general expression of the relation between l and s for a constant value a of the elasticity coefficient of substitution of labour for spare parts, as defined in footnote *11*, will be the power function:

$$s = k \cdot l^{-a}, \text{ where } k \text{ is a constant.}^{a}$$

In this case, the minimum value of total outlay:

$$l + s = l + k \cdot l^{-a}$$

will occur when: $1 - a \cdot k \cdot l_0^{-a-1} = 0$

[a] The values of k and a can, clearly, be only positive. A value of $a < 1$ means that the replacement of labour for spare parts is inelastic; that is, an additional outlay on labour will entail a less than proportional saving on spares, and *vice versa*.

$$\text{or: } 1 - \alpha \frac{k \cdot l_o^{-\alpha}}{l_o} = 1 - \alpha \frac{s_o}{l_o} = 0$$

which gives: $\alpha = \frac{l_o}{s_o}$ [b]

3) Furthermore, let λ and μ be the price ratio for labour and spare parts for a given under-developed country as compared with the developed country in which the relation $l : s$ has been studied. The outlays will then be for equal quantitative inputs:

$$l' = \lambda \cdot l \quad \text{and} \quad s' = \mu \cdot s.$$

[b] $\alpha = 1$ will thus correspond with $l_o = s_o$, which is in accordance with the result obtained in (1).

The elasticity coefficient of substitution of l' for s' will be the same as the elasticity coefficient of substitution of l for s. In fact, substitution of

$$l = \frac{l'}{\lambda} \quad \text{and} \quad s = \frac{s'}{\mu}$$

in: $s = k \cdot l^{-\alpha}$

gives: $s' = \mu\lambda^{\alpha}k \cdot l'^{-\alpha}$

or: $s' = k' \cdot l'^{-\alpha}$

The minimum aggregate outlay will thus again occur when $l'_o : s'_o = \alpha$, that is, for the same relation between the outlays for labour and spare parts as was observed in the developed country.

Appendix IV

EXAMPLE OF ESTIMATION OF OPTIMUM LIFETIME OF EQUIPMENT

Assumptions:

(*a*) Maintenance and repairs costs will, in the United States, increase by 0.5 per cent of the cost of equipment per year after the first five years of operation.

(*b*) In the United States, lifetime can be extended by one year with each increase in the annual cost of maintenance and repairs—calculated over the whole life period—of 0.5 per cent of the cost of equipment.

(*c*) Labour-cost ratio between the under-developed area and the United States is 0.40 to 1; cost ratio of spare parts and equipment 1.60 to 1.

The calculation is presented in table 4.

Table 4

ESTIMATION OF OPTIMUM LIFETIME

Years (*A*)	*Increase in annual averages of the variable part of maintenance and repairs*[a] *United States*[c] (*B*)	*Under-developed area*[d] (*C*)	*Decrease in annual costs of interest and depreciation*[b] *At 6 per cent interest* (*D*)	*At 12 per cent interest* (*E*)
8-9	0.68	0.34	1.40	1.36
9-10	0.69	0.35	0.12	1.07
10-11	0.70	0.35	0.91	0.86
11-12	0.71	0.36	0.75	0.70
12-13	0.72	0.36	0.63	0.58
13-14	0.72	0.36	0.54	0.48
14-15	0.73	0.36	0.46	0.40
15-16	0.73	0.37	0.40	0.34
16-17	0.73	0.37	0.35	0.29
17-18	0.73	0.37	0.31	0.25
18-19	0.73	0.37	0.27	0.22
19-20	0.74	0.37	0.24	0.19

[a] As percentage of cost of equipment.

[b] As percentage of cost of equipment; calculated on annuity basis.

[c] In accordance with assumption (*a*), the component of the cost of maintenance and repairs due to aging of the equipment will, in the *m*th year of operation, be $(m - 5) \times 0.5$ (as percentage of cost of equipment). Over the lifetime *n* this component will total:

$$P_n = 0.5 + 2 \times 0.5 + \dots + (n - 5) \times 0.5 = \frac{(n-4)(n-5)}{2} \times 0.5$$

The average annual value of P_n over the lifetime *n* is thus:

$$p_n = \frac{P_n}{n} = \frac{(n-4)(n-5)}{2n} \times 0.5$$

The increment of *p* between the years $(n - 1)$ and *n* will amount to:

$$p_n - p_{n-1} = \frac{(n-4)(n-5)}{2n} \times 0.5 - \frac{(n-5)(n-6)}{2(n-1)} \times 0.5 = \frac{(n+4)(n-5)}{2n(n-1)} \times 0.5$$

The increase in the annual cost of the part of maintenance and repairs that can influence the lifetime has, in accordance with assumption (*b*), a constant value of 0.5 per cent of the cost of the equipment for each extension of the lifetime by one year.

The total increase in the annual average cost of the variable part of maintenance and repairs between lifetimes $(n - 1)$ and *n* will thus amount to:

$$\frac{(n+4)(n-5)}{2n(n-1)} \times 0.5 + 0.5.$$

The values in column (B) are calculated with this formula.

[d] As was shown earlier, assumptions (*c*) correspond with a reduction of the ratio between the cost of maintenance and the cost of equipment to one-half in the under-developed area as compared with the United States, assuming that the relative use of labour and spare parts is adapted to the cost relations, and under the proviso of a constant elasticity of substitution. This means that in the under-developed area the percentages in assumptions (*a*) and (*b*) would be $0.5 \times 0.5 = 0.25$ instead of 0.5, and thus the figures in column (C) are one half of the corresponding figures in column (B).

Appendix V

NUMERICAL EXAMPLES OF DETERMINATION OF PRIORITY RATINGS OF REPLACEMENT PROPOSALS

The procedure for determining the priority rating of a replacement proposal, as discussed in the present article in connexion with the MAPI formula, is presented in the form of a numerical example in table 5. The calculation yields a priority rating of 20 per cent.

Table 6 illustrates the transposition to conditions in an under-developed area. The conversion ratios used in the earlier examples are maintained. Two replacement proposals are compared, both involving a net investment, in the United States, of $10,000. The first example is the same as that used in table 5, in which the advantage of the new as compared with the old equipment resulted mainly from savings on labour costs. In the other example, the emphasis is more on the advantage, in quality and quantity, to the production. From the table it will be seen that, whereas in the United States the first case would rate a higher priority than the second (20 per cent as against 18 per cent), in the under-developed area the order would be reversed (13 per cent as against 19 per cent).

It was mentioned earlier that the ratings obtained with this procedure are primarily used for the allotment of priorities; this implies that their relative values are, to a certain extent, of first importance. At the same time, the ratings are, as was also stated, indicative for the rate of return on the replacement investment. In this respect it is important to note that the ratings will, in general, in an under-developed area be lower—or at the most of the same order of magnitude—as compared with those in the United States. Taking into account that capital is normally scarce in under-developed countries and interest rates high, this means that replacements will tend to be profitable only after longer use of the old equipment when the comparative advantage of new equipment is greater. This confirms the conclusion reached in the section on optimum lifetime.

Table 5

DETERMINATION OF PRIORITY RATING FOR REPLACEMENT
(United States dollars, except where otherwise indicated)

Anticipated lifetime of new equipment (years): 15			(1)
Expected salvage value of new equipment (percentage of cost): 10			(2)
Required investment			
Installed cost of new equipment		10,000	(3)
Salvage value of old equipment	1,200		(4)
Capital additions required if old equipment is maintained	300		(5)
Total ((4) + (5))		1,500	(6)
Net investment required		8,500	(7)
Next year advantage from replacement[a]			
Increase in revenue:			
From better product	400		(8)
From better production	200		(9)
Total increase in revenue		600	(10)
Decrease in costs:			
Direct labour	1,200		(11)
Indirect labour	400		(12)
Fringe benefits	400		(13)
Maintenance and repairs	800		(14)
Supplies and power	600		(15)
Other operating costs[b]	--		(16)
Total decrease in costs	3,400		(17)
Less higher property taxes and insurance	200		(18)
Total net decrease in operating costs		3,200	(19)
Total increase in revenue plus net decrease in operating costs		3,800	(20)
Increase in capital consumption:			
Capital consumption of new equipment $\left[\frac{100 - (2)}{(1) \times 100} \times (3)\right]$	600		(21)
Decline of salvage value of old equipment, if kept	200		(22)
Net increase in capital consumption		400	(23)
Total next year advantage before tax		3,400	(24)
Total next year advantage after tax		1,700	(25)
Priority rating [(25) : (7)]:	20 per cent		(26)

Note: The presentation is adapted from **MAPI work** sheets.

In the example, in accordance with normal conditions in the United States, taxes are taken as 50 per cent of total advantage.

[a] For equipment with a significant break in period, use performance after break in.

[b] These may include: tooling, scrap and rework, down time, use of floor space, subcontracting, inventory, safety, flexibility and the like.

