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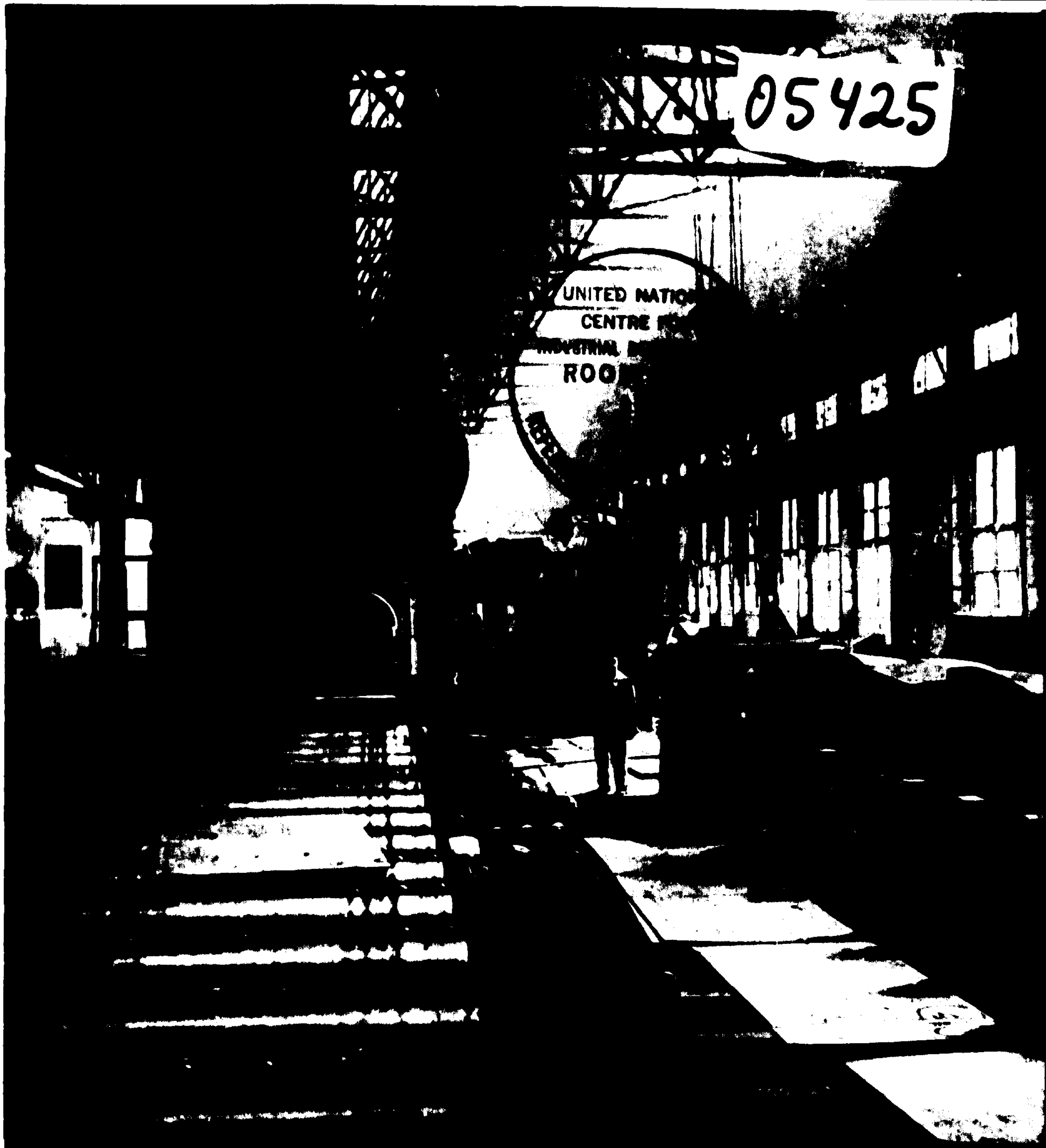
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org



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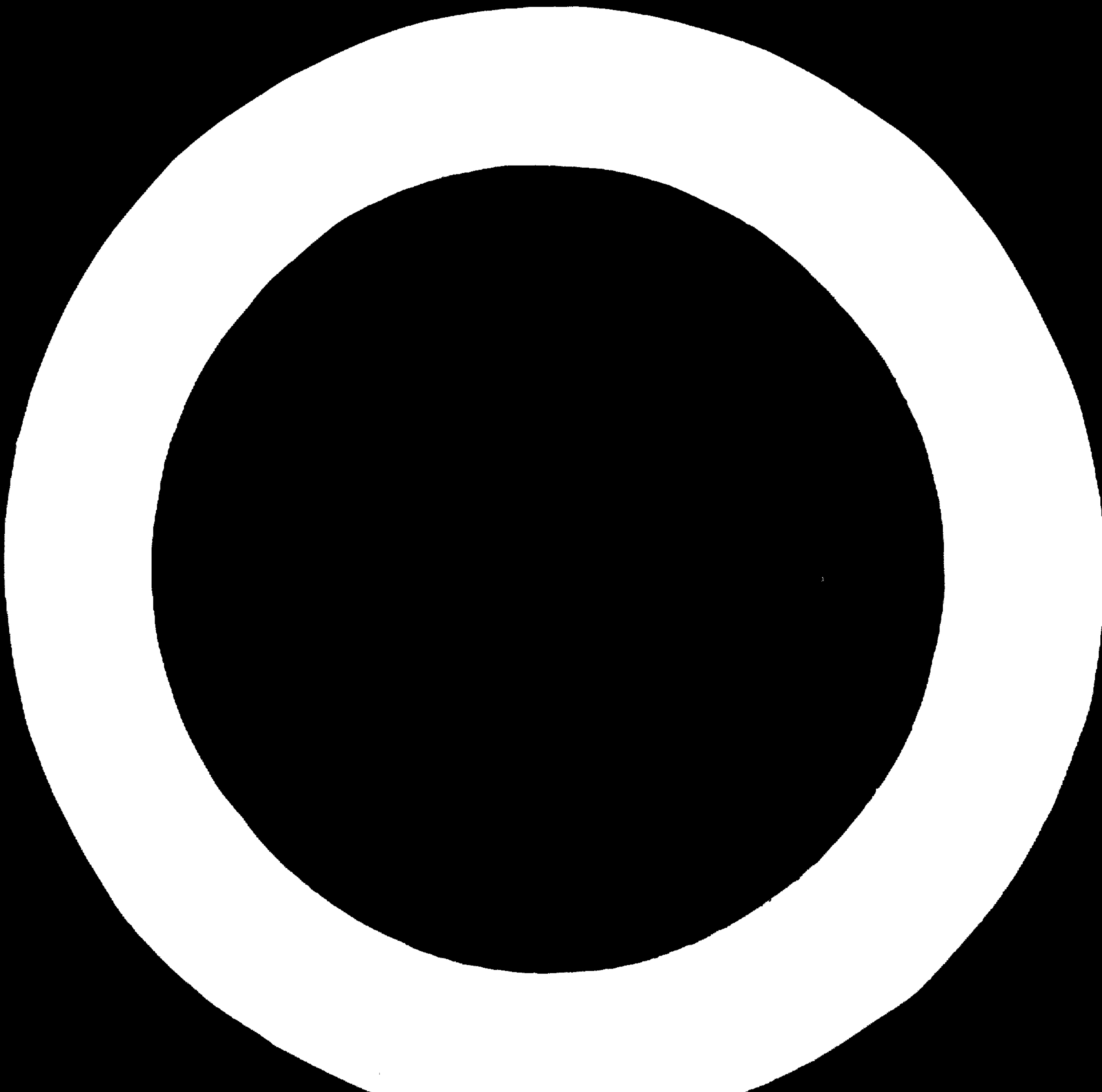

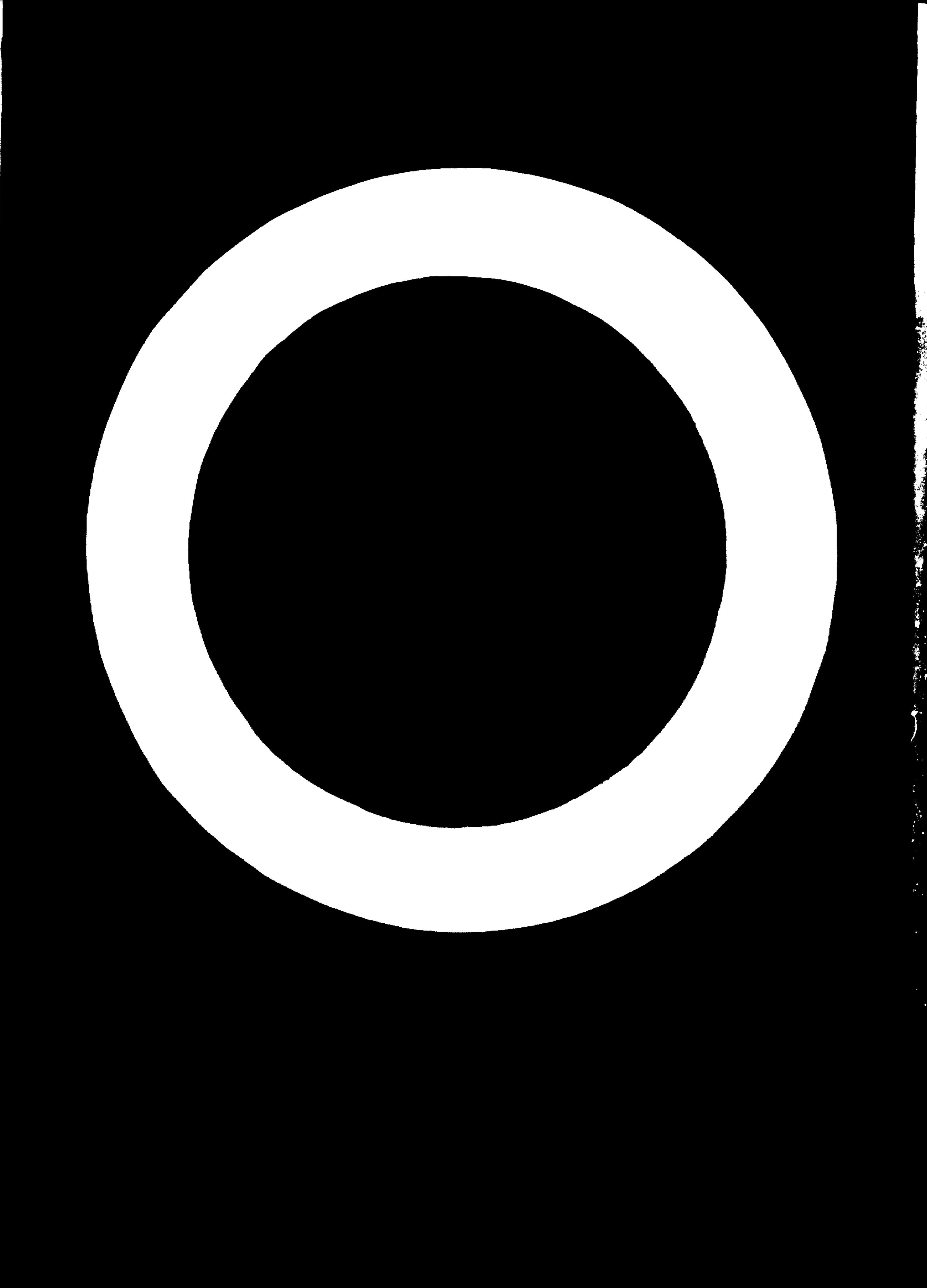

INDUSTRIALIZATION AND PRODUCTIVITY

8

In this issue

Cover illustration: Hydraulic shears cutting steel plates in the Amurstal Iron and Steel Works at Komsomolsk-on-Amur, a new town in the far east of the Soviet Union. An article in this issue discusses the evaluation of industrial projects—among which a number in the field of iron and steel—in centrally planned economies, including the Soviet Union.

Department of Economic and Social Affairs

INDUSTRIALIZATION AND PRODUCTIVITY

BULLETIN 8

UNITED NATIONS

New York, 1964

UNITED NATIONS PUBLICATION

Sales No.: 64. II.B. 6
Price: $U.S. 0.75
(or equivalent in other currencies)

Preface

THE FOUR ARTICLES contained in this issue of the *Industrialization and Productivity Bulletin* are concerned with certain broad subjects in the field of industrial development, some aspects of which have already been dealt with in previous issues of this publication. These subjects are evaluation of projects in planning and programming, capital intensity and scale of industrial production, size of plant and economies of scale, and adaptation of technology to the needs of the developing countries; one of these subjects—capital intensity—is discussed, with more or less emphasis, in all four articles.

The first article, "Evaluation of Projects in Centrally Planned Economies", parallels the study of evaluation of projects in predominantly private enterprise economies, published in the fifth issue of the *Bulletin* (Sales No.: 62.II.B.1). It discusses the policies and patterns of investment in centrally planned economies and analyses the methods used in evaluating industrial projects with reference to allocation of investment among alternative projects, choice of technology and factor proportions, economic calculation and investment analysis at the sectoral, inter-sectoral and plant levels, comparative analysis of projects designed to encourage import substitution or promote exports, and analysis of investment in large multi-purpose schemes. The article provides some examples of investment analysis actually carried out in a number of countries with centrally planned economies.

The article entitled "The Dual Nature of Industrial Development in Japan" examines some problems raised by the coexistence, in that country, of small-scale and large-scale industries, the former using predominantly labour-intensive techniques and employing workers at relatively low wage rates, the latter using processes of high capital intensity comparable to those in other industrialized countries. The article discusses, in particular, the elasticity of supply of labour and the price-wage structure, technological change and labour productivity, particularly in the small industry sector, and the measures designed to provide adequate rates of return to small industrial establishments.

The next article, "Plant Size and Economies of Scale", deals with some aspects of the problem of selection of industry, scale of production and technological processes in the developing countries. It examines the cost of production and its components by major inputs, in relation to the scale of production, the economies of scale resulting from technical or organizational factors, and the relationships between location of markets, transportation and the size of plant, on the basis of data from selected industries. Special attention is paid to the question of minimum size of plant in developing countries with relatively small national markets.

In the last article, "Aspects of the Design of Machinery Production During Economic Development", Professor S. Melman stresses the advantages of integrating design and production of the mechanical and control elements of machinery built in the industrializing countries, by making use of recent developments in production and the economics of the engineering industries. Among the subjects covered in the study are the use of common manufacturing facilities, standardization of parts and components, modular design of sections of machinery, and the problem of selecting the proper level of mechanization of industrial operations by considering various alternative techniques of different capital intensity and the related cost alternatives.

The first three articles appearing in this issue of the *Bulletin* were prepared in the Centre for Industrial Development, Department of Economic and Social Affairs.

View of the construction site of the Bratsk hydroelectric station in Siberia, taken from the upper concrete delivery trestle

Evaluation of Projects in Centrally Planned Economies

INTRODUCTION

THE UNITED NATIONS General Assembly, in resolution 1525 (XV), recommended that the Committee for Industrial Development should, *inter alia:*

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

"(*b*) . . . 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; . . .".

This article is based on a study prepared by the Research and Evaluation Division of the United Nations Centre for Industrial Development for submission to the Committee for Industrial Development. It deals with the methods and practical problems of industrial project evaluation in the centrally planned economies.

The particular interest in reviewing the experience of the centrally planned economies in the above-mentioned field stems from several factors. In the first place, in spite of differences in institutional and political structure, the problems faced by the centrally planned economies at the inception of their industrialization plans were in many respects similar to those currently faced by developing countries. Secondly, both types of countries, for different reasons, have been unable to base their industrial development policies and methods upon the historical experience of western countries, whose industry developed largely under the stimulus of the market and price mechanism. Thirdly, and for reasons which are related to the former considerations, the developing countries were faced with the extremely difficult and little explored problem of elaboration of "social" criteria of investment. In this respect, the experience of the centrally planned economies offers an interesting area of study.

It can be taken for granted that the use of adequate methods in project evaluation is of particular importance in the framework of centrally planned economies because of the centralized nature of all major decisions on investment allocations. This is, however, a complex task and while a great deal of progress has been made in the area of problems of evaluation there is still much to be done. In view of both this fact and the markedly accelerated progress of investment analysis in recent years, the present article must be regarded only as a preliminary progress report; it seems obvious that it will be useful to review this topic after a few years.

While most general criteria of investment allocation are clear enough, the technique of formulating adequate operational methods and criteria for use in evaluating each particular investment project raises complex theoretical problems. A number of different criteria of project evaluation have been proposed, such as the "synthetic" formula of economic effectiveness of investment, the overall and marginal national income investment ratio, the criterion of profitability and certain other techno-economic indices. It can be stated, however, that increasing numbers of economists in all these countries tend to favour the synthetic formula of economic effectiveness of investment. This is also reflected in the new official instructions concerning evaluation of industrial investment projects. Bearing this in mind, attention is centred in the present article on the description and development of the synthetic formula. However, emphasis is placed on practically applied methods rather than theoretical deliberations.

In line with this present tendency, much discussion is taking place in the economic literature of the centrally planned economies with regard to the theoretical basis of the synthetic formula, that is, the model of economic growth in the institutional framework of a centrally planned economy.

Different theoretical concepts are currently being widely tested in the practice of investment analysis. Two tendencies can be detected at the present time: one is to improve the methods of evaluation of individual investment projects by taking into account, in the computation of the synthetic formula, more and more economic factors; the second is to evaluate investment projects in the context of larger systems consisting of a number of such projects.[1]

Owing to the above-mentioned tendency to use a uni-

[1] Some sophisticated mathematical models of investment efficiency analysis, including sectoral allocation, have been elaborated in the centrally planned economies (especially in Hungary, Poland and the Soviet Union). So far, they can hardly be considered as operational devices.

form formula in project evaluation, attempts are now being made to extend the use of the synthetic formula to international comparison of investment projects among the centrally planned economies; this aspect of investment efficiency analysis is, however, still at its beginning. There are still considerable difficulties to overcome in such international comparisons—in particular, the problem of different economic structures and price levels.

It should be noted that, along with the problem of efficiency criteria, parallel discussion is going on with regard to the price problem. The two problems are complementary. The improvement of the analysis of investment efficiency criteria requires and stimulates the advancement of that relating to the price structure and *vice versa*. It has not been possible, however, to deal with this aspect of the analysis as well as with the role of the price structure in investment analysis in this article.

Finally, the very important issue of sectoral allocation of investment is not dealt with here in full. An attempt to explore this problem in the centrally planned economies would require a very extensive and separate study.

Some examples have been presented in an appendix to the present article in order to illustrate the scope and method of application of the synthetic formula of economic effectiveness of investment in project evaluation.[2]

[2] These examples are taken from the book, *Effectiveness of Investment*, published in Poland in 1961, and are presented in simplified form.

HISTORICAL OUTLINE

Over-all patterns of development and investment policy

At the inception of their industrialization plans the centrally planned economies were at rather different stages of industrial development. In spite of marked differences in industrial development and in general economic conditions, they have pursued, during the past decade, rather similar economic policies with regard to both development patterns and methods of running the economy. This can be explained, to some extent, by certain common features in their economic situation, but also by the similarities in their political and institutional structure.

The social and economic reforms carried out in the centrally planned economies at the early stages of their planned development made it possible for the central authorities to control income distribution and foreign trade and to control directly the allocation of capital investment; these reforms also paved the way for the application of comprehensive planning. While the institutional arrangements made it easier to launch and implement programmes of accelerated development, the economic problems faced by the Governments were in many respects similar to those of the developing countries throughout the world.

A salient feature of the economic situation of the centrally planned economies, before they engaged in policies of accelerated industrialization, was the structural disequilibrium between labour resources on the one hand and available capital on the other. It resulted in a low level of utilization of manpower, low labour productivity, and consequently low living standards of the population. This was the most important basis for the policy of high capital investment which was carried on throughout the period of post-war economic development by all these countries.

Since, in the centrally planned economies, the central authorities control income distribution through wages and prices and decide directly the bulk of total investment expenditure of the country—over 90 per cent of the total in the European centrally planned economies—the factors influencing the share of investment in national income are different from those in the free enterprise economies.

Generally speaking, the centrally planned economies tend to determine the volume of capital investment at a high level. In development planning as well as in current economic policy all the factors which determine the upper limit of investment possibilities are taken into account and the investment volume is set at that level.

Technical absorptive capacities constituted for a long time the largest bottleneck in expansion of capital investment and were, therefore, the most important factor in determining the upper limit of investment possibilities. The long-run solution of this problem consisted in developing capital goods industries, in practically all the countries. In order to increase investment capacities in the shorter run by way of foreign trade, import substitution was promoted wherever possible. Less emphasis was put on export expansion in earlier periods, although this has changed in recent years.

While during the first development periods investment capacities were the most important factor determining the volume of capital investment, in the later periods considerations of consumption levels and income distribution have grown in importance. The individual propensity to save does not play an important role in the centrally planned economies. Nevertheless, social factors and particularly social attitudes towards current consumption levels and income distribution patterns played an increasingly important role in determining the upper limit of the share of investment in national income.

On the whole it can be stated that it is not the propensity to save and invest but the physical and economic limitations that influence the volume of investment in the centrally planned economies. Therefore, ***the policy of high investment was pursued by way of bringing about structural transformations of the economy rather than by provision of incentives to save and to invest.***

Creation of favourable structural conditions for a fast

Table 1
DISTRIBUTION OF INVESTMENT OUTLAYS

Country	Total investment outlays	Productive investments[a]	Of which: Industrial sector	Of which: Agri-culture	Unpro-ductive investment	Of which: Residential construction
Bulgaria[b]						
1950-1955	100	79.0	52.4	10.2	21.0	3.7
1956-1960	100	84.6	59.7	12.4	15.4	2.6
Czechoslovakia						
1950-1955	100	63.7	41.7	10.8	36.3	11.5
1956-1960	100	69.4	40.0	16.3	30.6	16.2
Poland						
1950-1955	100	70.5	45.0	9.4	29.5	12.2
1956-1960	100	68.9	41.5	11.6	31.1	18.7
Romania						
1950-1955	100	80.6	55.8	10.9	19.4	4.4
1956-1960	100	80.3	51.1	17.6	19.7	6.1
Soviet Union						
1951-1955	100	75.5[c]	46.5	17.7	24.5	14.1
1956-1960	100	71.7[c]	42.0	18.3	28.3	11.6

Source: B. Zielinska, "Industrial Investments in Socialist Countries" (1950-1960), *Gospodarka planowa*, No. 3, 1962 (Warsaw).

[a] Covering investment outlays in the industrial sector, agriculture, transport and communications, trade and materials supply.

[b] State investment outlays.

[c] Estimates.

and steady growth through expansion of the countries' investment capacities determined the policy followed in allocation of investment. Thus, emphasis was put on: (*a*) fast expansion of domestic capital goods industries; and (*b*) preferential treatment of direct productive investment against unproductive investment, as can be seen from tables 1 and 2.

Considerations of capital intensity were disregarded in the choice concerning structural transformations. On the other hand, the relative abundance of labour was taken into account whenever possible with the aim of maximizing output, and particularly of increasing the output of capital goods (and exportable commodities).

Labour-intensive techniques were used mostly in construction works, in existing plants (by a maximum utilization of existing capacities), and in the ancillary operations of new plants.

Looking at the investment policy patterns of the centrally planned economies from the point of view of the relative scarcities of labour and capital, three general observations might be made:

1. Labour-intensive techniques were applied in all cases when they did not influence techniques in the longer run and did not affect the desired structural transformations of the economy. Labour-intensive techniques in construction works and multi-shift operation of plants are most typical of this category.

2. Much more caution was exercised as regards application of labour-intensive techniques in new plants, whenever the choice of equipment predetermined the level of technology for longer time periods.

In industries considered most important from the point of view of economic growth, the general tendency was to choose the most advanced techniques, while in industries of secondary importance more labour-intensive techniques prevailed. However, even in the high-priority industries the policy of high capital intensity was not applied uniformly. Thus, in these industries high capital/labour ratios were generally applied in those productive processes where such ratios were more or less technologically fixed; that is, where the standards of quality and uniformity of product could not be maintained with any other combination of production factors. In some countries, for instance, in such a high-priority industry as machine building, in-factory transportation, handling of materials, quality control and several other ancillary operations were almost entirely manual.

It would appear that the scarcity of skilled labour was another factor which, apart from growth and technological requirements, prompted the use of capital-intensive methods in high-priority sectors. Even where more labour-intensive methods could be applied, the maintenance of quality standards would have required a much

Table 2
DISTRIBUTION OF INVESTMENT OUTLAYS IN SELECTED INDUSTRIES, 1956-1960

Country	Investment outlays in heavy industry as ratio to those in light and food industries	Investment outlays in metallurgy as ratio to those in machine building industry	Investment outlays in chemical industry as ratio to those in metal-working industry
Bulgaria	4.32	2.26	0.59
Hungary[a]	6.83	1.63	1.24
Poland	4.56	0.89	0.87
Romania	8.03	2.30	1.73
Soviet Union[b]	8.37	0.62[c]	0.30

[a] 1957-1958.

[b] 1952-1958.

[c] Ferrous metallurgy only.

greater supply of highly skilled workers than was available at the earlier stages of development.

3. In the case of certain major structural problems of investment allocation which played an important role in increasing a country's investment capacities in the long run, the question of capital intensity was disregarded.

Stages of development and investment analysis

The methods of investment analysis in the centrally planned economies were developed along with the evolution of their economic situation and in accordance with the development strategy followed during the various development periods. They were shaped by the pressing practical needs and had to respond to concrete and changing situations. It is only in more recent times that economic theorists entered the field and attempted to develop more rigorous methods of investment analysis.

In the first post-war period all the centrally planned economies undertook a reconstruction policy aiming at restoration of the pre-war industrial potential. In that period the field of economic choice in the investment policy was very narrowly restricted—mainly to the time schedule of reconstruction of the various plants. An overall appraisal of investment capacities played a very important role. Overhead facilities—transport and electric power—were first on the priority list. Serious limitations in foreign trade made it necessary to proceed with the reconstruction of industry according to the needs of the technological interrelationships. Material balances were very helpful in this respect since they made possible the elaboration of internally consistent investment programmes, taking into account existing capacities.

High effectiveness of investment in reconstruction, taking advantage of external economies, was one of the factors calling for rapid expansion of investment capacities. Therefore, emphasis on capital goods industries already became apparent in this development period. The ratio of investment to national income was growing appreciably, although by and large without a negative impact on the living standards of the population.

By the beginning of the past decade most of the centrally planned economies entered a new development period—the period of accelerated industrialization. This period was different in almost all respects from the first one.

There was a wide scope of economic choice as regards a new economic structure which would create favourable conditions for long-run economic development.

As indicated above, the most serious problems appeared in economic choice concerning the volume of capital investment and the share of investment in national income. Appraisal of the socially acceptable saving ratio and of the countries' investment capacities for many years ahead proved to be a most difficult problem, which could not always be solved correctly. Realistic assessment of the cost of investment projects included in the programme was another difficult problem, since miscalculations in this area are likely to arise and in some cases did lead to serious consequences. Programming techniques by themselves were of little help in solving these two problems.

Full utilization of existing industrial capacity and a co-ordinated programme of new projects were two principles followed in investment programming.

In most of the centrally planned economies the initial phase of accelerated industrialization was conceived as one which should establish the foundations for expansion of the capital goods industries and for diversified industrial development. The main emphasis was therefore put on development of energy, raw materials and semi-finished products. Under this concept of development only general consideration was given to the place of a given country in the world economy and world trade. Further development made it necessary, however, particularly in the case of smaller countries, to appraise investment projects from the point of view of foreign trade also.

This phase of accelerated industrialization was characterized by a fast increase in the investment income ratio. This rapid growth was made possible, first of all, by fuller utilization of the existing economic resources—labour resources and industrial capacities.[3] The rise in the investment ratio was, however, brought to a halt after a few years. It encountered serious bottlenecks in investment capacities and, in some countries, social disturbances. Since also at about the same period—or a few years later—many of the new, big industrial projects were completed, the countries entered a new development phase.

The new development period, accompanied by reappraisal of many concepts and strategies applied in the past, can be defined as one in which the centrally planned economies achieved, by and large, the conditions for rapid long-run growth. Although for a few countries further acceleration may still be considered desirable, most of them achieved a rate of growth based on a generally stabilized ratio of investment to national income.

The new period is marked by a transition of emphasis—from a phase of highly dynamic structural changes accompanied by a drive for utilization of latent resources to that of more balanced allocation of resources. The latter implies a greater emphasis on economic calculations in investment analysis.

Evaluation of investment projects

Already in the earlier periods, when the investment needs—namely, the need to increase capacities in a given industry—were ascertained, investment solutions were sought by a comparative analysis of the various possible alternatives. The comparative analysis of investment projects was then conducted by using techno-economic coefficients. These covered detailed investment and current input data for each industry as regards raw materials, different types of labour force, power, fuel, and the like and specific technical parameters of performance. Particular attention was given to capital/output coefficients.

Since techno-economic coefficients have played an important role both in planning and project evaluation, they

[3] By means of multiplying shifts, raising labour intensity in ancillary operations, and so on.

Three large projects in Bulgaria:

Above: View of the shipbuilding yard "Georgi Dimitrov" at Varna;

Top right: Construction of an oil refinery near Bourgas;

Bottom right: The thermo-electric station "Maritza-East" near Dimitrovgrad

were very carefully assembled and evaluated by planning agencies and various projection organizations.[4] They were generally expressed in physical units, and are still very much used to evaluate the economic advantages of different technologies, sizes of operation, and so on, and to select the most appropriate engineering solutions.

In the course of time it became increasingly apparent that this method was inadequate for the purpose of evaluating such problems as the reconstruction of existing plants *versus* the establishment of new plants or import substitution and export promotion projects.

Technically, the comparison of two or more alternatives is eastest, in terms of techno-economic indices. The project maker is faced with homogeneous indices. But this method has its own limitations from the point of view of the choice of an optimum alternative. For instance, the project maker may have to deal with the evaluation of such alternatives as a lower rate of output

[4] The experience of Czechoslovakia and of Eastern Germany deserves special attention in this field.

per worker and a higher input of raw materials.[5] In such cases the tendency was to use actual or devised prices as weights and to compare investment alternatives in terms of two indices, investment outlays and operating costs. It was soon realized, however, that these more generalized indices (i) depended heavily on the structure of prices, (ii) left open the problem of substitution between capital outlays and current operating expenses, and (iii) did not take into account the impact of the tie-up of investments during the period of construction or technological progress. Attempts to override these difficulties in comparing investment alternatives led to supplementing the method of techno-economic coefficients by an appraisal of investment projects based on assessment of total outlays in value terms. The basis of forming a synthetic formula is, as will be seen later, taking into account the possible substitution between labour and capital.

The methods of dealing with the other factors mentioned above, such as the tie-up of investments during the maturation period, technical progress or the time pattern of production and current expenses, often differ from country to country.

This method of evaluation was initially applied for separate investment projects only, with the aim of finding the best techno-economic solution for a given investment target. The synthetic coefficients were also usefully compiled and compared for a number of projects within a given industrial sector—coal mining or power generation, for instance. An investment alternative was regarded as economically effective if its synthetic index was higher than that of any other alternative.

The research on and the methodology applied in the evaluation of the economic effectiveness of investment was based on the implied assumption of a "closed" economic system. This was due to the fact that (i) foreign trade in the Union of Soviet Socialist Republics is relatively small although increasing in relevance from the point of view of investment choices; (ii) the course of industrialization was to some extent autarkic in the initial periods; and (iii) domestic prices were generally

VOLUME OF EXPORTS AND IMPORTS PER CAPITA[a]

(Roubles)

	1950	*1960*
Bulgaria	34	133
Czechoslovakia	104	250
Eastern Germany	43	227
Hungary	62	177
Poland	49	85
Romania	25	67
USSR		47[b]

[a] B. Zotov and G. Shatalov, "Economic Efficiency of Foreign Trade", *Ekonomicheskaia gazeta* (Moscow), 24 November 1962.

[b] From the reply of the Government of the Soviet Union to the United Nations Questionnaire on Industrial Planning and Development of March 1963.

independent of world market prices because of the central control of prices and state monopoly of foreign trade. However, because of the rapid expansion of foreign trade, particularly in the smaller countries, it appeared necessary to introduce further refinements to the coefficients used. These aimed at indicating first of all the import content of exports or the optimal stage of processing of exports. Extensive research was also begun to bring into the efficiency check the differences in the foreign exchange implications of the investment variants. Analysis of the import substitution and export promotion projects called for a certain reformulation of the coefficient. A further refinement consisted in evaluating "systems" of projects. This brought a greater degree of sophistication into the methods of investment evaluations.

Along with the improvement of the methodological tools of project analysis, other developments occurred in the centrally planned economies. More and more emphasis was put on medium and long-term planning as against short-term planning. Elaboration of long-range development plans covering a planning period up to 1980—in all the centrally planned economies—had important repercussions on investment analysis in the individual industrial sectors. The centrally planned economies have also developed systems of spatial co-ordination and geographical planning. Thus, each investment project is being considered within a system of both sectoral and spatial connexions. Lastly, there has grown up a network of projections offices and industrial scientific institutes. The projections offices have compiled in particular a great store of pre-investment data for various alternatives.

[5] In 1958, the output of steel per open-hearth worker was 613 kilogrammes in Eastern Germany and 544 kilogrammes in Poland, whereas the average daily steel output per square metre of open-hearth floor was 4.57 tons and 5.00 tons respectively. Thus, the indices adduced are contradictory, and comparing them leads to no definite conclusions.

INSTITUTIONAL BACKGROUND

IN THE CENTRALLY planned economies state and co-operative ownership is predominant, and owing to this fact, planning covers the whole of the national economy. A plan of the national economy is a programme of action that co-ordinates (i) information, (ii) forecasts and (iii) directives concerning output and capital formation for the plan period.[6] The objectives for the development of a country's economy are elaborated by the planning com-

[6] In countries where the private sector—for example, agriculture in Poland—still plays an important role, the plan also comprises means of regulating this non-socialist sector.

mission and quite often presented in several more general or detailed versions which are discussed by competent technical and political authorities.