Table 6

TRANSPOSITION OF PRIORITY RATING FOR REPLACEMENT TO CONDITIONS IN A GIVEN UNDER-DEVELOPED AREA

(United States dollar equivalents, except where otherwise indicated)

Line [a]	*United States*					*Under-developed area*			
	Example A [b]		*Example B*		*Conversion ratios*	*Example A*		*Example B*	
(1)	15 years		20 years			21 years		28 years	
(2)	10 per cent		0 per cent		1.4[c]	10 per cent		0 per cent	
(3)		10,000		10,000	1.6[d]		16,000		16,000
(4)	1,200		—		1.6[d]	1,920		—	
(5)	300		—		1.6[d]	480		—	
(6)		1,500		—			2,400		0
(7)		8,500		10,000			13,600		16,000
(8)	400		1,000		1.2[e]	480		1,200	
(9)	200		1,500		1.2[e]	240		1,800	
(10)		600		2,500			720		3,000
(11)	1,200		200		0.4[d]	480		80	
(12)	400		—		0.4[d]	160		—	
(13)	400		50		[f]	96		12	
(14)	800		500		0.8[d]	640		400	
(15)	600		1,000		1.2[g]	720		1,200	
(16)	—		—			—		—	
(17)	3,400		1,750			2,096		1,692	
(18)	200		230		[h]	320		365	
(19)		3,200		1,520			1,776		1,327
(20)		3,800		4,020			2,496		4,327
(21)	600		500		[i]	686		571	
(22)	200		—		1.6[d]	320		—	
(23)		400		500			366		571
(24)		3,400		3,520			2,130		3,756
(25)		1,700		1,760	[j]		1,704		3,005
(26)	20 per cent		18 per cent		[k]	13 per cent		19 per cent	

[a] Compare table 5.

[b] This is the example given in table 5.

[c] Lifetimes are supposed to be approximately 40 per cent longer in the under-developed area than in the United States.

[d] In accordance with assumptions made earlier in the text.

[e] Products of comparable quality are assumed to sell in the under-developed area at prices 20 per cent higher than those in the United States.

[f] Fringe benefits are assumed to amount to 15 per cent of labour costs in the under-developed area, as compared with the assumed 25 per cent in the United States.

[g] Assumed to be equal to ratios used in lines (8) and (9).

[h] Assumed to amount to approximately the same percentage of increase in value of equipment as in the United States.

[i] Calculated on the basis of the same formula as in table 5 $\left[\frac{100 - (2)}{(1) \times 100} \times (3)\right]$.

[j] Taxes are assumed to amount to 20 per cent of profits in the under-developed area, as compared with 50 per cent in the United States.

[k] On the basis of the formula given in table 5 [(25) : (7)].

In-plant Training of Graduate Engineers

BY YAP KIE HAN

Each year many thousands of young engineers graduate from universities and colleges. At the moment of embarking upon their careers, they and the industries which they will serve are confronted with an increasingly serious problem. It is the problem of how to bridge the gap between the fundamental knowledge gained at the university and its application in industrial practice. In many cases, this gap widens as knowledge develops. Many universities endeavour to broaden the cultural and intellectual formation of their students by increasing the number of compulsory courses on general scientific and other topics; at the same time, as industry develops, it calls for cadres with increasingly specialized technical functions. In most cases, newly recruited engineers spend a large part of their time not simply making themselves familiar with their job, but actually learning it.

In-plant training is one way of helping young engineers bridge this gap. It is recognized in many industrial enterprises that the solution of the problem should not be left to chance, in other words, that it would not suffice to attach the graduate as an apprentice to skilled workers and foremen and hope that he will obtain the required experience in a reasonable period of time. In in-plant training, a close contact is maintained between trainees and operators. This, however, is only an incidental aspect of a programme whose purpose is to provide systematic and closely supervised guidance to the graduates in applying the basic scientific principles learned at the university to the many practical problems arising daily in the factory.

In-plant training should be of particular interest to newly industrializing countries where scientifically trained personnel is scarce and where, because of this, responsible functions have often to be performed by recently graduated, newly recruited engineers. The contribution which in-plant training can make to the operation of industries in these countries thus assumes particular significance.

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This article is concerned with engineers who have acquired at least a bachelor's degree in one of the engineering sciences, usually men between twenty-one and twenty-eight years of age. Two broad groups of engineering sciences may be distinguished for the purposes of this article: those based on mechanics and physics and those based on chemistry. Engineers trained in the former acquire an understanding of technological processes, many of which are based on human manipulative skills, though mechanization and automation are increasingly superseding these. In contrast, production of chemicals involves more "materials-oriented" processes.

A factor bearing on the type of in-plant training required is the extent to which practical technological education has been provided to the young engineer during his stay at the university. There is growing recognition in many countries that theoretical training should be combined with the practical during the undergraduate years, and, in leading schools of engineering, industrial practice has been made part of the curriculum along with theoretical instruction. Many universities encourage, and some of them require, practical industrial work during summer vacations. Table 1 shows, as an example, the duration of the practical work in industry made obligatory by the different engineering schools of the Technological University of Delft, the Netherlands. The time indicated refers to actual work in industrial establishments, and does not include additional practice in the laboratories, workshops and pilot plants of the university itself.

The main objective of these periods of practical work is to acquaint the student with the working conditions

Table 1

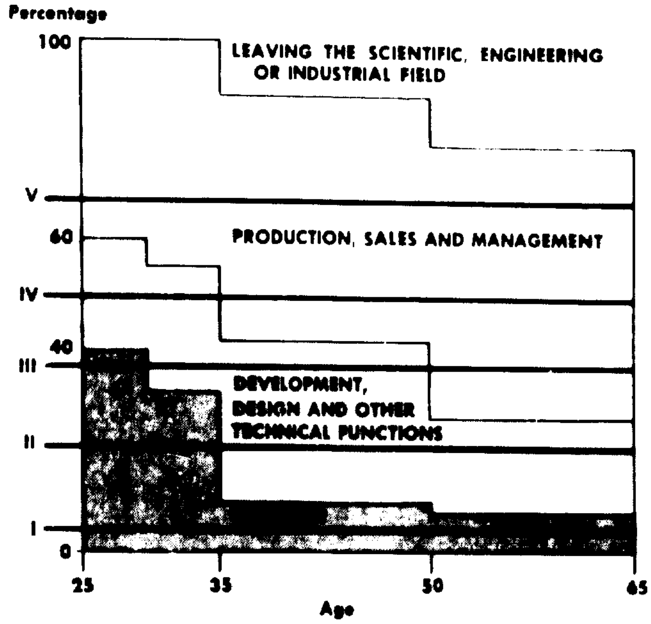
Technological University of Delft, the Netherlands: Duration of practical work in industry, by school[a]

School	*Duration of practical work in industry*
Mechanical engineering	6 months
Naval engineering	6 months
Aeronautical engineering	6 months
Electro-technical engineering	16 weeks
Chemical engineering	8 weeks
Metallurgical engineering	6 months
Mining engineering	5 months
Geodetical engineering	2 months
Physics	Not obligatory, but encouraged
Civil engineering	8 weeks
Architecture	9 months

[a] In each school of the Technological University of Delft, the duration of study is, in principle, from five to six years although students take, on the average, about seven years to complete their work. In all schools, except those of physics and civil engineering, practical work in industry may extend from four to eight months beyond the periods indicated in the table, if required for preparation of graduation theses. In the school of civil engineering, the additional period is from three to four months.

Chart 1

Functions of scientists and engineers, according to age, in a large European industrial concern



Career patterns:

I. Research only.

II. Research, product and process development, design and other technical functions.

III. Research, development, design, production, sales and management.

IV. Development, design, production, sales and management.

V. Production, sales and management.

Note. Production, sales and management are combined for lack of detailed data. In some companies, sales engineering is a distinct function in which some young engineers start their careers. No data on that score are, however, available for the company under consideration.

and atmosphere of industrial establishments and to give him the opportunity of observing the application in practice of engineering theory. The value of these periods is generally recognized, but a criticism frequently levelled by industry, universities and the students themselves is that they confine the student to observation and do not let him play an active role, however modest it might be.

As a contrast, in-plant training programmes emphasize the development of abilities, that is, the acquisition of skills and the exercise of judgement in concrete cases, rather than the addition to technical knowledge. In any event, knowledge and ability are complementary and the former may be expected to develop simultaneously with the latter in the course of the training. Another purpose is to make apparent the suitability of individual graduate engineers for particular occupations.

In-plant training will usually direct young graduates towards one of three broad groups of occupations: design and product development, production, and sales engineering. There is a division of opinion as to whether such training should be provided to foster careers in the field of research. Some companies consider research as a particularly suitable form of training for young engineers, rather than a career to which training should lead. Passage from one occupation group to another frequently occurs in the course of time. Chart 1 shows, as an illustration, the career pattern of scientists and engineers employed in a large European industrial company. In this company, 40 per cent of the engineers, chemists, physicists and mathematicians begin their careers in the company's research departments. As a rule, only a small number will continue their careers in this field. Most of them will transfer within ten years or so to product or process development, design, production, sales or managerial or executive functions. It will be seen from chart 1 that development and design is a particularly important group for scientists and engineers, thirty five to fifty years old, coming from research. Very few persons enter research from production, even though functional interchange between production and development is quite usual. In this company, research is primarily a preparatory stage for other occupations.

Different career policies are followed in other companies. In many oil corporations, for example, young engineers begin and end their careers in a particular sector—prospecting, research or production development—and transfers from one function to another are exceptional. It is true that, in these and certain other companies where a similar pattern is observed, each sector offers a wide enough spectrum of occupations to suit the needs of a normal career development.