The elaboration and discussion of the various versions make it possible to find an optimum solution, that is, one which brings the general long-run policy objectives into harmony with current policy objectives as regards income distribution, employment and related topics. The main targets provide a basic plan which is subject to endorsement by the authorities.

Three basic types of plans are being elaborated, according to the time horizon covered:

1. *Long term expansion plans* for fifteen or twenty years, sometimes called *perspective plans*. This sort of plan lays down the most general perspectives for the development of the national economy. Such plans—for twenty years—are already elaborated or in the process of being drawn up.

2. *Medium-term expansion plans*. The five-to-seven-year plans are a more concrete statement of the objectives of the perspective plan for this period. They are often considered the main type of economic planning in the centrally planned economies.

3. *Short-term*—mainly annual—*working plans*. The annual plans specify economic tasks for a year in line with the provisions of the medium-term economic plan.

All these types of plans are co-ordinated on sectoral and geographical levels. Generally plans are broken down according to the objective, time span and the structural—that is, organizational—set-up of the country as a whole. In the process of formulating a plan, particular attention is paid to one of the most important components of national economic plans, namely, the investment plan. Its importance—which is proportional to the length of the time horizon covered by a plan—is due to the fact that the implementation of an investment plan (*a*) increases productive capacities—a necessary condition for steady growth of an economy, (*b*) ensures necessary proportions among sectors, branches, and regions of the national economy in the process of its growth, and (*c*) secures optimal progress of technology.

The investment plan comprises targets in regard to: (i) amount of gross capital investment, which is broken down into (*a*) construction and assembly work, (*b*) equipment and tools and (*c*) other capital work and expenditure; (ii) the commissioning of fixed assets; and (iii) lists of capital investment projects (these include general techno-economic descriptions of projects).

The volume and structure of gross capital investment in the industrial sector are determined—in practice—by iterative balancing on the basis of the following analyses and data:

(i) Assumed increase of output in the course of a longer period of time—"plans of outputs";

(ii) Analysis of the degree in which the existing output capacity has been made use of—"output capacity balances"; and

(iii) Designing studies and cost estimates of individual productive projects—"efficiency analysis".

Thus, the aggregate of the social demand and the available production capacities to meet it are taken as a point of departure. As demand for industrial production always exceeds—in a rapidly growing economy—available production capacities, the margin has to be covered by means of a new investment. In other words, the investment requirements are inferred from a comparison of the output possible on the basis of existing capacities—at the maximum degree of their utilization—with the planned targets of industrial output.[7]

The volume and composition of industrial production depend—to a great extent—upon executed economic policy.

It may be observed that, in the past, four principles, among others, have been followed in developing the industrial sector:

1. To achieve a volume and structure of industrial production which would ensure a high and steady rate of growth of the national economy;

2. To achieve a higher degree of self-sufficiency as regards the production of means of production;[8]

3. To bring about an accelerated development of backward regions and a rational use of a country's natural resources;

4. To ensure national defence.

Once a given investment decision has been taken, involving, for instance, the development of the cement industry, there remain two essential tasks of a planning-administrative nature: one is to choose the size of capacity of (cement) factories and the number to be built; the other is to organize the actual work of construction.

The task of preparing blue prints, estimating costs, comparing alternative projects and submitting possible variants to higher authority for decisions, if necessary, is undertaken by specialized "project-making (designing) organizations" which exist, for example, in the Soviet Union at all-union, republican, sovnarkhoz, and local levels, specializing in projects for particular types of construction.[9] These organizations play an important role in the practical implementation of investment programmes. The problems of choice between investment alternatives, to be discussed in the following section, are deliberated in these offices and technical recommendations are made by them.

Besides being analysed by the project-making organization itself, a particular investment project is analysed again either by a special commission or a group of experts at the appropriate level—enterprise, ministry or council of ministers.

[7] The way in which an industrial output programme is formulated is not discussed here. Investments and increases in production are planned at fixed, non-rising prices.

[8] This principle is being reformulated. Benefits from the international division of labour, especially within centrally planned economies, are being underlined. It means, among others, that "foreign trade variants" of meeting certain demands must be weighted to a greater extent.

[9] In some other countries the project-making organizations are attached to the ministries, but usually located in the districts where the industries for which they prepare projects are concentrated.

Iron ore storage yard at the new Klement Gottwald Iron Works at Kunčice, Czechoslovakia

Hot metal transfer at the United Steel Works at Kladno, Czechoslovakia

The project also needs the approval of the territorial administrative unit which is responsible for the development of the region within which the investment project is to be built. The territorial administrative unit, of course, analyses investment projects from the standpoint of the optimal development of its region. Since the basis of such analysis is supposed to be a regional plan of social and economic development, this necessitates the elaboration of regional and city plans.

Financing of industrial investment projects is effected by means of budget allotments, bank credits and internal resources of enterprises proceeding from profits and sinking allowances not transferred to the budget. The scope of investments financed from various sources is governed by rather detailed regulations.

The major part of investment in the state sector is financed by non-returnable budgetary grants. However, a sizable and increasing share is financed from the enterprises' own resources, primarily from a portion of profits and from amortization. With minor exceptions, these sums are transferred to specialized investment banks, which issue them when and if the expenditure is justified by the investment plan, or, in the case of extra-plan investment expenditures, when they fall under the regulations governing them.

The extent to which the investment planning process is centralized has varied considerably in the history of centrally planned economies. From this standpoint, investments in the state sector can be divided into several categories. There is, first of all, the distinction between "above-limit" and "below-limit" investments. Investment projects of a value exceeding a certain sum[10] must be approved by the centre, while those below these value limits do not require approval separately, but form part of aggregate sums allocated for investment purposes to the given sector.

There is also a distinction between ***centralized*** and ***decentralized*** investments. Centralized investments are those covered by the central investment plan, and include "below-limit" investments if expenditure on them is provided for in the plan. Decentralized investments are financed from sources not covered by the plan at all, such as, for instance, the enterprise fund, projects of local industry or "mechanization" credits from the state bank. The extent of decentralized investments was severely restricted at certain times in the past. In recent years, however, their amount has again increased.

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[10] This has varied between economic sectors and at different periods.

Partial view of the Slovnaft oil refinery in Bratislava, Czechoslovakia

Of course, these decentralized investments are by no means uncontrolled.[11] There are restrictions on the types of investments permitted; for example, in the Soviet Union a decree in 1958 forbade local investment in certain types of construction—offices, sport stadiums, and the like—without the special authorization of the republican government. Again, the control over allocations of materials and equipment provides a further means of preventing diversion of resources into forms of investment not desired by the authorities.

An unavoidable condition for the most efficient use of a given investment fund is creating a system of incentives that would act as a stimulus (i) to restrain the investment propensity of all economic units (enterprises and such) to actual needs—a planned expansion of production, (ii) to choose the best technological variants, and (iii) to shorten as much as possible the time of the commissioning and construction of industrial projects.

It is well known that up to now the system of incentives in centrally planned economies has produced some tendency to excessive investment demand. The current organizational changes in centrally planned economies aim at substituting for this system a more adequate one.

In order to choose the best technological variant for a given industrial project, it is necessary to have correctly devised criteria of the economic effectiveness of investment and an effective system of incentives to stimulate the elaboration by project-designing organizations of more than one technological variant. Permanent excess of demand for the work of project-designing organizations forces centrally planned economies to look for such substitute solutions as comparison between variants at the initial stages of their elaboration and obtaining more than one technological variant for at least some parts of a given project—partial alternatives. There exist material incentives to encourage project-designing organizations not only to prepare more technological alternatives, but to prepare as well the most economical technological variants for a given project.

[11] The cost of investment projects is carefully controlled. Based on prices of materials, machinery and labour, on centrally approved norms—for example, of depth of foundations or thickness of walls—and when possible on approved architectural designs, cost estimates are approved, and form the basis for the issue of money by investment banks.

EVALUATION OF ALTERNATIVE SOLUTIONS

SCOPE AND CHARACTER OF INVESTMENT ALTERNATIVES

One of the most important requirements in elaborating a long-term expansion plan is to set the pattern, not only of the rate of growth, but also of consumption and investment. This necessitates the determination of a ***programme of production*** for the economy as a whole and for particular sectors (industrial,[12] agricultural, transportation, construction, and so on), economic branches and commodities.

The first draft of such a programme(s)[13] of production serves, in turn, as the base and the point of departure for the elaboration of the first draft of an ***investment programme***, for the industrial sector as well as others. Using capital/output ratios (for all branches of the industrial sector), it is possible to get the first sketch of

[12] In the centrally planned economies, the concept of ***industry*** covers manufacturing as well as electric power generation and the extractive industries. In the present context, the term ***industrial sector*** is used to cover these activities.

[13] The final programme of production is achieved in the course of successive iterations in the optimizing and balancing process. Owing to this fact, the technological matrix of the national economy is adjusted through the substitution of more abundant for scarcer resources.

sectoral allocation of capital investment.[14] If the programme of production for the industrial sector were to be regarded as definitely fixed, then the essential part of the programme of investment (sectoral allocation of investment) would in principle be determined. It follows that in such a situation the planning authority would have free choice only in respect to:

(i) Building the new plants *versus* modernizing and expanding the existing plants in different branches of the industrial sector;

(ii) Capital or labour intensity of particular investment projects;

(iii) Location of investment projects.

However, especially in the long-term perspective plan, a given set of production targets, even on the level of individual goods, represents only the general pattern of consumer and investment needs which is planned to be achieved.

Taking into consideration feasibilities of satisfying the same kind of consumer and investment needs by different goods and possibilities of expanding foreign trade, there exist more alternative solutions to meet a given planned structure of consumer and investment needs. The choice of one or another solution depends, first of all, upon investment analysis and economic calculations.

Investment analysis is carried on in the centrally planned economies within the framework of plan elaboration,[15] although not only within this framework. Studies are being made for various industrial branches in respect to certain complex inter-sectoral problems, for regional systems, or for separate new projects for existing plants. The work on these problems does not always coincide with the procedure of plan elaboration. Investment analysis is considered a task of the various planning agencies and of other bodies—project-designing organizations, industrial scientific institutes, and the like—which should be performed on a continuing basis.

In the process of elaborating the five-year and the perspective plans, full account is taken of the various investment studies, and many new studies are being initiated. Particular attention is paid to projects to be included in the first years of the plan. Projects for further years may not always be studied in detail; work on them will continue during plan execution, and all necessary changes will then be introduced into the plan.

It seems appropriate to present the scope and character of investment analysis not within the framework of plan elaboration but rather according to certain levels of such analysis. The following main levels of investment analysis can be distinguished in the centrally planned economies:

1. Programming of the industrial sector as a whole and as part of the national economy. Most of the problems involved here belong to general planning rather than to investment analysis proper. Certain inter-sectoral problems appear, however, which are analysed with the help of methods appropriate to investment analysis;

2. Programming of an industry and analysis of larger industrial systems;

3. Evaluation of individual projects and of small groups of connected projects;

4. Evaluation of partial engineering solutions.

Evaluation of real investment alternatives covers different problems at each level.

1. Although, in principle, the allocation of capital investments among industries in the industrial sector is not determined, in the practice of the centrally planned economies, by quantitative analysis of economic effectiveness of investment,[16] there are important exceptions to this general principle.

This evaluation is strongly recommended in selecting the branch of production to meet a definite requirement of the national economy when there are several branches producing similar or interchangeable goods. In these cases, effects of investing in different industries are easily comparable, for example, in physical units of substitutable goods or in foreign currency. Such substitutability of effects and, in consequence, legitimate use of economic-effectiveness-of-investment quantitative analysis in inter-industry studies, appears whenever:

(*a*) Industrial outputs are substitutable, that is, may satisfy similar consumer or producer needs—oil *versus* coal, for instance;

(*b*) Projects aim at promoting exports or reducing imports, that is, at earning foreign currency;

(*c*) Increase of output in producers' goods in some industries allows for economies in other industries, implementing successive stages of transformation of raw materials into final products;

(*d*) Projects aim at saving labour, raw materials, and energy.

Thus, it is evident that many important inter-industry issues can be quantitatively evaluated within the framework of the economic effectiveness of investment analysis.[17]

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[14] "Capital output coefficients are applied mainly in the course of the elaboration of first variants of long-term plans" (Reply of the Polish Government to the United Nations Questionnaire on Industrial Planning and Development of March 1963). For details of the method of determining capital-output ratios, *see* V. Krasovsky, V. Pomerantsev and A. Tolkachev, "The method of determining capital-output ratios," *Planovoe khoziaystvo*, No. 6, 1962 (Moscow).

[15] The calculation of the effectiveness of capital investments is supposed to be an integral part of planning at all levels: in the Soviet Union, for example, from the State Planning Committee down to the economic councils and enterprises.

[16] "The standard methodological rules proceed from the premise that the allocation of capital investments among branches of the national economy for the purpose of their balanced and proportional development, with the priority growth of the production of the means of production, is decided on the basis of the balance sheet method of planning. At the same time, the choice of the most effective ways of solving the problems set should be made with due account for the economic effectiveness of the capital investments." (*Standard Methodology for Determining the Economic Effectiveness of Capital Investments and New Technology in the National Economy of the USSR*, Academy of Sciences of the USSR, Moscow 1960).

[17] There is another important correction to the principle of non-evaluation, quantitatively, of the economic effectiveness of alloca-

Mining of brown coal in open pit mine at Turoszów, Poland

2. In the stage of elaborating a "general" programme for an industry, efforts are concentrated on selection of the optimum combination of existing and anticipated new productive units. They are considered as one complex—an industry—in such a way that combined expenditure for combined industrial effects should be at a minimum. Before final quantitative evaluation, different alternatives of development are carefully considered in a series of interrelated studies, such as:

tion of investment resources among alternative industries.

This correction is the result of the analysis which takes place in the next stage, "industry programming", that is, when combining re-equipment or expansion of existing plants with construction of new plants is considered in such a way that an optimum organization and an optimum path of development of an industry could be ensured, meeting targets established in long-term plans. Very often conclusions reached in these extensive industrial studies are used for improving plans: for example, if investment—direct and indirect—required for development of an industry proves to be substantially under-estimated or over-estimated in the long-term plan, this conclusion is likely to result in target changes of the long-term plan. This evaluation of economic effectiveness of investment of internal distribution of industrial targets within a particular industry, as an indirect effect, necessitates change even in investment allocation between sectors and branches.

(*a*) Detailed descriptions of all plants actually operating in this industry; determination of their actual capacities and outputs, labour productivities, technical and economic coefficients;

(*b*) Alternative prospects of reaching optimum sizes of individual plants; enumeration of plants to be liquidated because of physical deterioration or economic obsolescence; alternative combinations of productive units —existing and new plants—aiming at reaching planned capacities in adequate time and with optimum economic effects;

(*c*) Analysis of principal raw materials and type of power used;

(*d*) Analysis of regional aspects of different alternatives of development.

In all these studies quantitative methods of analysis are used along with qualitative considerations.

3. In elaborating a programme for an individual plant, evaluation usually takes in:

(*a*) Choice of the optimum size, kind, assortment and quality of output with due attention paid to specialization and to existing and anticipated co-operation of plants;

(*b*) Choice of technology, of raw materials, of fuel and power;

(*c*) Choice of location—general and specific—and of the type of geographical co-operation. Very often evaluation is carried on jointly for two or more closely combined projects.

4. When solutions are sufficiently evaluated in the stage of project engineering, the analysis concentrates on the choice of the following solutions suggested by project engineers:

(*a*) Final choice of the level of technology and of plant layout;

(*b*) Choice of specific location and evaluation of its territorial consequences;

(*c*) Choice of adequate construction and gestation periods.

A special type of analysis constitutes "evaluation of economic effectiveness of introducing new technology". This type of capital investment differs from typical industrial projects in that:

(*a*) It consists mostly in re-equipment or smaller-scale expansion of existing plants;

(*b*) It is carried on, practically on a continuing basis, in all industrial plants;

(*c*) Methods of evaluating and introducing the technical innovations concerned must be very simple and applicable in several thousands of smaller and bigger plants.

The experience of the centrally planned economies in investment analysis on various levels has demonstrated that the choice of the scope of analysis of particular problems is of great importance. Once the scope of analysis is chosen, the various alternative solutions are elaborated for it, and comparative analysis and evaluation are undertaken. Attention is paid to selecting and appraising all real, relevant alternative solutions appearing in the analysed field.

Formulation of a scope for which alternative solutions are considered is a first important step in investment analysis. While in earlier periods investment analysis was most often limited to various alternative solutions of single projects, there is a strong tendency towards analysing larger systems. For example, thermal power plants are analysed within a system embracing coal mines, transport facilities, transmission lines, and so forth. Projects using large quantities of energy, such as aluminium plants, are analysed together with power plants. Whenever possible the impact of a plant on utilization of capacities in other fields (other industrial plants, transportation facilities) is considered. Foreign trade is introduced into the analysed systems whenever it is a real alternative in one respect or another.

While on the level of project analysis there is a tendency to embrace larger systems (groups of closely connected plants and various necessary facilities), this work is carried out on a parallel with the work on higher levels embracing still larger sectoral or inter-sectoral systems. Here again, choice of the scope of analysis for which alternative solutions are considered is of great importance. The systems formulated for analysis have to be manageable and cover all important problems of economic choice appearing in the economy and connected with the analysed field. The analysis of larger systems is carried on irrespectively of the organizational subdivision of the various projects and related fields.

Role of economic calculation

Evaluation of the above-mentioned alternative solutions is an important theoretical and practical problem in an economic system of socialization of practically all industrial capital. The State assumes, in the centrally planned economies, both the right of and the responsibility for adequate allocation of investment resources directly or through its enterprises or semi-autonomous co-operatives. The rate of growth of the national economy and, consequently, improvement of standards of living depend to a large degree on the success of the most effective allocation of investment. This is also a difficult theoretical and practical problem. On the one hand, "social" effectiveness of investment depends on numerous factors, not only economic, but also extra-economic (political, humanitarian, or military); not only quantifiable, but also difficult to quantify or simply unquantifiable, and not only actual but also anticipated. Thus, elaboration of the most appropriate methods of project evaluation requires both extensive scientific research and long industrial experience.

On the other hand, in past practice, investment decisions had to be taken currently without delay, by planning agencies, government authorities and industrial organizations (especially at the third and fourth level). Projects had to be elaborated, approved and implemented even without sufficiently satisfactory economic analysis. Lack of sufficient economic analysis was never considered as an argument for slowing down the rate of capital expansion. The role of both quantitative and qualitative considerations in the making of investment decisions had not been clearly defined.[18] This led to serious methodological disturbances and lengthy theoretical discussions.

At present, this aspect of the problem of economic effectiveness of investment appears to be settled in most centrally planned economies. A need for quantitative criteria is generally recognized. Official "standard methodologies" recommend use of definite quantitative criteria.

"A quantitative analysis is a fundamental tool of economic effectiveness of investment evaluation and a necessary evaluation for selecting investment decisions most advantageous for the national economy. It consists of an analysis of all quantifiable aspects of constructing and operating a plant-to-be, as well as of their appraisal from the angle of reducing to a minimum the total expenditure of social labour. Thus, quantitative analysis comprises both specific calculations and synthetic evaluation

[18] There were various reasons for this attitude. It rested largely on the view, dominant if not necessarily made explicit, that in a socialist society preferences in general, and time preferences in particular, are multi-angled, and that they do not lend themselves to useful quantification, let alone reduction to a common and simple basis of measurement.

of all inputs and effects."[19] Although quantitative analysis of the economic effectiveness of investment does not exclude nor replace qualitative consideration, it is, however, an obligatory part of analysis even in the case when unquantifiable economic or extra-economic factors prevail in justification of investment necessity. In those cases, quantitative analysis is not an exclusive basis for investment decisions. Therefore, the project selector is now under obligation to check alternatives from the point of view of "comparative efficiency". It is this which is his principal guide, and, other things being equal, it is decisive.

An attempt is made, from now on, to summarize the practical experience of the centrally planned economies in the utilization of different quantitative expressions of economic effectiveness of investment. This attempt must be considered as preliminary, as both extensive practical experience[20] and scientific research in this field is still continuing.[21]

It can be observed that in this research three leading methodological principles are widely accepted:

1. Criteria used for evaluation of economic effectiveness of investment of particular projects should comply with macro-economic criteria, especially with such a principal criterion as maximization of national income in the longer run.

2. Criteria of economic effectiveness of investment for particular investment projects should be applied within certain restrictions imposed upon them and derived from the general economic plan or economic analysis carried out on higher levels.

3. Account should be taken of the desirability and necessity of transition from simpler to more complicated[22] models of economic growth of planned economy from which criteria of economic effectiveness of investment of industrial projects are derived.

In the light of these principles, it is not surprising to find in the practice of project evaluation of centrally planned economies employment of similar quantitative criteria on all levels of investment analysis.

Basic form of synthetic formula

In investment analysis, on the sectoral level and for single plants, the task of investment evaluation is practically reduced to *choice of one out of various investment variants* (solutions) bringing about equivalent productive effects. Bearing in mind such an assumption, the issue which must be regarded as an essential in the evaluation of economic effectiveness of investment is a choice of the proper level of technique of a given investment project. Attempts to quantify the difference among alternative variants from that point of view have enabled laying down the basic and simplest form of synthetic index of economic effectiveness of investment.

The differences between two investment variants (for a set of projects or for a single project) are presented in total costs per unit of increased capacities (per unit of output). The point of the matter has been found, however, in the computed costs. They are not the actual costs but "accounting" costs calculated according to certain rules, elaborated especially for investment calculation.

An important problem which comes up in the discussed context and which is of special interest when comparing the methods of investment calculation in the centrally planned economies is that of the possible discrepancy between "accounting" costs and actual costs, between computed coefficients of a project and its actual returns. "Accounting" costs are easily applied in the centrally planned economies since financial returns are not a most important criterion for running the enterprises.

In the computed costs (in the calculation formula), great attention has been paid to different treatments of investment costs and of operating costs. It has been considered that these two kinds of costs are rather different in economic implications and that, therefore, they cannot be simply added together. A practical solution which has been accepted consisted, first of all, in recalculating (enlarging) investment costs—utilizing for that purpose the so-called "coefficient of efficiency". Theoretical interpretations of this solution are not uniform. Many economists, starting from a statement of scarcity of capital, base the "coefficient" on the rate of substitution between the additional investment outlays[23] and eventual decrease of

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[19] Komisja planowania, *Instrukcja ogolna—*(1960) *w spr . . . metodyki badan ekonomicznej efektywnosci inwestycji* (W . . . 1960).

[20] This practical experience is currently published in several engineering and economic periodicals.

[21] Most important scientific contributions are listed in the selected bibliography at the end of this article.

[22] That is, taking into account more and more factors influencing rate and pattern of growth.

[23] The term "investment" consists of three elements in the centrally planned economies:

Direct investments, that is, outlays directly connected with completion of the particular project;

Ancillary (associate) investments, that is, works that are not directly connected with the core of a project, such as electric installations or railroad sidings, which are normally planned and executed by organizations independent of the industrial ministry supervising the main undertaking.

Indirect investments, that is, all those additional investment outlays that must be made to supply the requisite amount of inputs to a project plant once it will be working at capacity. Among the first-order linkages of this sort may be cited the expense of expanding coal output to supply coal for new thermal plants—an important consideration in choosing between hydroelectric and thermal power—and the cost of adding capacity to the cement industry in order to furnish the concrete needed for building dam sites for hydroelectric projects. It is an important feature of calculations of economic effectiveness of investment in the centrally planned economies that "ancillary" investments, irrespective of the enterprises or other economic organizations which pay for them, are included in calculations. It is not a common rule, however, that "indirect" investments are included in calculations. In this respect the problem is partly solved by analysing larger systems. Besides, only in cases when one alternative solution brings real savings of investment to indirectly connected plants (or other facilities), are savings included in calculations in the form of "indirect" investment.

production (operating) costs.[24] As the latter can be reduced to labour, this rate of substitution might be treated as the *individual marginal* rate of substitution between labour and investment.[25]

This implies, of course, an assumption of a simple two-factor production function. It is rather a drastic abstraction from reality since in the centrally planned economies, in rapidly developing economies, certain raw materials and intermediate goods sometimes constitute acute bottlenecks which cannot be ignored when techniques are selected. This is a reason why standard methodologies also *recommend other yardsticks in the choice-making process besides the use of a synthetic index*. Reference here is mainly to the use of indices in physical terms—techno-economic indices—such as input of fuel, power, and other materials per unit of output, output per unit of equipment, and the like.

A most typical reasoning is presented below, showing the way in which the evaluation formula is derived from the capital/labour substitution. Assume two different variants of an investment project where production of each variant is the same: for these two variants it is assumed:

(1) that $I_1 < I_2$ where I_1 and I_2 are investment outlays of the respective variants being compared;

(2) and that $C_1 > C_2$ where C_1 and C_2 are the annual operating costs of these variants.

Denote: T the period of recoupment of the additional investment outlay (or marginal rate of substitution between capital and labour);

E a reciprocal of T (in the terminology used in centrally planned economies, the coefficient of comparative effectiveness of capital investment).

Both T and E are determined by comparing the assumed variants—they might be: existing and newly planned plants, both planned variants, two types of new technology, etc.

$$T = \frac{I_2 - I_1}{C_1 - C_2} \text{ and } E = \frac{1}{T} = \frac{C_1 - C_2}{I_2 - I_1} \qquad (1)$$

While, however, in the above, T is the "recoupment" period relating to the comparison between any given pair of investment variants, for the obligatory evaluation formula, the necessity of using the social marginal recoupment period is acknowledged. Thus, for additional investment costs the following inequality is accepted as a condition of effectiveness.

$$\frac{I_2 - I_1}{C_1 - C_2} < T^* \qquad (2)$$

where T^* is now the social marginal rate of substitution;[26] T^* is determined normatively by the central authorities and has to be applied by all organizations evaluating investment projects.

The economic meaning of formula (2) is clear. Additional investment outlay cannot be accepted, unless recouped by sufficient economies in operating costs, because in other sectors or branches of the economy the same investment outlay may bring about better economic results.[27]

Formula (2) can be expressed also as

$$\frac{I_2}{T^*} + C_2 < \frac{I_1}{T^*} + C_1 \text{ or } I_2 + T^*C_2 < I_1 + T^*C_1$$

[24] Operating costs are to be considered and anticipated for the whole operation period. They usually include costs of maintenance and capital repairs but they do not include depreciation allowance.

[25] Some authors, especially in the Soviet Union, have proposed also to take into consideration in the choice-making process something like the *average* rate of substitution.

Thus far, they say, designing and economic calculations have limited the estimate of recoupment in the different variants only to additional capital outlays. Yet, in many cases, the magnitude of additional investments in one of the variants is insignificant as compared with the total volume of investments in all variants. The calculated magnitudes of recoupment of the additional investments are not characteristic of the total period required for the recoupment of all capital investments. There may be cases in which the additional investments are recouped in a short time, while the period for the recoupment of all outlays will be long even in the best variant. Thus, whereas the recoupment of partial investments in mechanization and automation in the iron and steel industry may take about a year or a year and a half, the recoupment of all investments, according to data of the State Institute for Planning Metallurgical Enterprises, takes from ten to eleven years. That is why, for planning purposes, it is the recoupment of all investments that acquires great importance and not recoupment of partial outlays. The period of recoupment of all investments is determined by calculation of expected saving as against the average cost of production in the given branch or as against the sales prices—if the latter conform to the average cost of production in the branch.

[26] It seems that T, computed in accordance with one of the methods proposed in the Soviet Union, has a different nature. According to it, an approximation of T might be reached on the basis of either past or planned investment—saving in operating cost ratio, that is:

$$T = \frac{I}{(C_1 - C_2)P_2}$$

where:

I — investment outlays in a given period (for example, five-year);
C_1 — unit operating costs (excluding depreciation allowances) in the first year of the period;
C_2 — unit operating costs (excluding depreciation allowances) in the final year of the period;
P_2 — output in the final year.

The authors of this proposal hold the view that T computed in this way, both for the industrial sector as a whole and various industrial branches, gives valuable information about development trends of the economy and techniques and therefore should be an influential factor in determination of the investment policy. A doubt has been raised, however, as to the sufficiency of T so computed as the investment criterion. This concept of T seems to bear close resemblance to what was earlier called average rate of substitution. It should be mentioned here that there does not seem to be an accord with regard to an interpretation of the recoupment period in various centrally planned countries. Only the Polish planners rely explicitly on the interpretation of T with the help of related scarcities of labour and capital.

[27] However, it must be stressed again here that a given investment project is not necessarily dropped as a result of economic effectiveness of investment evaluation if the urgency for the project was established and confirmed earlier by a balance sheet analysis.

In general, the most effective use of capital is achieved by selecting a project I_1 such that $I_1 \cdot \frac{1}{T^*} + C_1$ (or $I_1 + T^* C_1$) is the lowest among a given set of alternatives. More generally, for the purpose of comparison among alternatives resulting in different levels of annual output, the evaluation formula can be expressed as:

$$\frac{I \cdot \frac{1}{T^*} + C}{P} = \text{minimum} \qquad (3)$$

where P indicates annual production.

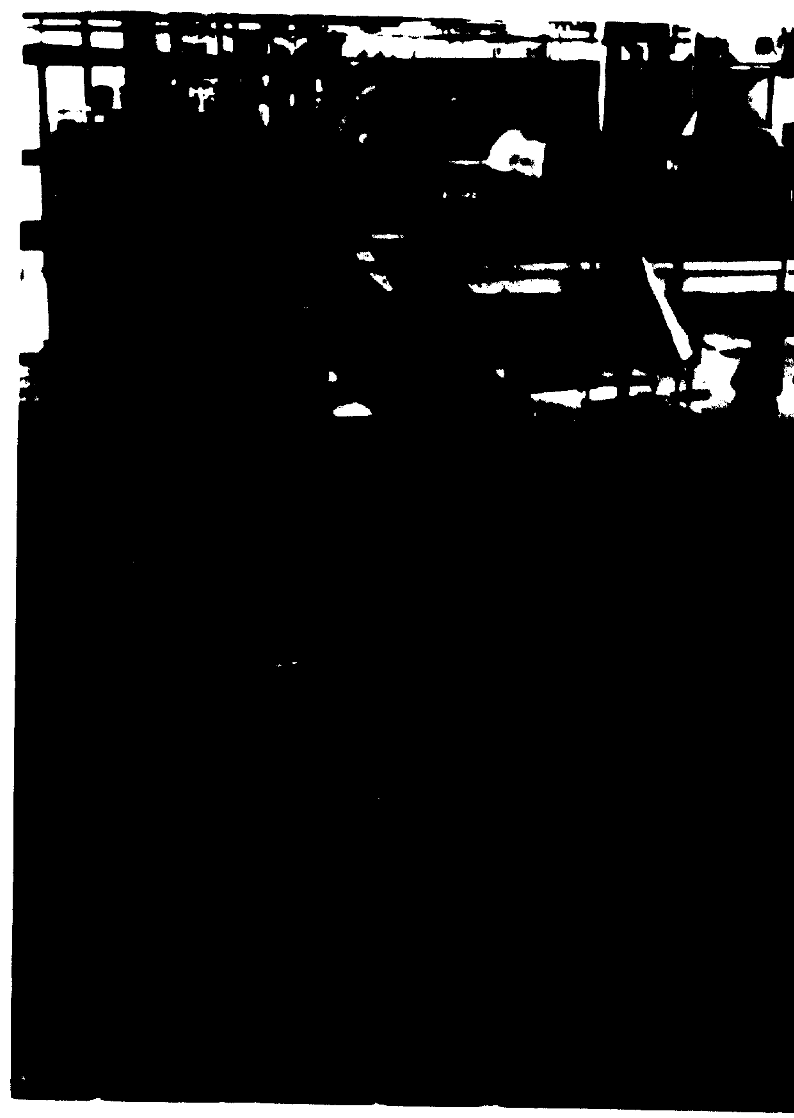
This basic form of the synthetic formula is the simplest device used for comparing various investment alternatives, taking into account relative scarcities of labour and capital. It has been accepted than there does exist an optimal social marginal rate of substitution which is equal to $O < T < A$, where A = period of amortization.[28]

However, to achieve an exact quantitative estimation of the social MRS (marginal rate of substitution between labour and capital)—or, in other words, the standard period of recoupment—is obviously impossible, owing to the existence of an almost infinite number of investment variants during the planned period under consideration.

An approximation of the social marginal rate of substitution has been arrived at, for example, in Poland, by means of a survey which is said to indicate that for the bulk of the existing old industrial plants, their modernization can yield a recoupment period above five; this is considered as a real alternative to which other calculations can be compared. Rough corrections were made for a few other factors, such as the saving on raw materials and transport and on the cost of transfer and urbanization of rural manpower. Finally, a value of 6 was adopted for T^*.

In countries where a uniform standard period of recoupment prevails, it has been established in limits of five to six years; for Hungary five, for Poland six, for instance.

It was realized very soon in these countries, however, that the common fact of limited substitution and mobility of production factors should be somehow taken into account, either by setting different normative periods of recoupment for each branch and economic region or in some other way.



Processing staple in synthetic fibre plant at Toruń, Poland

In some centrally planned economies—first of all in the Soviet Union—the differentiation of T^* for branches and economic regions is conceived as an important instrument to ensure certain preferences of planning authorities. Since T^*'s level undoubtedly influences investment decisions left to lower echelons, its differentiation is being used to bring these investment decisions in line with the general line of investment policy pursued by central planning authorities. In general, according to both current practice and proposals raised, planning authorities in the centrally planned economies can influence investment choice by means of the two following methods, among others:

(i) Establishment of differentiated T^*'s for different branches and economic regions;

(ii) Employment of differentiated coefficients in order to correct wages, prices, and so on.[29]

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[28] In this long discussion, two extreme positions have been refuted.

Those who postulated minimizing capital/output, that is, those who advocated the least capital intensity of the process of reaching the targets ($T = O$) laid themselves open to the charge that their criterion cuts across the path of technological progress and results in waste of labour force. Clearly this could not be accepted as a principle of economic policy.