An in-plant training programme will reveal the limitations as well as the abilities of the graduate by testing these against objective standards of practical performance, and will contribute to developing his talent. Moreover, it will teach him by experience the need and value of team-work in industry. It might also enable trainees from newly industrializing countries to gain a correct appreciation of the worth of direct productive work as a pre-condition to achieving the development of a modern industrial economy.

SOME IN-PLANT TRAINING PROGRAMMES

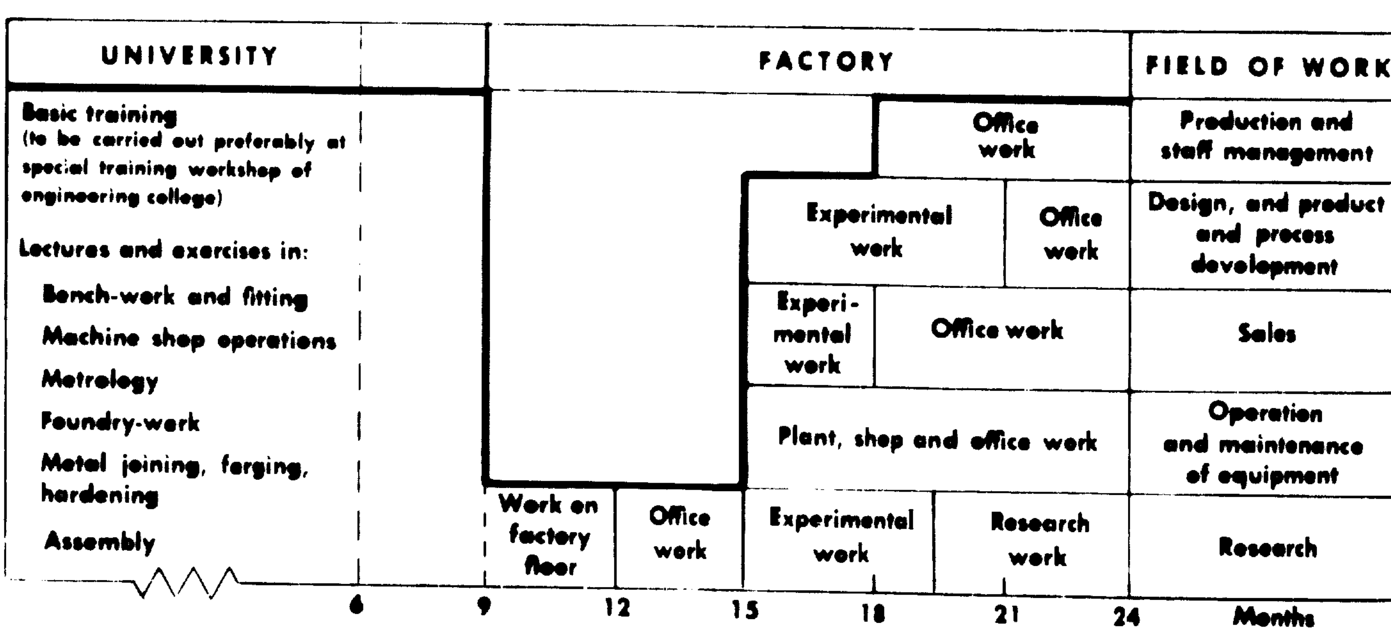
A programme of practical in-plant training is schematically represented in chart 2. This programme, which was recommended by the Committee on Practical Training set up by the Council of the Institute of Mechanical Engineers of the United Kingdom, presents analogies with programmes organized in other countries.

The programme would consist of two successive stages. The first, lasting from six to nine months, would provide basic practical training, and would take place at the university. The second would last fifteen or eighteen months; training would take place at the factory and would cover research, operation and maintenance of equipment, sales, design, product and process development, and production.

The programme would evidently have to be adapted to fit specific conditions, in particular those of the factory where the training would be provided. Thus, a two-year programme carried out in a large metal-working plant was divided into two equal periods. During the first year, theoretical courses were provided for one week at the beginning of the training, for another week at the end of three months, and for a further two weeks at the end of six months. About three

Chart 2

A PROGRAMME OF PRACTICAL TRAINING



Source: Institute of Mechanical Engineers, *Report on Practical Training* (London, April 1958).

months were devoted to training in the workshops, three months to assembly of mechanical equipment, and six months to work in the tool room and the fabrication, machining and mechanical testing departments. Towards the end of the first year, interviews with the students were arranged in order to plan the second year programme. During the second year, specialized training was provided, according to the interests of the students, in design, development, research and other occupations. Theoretical courses in these fields were provided for two weeks at the end of three months and for a further week at the end of the programme.

Some specialists think that the two-year duration of these programmes is unnecessarily long for university graduates.[1] In their view, careful analysis and planning of the programme might cut the length of training to between ten and fifteen months, while maintaining comparable education standards.

Not enough comparative experience has been gained on such programmes to support a firm conclusion on this question. Leaving aside the quality of the programme itself, much will depend, in any event, on the adequacy of the education received at the university, the care exerted in selecting the trainees, and the field of engineering in which training is provided.

A few illustrations may show more clearly the type of work required from the trainees. The following examples consist of exercises which trainees had to perform in such fields as factory-floor practice, machine design and process and product development, sales engineering and management. They concern work in mechanical-physical industries and chemical industries. Because of the diversity of sources, there are variations in the presentation of the instruction briefs.

Factory-floor practice

Factory-floor practice is usually the first step of in-plant training. It will reveal to the trainee the potentialities and limitations of basic technological processes, and the abilities and skills required from the men who carry them out.

Example 1. Exercise in machine operation and operation planning

Machines: three lathes, one horizontal milling machine, one multi-spindle drilling machine.

(1) Set lathe for batch production on the basis of a drawing (supplied) and the cutting data below.

(2) Produce six components in accordance with the drawing.

(3) Proceed to milling machine. Set machine and carry out milling operations.

(4) Remove sharp corners.

(5) Proceed to drilling machine and carry out drilling and reaming operation.

Use the following cutting data:

[illegible]	[illegible]	[illegible]
Turning	80	.005
Milling	40	.003 per tooth
Drilling	80	.005
Reaming	15	.010

On completion of components, make a short report containing, among others, a recording of the selected sequence of operations and the floor-to-floor time on each machine. Comment on any possible improvements.

Example 2. Exercise in alignment tests on machines

Check machine and find the amount of error in alignment; decide what work should be done on machine before overhauling; suggest methods of correcting errors in alignment and see whether correction of these errors introduces any further errors; if this is the case, indicate how it can be avoided or rectified.

Checking will be done with the following testing equipment: test bar, clock gauge and clock stand. Carry out checking according to the Schlesinger standard testing procedure.

Example 3. Exercise in chemical plant operation (nitric acid plant)

The trainee is assigned to spend a period with each of the following process personnel: *(a)* burner-house operator in charge of five to eight units, for one shift; *(b)* absorption operator in charge of five to eight units, for one shift; *(c)* plant chargehand, for two shifts.

(1) Describe briefly the work carried out by the first two process operators during their shifts and state what, in your opinion, are the most important aspects of their work. Among the types of operations which they carry out are: inspection recordings; adjustments; change-over of equipment; sample taking; cleaning; emergency action.

One or perhaps two instruments usually need to be consulted to determine whether the operation of a plant is safe and under control. Such instruments may be described as key instruments. They are usually inspected by the process operators, at fairly frequent intervals. In consultation with the operators, decide which of the instruments on the burner and absorption sections are key instruments.

(2) Record briefly the work and duties of the plant chargehand. The following list, which is by no means comprehensive, will provide guidance in considering the different aspects of his work: inspection; operation; stock control; consultations with, and receipt of instructions from, foreman and plant manager; passing instructions on to operators; control of labour; checking on plant conditions; checking on plant tidiness; liaison with other plants; liaison with maintenance; issuing and signing of clearances; starting up plant; keeping plant log, bonus sheets, materials export and import schedules, and so on; emergency action.

(3) On the basis of the experience gained, state what action would be necessary in the event of: *(a)* alarm sounds indicating low level in waste heat boiler; *(b)*

[1] Institute of Mechanical Engineers, *Report on Practical Training* (London, April 1958), appendix A, "Comments on Existing Schemes".

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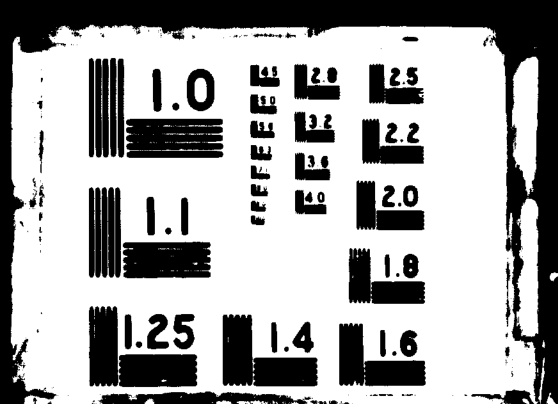

ammonia gas valve trips; (*c*) sudden emission of large quantities of brown fume from exhaust stack; (*d*) falling pH value of cooling water.