On the other hand, those who advocated minimizing current costs/output ($T = A$) ignored an important question in running the developing economy—the shortage of capital, and in a sense this means a waste of scarce investment funds. True, they could point out *prima facie* good reasons that in the current costs/output "index" the dividend by definition takes care of capital outlay, since it includes depreciation allowances. However, depreciation allowance per unit of output amounts as a rule to very little, while in the planned economy, the absolute magnitudes of capital involved in this or that project are of paramount importance.

[29] The correction of the labour costs by means of an appropriate coefficient designed to reflect the availability of labour in a given economic region has been proposed in an instruction issued in Poland. Problems of prices of imported or exportable commodities are described below (*see* pages 23 to 25).

These methods by no means exclude each other.

Among factors which are taken into account in differentiating T^*, for example, for branches, attention is most often called to the following:

1. Differences in capital longevity; it is considered that plants with a longer life period should have longer periods of recoupment;

2. The importance of a particular branch for the over-all economic development of a country; longer periods of recoupment for those branches ensure preferences for extra progress of techniques;

3. Differences in pace of technical progress in various branches; branches with a higher rate have a shorter period of recoupment;

4. Differences in capital endowment; it is considered that branches with a high capital-labour ratio should have a longer period of recoupment.

The factors enumerated do not exhaust all aspects which are taken into consideration in differentiating T^* for particular branches. This problem is under current study.

Some countries which use, in principle, a uniform T^* for the whole country allow its differentiation by means of quantifiable criteria. In Poland, for instance, introduction into the synthetic formula of a coefficient that takes into account the duration of the operation period, means, indeed, real differentiation of T^*. Preliminary computations proved that, for instance, in Poland where the uniform period of recoupment is used together with such a correcting coefficient, the results obtained do not differ substantially from those obtained in other countries where differentiated T^*'s are used. Actually, in most centrally planned economies, normative periods of recoupment are three to seven years, that is, coefficients of comparative effectiveness are established on the level of 0.15—0.3. An investment variant with "worse" coefficients—that is, lower coefficients of comparative effectiveness or longer periods of recoupment—can be accepted only in exceptional cases.

Development of the synthetic formula

Formula (3) represents the simplest, therefore basic, form of synthetic formula of economic effectiveness of investment. Investment variants differ not only in respect to substitution between labour and capital. The synthetic formula has been gradually developed by taking into account differences among investment variants with regard to different patterns of gestation and fruition: (i) extent of immobilization—tie-up or "freeze"—of investment during construction; (ii) length of period of exploitation; and (iii) time-shape of production costs during the period of exploitation.

It must be observed, however, that even this synthetic formula is a rather general one, which is changed or adapted to suit the particular requirements of any system analysed. It is not applied indiscriminately and schematically for all cases.

Period of construction

In comparing investment variants, if they differ in the duration of construction, account is taken of shortening or lengthening the period of commissioning and building.

Economic effectiveness of a particular investment variant depends heavily on its "construction period", that is, on the scope of "immobilization" of the investment resources. It is obvious that longer construction periods imply simply longer periods of "immobilization"[30] of investment resources employed in the construction of a plant. This impact of the duration of construction period upon economic effectiveness of investment of a given investment variant can be included in the synthetic formula in different ways.

In the Soviet Union a coefficient (I_{pr}) has been introduced, which takes into account the average immobilization effect that can be obtained in a given branch by the productive use of capital investments, and is determined according to the compound interest formula:

$$I_{pr} = (1 + E^*)^t, \qquad (4)$$

where E^* is the normative coefficient of effectiveness in the given branch and t is the immobilization period measured in years.

In cases in which the deviations of actual construction periods from average are very small, coefficient I_{pr} can be determined according to the simple interest formula:

$$I_{pr} = 1 + Et'.^{31} \qquad (4a)$$

In Hungary[32] and Poland[33] the average "immobilization period", as it is called, is computed according to the following formula:

$$n_z = \frac{\sum_{t=t_0}^{t_b} I_t(t_b - t)}{I} \qquad (5)$$

where:

n_z — average "period of immobilization";

I_t — investment outlays spent in time "t" dating from the beginning of construction period;

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[30] The immobilization period of particular parts of investment outlays during the period of construction signifies the period between the date when such outlays are incurred and the date when the project as a whole is put into operation.

[31] *Tipovaya metodika*. Recently V. Vybornov, in "Ekonomicheskaya otsenka faktora vremeni pri rekonstruktsii deistvuyushchikh predpriyatiy", *Voprosy ekonomiki*, No. 8, 1962 (Moscow), has exposed in detail a method very similar to that presented in Hungary and Poland.

[32] Miklós Ajtai, "Vliyanie srokov stroitelstva na effektivnost kapitalnykh vlozheniy", *Planovoye khoziaystvo*, No. 10, 1961. M. Ajtai expresses the cost of the "freeze" as an integral of a time function.

$$\int_{t_1}^{t_n} b\,dt$$

where t is the number of years, and $b = f(t)$, the investment input. Then, aiming at an operational approximation, he deals with the problem substantially in the same way as Polish methodology does.

[33] M. Kalecki and M. Rakowski, "Uogolnienie wzoru efektywnosci investycji", *Gospodarka planowa*, No. 11, 1959.

t_b construction period;

I total investment

$$\left(= \sum_{t=t_0}^{t_b} I_t\right)$$

For practical purposes it is often assumed that $n_z = t_b/2$. (This assumption is theoretically correct when investment expenditure is equally distributed over the construction period.) With the average "immobilization period" n_z, total investment expenditure calculated in the evaluation formula amounts to:

$$I(1+q_z \cdot n_z) \tag{6}$$

where q_z = the "immobilization coefficient". Thus, the basic formula takes the shape:

$$\frac{I \cdot \frac{1}{T}(1+q_z \cdot n_z)+C}{P} \tag{7}$$

It may be noted that formula (6) is similar to formula (4a) used in the Soviet Union; in (4a) there appears $(1+Et')$ while in (6) there is a term $(1+q_z \cdot n_z)$. The resemblance is only formal, however. Economic interpretation of the coefficient q_z in (6) and E in (4a), delivered by theoreticians, is rather different. While in the Soviet Union it is simply accepted that E is equal to $1/T$, in Poland a rather sophisticated reasoning is presented to justify the application of q_z and final basis for its calculation. The main lines of this reasoning are presented below. As a starting point one assumes that longer gestation means losses incurred by the national economy. Those losses can be measured and expressed by coefficient q_z. This coefficient has not been assumed as equal to $1/T$, but derived from a combination of the marginal net output/capital ratio and T.[34]

For the purpose of planning and control, the centrally planned economies have elaborated the normative coefficients for the construction period which should be followed in investment planning for the various kinds of plants.

Operation period; impact of technological progress

Variants of an investment project usually also differ from the viewpoint of length of productive operation. At the beginning of evaluation of economic effectiveness of investment in some centrally planned economies, the period of operation in calculations was assumed equal to the physical life of the equipment. However, the necessity to take account of "moral" obsolescence of equipment caused by technical progress was more and more obvious.

In some Soviet industries the method of "discounting" outputs and operating cost is used. For instance, *Standard Methodology for Determining Economic Effectiveness of Power Plants* recommends the following method:

"Par. 13. When capacity varies in function of time . . . variants may differ in the volume and timing of investment and operating costs in successive operation units. For making them comparable, investment and operating costs should be converted using:

(*a*) Compound interest formula

(*b*) Economic effectiveness of investment standard coefficient—12.5 per cent as the discount factor

(*c*) Developed capacity period."

According to the Polish standard methodology, formulae (3) and (7) were derived under the assumption of a period of operation equal to an average—so-called standard—period of operation within an industrial sector.

In the case when the anticipated operational period of the investment variant under consideration differs from the standard operational period n_s—in Poland n_s about 20 years—it becomes necessary to make an appropriate correction with regard to both output and operating costs adopted in the synthetic formula (7). This correction has been based on the reasoning according to which individual investment projects are treated as part of the investment process in the economy as a whole.

For this purpose, a conventional model of economic growth, fairly close to the real conditions, has been constructed. In this model it is assumed that:

(i) Over-all investment increases annually at a constant rate of 7 per cent; whereas

(ii) Operating costs increase annually at a constant rate of 3 per cent; and that

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[34] If gross capital/output ratio $= m$, then national income "produced" each year by one unit of gross investment $= 1/m$, and national income "produced" by one unit of net investment $= (1/m - r)$, where r is a coefficient of replacement of fixed assets. To increase national income, however, it is necessary not only to invest but also to employ an additional labour force. When the labour force is already in full employment, there is need for some additional investment in order to "free" the required labour force.

Therefore, an increase in national income equal to "d" can be obtained by:

(i) some direct investment equal to $m \cdot d$, and

(ii) some additional investment equal to $(r \cdot d)$ in order to "free" the required labour force; the term "r" denotes real wage ratio.

Additional investment $r \cdot d$ required during the maximum acceptable recoupment period T^* would be $r \cdot d \cdot T^*$, and an increase of the gross national income by the amount of "d" units requires "additional" investment equal to $m \cdot d + T \cdot r \cdot d$. Under these assumptions, gross national income per year, produced by one unit of investment, is equal to

$$\frac{d}{m \cdot d + T \cdot r \cdot d} = \frac{1}{m + T \cdot r}$$

Thus, assuming full employment, it follows that:

—one unit of gross investment "produces" $1/(m+Tr)$ of units of national income,

—one unit of net investment "produces" $1/(m+T \cdot r) - r$ of units of net national income, and that is q_z.

For Polish conditions, the following values were accepted for calculating q_z: $m = 2.5$; $T = 6$; $r = 0.5$; $r = 0.03$—depreciation amounts to 5 per cent but it has been assumed to be 3 per cent, taking into account high rates of economic expansion. Thus, $q_z = 0.15$.

In Hungary q_z is assumed as equal to $E = 1/T$.

(iii) The standard length of operation periods of new investment projects is twenty years.

Under these assumptions, the values of Z_n — corrective coefficient for output —[35] and of Y_n — corrective coefficient for operating costs —[36] corresponding to various operation periods (n) can be calculated as shown in the following:

n	5	10	15	20	25	30	35	40	45	50	∞
Z_n	0.387	0.663	0.860	1.00	1.100	1.171	1.222	1.258	1.284	1.302	1.35
Y_n	0.308	0.570	0.802	1.00	1.171	1.318	1.445	1.554	1.649	1.731	2.25

It follows that projects of a twenty year period of operation can be replaced by those of a forty year period of operation, provided that the capital output ratio of the latter is higher than that of the former by no more than 25.8 per cent.

Thus, the Polish formula of effectiveness re-evaluates the values of P and C for a given project in terms of the standard operation period.

$$E = \frac{I\left(\frac{1}{T}\right)(1+q\,n) + C\cdot Y_n}{P\cdot Z_n} = \text{minimum} \qquad (8)$$

According to this formula, it may be easily illustrated how the value of E changes with different operational periods. For that purpose, all other parameters T, I, n, C and P are assumed constant; it is convenient to decompose formula (8) into investment and cost components; namely,

$$E = \frac{\frac{1}{T} I(1+q\,n)}{P Z_n} + \frac{C}{P}\cdot\frac{Y_n}{Z_n} \qquad (8a)$$

The table below presents the values of these two components of E assuming the following numerical values for the parameters: T = six years; I = 200; n = two years; C = 100; P = 1.

		Operational period n							
	5	10	15	18	20	25	30	35	40
(1) $\frac{\frac{1}{T} I(1+q\,n)}{P Z_n}$	113.5	66.2	51.1	46.2	44.0	40.0	37.6	36.0	34.8
(2) $\frac{C}{P}\cdot\frac{Y_n}{Z_n}$	79.4	86.3	93.2	97.3	100.0	106.3	112.6	118.3	123.5
E = (1) + (2)	192.9	152.5	144.3	143.5	144.0	146.3	150.2	154.3	158.4

[35] It has been assumed that every year some investments of average durability n years are carried on. These investments grow each year at the rate of "a" per cent. Thus, if current investment is I ($k = o$), investment of the previous year ($k = -1$) is $I/(1+a)$ and as of ($n - 1$) years ago $I(1+a)^{-(n-1)}$.

The value of fixed assets operating in a given year equals the sums of net investment completed during the period of n years from $k = -(n-1)$ to $k = o$; namely,

$$M_n = \sum_{i=0}^{n-1} I(1+a)^{-i} = I\left[\frac{1-\left(\frac{1}{1+a}\right)^n}{1-\left(\frac{1}{1+a}\right)}\right]$$

If the capital output ratio is "m", output of existing fixed assets equals:

$$P_r = \frac{M_n}{m} = I\cdot\frac{\left[1-\left(\frac{1}{1+a}\right)^n\right](1+a)}{a\cdot m}.$$

Advantages of constructing plants with a longer period of operation than the standard period n_s is expressed by the equation:

$$Z_n = \frac{P_n}{P_{n_s}} = \frac{1-\left(\frac{1}{1+a}\right)^n}{1-\left(\frac{1}{1+a}\right)^{n_s}}.$$

Coefficient Z_n can be used to replace the denominator of the synthetic evaluation formula P (annual output of a given project with an operation period of "n" years) by the equivalent output ($Z_n \cdot P$) of a project with the standard operation period (n_s).

[36] A longer period of exploitation corresponds not only to the flow of greater outputs but also to the flow of greater costs. A similar form of equation can be obtained for the "cost" side of the implications of differential operation periods by analogy with the previous reasoning:

$$Y_n = \frac{C_n}{C_{n_s}} = \frac{1-\left(\frac{1}{1+c}\right)^n}{1-\left(\frac{1}{1+c}\right)^{n_s}}$$

The only difference is in the value of "c", which is the discount rate for operating costs. Whereas the flow of output increases at the annual rate of "a", costs increase, in comparison with previous years, normally at a lower rate, as a result of the successive reduction of operating costs per unit of output in the more modern, later built plants. In Poland "c" is assumed equal to 3 per cent while "a" is set at 7 per cent.

It follows that:

(i) E is at minimum for the period of operation n = 18 years, which is even shorter than the standard period; the physical life of the project may be much longer than that.

(ii) E is a decreasing function of n up to this point but thereafter it is an increasing function of n.[37]

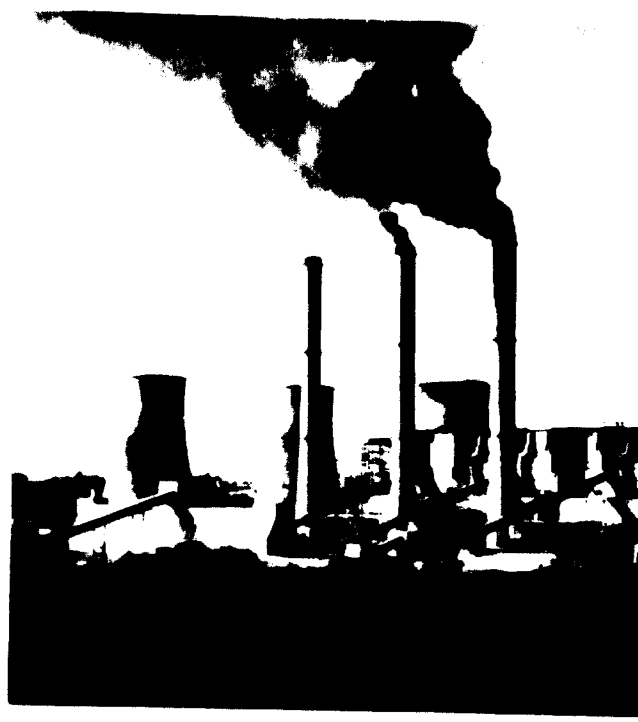
For the sake of simplification of the calculation, synthetic formula (8) can be presented in the following form:

$$E = \frac{\left(\frac{1}{T} J + C\right) b}{P} \qquad (9)$$

where $J = I(1 + q \cdot n)$ and the value for b[38] are given in a special table. For practical application, formula (9) is further elaborated into the form:

$$E = \frac{\left(\frac{1}{T} J + C\right) b + S}{P} \qquad (10)$$

where two categories of operating costs are distinguished, C standing principally for labour costs and S for other components of operating costs, particularly raw materials and repairs.[39] This method permits bringing up the advantages of the variant characterized by a smaller use of raw materials and other materials.



Thermo-electric plant at Turoszów

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So far it has been assumed in the synthetic formula that output and operating costs remain constant during the whole operation period. A method has been developed which permits taking into account various time patterns of output and operating cost during the operation period.

The way of reasoning is similar to the case of generalization of formula (9) for projects with different operational periods.

Evaluation of import substituting and export promoting projects

As already indicated, the centrally planned economies and particularly the smaller countries, such as Czechoslovakia, East Germany, Hungary and Poland, pay a growing attention to foreign trade. This is apparent in all the fields of economic policy—development planning, pricing policy, investment evaluation, and so on.

At the inception of the first industrialization plans and during their execution, the prospective returns in foreign trade were not considered as a very important factor for investment allocation in the centrally planned economies. On the contrary, it was considered that following the comparative advantage argument would petrify the old,

[37] It may be observed that from the Polish formula there follows an optimal operation period which is a function—given the parameters—of relation between investment and operating costs:

$$\frac{J \cdot 1 + q \cdot n}{C}$$

It is acknowledged that the optimal operation period should depend on the rate of technical progress in each industry. The analysis of technical progress has not been sufficiently advanced yet to allow for formulation of different normative "c"'s. It is allowed, however, in practice to change the calculation on account of the rate of technical progress which is distinctly different from the general—normative—one.

[38] Coefficients b have been calculated so that the result of calculation, according to simplified formula (9), is equal to that of the developed formula, that is,

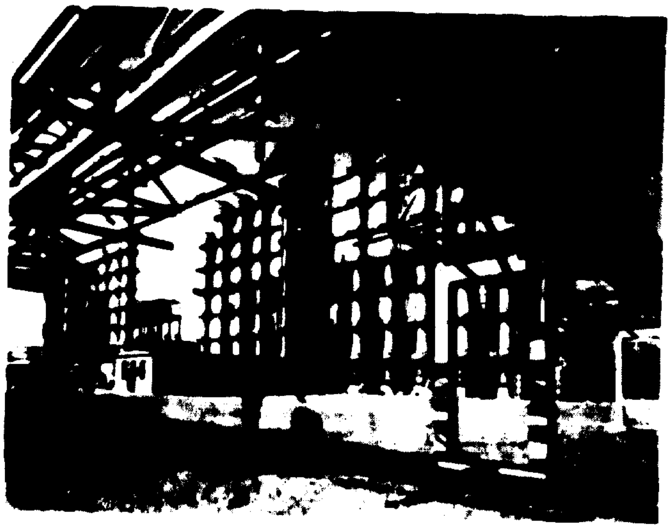
$$\frac{\left(\frac{1}{T} J + C\right) b}{P} = \frac{\frac{1}{T} J + C Y_n}{P Z_n}$$

This equation is fulfilled if:

$$b = \frac{\frac{1}{T} \cdot \frac{J}{C} + Y_n}{\left(\frac{1}{T} \cdot \frac{J}{C} + 1\right) Z_n}$$

Thus, the value of "b" is definite for a given ratio J/C and for given n. It has been found that in Poland the recoupment period so corrected for various industrial sectors—according to their average operating period—is not so different from that in other countries which use different recoupment periods for various sectors.

[39] It is recommended that, for materials purchased from closely connected plants and also for other main raw materials, costs should be calculated not on the basis of existing prices, but, as far as possible, on the basis of value for E known for those raw materials.



Partial view of the synthetic rubber complex at Onesti, Romania

Tractors ready for delivery at a factory in Brasov, Romania

Part of tyre factory "Danubiana" in Bucharest

backward economic structure of a country. Efforts were directed towards creating a new economic structure favourable to a fast and steady development, on a diversified industrial basis. Achieving this principal aim, that is, having developed new capacities in fuels and in basic semi-finished products for the capital goods and chemical industries, the centrally planned economies changed their attitude towards foreign trade. This was reflected in price reforms, bringing internal price relations closer to world price relations, in development planning, and also in methods and criteria applied to investment allocation.

The formulae developed for evaluation of investment projects, serving for comparative analysis of the various technical solutions of given investment targets, were being adopted for comparative analysis of the various projects for export promotion and import substitution.

It is explicitly expressed in Polish literature and official instructions that the synthetic formula elaborated for investment project evaluation can be applied in evaluating investment projects connected with foreign trade—substituting domestic products for imports and promoting exports. Thus, the investment evaluation which was initially confined within a narrow field of alternative solutions of a given investment target is being given wider application.

Certain modifications are introduced in the Polish formula when it is to be applied for evaluation of projects connected with foreign trade. For that purpose the formula usually has the following form:

$$^{E}D_{n} = \frac{\left(\frac{1}{T}J + C\right)b + S'}{D_{n}} \qquad (13)$$

In this formula D_n indicates net annual exchange earnings; it is calculated by subtracting the foreign inputs (specifically, the value of imported and exportable commodities) from the gross exchange earnings. Also, therefore, S' stands only for part of raw material inputs which are not subtracted from gross exchange earnings.

For smaller projects, carried on by decentralized enterprises, a further simplification is used:

$$\frac{q\,I + C_a}{P - S_a}$$

where:

q — coefficient of efficiency (q = 0.2);

C_a — annual operating costs excluding depreciation allowances and foreign inputs;

P — annual value of output, calculated on the basis of foreign market prices and then converted into domestic currency at a special exchange rate;

S_a — value of imported and exportable commodities which were subtracted from operating costs.

The project can be acceptable whenever the value of the ratio above is smaller than one. In guiding the evaluation of small investment projects, coefficient q and the exchange rate are used as instruments of the investment policy.

In Hungary, where foreign trade is of great importance, even the "basic" formula[40] of economic effectiveness of investment differs substantially from the type of "basic" or "comparative" formulae used in other centrally planned economies. Special attention is paid to correct both inputs and outputs of new projects for "social" accounting prices, based upon the actual purchasing power of Hungarian currency and world market prices of commodities. The economic effectiveness of an investment is expressed in its "internationally comparable" values in the following formulae:

(i) On the level of a plant:

$$g\ddot{u} = \frac{T - A_i - A_h - L}{M + B_h + F_h}; \qquad (14)$$

(ii) On the level of the economy as a whole:

$$gn = \frac{T}{M + A_i + A_h + L + F_h}. \qquad (15)$$

Letters used in the formulae denote:

T = gross value of production expressed in forints. It is obtained by multiplying the world market prices of the products by the respective quantities produced. In calculating forint equivalents from rouble and dollar prices, exchange rates of 3.00 and 45.00, respectively, are to be applied;

A_i = value of used imported materials in forints, calculated at the same rates of exchange;

A_h = value of domestic raw materials;

L = allowance for depreciation;

M = total wage costs on plant level including taxes and social security contributions;

B_h and F_h = amounts of national income not realized because of the "immobilization" effect of investment. B_h denotes the immobilization effect of the fixed investment and F_h that of the circulating capital.

Thus, coefficient $g\ddot{u}$ expresses value added (depreciation excluded) per unit of wage costs combined with "immobilization" effect of investment. Coefficient gn, used for calculating effectiveness on the level of the economy as a whole, expresses gross value of output per unit of appropriately calculated full social operating cost.

These formulae of economic effectiveness of investment permit a comparative analysis of various projects connected with foreign trade. Comparative analysis is being carried out within the industrial sectors and also among different sectors. Apart from its merits in project evaluation, it also helps in understanding where and why economic efficiency varies because of international conditions.

It is considered particularly instructive to perform the comparative analysis by following the links from one technological process to another within an industrial sector—this is called the effectivity analysis of the subsequent phases of production. This type of analysis is particularly recommended for the steel and the chemical industries.

It is also acknowledged that the comparative analysis is not sufficient for project evaluation. While, when correctly performed, it can show which alternative is better and which is worse, it does not say whether "worse" means "still good" or whether "better" means "sufficiently good". This problem is not solved by the formulae. It is rather exceptional for a final criterion to be established by the authorities. This is the case, as shown above, for small investment projects in Poland. As a rule, the final choice is taken by the authorities who, taking into account the general economic situation and the development policy, put certain limits on the values of economic effectiveness of investment coefficients.

Analysis of investment in larger systems

The inadequacy of investment efficiency analysis confined to individual projects is commonly recognized in the centrally planned economies. It has brought about attempts to scrutinize investment in larger systems. The predominance of state ownership facilitates an investment analysis of large programmes consisting of sets of projects or even branches. Completely satisfactory methods of analysing investment in larger industrial systems have not yet been worked out. They are still in a preliminary phase of elaboration and experimentation. Among them, particular mention may be made of some simple methods applied to the analysis of: (i) large multi-purpose projects; and (ii) systems of closely connected projects.

An analysis of multi-purpose projects is most often conducted in the following way: a given multi-purpose investment project is broken down into component parts

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[40] The description is based on a draft instruction prepared in August 1959. In the memorandum for the Second Conference of Chief Economic Advisers, held in November 1962, *Criteria of Investment Allocation in the Hungarian People's Republic*, the formulae were presented in a slightly different manner:

$$e_e = \frac{P_g - M - A}{W + 0.2\,(I + C)} \qquad (1)$$

$$e_n = \frac{P_g}{W + M + A + 0.2\,(I + C)} \qquad (2)$$

where:

e_e = indicator of economic efficiency at enterprise level;
e_n = indicator of economic efficiency at national economic level;
P_g = gross value (per annum) of production;
M = outlays (per annum) for materials, energy, intermediate goods, etc.;
A = annual sum of amortization;
W = annual outlays for wages;
I = outlays for investment;
C = working capital needed to operate investments;
0.2 = normative coefficient showing how much a unit of fixed and working capital funds contributes to the increase of net national income.

While in formula (1) the values of M, A, W, I and C are computed by taking into account only the outlays of the enterprise which is going to operate the investment project in question, in formula (2) these outlays are calculated for the national economy as a whole. It is observed that "whenever it is possible, formulae are calculated also on the basis of export and import prices prevailing at the given period".

which are, in turn, compared with their feasible alternatives. Such an "analytical division" of a given multi-purpose investment is most often made by a clear-cut specification of final effects of this investment and the distribution of both investment outlays and operating costs in accordance with those final effects.

Some difficulties arise, especially with regard to the distribution of outlays for such a project, which may render services to different final effects. In some cases both investment outlays and operating costs of such a service-rendering project (a part of a multi-purpose investment project) are apportioned among the final effects using its services according to the amount of services.[41]

Thus, a multi-purpose investment project is "analytically" broken down into parts, which are compared with their alternatives. An alternative might be, for instance, a completely independent project. The ability to formulate all real alternative solutions is one of the most important skills in investment analysis.

In other cases, other methods of efficiency analysis of multi-purpose investment projects are employed. For instance, in the evaluation of large investments involving the use of water for irrigation, energy, flood control, transportation, and the like, the following method has been used.

Outlays referring to each component part of such a multi-purpose investment (for example, irrigation) have been assumed as equal to outlays on an individual (irrigation) project with the same capacity. Then, outlays for all parts, compiled in the same manner, have been totalled and compared with real outlays on a given multi-purpose investment project. This method does not exclude, however, the necessity of elaboration and comparative analysis of different variants of multi-purpose projects with respect to localization and technical solutions, among others. Multi-purpose investment projects differ from systems of connected projects. While, in the first case, investment is usually carried on by one economic organization, in the second case, series of projects are initiated by different organizations. According to research experience, substantial benefits can be obtained by analysing systems of projects which are closely connected.

Two specific categories of closely connected investment systems may be distinguished:

(i) Different projects, quite often, are so connected that a solution concerning one of them exerts an influence on solutions for others with respect to localization, size and related factors;

(ii) A given system of connected projects exerts influences on a whole economy which may be satisfactorily detected by means of ordinary calculations of costs based on existing prices (improvement of the transport system, for instance).

These systems of closely connected projects most often appear in an analysis of mining and manufacturing projects may be exemplified by:

Alternative energy systems:

1. Coal mine combined with thermal power station and transmission lines;
2. Brown coal mine with thermal power station and transmission lines;
3. Water power station with transmission lines.

Alternatives of sulphuric acid manufacturing system:

1. Elemental sulphur mine with sulphuric acid manufacturing plant;
2. Anhydrite mine with sulphuric acid manufacturing plant.

The first question which arises in the process of analysis of systems of connected projects is to determine the scope of a system to be analysed and to formulate all its real alternatives. Bringing out as many real alternatives as possible is one of the main requisites to discovering an optimal solution.

In simple cases, quantitative analysis with regard to systems of connected projects might be conducted by means of the same evaluation formulae employed for individual projects.

In more complicated cases, the formula used must be adjusted to the nature of the problem to be analysed. The Polish instruction recommends the following formula applicable to systems of connected projects:

$$E_{s.c.m} = \sum_i E_i \, a_i$$

where:

$E_{s.c.m}$ effectivity index of a system of connected plants;

E_i effectivity index of the *i*-th plant (calculated according to the explained synthetic formula); in it S_i (raw materials) covers only those raw materials, semi-finished products, etc. which are purchased from outside the system;

a_i coefficient denoting the use of the product (service) of the *i*-th plant per unit of the final product of the system; thus, this coefficient shows how many units of the product of the *i*-th plant are necessary to obtain a unit of the final product of the analysed system. Hence, coefficient a_i for the plant which is the last link of the system is equal to 1.

Evaluation of investment in existing plants

In the centrally planned economies, more attention has recently been paid to comparative efficiency evaluation of investment in new plants *versus* expansion of existing ones. Especially now, after a series of basic projects in mining, electric energy, metallurgy and chemistry have been commissioned, it is often possible to increase production efficiently by means of expansion and modernization of existing plants. From the viewpoint of potential demand and smooth assured flow of inputs, the purposefulness and concept of the modernization to be undertaken are analysed by taking into account perspective development of whole branches.

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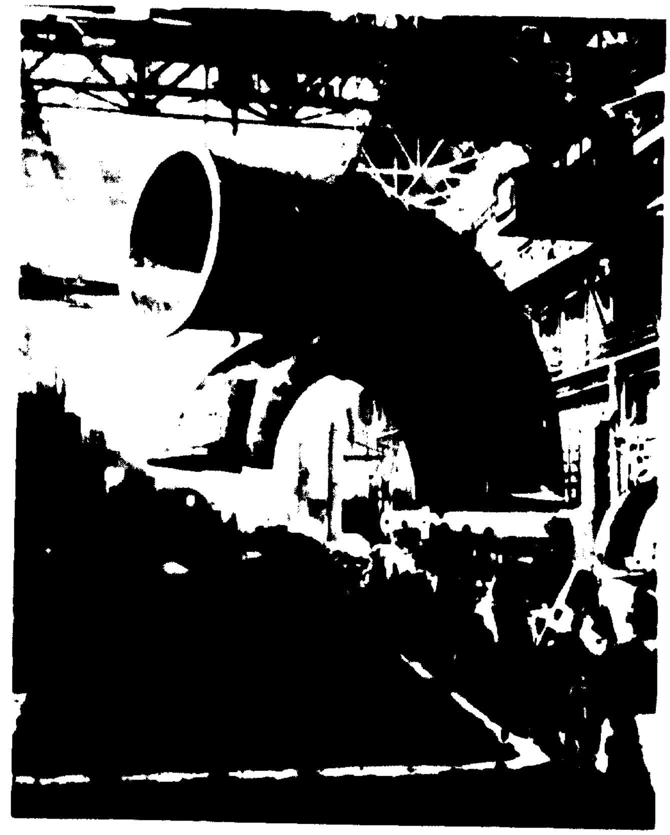
[41] G. Matlin, "Krupnye problemy ekonomicheskoy effektivnosti kapitalnykh vlozheniy i elektrifikatsii", *Voprosy ekonomiki*, No. 2, 1962.

Assembling a steam turbine of 100,000-kilowatt capacity in a Leningrad factory



Segments of blowing machinery are hoisted for assembly in the Nevsky Engineering Plant of Leningrad

Some pertinent methods employed in Poland are presented below, for in this country they have been described in official instructions in more detail. Although slightly different methods are used in other countries, the general approach does not differ substantially from the one presented.

As regards evaluation of investment in existing plants, in principle, the same evaluation methods as applied in the case of comparisons of new projects is recommended. It is assumed, as a general rule, that in such analysis calculation covers: (i) only those investment outlays which are to be incurred in an existing project, but it does not take into account those outlays which were incurred in the past and are expressed in the value of the existing assets; (ii) operating costs and output (subsequent modernization investment).

With due attention to this general rule, comparative analyses of different kinds of investment in existing plants, such as modernization, expansion and renovation, among themselves and against the new project are examined. In particular, thorough efficiency analysis of expansion and modernization is carried on in the case when an alternative of a new project is feasible.

It is recommended, moreover, to maintain a continuous analysis of all feasible additional investments in existing plants. As a basis of comparison, in such an analysis, an alternative of increase in output obtained by building a new plant is used. Generalized characteristics of modern projects might often be used as such a basis.

In evaluation of investment in an existing plant, it is recommended to explore: (i) purposefulness of liquida-

Pouring metal at the continuous casting installation of the iron and steel works of Novo-Lipetsk in the Russian Soviet Federal Socialist Republic

A thirty-ton part of a giant four-hundred-ton planing, milling, boring and drilling machine tool being mounted in place in the Stankolit Works of Leningrad. The machine will be able to handle work-pieces weighing up to one hundred tons

tion, or extending its operating period by means of major repairs, involving important replacements; (ii) effectiveness of different modernization solutions. Liquidation of the old plant is justified when its modernization alternatives, as well as the effectiveness of major repairs, are lower than the effectiveness of building a new plant. Such a result of calculation, although essential for undertaking a decision to liquidate, must be supplemented by analysis of other factors also.

A comparison of various modernization variants is conducted by means of a general formula of economic effectiveness of investment. It has already been stated that an approval of a modernization variant should be checked against the new project.

It is neither possible nor adequate in all cases to compare investment in existing plants with investment in a new project. For instance, in efficiency analysis of investment, bringing about so-called saving effects in some raw material input coefficients, different methods of evaluation are employed.