Explain the reasons for these events, describe the checking procedure to identify their causes and outline the steps taken to correct deviations and return the plant to normal working conditions.

Design, and process and product development

The purpose of practice in the fields of design and process and product development is to acquaint the trainee with the role of technical innovation, the potentialities and limitations of the different engineering sciences and the means of applying them in practice. The following example relates to machine design.

Example 4. Exercise in machine design

Study the design of two machine tools similar in type but differing in detail, and make a report on these differences under the following headings:

(1) Capacity, by type of operation, size of work-piece, range of speed, feed;

(2) Rigidity and strength of the machine;

(3) Adaptation to operation: design and position of controls, instrumentation;

(4) Ease of manufacture with special reference to the machining operations required;

(5) Methods of assembly and adjustment;

(6) Special features.

Sales engineering

The purpose of practice in the field of sales and service is to train sales engineers or to acquaint design engineers and production engineers with sales techniques.

Example 5. Exercise in sales engineering

Record all customer contacts in sales area No. Y and make a report on the following aspects:

(1) Amount of orders placed by each customer;

(2) Service arrangements required;

(3) Calling routes for salesmen and service engineers;

(4) Promotional material;

(5) Practice of competitors.

Management

Training in the field of management aims at acquainting young engineers with the types of problems to be solved by management at various levels, the distribution of tasks among executives and the practical application of management techniques and procedures. Another purpose is to impart elementary supervisory skills, such as planning of work and job instruction, which are of importance in any department, whether it be design, sales or production. More intensive training in management techniques will be required for those specializing in this field.

Example 6. Exercise in cost reduction

Study the machine layout throughout the plant and the arrangements for storage and transportation of materials and components, from storage of raw materials to dispatch of finished products. Draft a report suggesting possible improvements and calculate the corresponding savings in production costs.

Example 7. Exercise in quality control

Select a major item produced in the factory, and describe in full detail the quality specifications prescribed to the following departments: (*a*) design; (*b*) work planning and production; (*c*) sales.

Comment on quality control at various stages of the manufacturing process, from purchase of raw materials to final testing before shipment.

In certain cases actual supervisory practice might also be included as part of the graduate engineer's training programme. This is, for example, the case in a chemical factory where the graduate trainee is allowed to assume the responsibilities of a section foreman during certain short periods, for instance, when the foreman is on vacation or on leave of absence. For about twelve weeks, the trainee acquaints himself in a general way with the section's duties, the layout of installations, instrumentation, control-room procedures, safety regulations, and so on. He also works with the operators of the section. For a time, he serves as understudy to the foreman in all his duties and writes up the section's log-book; this is followed by the actual assumption by the trainee of operational responsibility for the section as a whole.

THE ROLE OF THE TRAINING SUPERVISOR

The task of the training supervisor varies with the organizational structure of the enterprise. In general, the duties in the field of training are apportioned as follows.

(1) Selection of trainees. Selection of graduate engineers is generally the responsibility of the director of personnel and the final decisions are made with the agreement of a senior manager. It would be useful if the training supervisor were the third member in the selection panel. The procedures include examination of personal and educational records, and interviews.

(2) Programming. Establishment of training schedules is the specific responsibility of the training supervisor.

(3) Instruction and supervision. General instruction is usually the training supervisor's responsibility; other officers of the company are called upon to provide specialized training. The supervision of the trainee during his assignment is sometimes regarded as the responsibility of the officers in charge of the departments concerned, the training supervisor acting in an advisory capacity. Sometimes the training supervisor assumes full supervisory responsibility. In all cases, the training supervisor is responsible for evaluating periodically the progress made by the trainee. The training supervisor provides group instruction and individual coaching; he maintains liaison with the various departments in which the trainees are placed.

(4) Career planning. The training supervisor plays an important advisory role in placing young engineers after completion of their training; he may also provide guidance at further stages of their careers. Much of the success of the training programme will depend upon the training supervisor's ability to perceive correctly the needs—of both student and company—which the programme is designed to meet.

If the training supervisor is to command respect from the graduate trainees, he should himself be a university graduated engineer with a good scholastic record and should possess the right personality and adequate practical experience in industry. The function of training supervisor can be an appropriate intermediate step for an engineer with from five to ten years' experience who is being considered for higher managerial responsibilities. On the one hand, such an assignment will provide him with an insight into the future development needs of his organization; on the other, it will prepare him for an important but often neglected part of the responsibilities of a manager—that of developing the talents of his subordinates.

Experience indicates that the number of trainees per group assigned to one full-time training supervisor should not exceed fifteen to twenty-five. If particularly intensive work is required on the part of the supervisor, for example, if the programme includes coaching sessions with a frequency of, say, one session a week per person, the group should be limited to twelve to fifteen trainees.

Appointment of a full-time training supervisor will, as a rule, be feasible only in large enterprises. If graduate training programmes are to be carried out in medium-sized and small companies, co-operative action among these companies will have to be arranged. It may be noted, in this connexion, that trainees in small or medium-sized enterprises may benefit from the fact that the interrelationships between the various managerial functions and activities—production, sales, personnel, finance, and so on—may be more readily observed in such enterprises than in larger concerns.

A training programme involving the co-operation of small and medium-sized enterprises has been organized by the Research Institute for Management Science in Delft. This programme is at present limited to instruction in management occupations. Training in design and development is not provided because, under the Dutch educational system, the trainees have already had, during their undergraduate years, adequate factory-floor practice and some experience in design and research. The programme has a duration of from four to six months and consists of the following:

(1) A preparatory course of approximately one month providing comprehensive instruction in the principles and techniques of industrial management, including cost accounting, their practical application in medium-sized and small-scale industries, and job instruction, report writing and other practical skills;

(2) A period of individually supervised practical work, preferably in the enterprises employing the graduates. The assignments are chosen in consultation with the firms' managements and are related to actual problems in the fields of production, sales or office management, a feature which has proved to be of some benefit to the participating enterprises;

(3) A series of group discussions to promote the exchange of experience among trainees.

(4) A number of information meetings with the managements of the participating companies.

Several groups are set up, each consisting of from eight to twelve trainees, for instruction in different branches of industry. A staff member of the Institute is attached to each group as training supervisor. Individual coaching is provided. So far, the participating enterprises have been mostly of medium and small size, and one to three trainees at most could be placed in each factory.

Three broad categories may be distinguished in the instruction briefs given to the trainees, by degree of complexity.

(*a*) The trainee is required to analyse a very complex problem and to present his findings in a research report (research assignment).

(*b*) The trainee is required to analyse a problem with a view to presenting a practical solution and to defend his suggestions before a committee consisting of managers of the company (consultation assignment).

(*c*) The trainee is required to solve a problem and to implement the solution in practice. In view of the relatively short time available, the problem is generally relatively simple (implementation assignment).

Table 2 shows the distribution of trainees by type of work, branch of industry and branch of engineering. The total number of trainees was sixty-four.

Operating a multiple milling machine

CO-OPERATION BETWEEN UNIVERSITIES AND INDUSTRY

According to the circumstances, arrangements for co-operation between universities and industry will be made on a local or regional level. The in-plant training programme may be sponsored either by industry with university assistance, or *vice versa*. Several universities may participate in the programme. Experience in the Netherlands since 1956 has been that, out of 100 to 125 graduate students, fifteen to twenty were found eligible for in-plant training. Out of 300 small or medium-sized enterprises in the area adjoining the university, fifty to sixty were willing to participate in the programme. On the average, each firm agreed to take a student once every three years. As far as possible, the training courses were devised so that they would be of use to the participating companies. Over the period from 1956 to the end of 1958, thirteen colleges and institutions of higher education had participated in the programme. A total of 120 students had been assigned to an approximately equal number of industries. The trainees had the status of salaried employees at a junior engineer's level; this stressed the business-like character of the assignments and the fact that practical achievements were expected from the trainees.

IN-PLANT TRAINING PROGRAMMES FOR GRADUATE ENGINEERS FROM DEVELOPING COUNTRIES

As a whole, the procedures described above are applicable for organizing in-plant training programmes either in industrial or developing countries for the benefit of graduate engineers from the latter countries. Irrespective of the type of country in which training is provided to these engineers, certain subjects should be emphasized which, in programmes devised for trainees from advanced countries, may be given less attention. This applies to training in such matters as maintenance and repair, selection of productive capacity of equipment, use of non-mechanized or little-mechanized techniques in certain operations—for instance, materials handling, packaging and other ancillary activities—and training of machine operators. In view of the lack of industrial tradition in many newly industrializing countries, in-plant training programmes might also prepare young engineers to play a role in bringing about the social changes which normally accompany industrialization. This preparation would include practical instruction in such matters as wage systems, productivity incentives, industrial safety, and housing and related facilities.

In view of the limited educational and industrial resources of many under-developed countries, a large measure of international co-operation will be required if in-plant training programmes are to be organized, either at home or abroad. Co-operation will be needed between universities and between industries in developed and developing countries for exchanging information on curriculums, defining admission criteria and procedures, selecting trainees, securing the co-operation of industrial establishments, placing students, and so forth.