Case of Yugoslavia

The economic system of Yugoslavia is substantially less centralized than that of other socialist countries. More emphasis is laid on market mechanism and economic autonomy of state enterprises.

While the general principles of evaluating the economic effectiveness of investment remain similar,[42] some practical criteria used in Yugoslavia differ substantially from those discussed in the preceding sections. By way of illustration, a short description is given of the methods used in the Yugoslav State Investment Bank when proposals are made for obtaining loans.[43]

The plans (federal, republican and local) set the global proportions of resources to be engaged for certain purposes (sectoral allocation) and the banks organize competitive bidding for the financing of projects within the limits of these propositions. Prospective investors send in their investment programmes comprising detailed technical and economic documentation in respect to investment costs and expected effects. The bank submits these investment programmes to a detailed scrutiny along the general lines prescribed in the Decree of Investments. In this law certain criteria are mentioned, such as the rate of interest, the level of self-participation in investment outlays, the repayment term for the loan, the term within which the construction is to be completed, and the investment cost per unit of output. All these criteria, however, are mentioned for the sake of example and no order of priority is specified.

For the organization of new competitive bidding, the Board of Directors of the bank establishes a definite order of priorities, using both the criteria mentioned above and a number of additional ones. Thus, for example, in the decision as to the organization of competitive bidding for projects of expansion and modernization of existing sugar refineries and building new ones, it is provided

[42] *Cf.* Albin Orthaber, "Scientific and Methodological Problems of the Choice of Production and Investment Variants", *Ekonomista*, No. 1-2, 1958 (Warsaw); and Dimitrije Misić, "Problems of Implementation of Investment Policy", *Z prac ekonomistow jugoslowianskich* (Panstwowe Wydawnictwo Naukowe, Warsaw, 1963).

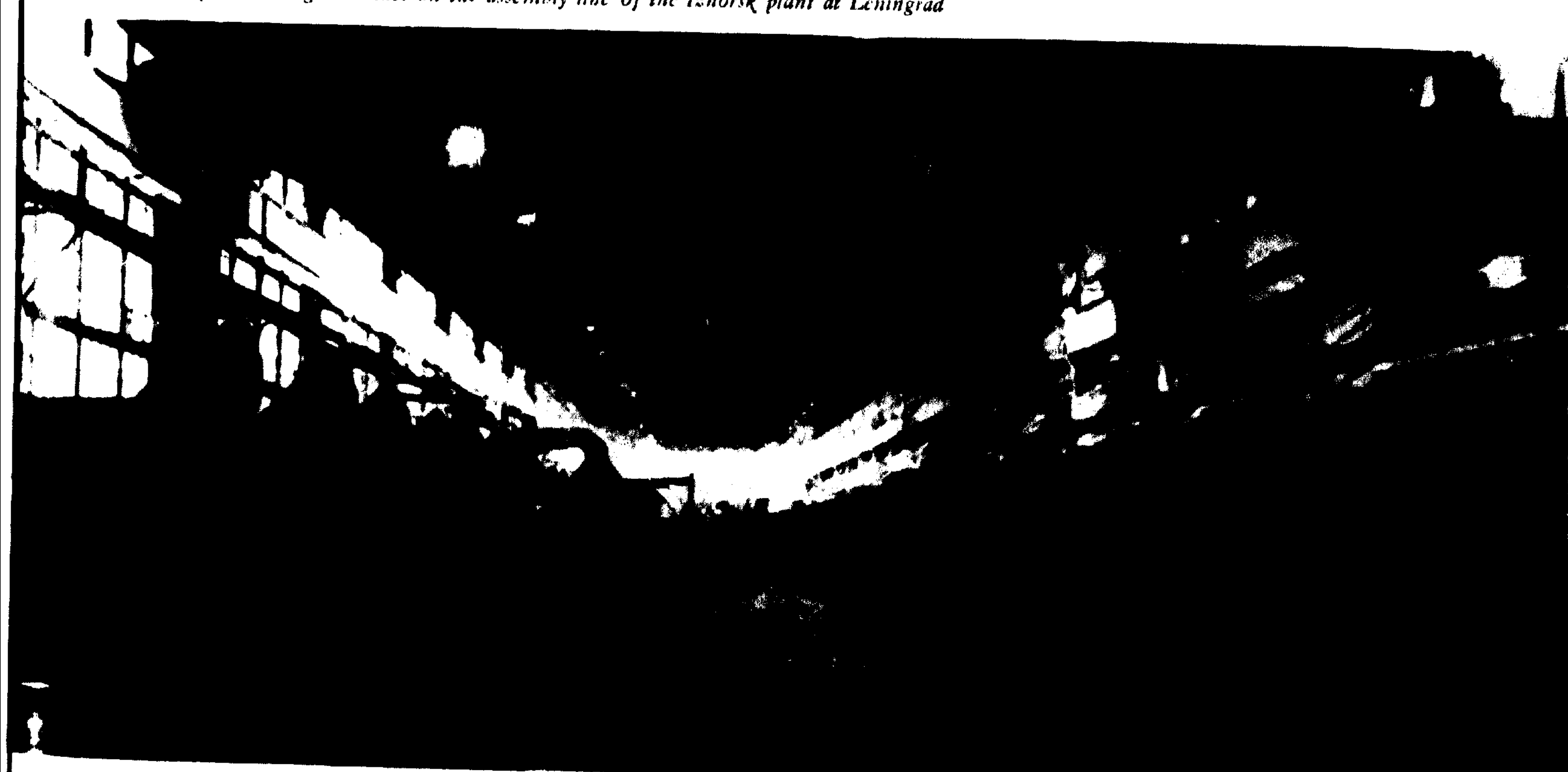
[43] Filip Vasić, "The Yugoslav System of Investment Financing and the Application of Criteria in the Selection of Investment Projects", *The Engineering Economist* (Hoboken, New Jersey), October-November 1960.

View of the cooling table of pipe mill at Sumgait, Azerbaijan SSR

that prospective investors fulfilling the following conditions will be given priority:

1. The most favourable conditions for the supply of needed raw materials;
2. The largest volume of total production of sugar in relation to the amount of invested resources;
3. The largest self participation in investment outlays over and above the prescribed percentage;
4. The shortest period, from the time the investment loan is granted, within which the normal run of the new capacities could be started;
5. The shortest term of loan repayment.

Silo crop harvesting combines on the assembly line of the Izhorsk plant at Leningrad



Appendix

EXAMPLES OF INVESTMENT ANALYSIS[a]

1. The economic effectiveness of the manufacture of sulphuric acid from various raw materials

The economic effectiveness of sulphuric acid manufacture depends to a high degree on the choice of raw material used for its production. Sulphuric acid can be produced from various raw materials. The use of a given raw material determines the employment of a specific technological method of production.

Poland is richly endowed in two kinds of sulphuric raw materials: elemental sulphur and gypsum. In the development plan sulphuric acid manufacture is based on elemental sulphur. Some experts, however, insist on basing sulphuric acid production on gypsum also.

Generally, *gypsum as a raw material is cheaper*[b] *but its transformation costs*—into sulphuric acid—*are higher than those for elemental sulphur.* In view of the special role played by raw materials, the following calculation is made to compare the effectiveness of sulphuric acid manufacture between a project using elemental sulphur and a project using gypsum. For the sake of simplicity, it has been assumed that the period of operation of the investment projects considered equals twenty years. Table 1 presents data used in calculation and coefficients of economic effectiveness computed on the basis of these data.

Table 2 points out that the coefficient of effectiveness of sulphuric acid manufactured from gypsum is equal to 1,086

[a] Taken from "Efektywnosc Investycji", edited by M. Rakowski, in *Panistrowe wydawnictwa gospodarcze* (Warsaw, 1961), and presented in simplified form.

[b] In order to produce one ton of sulphuric acid, 0.340 tons of elemental sulphur (worth 465 zlotys) or 2.3 tons of gypsum (worth 57 zlotys) are needed. The latter raw material is eight times cheaper.

Table 1

Effectiveness of sulphuric acid manufacture from elemental sulphur

Type of investment	*Investment annual output ratio (zlotys per ton)*	*Annual operating cost[a] (zlotys per ton)*	*Period of immobilization of investments (years)*	*Period of exploitation (years)*	*Coefficient of effectiveness of investments (zlotys per ton)*	*Input for one metric ton of sulphuric acid*
Extraction and refining of elemental sulphur	3,160	682	2	20	1,367	0.340
Manuafacture of sulphuric acid	600	104 + 0.34 × 1,367 = 569	1	20	684	

[a] In annual operating cost of sulphuric acid manufacture, input value of elemental sulphur was separated and was computed as a product of input times coefficient of effectiveness of extraction and refining of elemental sulphur.

Table 2

Effectiveness of sulphuric acid manufacture from gypsum[a]

Type of investment	*Investment annual output ratio (zlotys per ton)*	*Annual operating cost (zlotys per ton)*	*Period of immobilization (years)*	*Period of exploitation (years)*	*Coefficient of effectiveness of investment (zlotys per ton)*	*Input per one ton of sulphuric acid and cement*	*Input per one ton of cement*
Extraction of gypsum	30.8	19	1	20	24.9	2.3	
Extraction of coal	—	—	—	—	350	0.660	0.335
Sulphuric acid and cement manufacturing	3,900	540+2.3×24.9 +0.66×350 =828	1.5	20	1,624		
Cement manufacture	1,100	183+0.335×350 =300	2	20	538		

[a] In this technological process, sulphuric acid and cement are received simultaneously in the ratio 1:1. Thus, data concern the plant manufacturing sulphuric acid and cement, both in equal quantities. For the sake of comparability, the coefficient of effectiveness of cement manufacture is subtracted from the total coefficient of effectiveness.

(1,624 minus 538) zlotys per ton. Since the coefficient for sulphuric acid manufactured from elemental sulphur was shown to be 684 zlotys per ton, in table 1, production of the latter is evidently more effective.

* * *

The comparative effectiveness of the above-mentioned methods of sulphuric acid manufacture can also be analysed from the standpoint of international trade balance. While elemental sulphur is exportable and gypsum is not, planning authorities face the possibility of producing sulphuric acid from gypsum and of exporting "released" elemental sulphur when the supply of the latter is inelastic.

A comparison is made between two equivalent productive sets producing sulphuric acid and cement. The first set consists of a plant manufacturing sulphuric acid from elemental sulphur and a cement factory. The second comprises a plant jointly producing sulphuric acid and cement from gypsum and gypsum mines. Table 3 presents relevant coefficients for both sets; in this table, the value of input of raw materials was separated and is expressed in dollars.

Table 3

COMPARISON OF TWO EQUIVALENT PRODUCTIVE SETS

			Raw material input per ton of sulphuric acid produced		
	Investment outlays[a] *(zlotys)*	*Transformation costs*[b] *(zlotys)*	*Kind and quantity (tons)*	*Dollars assuming price of one ton of elemental sulphur to be* $30	$25
Set I					
Sulphuric acid	600	104	Elemental sulphur, 0.34	10.2	8.5
Cement	1,100	187	Coal, 0.33	3.0	3.0
Total of Set I	1,700	291		13.2	11.5
Set II					
Sulphuric acid and cement	3,900	540	Coal, 0.66	6.0	6.0
Gypsum mine	71	44			
Total of Set II	3,971	584		6.0	6.0
Difference (II − I)	+2,271	+293		−7.2	−5.5
Cost of "one dollar",[c] assuming the price of elemental sulphur to be:					
$30	315	41			
$25	413	53			

[a] Consisting of outlays on gypsum mining, but not on elemental sulphur and coal mining. Increment of the latter is considered due to the change in international trade, in this case, as a result of a decrease in exports.

[b] Not including inputs of exportable raw materials, that is, elemental sulphur and coal. The world market price for coal has been assumed to be $9 per ton and for elemental sulphur, $30 or $25 per ton.

[c] Obtained by dividing the extra investment outlays (2,271 zlotys) and transformation costs (293 zlotys) by the dollar gains ($7.2 or $5.5).

The difference between sets I and II expresses the effectiveness of choosing solution (set) II. It permits additional exports of elemental sulphur, which means a "gain" of $7.2 on each ton of sulphuric acid. However, the dollar "gain" is conditioned by both additional investment outlay of 315 zlotys and additional operating costs of 41 zlotys. A synthetic index of effectiveness of the dollar "gain", given an immobilization period of investment of 1.5 years, would be:

$$\frac{315}{6}(1 + 0.15 \times 1.5) + 41 = 105 \text{ zlotys.}$$

This is under the assumption that one ton of elemental sulphur costs $30. In the case of $25 per ton, the dollar price would be 137 zlotys. Bearing in mind that the marginal exchange ratio has been equal to 78 zlotys per dollar, alternative II is fairly ineffective. Therefore, the manufacture of sulphuric acid from gypsum is ineffective, from the point of view of both internal structure of costs and prices and international balance of trade.

2. THE EFFECTIVENESS OF EMPLOYING A NEW TECHNOLOGICAL PROCESS IN THE STEEL-MAKING INDUSTRY

The main tendency in recent years in steel production has been a growing use of oxygen in varying degrees in all steel-making processes. Special attention is paid to the use of oxygen in Martin furnaces, and the introduction of oxygen converters. While oxygen converters seem to be the most economical from the point of view of capital investment and operational expenses, it should be emphasized that the choice of process depends on the conditions of existing steel mills. A comparative analysis will be made as regards the economic effectiveness of various alternative solutions. Table 4 presents the data for the following six different types of steel mills which can be used for such a comparative analysis.

(1a) A new oxygen-converter steel mill with capacity of 3 to 3.2 million tons per year;

(1b) A similar oxygen-converter steel mill with capacity of 600,000 tons per year;

(2a) A Martin steel mill with capacity of 2.1 million tons per year;

(2b) A modernized Martin steel mill (with use of enriched air) with an increased capacity of 2.5 million tons per year;

(3a) An old small steel mill with capacity of 200,000 tons per year;

(3b) Modernization of the old small steel mill (3a) by use of enriched air (oxygen) with its capacity increased to 240,000 tons per year.

An illustrative analysis is made as below to indicate the comparative effectiveness of these different types of steel mills.

Table 4

DIFFERENT TYPES OF STEEL MILLS: DATA FOR COMPARATIVE ANALYSIS

	Unit	(1) *Oxygen converter steel mill* (a) *Big*	(b) *Small*	(2) *Modern Martin steel mill* (a) *Without oxygen*	(b) *With oxygen*	(3) *Old steel mill ("Kosciuszko")* (a) *Without oxygen*	(b) *With oxygen*
Annual capacity	Thousands of tons	3,000	600	2,100	2,500	200	240
Total investment outlays	Millions of zlotys	1,680	390	2,240	2,420	—	50
Investment/output (steel) ratio	Zlotys per ton	560	650	1,070	968	—	[illegible]
Operating costs (excluding fuel and depreciation allowances) per ton of steel	Zlotys	130	155	180	145	310	280
Investment outlays on fuel required per ton of steel[a]	Zlotys	80	80	320	300	520	400
Operating cost of fuel required per ton of steel[b]	Zlotys	16	16	64	60	104	80
Period of immobilization of investment outlays on steel mill	Year	2	1.5	2	0.5	—	0.5
Period of immobilization of investment outlays on fuel	Year	3	3	3	3	3	3

[a] Investment outlays on fuel comprise those on both coal mining and transformation of coal into gas.
[b] Operating costs of fuel comprise those of both gas and oxygen.

The effectiveness of constructing an oxygen converter steel mill with capacity of 3 million tons per year (1a)

This steel mill is treated on a comparable basis. Its effectiveness is calculated according to the formula:

$$E = \frac{\frac{1}{T} I (1+q_z n_z) + C_p Y_{n_{opt}}}{P \cdot Z_{n_{opt}}}$$

The optimal period of the mill's operation is determined as follows:

$$n_{opt} = f\left[\frac{I(1+q_z n_z)}{C}\right] = f\left[\frac{560\times(1+0.15\times 2)}{130}\right]$$

$$= f(5.6) = 25 \text{ years.}$$

Correcting coefficients are:

$Y_{25} = 1.17$

$Z_{25} = 1.10.$

Thus, the synthetic index of effectiveness is:

$$E_{conv} = \frac{\frac{1}{6}\times 560\times(1+0.15\times 2)+130\times 1.17}{1.10} = 248 \text{ zlotys per ton.}$$

The effectiveness of constructing a Martin steel mill with a capacity of 2.1 million tons (2a) in comparison with (1a)

The differences in fuel input values between oxygen-converter and Martin processes must be taken into account in this case. For this purpose, first the cost of fuel input has to be determined in terms of the synthetic index which incorporates the costs of investment outlays required to obtain fuel. Such an index is designated by E_{pal} in the following. By definition,

$$E_{pal} = \frac{\frac{1}{T} I_{pal}(1+q_z n_z) + C_{pal} Y_{pal}}{Z_{pal}}$$

where I_{pal} is investment outlay on fuel required per ton of steel and C_{pal} is operating cost of fuel required per ton of steel. In case (2a),

$$E_{pal_{mart}} = \frac{\frac{1}{6}\times 320(1+0.15\times 3)+64\, Y_{opt}}{Z_{opt}}$$

Since $n_{opt} = f\left[\frac{320\times(1+0.15\times 3)}{64}\right] = f(7.25) = 27$ years,

$$Y_{27} = 1.23;\ Z_{27} = 1.13.$$

Hence,

$$E_{pal_{mart}} = \frac{\frac{1}{6}\times 320\times 1.45+64\times 1.23}{1.13} = 138 \text{ zlotys per ton of steel.}$$

Per analogiam E_{pal} of oxygen-converter steel mill (1a) is smaller than E_{pal} of Martin mill (2a) in proportion 16:64. Therefore,

$$E_{pal_{conv}} = 138\times\frac{16}{64} = 35 \text{ zlotys per ton of steel.}$$

In order to compare the effectiveness of two steel mills (1a) and (2a), it is necessary to add to Martin's transformation costs (C_{mart}) the difference between fuel input values $\Delta C_x = 138-35 = 103$ zlotys per ton.