In the less developed parts of the world, efforts to set up regional in-plant training programmes would be worth while. In many regions, suitable technical institutions and groups of advanced industrial establishments exist where training could be provided to graduates from neighbouring countries as well as to na-

Table 2

EXPERIMENTAL TRAINING PROGRAMME SPONSORED BY THE RESEARCH INSTITUTE FOR MANAGEMENT SCIENCE, DELFT, THE NETHERLANDS: NUMBER OF TRAINEES BY TYPE OF WORK, BRANCH OF INDUSTRY AND BRANCH OF ENGINEERING

	Branch of industry				Branch of engineering			
Type of work	*Metal*	*Building*	*Other*	*Total*	*Mechanical*	*Civil*	*Other*	*Total*
Technological-economic	9	—	5	14	9	—	3	12
Methods improvement, equipment layout	6	—	10	16	12	1	—	13
Quality control, measurement techniques, tolerances and costing	22	—	7	29	13	—	1	14
Materials handling and routing	7	10	6	23	15	11	1	27
Planning, job preparation, administration	6	1	—	7	4	1	1	6
Miscellaneous	3	1	12	16	10	1	4	15
Total	53	12	40	105	63	14	10	87
Less number of trainees belonging to several groups	—	—	—	—	23	—	—	23
Total number of trainees	—	—	—	—	40	14	10	64

Source: Research Institute for Management Science, Delft.

tionals of the host country. The fact that training would take place in an institutional setting with advanced features amidst an environment presenting many of the basic economic and social characteristics of the less developed countries would contribute to its effectiveness. Regional training programmes might also present advantages from the standpoint of costs.

CONCLUDING REMARKS

In this article, in-plant training has been discussed with reference to young graduate engineers. Yet the application of this method is by no means restricted to engineers—young or graduate. With appropriate modifications, in-plant training might be usefully provided to undergraduate students, as is already done in certain European universities. It may also be devised for industrial cadres of all levels and age groups, including senior management, whenever it is desired to provide better understanding and more practical experience in certain fields of industry. Thus, in 1958 59, the Research Institute for Management Science of Delft organized a training programme in the use of electronic computers for industrial management; the trainees were senior officers of industrial companies with educational backgrounds in engineering, economics and mathematics. Organization of both forms of training may, however, meet with more difficulties in developing countries than in advanced ones.

In-plant training of the type described in this article is a starting step, though a major one, in the broader task of promoting and assisting the career development of industrial cadres. There is already an awareness of the importance of this problem in some industrial enterprises—generally in the larger ones—in certain developed countries, and some industry-sponsored testing and training programmes have been organized. The question deserves further study on the part of universities, technical schools of higher education, and industry.

The organization of in-plant training programmes of all types calls for close co-operation between industry and educational institutions. In many countries the co-operation of government authorities will also be required. In-plant training programmes, including those devised for undergraduate students, will provide experience which will be of value for achieving adjustments of university curriculums and industry requirements. The adjustments in the curriculums would tend to place more emphasis than is usually done on the practical application of engineering sciences. Direct contacts with industrial practice would induce the teaching staff to keep abreast with, and impart to the students, the latest scientific and technological advances. This aspect of university-industry co-operation would be of special importance to newly industrializing countries desiring to sustain a rapid rate of growth.

International co-operation between universities and between industries is needed if in-plant training programmes are organized for the benefit of engineers from the less developed countries. To organize such programmes in these countries, information on the experience gained in the more advanced countries would be useful. If need be, arrangements for providing supervisory training personnel from developed nations should be made. If training is to take place in industrial countries, information and analytical studies on the needs of developing countries should be provided to universities and participating industries.

Developing engineering talent is one of the prerequisites to the industrialization of the less developed countries. It might be advisable for the Governments of these countries to request technical assistance to organize in-plant training programmes for their engineers at home or fellowships or scholarships for training them in plants in foreign countries. Since projects in this field call for international co-operation, assistance by international organizations would be particularly appropriate. Such assistance would complement the efforts already made, in particular by the United Nations and its specialized agencies, to promote the growth of industry in the less developed countries by helping them to set up educational and training institutions and by granting fellowships and scholarships to their engineers and technicians.

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Health Problems of Industrialization

BY R. S. F. SCHILLING

IN THE NINETEENTH century, the rapid progress of industrialization and urbanization in Europe and America gave rise to new forms of poverty, disease, squalor and ugliness. While many of these evils remain, some of their worst forms have been controlled or eliminated through better education and a growing sense of responsibility for health and welfare on the part of both public authorities and private social and economic groups. Much of the effort went into devising measures of prevention and control: planning the development of new industries and towns, providing for public health and medical care, and passing appropriate legislation and providing services to protect the health and safety of workers.

Industrialization and urbanization are now spreading all over the world, much of this development taking place in the economically under-developed countries (1).[1] If left unplanned and uncontrolled, the growth of industry and cities may lead to overcrowding and an increase in communicable diseases, malnutrition and exposure to new risks of occupational disease and accident. It is therefore essential that these countries avoid the errors of the past and take every possible measure to integrate their industrial development with the relevant action in the social and health fields.

[1] Figures in parentheses relate to the references at the end of this article.

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The scarcity of resources which is characteristic of these countries may often necessitate a scaling down of programmes in which economic and social goals are reconciled, and the establishment of priorities between such goals. In many cases, the integration of medical care and health protection in industrialization projects can be done with moderate outlays and without experiencing critical shortages of skilled personnel. The purpose of this article is to draw the attention of both national planning authorities and technical assistance advisers to the need for, and possibilities of, such integration and to describe some of its requirements and some of the results which it may be expected to achieve.

PLANNING OF INDUSTRIAL AREAS

Certain aspects of industrial planning have a direct bearing upon community health. Among these are the location of factories, the size and type of industries and the availability of housing.

New industrial areas should be planned as zones with immediate access to, but separate from housing areas. A well selected location should ensure easy access to work and lower the risk of road accidents. It should aim at reducing as much as possible the long and tiresome journeys which are so often a feature of life in the highly developed countries. In London, between the First and Second World War, new housing estates were built on the east side while most of the new factories were erected in still vacant spaces on the west side. As a result, many workers have had long and expensive journeys across the whole width of the metropolitan area (2). Meteorological conditions should be taken into account in siting both factories and dwellings so as to avoid exposure to harmful concentrations of pollutants.

As large a degree of diversification as possible should be aimed at in planning new industrial areas so as to increase job opportunities and reduce employment sensitivity to trade depressions. A wide choice of jobs and good employment prospects are themselves important for maintaining a good social climate and even for safeguarding community health. In the past, some unfortunate consequences were brought about by the fact that unplanned new towns became economically dependent on one industry. When that industry slumped, the inhabitants were faced with economic and social disaster.

There is some evidence that the rate of absence due to sickness, accidents and voluntary absenteeism, and the frequency of strikes, are associated with the size of manufacturing establishments. In the following table, which shows the average number of days lost per employee, by cause and size of productive unit, in a large public corporation in the United Kingdom, the coefficient of concordance between the rankings of the six groups of works classed by size and the three types of causes of absence is approximately 0.70, which is statistically significant at the one per cent level (3). The evidence suggests that the size to be given to industrial concerns has important social implications, and that special attention has to be paid to health protection, medical care and morale in the larger industries.

Provision of housing is an important element in industrialization. The establishment of factories in industrial agglomerations entails large immigration of

"Factories and dwellings should be sited so as to avoid exposure to harmful concentrations of pollutants..."

A steel mill in Japan

Average number of working days lost per employee by cause and size of unit at sixty-seven works operated by a public corporation in the United Kingdom, 1954

Size of unit (number of employees)	*Number of units*	*Average number of working days lost per employee on account of*			
		Accidents	*Sickness*	*Other causes*	*Total*
Above 500	4	1.08	15.01	4.43	20.52
220-499	8	0.72	12.83	4.04	17.59
100-199	16	0.88	10.03	2.85	13.75
50-99	12	1.23	11.59	2.57	15.38
25-49	10	0.80	9.76	1.68	12.25
Below 25	17	—	10.88	0.38	11.26

Source: Chapter on "Morale and the Size of the Working Group" in *Modern Trends in Occupational Health*, by R. Revans (London, 1960).

workers from rural areas. They frequently leave wives and children behind and come in vast numbers and squat in self-made camps or crowd into existing dwellings which rapidly deteriorate and become insanitary. This may have far-reaching effects on community health and contribute to mental illness and behaviour disorders such as delinquency, prostitution and alcoholism.

An investigation of housing and other social conditions and needs should be a prerequisite to planning industrial projects. In large industrial schemes, which may profoundly modify the economic and social environment of a given area, investment in social facilities should be considered as a necessary part of the cost of the project.

OCCUPATIONAL HEALTH SERVICES

In the nineteenth century, industrialization in Europe led to the development of labour laws to protect women and young persons who were especially vulnerable to accidents and the fatigue of excessively long and arduous work. Little by little, broader and more effective legislation was introduced to protect the health, safety and welfare of all industrial workers. Later, industry recognized that these laws and their enforcement by government authorities were not enough, and many enterprises developed their own occupational health services. At first, this was done on a rather narrow scale by the larger firms to protect their labour force against hazards of occupational injury and disease. Some smaller firms gradually followed suit. Today, occupational health services are considered, in industrial countries, as a necessary part of the operation of an industry. They aim at placing workers in jobs for which they are physically and psychologically suited, providing treatment and controlling health hazards associated with the work. In many of these countries, however, lack of co-ordination between health services frequently results in overlapping or in inadequate servicing and coverage.

In under-developed countries, health services are of the utmost importance to new industries employing peasants who are unfamiliar with the hazards of machinery and toxic processes, and who are not used to the discipline of factory life. The early planning of such services would provide unique opportunities for integrating preventive and curative medicine and avoiding the pitfalls found all too frequently in the more developed countries.

Services provided

Modern occupational health agencies usually provide the following services (4).

Medical examinations by plant physicians

These include pre-employment medical examinations, periodic examinations and special check-ups.

Pre-employment examinations are the foundation stone of an occupational health service. They enable physicians to recommend suitable work for the new employee, and permit detection and treatment of disease. They are especially important in placing workers in hazardous jobs, particularly persons belonging to vulnerable groups such as women and young and elderly people.

Periodic examinations are usually given to workers exposed to occupational hazards and to those belonging to the vulnerable groups. Special check-ups are given to employees returning to work after illness and those presenting symptoms of disease which may be associated with their occupation.

First-aid and medical care

First-aid plays a major role in limiting disability resulting from accidents and in hastening recovery. An efficient first-aid service may have a profound effect on the morale of workers, particularly of those in dangerous industries. For these reasons, first-aid is an essential part of any occupational health programme. In the factories and mines of many industrial countries, first-aid is the only service provided and only emergency and on-the-job treatment is given for occupational and non-occupational disabilities. In countries in which industrialization is developing rapidly, and in some isolated areas, a much broader programme of treatment

"In the factories of many industrial countries, first-aid is the only service provided. In industrializing countries, a much broader programme of treatment should be provided for the worker and his family . . ."

TOP LEFT: *First-aid room in a Louisiana refinery* TOP RIGHT: *First-aid room in a DDT production plant in New Delhi* BOTTOM LEFT: *Treating a child in an Iraqi health centre* BOTTOM RIGHT: *Mothers and children waiting for examination in a Syrian dispensary*

should be provided for the worker and his family. The occupational health service should materially contribute to the health of the community as a whole, particularly in countries where community health services are inadequately developed.

Control and supervision of the working environment

An occupational health service should advise management about potential hazards to health when it is planned to introduce new materials or processes or to make major alterations in the plant. It should make periodic inspections and measurements of environmental conditions in plants where there are known or suspected hazards. For example, it is the practice for well-organized health services in factories or mines, where there is a risk of occupational disease from exposure to toxic dusts or gases, to make routine measurements of the concentration of toxic materials in the air in order to ensure that exposures are kept within safe limits.

The staff of the health service should co-ordinate clinical and environmental investigations to evaluate the influence on health of physical factors, such as lighting, temperature, humidity, ventilation, atmospheric pollution, radiation, vibration and noise. It should study various physiological and psychological aspects of work, such as fatigue, weight lifting, seating posture, night work and shift work, and ensure that good standards of hygiene are maintained in workrooms, canteens, lavatories and cloak-rooms.

Health education

Industry physicians and nurses have special opportunities for providing health education and counselling in order to help workers adjust to their new environment. This function is discussed in more detail below.

Organization of occupational health services

Integration with other services

In the developed countries occupational health services are usually separate from, and not co-ordinated with, other medical programmes. This situation is principally explained by the fact that occupational health is a relatively new field which cannot always be readily integrated with the practice of the older established institutions. Sometimes the activities of occupational health services overlap those of other medical agencies; in general, however, the scope of the services which they provide is rather limited. As a rule, they exist only in the larger industrial firms.

In the industrializing countries unhampered by set customs, occupational health services may have a broader scope; they may be linked with other services, particularly with those providing medical care, and can be organized to serve small as well as large concerns. Reorganization of health services along these lines, with a view to meeting the needs of industrializing communities, has taken place in several countries, for example, the Union of Soviet Socialist Republics, Czechoslovakia, Yugoslavia and Turkey. In the United Kingdom, the National Health Service does not provide for occupational health, and its preventive and curative branches are functionally separate. Services for medical care and public and occupational health were, however, integrated when building the "New Town" of Harlow (5).

In large industrial undertakings there are advantages in having health centres or even hospitals providing for both occupational health and medical care. Health centres in industrial areas should also be organized to provide for the community at large outside the plants medical care, preventive services such as environmental hygiene, maternal and child health assistance, control of communicable disease and occupational health services for smaller factories, service industries and agricultural workers.

Facilities, equipment and staff

Examples of well-equipped and well-organized occupational health services can be found in countries all over the world. In industrial countries, many thousands of physicians and nurses and an increasing but still small number of occupational hygienists are employed in factories, mines, docks, farms, shops, offices and universities. Their work is highly specialized and it is now widely accepted that they need to be specially trained for it (6), (7). The following two examples relate to facilities in two new United Kingdom centres.

A large chemical works with 14,000 employees has recently set up a medical centre with a staff including three full-time industrial medical officers, a dentist, a radiographer, a physiotherapist, two laboratory technicians and eleven state registered nurses. The service is equipped to deal with every emergency and includes a recovery ward for serious injuries, chemical burns and poisonings. The labour department of the factory, which is responsible for recruitment and welfare, works in co-operation with the medical centre (8).

In the New Town of Harlow, which includes an important industrial estate, an occupational health ser-

vice has been established as a co-operative project of local employers, to serve medium-sized and small factories, building contractors, shops and offices (9). The employers subscribe £2 per employee per annum. The Nuffield Trust provided the necessary capital to build and equip the centre and to meet running costs during the early stages of development. Now five years old, this service is nearly self-supporting. It caters for about 9,500 employees in sixty separate establishments. Its staff comprises a director, fifteen general medical practitioners, employed part-time, two full-time and three part-time state registered nurses.

Organization of co-operative projects of this type is essential to meet the needs of the smaller factories. It is often difficult, however, to persuade employers to associate and provide the initial cost of the schemes.

OTHER SERVICES

Medical care

The aim of medical care is to restore health to the sick through medical treatment and rehabilitation. Medical care also includes measures to promote health, prevent disease and discover the earliest stages of disease. Thus, health counselling, immunizations and prophylactic health examinations come within its purview.

Large industrialization projects should make provision for medical care programmes to keep pace with the requirements of a rapidly expanding population. These would include construction of health centres, polyclinics and hospitals (10). As mental illness appears to become an increasingly serious problem in growing industrial communities, special provision may have to be made for mental health clinics in health centres and psychiatric out-patient departments in polyclinics and hospitals (11).

In new communities it may take a longer time to construct hospitals and polyclinics than to build houses; temporary buildings for such centres may need to be provided.

Environmental hygiene

The control of environmental factors which have a deleterious effect on health is a major task for any community health service. Industrial communities have special problems in this field. Work places involve risks from exposure to toxic dusts and gases, radiation, noise, and infections and infestations such as anthrax and hookworm disease.

Some of the hazards which arise from industrial processes may constitute a danger to the whole community. Atmospheric pollution from factory chimneys, disposal of toxic materials, such as beryllium, cyanides and radioactive substances, and contamination of the water supply with chemical effluents and toxic pesticides are common and wide-spread problems. There is enough evidence to show that people and farm animals in industrial areas have been seriously affected by the discharge of industrial wastes into the air and rivers or onto the land. These dangers to the whole community are often ineffectively controlled because the responsibility for environmental hygiene inside and outside industry belongs to different health authorities. Centralization of responsibility or co-ordination of activities in this field is clearly needed.

Control of communicable disease

Industrialization has been blamed for many of the serious epidemics of the nineteenth century, for example, the visitations of cholera and typhus in England. Today, communicable diseases likely to be associated with industrialization include venereal disease, pulmonary tuberculosis, pneumonia, which is often a problem among people from rural communities overcrowded in industrial lodgings and hostels, virus diseases such as poliomyelitis and influenza, bilharziasis, which may be a serious problem in irrigation schemes, and diarrhoeal diseases which spread as a result of poor water supplies and faulty methods of disposing of human excreta.

"An occupational health service should make periodic inspections and measurements of environmental conditions in plants ..."

LEFT: *Check-up to detect contamination by gases* CENTRE: *Checking chimney for proper evacuation of vapours* RIGHT: *Checking noise level of machine*

"The diet of rural workers may be seriously affected by their migration to urban centres..."

LEFT: *Lunch-time in workroom of Indian factory* RIGHT: *Indian woman preparing meal of chappati, a bread made of wheat flour*

The control of communicable disease is an important function of occupational health services, as well as of public health services, because there are hazards of infection at work and because the place of work provides opportunities for finding, treating and rehabilitating patients with communicable diseases.

In planning health services for new industrialization schemes, there are unique opportunities for co-ordinating preventive services inside and outside industry. This would open prospects of solving common problems of pollution of air, water and land and of controlling communicable disease.

Nutrition

In the economically developed countries, industrialization and urbanization have been accompanied by increasing productivity in agriculture. This is often not the case in the less developed countries undergoing a process of rapid industrialization. Serious problems of urban food shortage may arise because of the incapacity of existing agrarian systems to expand production to meet increasing needs. Difficulties in transport and storage of foodstuffs may further aggravate the situation.

The diet of rural workers may be seriously affected by their migration to urban centres. The change may be for better or for worse according to the regularity of their employment, the level of their incomes, and the number of their dependents. Other relevant factors are the availability in towns of foods to which they are accustomed, their being used or not to purchasing food, and the responsibility which their employers may take for their diet.

There are many indications that a rise in national income first leads to a general increase in food consumption, including that of the more expensive and protective foodstuffs. This has been the case in India and other under-developed countries. In Japan, the most highly urbanized and industrialized country in eastern Asia, increases in the per capita consumption of milk, meat, sugar, fats and tea ranged from 13 per cent to nearly 40 per cent during the eight-year period from 1930-31 to 1938-39.

However, in spite of the increase in incomes, the diets of rural people can deteriorate when they move to urban centres. For example, the Bantus' normal diet, consisting of whole-grain cereals and milk, was reported to be replaced by an inadequate one of maize meal, white bread and mineral water when they moved into the towns. In Malaya, there was an increase of beri-beri when rural people migrated to industrialized areas and changed their normal diet of home-pounded rice for one of highly-milled, vitamin-deficient white rice (12).

Providing advice to industry for supplying well-balanced meals to workers and educating them to improve the composition of their diet would be important functions of the health services.

Health education

Health education has an important role to play in industrialization programmes. It may help new communities to adapt to new ways of life, induce people to place a value on health and thereby ensure a proper development and use of services and other measures to promote health. Provision of health education requires close collaboration between health educators and social scientists. It is often a difficult undertaking because of great differences between the ways of life and thinking of those who provide such educational services and those for whom the services are intended. At the outset, illiterate peasant communities may have all sorts of customs and taboos with respect to health and illness. They may be faced with new ways of life and work which are potentially dangerous to their health, and have health services provided for them of a standard and type which are completely foreign to their ways of thinking. The planners may have a much too limited understanding of these factors. "These problems", as G. M. Foster said, "cannot be solved by hiring friendly, understanding, well-meaning persons" (13).

CONCLUDING REMARKS

In the future development of industry, if man's social and economic needs, the basic necessities for his health, are considered together and as of equal importance, the new industrial town can be a place where he can find happiness, leisure and learning—the influences that civilize outlook and habit (14).

Industrializing communities are faced with new problems of mental health and physical disease, the causes of which are not fully understood and therefore not prevented. In countries which are undergoing rapid industrialization and urbanization, it may be easier than elsewhere to study, measure and understand the effects of these developments on health and social relationships. The knowledge gained would be of value to old and new communities. In the meantime, intelligent application in the industrializing countries of the lessons already learned in developed countries would ease their transformation into better balanced and healthier societies.

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United Nations Activities in Industrialization

Developments in the programme of work and establishment of a committee for industrial development

During the past five years, the Secretary-General of the United Nations has submitted to the Economic and Social Council, at the request of that organ, a number of proposals for a programme of work in the field of industrialization and productivity. In the same period, proposals were made by members of the Council for the establishment of a special body to deal with matters relating to industrialization.

The Council's concern with the work programme and the creation of a special body reflected its awareness of the major role played by industrialization in the economic development of under-developed countries and of the increasing responsibilities and duties of the United Nations in furthering its progress. Both matters were discussed at several sessions and at its twenty-ninth session in April 1960, the Council adopted a resolution by which it established a standing Committee for Industrial Development (1).[1] In December of the same year, the General Assembly adopted a resolution in which it took note of the action of the Council and made further recommendations regarding the activities of this Committee (2). The texts of both resolutions are reproduced below.

According to its terms of reference, one of the main functions of the Committee is to examine for the Council the work programme of the United Nations on industrialization and to make recommendations concerning its further development. The present note gives some highlights of the development of this work programme over the past few years, particularly as regards its general orientation. Details of specific projects contained in the programme and the progress in their implementation may be found in some of the documents listed below. The note also gives a brief historical account of the action taken by the Council in the field of industrialization.

In 1955, at its nineteenth session, the Council adopted a resolution (3) in which, among other things, it recognized the need for further and more intensive studies of the problem of industrialization and in particular of methods to raise industrial productivity in under-developed areas. The Council requested the Secretary-General to submit a survey of the work currently being undertaken in that field under the aegis of the United Nations, including the specialized agencies, and, in the light of the conclusions of that survey, to prepare and submit to the Council at its twenty-first session a programme of work to be carried out by the Secretariat, bearing in mind the necessity for accelerating industrialization, raising productivity in under-developed countries and utilizing available forms of international assistance as fully and efficiently as possible to that end.

In 1956, the Secretary-General submitted to the Council, at its twenty-first session, two reports in implementation of this resolution. The first (4) contained a survey of current work on industrialization and productivity by the United Nations, including that of the regional economic commissions, and by the specialized agencies, and discussed the scope of these activities by broad categories of subject. The second (5) contained proposals for a work programme in the field under consideration. In drawing up the programme, the Secretary-General was guided by the following criteria.

(*a*) Attention would be given to problems of planning, programming and developing the industrial sector as a whole but, at the same time, the programme would con-

[1] Figures in parentheses relate to the references at the end of this note.

centrate on the area lying between the assessment and allocation of resources and macro-programming of sector targets, on the one hand, and the designing of productive plant and facilities, on the other. In this area, the studies would involve a micro-economic approach based upon actual industry practice, rather than an analysis based on statistical aggregates.

(*b*) Individual industries would be studied under the programme with a view mainly to developing a methodology for further research. The relevant projects would be in the nature of case or prototype studies, the analysis of the economic and engineering data of the selected industry leading to conclusions of more general applicability. In this way it is expected to develop basic criteria to guide the design, operation and development of plant and productive facilities.

(*c*) In general, the problems studied under the programme would be dealt with in the context of concrete situations, particularly of those arising in connexion with national or regional efforts to accelerate industrial development; the projects would seek to meet immediate needs. In particular, the programme would be largely oriented towards supporting the activities in industry of the United Nations technical assistance programmes.

(*d*) Attention would also be given to problems of small-scale industry which plays an important part in the development of the industrial sector in many under-developed countries.

The Council endorsed in principle the proposals of the Secretary-General as a general framework for appropriate activities of the United Nations to be initiated in the immediate future (6), and at its request, a number of projects were selected by the Secretary-General for early implementation (7). Priority was given to projects likely to be of immediate practical interest to countries in the early stages of industrialization and to projects which would make use of the fund of relevant information and experience available as a result of the activities of the various units of the Secretariat, in particular of those carried out under the United Nations technical assistance programmes.

In 1958, at its twenty-fifth session, the Council invited the Secretary-General to establish a committee of experts for the purpose of reviewing the programme of work on industrialization and making recommendations to the Secretary-General on its further development and implementation (8). The Advisory Committee on the Work Programme on Industrialization met in February 1959 and submitted to the Secretary-General a report (9) which was transmitted to the Council. On the whole, the programme recommended by the Advisory Committee derived from the existing one and was based on proposals of the Secretariat as amended and amplified by the Committee. Its general orientation was as follows: studies on industrialization should provide Governments of under-developed countries with a basis for practical action to promote general economic development; an even closer relationship should be established between projects under the programme and United Nations technical assistance and Special Fund activities; the research work of the Secretariat, which had so far largely concentrated on the micro-economic aspects of industry, should give more emphasis to studies of a macro-economic nature since systematic work relating to general development policies and techniques of programming would enhance the over-all effectiveness of the research activities.

In 1959, at its twenty-seventh session, the Council took note of the report of the Advisory Committee and requested the Secretary-General to prepare proposals for future work with a view to further discussion by the Council of priorities in the programme (10). The Secretary-General's proposals (11), submitted to the Council in 1960 at its twenty-ninth session, were made in the light of a general appraisal of United Nations programmes in the economic, social and related fields and followed broadly the lines recommended by the Advisory Committee.

The discussion in the Council, at the twenty-ninth session, concentrated on two main subjects: the establishment of a subsidiary body of the Council to deal with problems of industrial development, and the work programme on industrialization (12). In discussing the first, the Council considered several alternatives—to set up either a standing committee, a functional commission, or an advisory group of experts; there was also a feeling among some delegations that the establishment of a specialized agency for industrialization was warranted. Eventually, the issue was narrowed down to a choice between a standing committee and a functional commission. At the conclusion of the debate, the Council decided to set up a standing Committee for Industrial Development (1) to advise the Council in matters related to the acceleration by less industrialized countries of their industrial development. To that end, the Committee will examine for the Council the work programme on industrialization and make recommendations concerning its further development; initiate, propose and encourage studies and seminars dealing primarily with industrial methods of production and management techniques, economic programming techniques, financial, fiscal and administrative policies, and distribution and marketing techniques, related to the industrialization of under-developed countries; undertake, propose or encourage the collection, evaluation and dissemination of information derived from these studies and of other information relevant to industrialization, and perform such other relevant functions as the Council may assign to it from time to time. As already mentioned, the General Assembly decided, in 1960, to expand the terms of reference of the Committee (2).[2]

[2] The membership of the Committee is currently as follows: (*a*) members of the Economic and Social Council: Afghanistan, Brazil, Bulgaria, Denmark, El Salvador, Ethiopia, France, Japan, Jordan, New Zealand, Poland, Spain, Union of Soviet Socialist Republics, United Kingdom, United States of America, Uruguay, Venezuela and an additional member to be elected by the General Assembly at its resumed fifteenth session in March 1961; (*b*) other Members of the United Nations or the specialized agencies: Federal Republic of Germany, India, Ivory Coast, Madagascar, Mexico, Pakistan, Peru, Philippines, Sudan, Tunisia, United Arab Republic and Yugoslavia.

As regards the programme of work, the Council generally approved the Secretary-General's proposals. The opinion was expressed that the work programme of the Secretary-General had so far been, and still was, characterized by an effort to maintain a balance between macro-economic and micro-economic studies and that this approach was correct since neither could be disregarded. However, suggestions were also made to the effect that the main emphasis in the programme should be put on the study of problems related to economic policies of, and measures for, industrial development which involved a macro-economic approach. The Council finally adopted a resolution (15) in which it requested the Secretary-General to submit proposals for a longer-range and expanded work programme for consideration by the Committee for Industrial Development and by the Council.

The Secretary-General's proposals, prepared for submission to the Committee at its first session in March 1961 and the Council at its thirty-first session in April 1961, took into account the terms of reference of the Committee, the relevant resolutions of the Council and the Assembly, and the debates in these two bodies. Pursuant to the Council's request, the programme was expanded, but its general orientation remained the same as that indicated earlier (9).

The broad fields covered by the programme include: industrial programming and policies; industry studies; fiscal and financial aspects; training and management; problems of small-scale industry; problems in technology and engineering related to industrialization of under-developed countries. A number of specific projects were proposed under each of these categories (14).

Economic and Social Council resolution 751 (XXIX). Establishment of a Committee for Industrial Development

The Economic and Social Council,

Having considered General Assembly resolution 1431 (XIV) of 5 December 1959,

Convinced of the need to accelerate the process of industrialization of under-developed countries, by the expansion of the means of providing advice, information and assistance through the United Nations in the planning and execution of their industrial development, and to keep the General Assembly informed of the pace of their industrial growth,

Bearing in mind the value of developing new approaches to industrial development, by bringing together the heads of national economic development agencies or other qualified experts from less industrialized and from highly industrialized countries to discuss problems of common concern on the basis of their respective views and experiences,

Establishes a standing Committee for Industrial Development with the following terms of reference:

1. The Committee for Industrial Development shall advise the Economic and Social Council in the matters related to the acceleration by less industrialized countries of their industrial development, and to this end it will:

(*a*) Examine for the Council the work programme on industrialization and make recommendations concerning its further development;

(*b*) Initiate, propose and encourage studies and seminars dealing primarily with:

(i) The most effective application of modern industrial methods of production and management techniques to the establishment and operation of industries in the under-developed countries;

(ii) Economic programming techniques as applicable to industrialization;

(iii) Financial, fiscal and administrative policies conducive to the acceleration of industrial development;

(iv) Effective techniques of distribution and marketing of industrial products, taking into account the progressive industrialization of under-developed countries;

(*c*) Undertake, propose or encourage the collection, evaluation and dissemination of information derived from the studies under sub-paragraph (*b*) above and of other information relevant to industrialization;

(*d*) Perform such other relevant functions as the Council may assign to it from time to time.

2. The Committee may establish or propose *ad hoc* bodies to facilitate its tasks.

3. The Committee shall exercise its functions without prejudice to the activities of the regional economic commissions.

4. The Committee shall consist of all members of the Economic and Social Council together with an additional six members to be elected for three-year terms by the Council from amongst States Members of the United Nations or members of the specialized agencies or the International Atomic Energy Agency with due consideration to the principle of geographical distribution and to the adequate representation of under-developed countries in view of the fact that their industrial development is the main objective of the Committee. The Committee is authorized to sit, with the approval of the Council, while the Council is not in session. In the event that any of the six additional members becomes a member of the Council, the Council shall elect another State to the membership of the Committee for the remainder of the term of office of that member.

5. Any State Member of the United Nations or member of the specialized agencies or of the International Atomic Energy Agency not represented on the Committee may bring to the attention of the Committee any problem relating to its industrial development and take part, in a consultative capacity, in the deliberations on the subject.

6. The States members of the Committee should endeavour to designate representatives who hold key functions in the planning or execution of national economic development or other experts qualified to discuss the problems of industrial development.

7. The Committee shall assist the Economic and Social Council to maintain the necessary liaison between the activities in the field of industrialization of the regional economic commissions, the specialized agencies, the International Atomic Energy Agency and other bodies working in the same field, with a view to ensuring the utmost efficiency and co-operation in their work.

8. The Committee shall report and make its recommendations to the Economic and Social Council.

9. The agenda of the Committee shall be established in accordance with paragraph 1 above.

1105th plenary meeting
12 April 1960.

General Assembly resolution 1525 (XV). Activities of the United Nations in the field of industrial development

The General Assembly,

Recalling its resolution 1431 (XIV) of 5 December 1959, which recommended that the Economic and Social Council give consideration to the prompt establishment of a commission for industrial development,

Noting Economic and Social Council resolution 751 (XXIX) of 12 April 1960 on the establishment of the Committee for Industrial Development,

Taking into consideration the substantial interest of the economically less developed countries in developing their own industries as one of the main ways of diversifying their economic structures and developing their national economies generally,

Being convinced that the activities of the United Nations in the field of industrial development should be widened and accelerated,

1. *Recommends* that the Committee for Industrial Development should consider in drawing up its programme of work, in conjunction with the functions set forth in Economic and Social Council resolution 751 (XXIX), the following:

(*a*) To review the methods and techniques of programming general industrial development which have been evolved by different countries and regions, and to contribute to international co-operation in this field;

(*b*) To work out general conclusions on the basis of the experience of industrial development in all countries with a view to promoting the exchange of experience in the field of industrial development between countries of different regions and having differing economic systems;

(*c*) To encourage the preparation of long-term economic projections in the field of industrial development, taking into account social aspects of industrialization in the economically less developed countries as well as its influence on international economic relations and trade;

(*d*) To follow developments in the field of the financing of new industries in the economically less developed countries and to make appropriate recommendations thereon;

2. *Recommends* that the Economic and Social Council at its resumed thirtieth session enlarge the membership of the Committee for Industrial Development to thirty members in order to ensure a more balanced representation of Member States in that Committee, in accordance with the principles enunciated in paragraph 4 of the Committee's terms of reference as set forth in Economic and Social Council resolution 751 (XXIX), and taking into account, in particular, the countries of Africa;

3. *Appeals* to the Governments of the States members of the Committee for Industrial Development to designate their representatives to the Committee in the near future and in accordance with the principle in paragraph 6 of its terms of reference;

4. *Decides* to include in the General Assembly's provisional agenda, beginning with the sixteenth session, an item entitled "Industrial development and activities of the organs of the United Nations in the field of industrialization.

948th plenary meeting,
15 December 1960.

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(2) *Official Records of the General Assembly, Fifteenth Session, Supplement No. 16, vol. I*, resolution 1525 (XV). At its preceding session, the General Assembly had recommended in resolution 1431 (XIV) (*Ibid., Fourteenth Session, Supplement No. 16*), that the Economic and Social Council give consideration to the prompt establishment of a commission for industrial development.

(3) *Official Records of the Economic and Social Council, Nineteenth Session, Supplement No. 1*, resolution 560 (XIX).

(4) *Ibid., Twenty-first Session, Annexes*, agenda item 5, document E/2816. This survey was brought up to date in an article entitled "Current Activities under the Aegis of the United Nations in the Field of Industrialization and Productivity" in *Bulletin on Industrialization and Productivity*, No. 1 (Sales No.: 58.II.B.2).

(5) *Ibid.*, document E/2832.

(6) *Ibid., Supplement No. 1*, resolution 597 A (XXI).

(7) *Ibid., Twenty-second Session, Annexes*, agenda item 4, document E/2895.

(8) *Ibid., Twenty-fifth Session, Supplement No. 1*, resolution 674 A (XXV).

(9) *Ibid., Twenty-seventh Session, Annexes*, agenda item 5, document E/3213 and Add.1. A summary of this report is contained in an article entitled "Report of a Group of Experts on the United Nations Secretariat's Work Programme on Industrialization" in *Bulletin on Industrialization and Productivity*, No. 2 (Sales No.: 59.II.B.1).

(10) *Ibid., Supplement No. 1*, resolution 709 A (XXVII).

(11) *Ibid., Twenty-ninth Session, Annexes*, agenda item 6, document E/3328.

(12) *Official Records of the General Assembly, Fifteenth Session, Supplement No. 3.*

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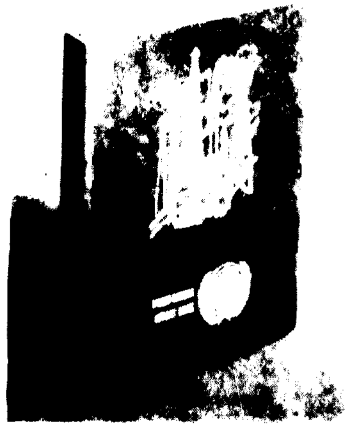

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