Thus, the effectiveness of Martin steel mill (2a) is equal to:

$$E_{mart} = \frac{\frac{1}{T} I(1+q_z n_z)+(C_{mart}+\Delta C_x)\, Y_{opt}}{Z_{opt}}$$

$$n_{opt} = f\,\frac{1{,}070\times(1+0.15\times 2)}{180+103} = f(4.9) = 24 \text{ years.}$$

$$Y_{24} = 1.14;\ Z_{24} = 1.08.$$

$$E_{mart} = \frac{\frac{1}{6}\times 1{,}070\times(1+0.15\times 2)+(180+103)\times 1.14}{1.08}$$

$$= 514 \text{ zlotys per ton.}$$

A comparison of E_{mart} (2a) with E_{conv} (1a) points to the obvious conclusion that the synthetic index of effectiveness of (2a) is more than twice as ineffective as that of the oxygen converter. Therefore, in metallurgical enterprises with integrated steel works, oxygen converters are mainly being constructed.

Bearing in mind the great difference in effectiveness between the two types of steel mills, the question may arise as to whether or not to destroy the existing Martin furnaces and replace them by oxygen converters. This replacement can be regarded as effective if the following inequality is satisfied:

$$C_{st}\frac{Y_1}{Z_1} > E_{n_{opt}}$$

where:

C_{st} = annual operating cost per unit in the Martin steel mill;

$E_{n_{opt}}$ = index of effectiveness of the oxygen-converter steel mill, assuming optimal n;

Y_1 and Z_1 = correcting coefficients, assuming one year of operation of Martin furnaces.

In this case $(180+103)\cdot 0.0651 / 0.0882 = 209 < 248$.

This means that replacing the existing Martin steel mill by the new oxygen-converter steel mill would not be efficient.

An efficient period of operation of Martin furnaces is then computed according to the formula:

$$E_{n_{opt}}\left(\frac{1+c}{1+a}\right)^t = C_{st}\frac{Y_1}{Z_1}$$

where:

c = annual rate of increase in costs;

a = annual rate of increase in investment.

Thus,

$$248\cdot\left(\frac{1.03}{1.07}\right)^t = 209;\ t = 5 \text{ years.}$$

The effectiveness of modernization of a Martin steel mill (2b) in comparison with (1a)

Since the replacement of existing Martin furnaces by oxygen converters turned out to be inefficient, another alternative solution—a modernization of these Martin furnaces by the use of enriched air (oxygen)—is now examined briefly.

Operating costs of the modernized Martin furnaces (2b) are:

$$C_{mod} = 145 \text{ zlotys} + \Delta C_x.$$

Since

$$\Delta E_{pal_{mod}} = \left(\frac{60}{64}\right)E_{pal_{mart}} = 130 \text{ zlotys per ton,}$$

and the difference with regard to E_{pal} between the modernized Martin furnaces and the oxygen converters is: $130-35=95$ zlotys per ton, the operating costs of the modernized Martin furnaces $C_{mod} = 145+95 = 240$ zlotys per ton.

An efficient period of operation of the mill after modernization is determined in relation to (1a) as:

$$C_{mod}\frac{Y_1}{Z_1} = E_{n_{opt}}\left(\frac{1+c}{1+a}\right)^t.$$

Inserting relevant data:

$$240\times\frac{0.0651}{0.0882} = 248\left(\frac{1.03}{1.07}\right)^t;$$

hence $t_{mod} = 9$ years.

Furthermore, calculations based on the formula of effectiveness of modernization prove that modernization is economically efficient.

Replacement of the old small Martin furnaces by oxygen converters

The old Martin steel mill with annual capacity of 200,000 tons (3a) is to be replaced by a new "small" oxygen converter steel mill with annual capacity of 600,000 tons (1b).

The index of effectiveness for an oxygen converter steel mill with smaller converters (1b) is:

$$E = \frac{\frac{1}{6}\times 650\times(1+0.15\times 1.5) + 155)}{Z_n}$$

Since

$$n_{opt} = f\left|\frac{650\times(1+0.15\times 1.5)}{155}\right| = f(5.1) = 24 \text{ years,}$$

$$E = \frac{\frac{1}{6}\times 650\times(1+0.15\times 1.5) + 155\times 1.14}{1.08} = 283 \text{ zlotys per ton}$$

This index is less favourable than that of the "big" oxygen-converter steel mill (1a), owing to the smaller size of converters.

Operating costs of the old Martin furnaces (3a) to be replaced (410 zlotys per ton) must be augmented by the amount equal to the difference in indices of effectiveness of fuel input values between (3a) and (1b). E_{pal} of (1b) is exactly the same as that of (1a), namely, 138 zlotys per ton. Therefore, for (3a),

$$\Delta C_x = 138\times\frac{104}{64} - 35 = 192 \text{ zlotys per ton;}$$

$$C_{mart} = 410 + 192 = 602 \text{ zlotys per ton.}$$

Since the condition under which it is effective to replace the old Martin furnaces by the small oxygen converters is expressed by the formula already used:

$$C_{st}\frac{Y_1}{Z_k} > E_{n_{opt}},$$

it appears that this condition is fulfilled:

$$602\times 0.74 = 446 > 283 \text{ zlotys per ton.}$$

Modernization of the old small Martin steel mill (3b)

Due to modernization, total operating costs of the old mill will decrease. $E_{pal} = 138\times 80/64 = 172$, which implies that, in comparison with (1b), the total operating costs of (3b) amount to:

$$C_{mod} = 280 + (172-35) = 417 \text{ zlotys per ton.}$$

Since

$$C_{mod}\cdot\frac{Y_1}{Z_1} = 417\times 0.74 = 308 > 283 \text{ zlotys per ton,}$$

this modernization is also inefficient in relation to the new small oxygen-converter mill (1b), and hence it had better be replaced by the latter.

3. Choice of materials in wall construction

A considerable range of substitution exists among wall materials used in construction. The analysis below is confined to the comparison of efficiency of three types of walls built from (1) regular bricks with both sides of plaster; (2) cinder blocks with both sides of plaster; and (3) gypsum blocks combined with granulated cinder. All these types possess similar isolation qualities and widths (38 centimetres). However, the second and third types can be used only as a curtain wall or interior partition. In the following computations, "direct" investment outlays on a given wall component and "indirect" investment outlays—for example, in the case of cement, outlays on fuel and electric power necessary for the production of cement—have been taken into account.

Since the data for operating costs comprise depreciation allowances (reckoned from "direct" and "indirect" investment outlays), the following modified formula of synthetic index is used in order to exclude these depreciation allowances:

$$E = \frac{\frac{1}{T}\left(I + I_p\right)\cdot\left(1 + q\,n\right) + \left(C - \frac{I + I_p}{20}\right) Y_s}{P Z_s}$$

where C = annual operating costs, including depreciation allowances (period of amortization = twenty years). Indirect investments (I_p) per one cubic metre of cinder blocks consist of the following three elements:

$I_{p\,coal}$ = 40 kg of coal + 14 kWh × 0.5 kg per kWh of coal × 0.6 zlotys per kg = 28.20 zlotys,

$I_{p\,cinder}$ = 1.05 m^3 × 35 zlotys per m^3 = 36.75 zlotys, and

$I_{p\,cement}$ = 230 kg × 0.863 zlotys per kg = 198.00 zlotys.

Therefore, $I_{p\,cinder\,blocks}$ = 28.20 + 36.75 + 198.00 = 263 zlotys per cubic metre. Indirect investment outlays computed in similar ways for other wall materials:

	Brick	Lime	Cement	Gypsum
I_p	0.22 zlotys per unit	0.155 zlotys per kg	0.204 zlotys per kg	0.052 zlotys per kg

To arrive at the average period of immobilization of investment outlays, suppose that the following time distribution of investment outlays is known:

Year of construction	First	Second	Third	Fourth	Fifth
i_t = annual investment outlay in millions of zlotys	100	200	200	350	150
Immobilization period of each annual outlay ($t_k - t$)	4.5	3.5	2.5	1.5	0.5
$i_t(t_k - t)$	450	700	500	525	75

Then, the average immobilization period of the total investment outlays can be calculated as:

$$n = \frac{\sum_t i_t (t_k - t)}{\sum_t i_t} = 2.25 \text{ years.}$$

The values of n calculated in this manner for various wall materials are as follows:

Brick	Lime	Cement	Cinder blocks	Gypsum
1.2	1.53	2.25	1.1	1.37

Other data, namely, "direct" investment output (I) and total operating costs (C_t) are as follows:

	Brick	Lime	Cement	Cinder blocks	Gypsum
I zlotys	1.40 per unit	0.544 per kg	0.863 per kg	178 per m^3	0.359 per kg
C_t zlotys	0.69 per unit	0.18 per kg	0.266 per kg	157.7 per m^3	0.112 per kg

Coefficients Z_s and Y_s are computed under the assumption that the period of operation is fifteen years for cinder blocks and thirty years for other materials.

Economic effectiveness of use of bricks

$$E_{brick} = \frac{\frac{1}{6}(1.40 + 0.22)(1 + 0.15 \times 1.2) + \left(0.69 - \frac{1.40 + 0.22}{20}\right) \times 1.32}{1.17}$$

= 0.957 zlotys per unit.

In exactly the same way, E's for all other wall materials are:

Lime	Cement	Cinder blocks	Gypsum	Granulated cinder	Sand
0.290 zlotys per kg	0.444 zlotys per kg	226.1 zlotys per m^3	0.171 zlotys per kg	32.31 zlotys per m^3	21.57 zlotys per ton

Table 8

SYNTHETIC INDICES OF ECONOMIC EFFECTIVENESS FOR THREE KINDS OF WALL PRODUCTION

	Unit of measure	Brick wall	Cinder block wall	Gypsum block wall
Brick				
a	Zlotys per unit	0.957	—	—
b	Unit per m^2	144.80		
c	Zlotys per m^2	138.57		
Lime				
a	Zlotys per kg	0.290	0.290	0.290
b	Kg per m^2	25.93	9.23	4.1
c	Zlotys per m^2	7.52	2.68	1.19
Cement				
a	Zlotys per kg	0.444	0.444	—
b	Kg per m^2	4.74	10.64	
c	Zlotys per m^2	2.10	4.72	
Sand				
a	Zlotys per ton	21.57	21.57	21.57
b	Ton per m^2	0.179	0.104	0.05
c	Zlotys per m^2	3.86	2.24	1.08
Cinder blocks				
a	Zlotys per m^3	—	226.10	—
b	M^3 per m^2		0.275	
c	Zlotys per m^2		62.18	
Cinder				
a	Zlotys per m^3	—	—	32.31
b	M^3 per m^2			0.186
c	Zlotys per m^2			6.01
Labour	Zlotys per m^2	36.90	32.18	43.37
Equipment	Zlotys per m^2	6.97	5.55	14.00
Casting mould	Zlotys per m^2	—	—	0.23
E_i for wall production	Zlotys per m^2	195.92	109.55	102.83

Note: $a = E_i$ for the production of a given material (i); $b = a_{ij}$, that is, input of a given material per square metre of wall; $c = E_i a_{ij}$, that is, value input of a given material per square metre of wall.

The synthetic index of effectiveness (E_j) for each j kind of wall involves the sum of the coefficients (E_i) for required materials weighted by their input coefficients (a_{ij}); that is, $\sum E_i a_{ij}$. As can be seen in table 5, E_j is thus obtained as the sum of this combined material cost per square metre of wall and the labour and equipment costs per square metre of wall.

The type of calculation shown above has played an important role in determining development programmes with respect to wall materials. For instance, in the Five Year Plan for 1961–1965, output of bricks was planned to reach 130 (1960 = 100), whereas output of gypsum for construction purposes was planned to reach 230, on account of the relatively low material costs (low value of $\sum E_i a_{ij}$) involved in the production of gypsum wall.

4. Economic effectiveness of the modernization of an existing spinning mill

The following example illustrates a typical analysis relating to the economic effectiveness of the modernization of existing plants.

Description of a spinning mill to be modernized:

Number of spindles: 104,100;
Annual output: 9,800 tons of yarn;
Unit operating cost: 32,520 zlotys per ton, of which material input is 25,800 zlotys per ton, labour input is 6,720 zlotys per ton.

In order to maintain the same output level, it is necessary to:

(*a*) Expend 63.4 million zlotys on "essential" repair outlays in the first year, of which 50.1 million zlotys are expended on equipment repairs and 13.3 million zlotys on building repairs, and then

(*b*) Conduct "essential" repairs of equipment every five years, and of buildings every ten years.

Description of the modernization:

By means of 160 million zlotys of investment outlays, it is possible to:

(*a*) Replace 70 per cent of existing spindles;
(*b*) Install new spindles to the total amount of 110,900; and
(*c*) Renovate ventilation system and buildings.

This results in an output increment of 2,260 tons per year and a decrease in unit operating cost to the level of 31,600 zlotys per ton (of which material input is 25,750 zlotys and labour input, 5,850 zlotys).

The "immobilization" of investment outlays brought about by this modernization is estimated under the following assumptions:

(*a*) Total investment outlays of 160 million zlotys are being expended:
In the first year: 93.9
In the second year: 40.6
In the third year: 25.5

(*b*) Increases in output in per cent of the total increase of output (165 million zlotys per year) due to modernization amount to 0 per cent in the first year, 5 per cent in the second year and 65 per cent in the third year.

These increases in output prior to the end of investment period represent re-mobilization of investment outlays.

Table 6

IMMOBILIZATION OF INVESTMENT OUTLAYS
Millions of zlotys

	Investment outlays	Immobilized value	Remobilized value	Net immobilization
During the first year	93.9	93.9/2 = 46.95	—	46.95
During the second year	40.6	93.9 + 40.6/2 = 114.20	8.0	106.20
During the third year	25.5	93.9 + 40.6 + 25.5/2 = 147.25	8.0 + 96.0 = 104	43.25
Total for the 3 years	160.0	308.40	112.0	196.40

Thus, $n_2 = 196.4/160.0 = 1.228$ year.

Description of the alternative solution: construction of a new spinning mill with 50,000 spindles:

Investment outlays: 200 million zlotys;
Immobilization n_2: 1.85 year;
Annual output: 5,280 tons of yarn;
Operating costs: 31,000 zlotys per ton, of which material input is 25,500 zlotys and labour input is 5,500 zlotys.

In order to compute the synthetic index of effectiveness for a new spinning mill, it is necessary to know its optimal period of exploitation (n). In the first stage of computation of that optimal period, the outlays on essential repairs were not taken into account because such outlays depend themselves on the length of period of exploitation.

Thus, the optimal $n(n_{opt})$ is computed first as a function of the ratio of investment outlays (including immobilization) to transformation costs (labour input).

$$n_{opt} = f\left[\frac{200\times10^6\times(1+0.15\times1.85)}{5{,}500\times5{,}280}\right] = f\,(8.8) = 31 \text{ years.}$$

Assumptions in respect to essential repairs in the new spinning mill:

	Millions of zlotys
After 10 years	8.5
After 15 years	10.5
After 20 years	19.1
After 25 years	20.8
After 30 years	40.3

Since inclusion of major repairs in operating costs shortens n_{opt}, essential repairs after thirty years do not have to be taken into account. Total repair requirements during the first thirty years amount, therefore, to: 8.5 + 10.5 + 19.1 + 20.8 = 58.9 million zlotys; that is, about 2 million zlotys per year.

Adding the amount of annual major repairs to transformation costs, the recomputed value of n_{opt} turns out: $n'_{opt} = f\,(8.2) = 30$ years. The synthetic index of effectiveness for the new spinning mill is:

$$E_b = \frac{\frac{1}{6}\times200\times10^6\times(1+0.15\times1.85) + (5{,}500\times5{,}280 + 2\times10^6)\,Y_{30}}{5{,}280\,Z_{30}}$$

$= 13{,}491$ zlotys per ton, where $Y_{30} = 1.3179$ and $Z_{30} = 1.1712$.

The first question is: Has the old spinning mill the right to survive as it is?

The answer is positive, if

$$E_{st} < E_h$$

where:

E_{st} = synthetic index of the operating costs of the old spinning mill,

E_h = synthetic index of the new spinning mill.

Since $E_h = 13{,}491$ zlotys per ton, and $E_{st} = 0.74\ C_{st} = 0.74 \times (6{,}720 + 25{,}800 - 25{,}500) = 5{,}195$ zlotys per ton[c] survival of the old spinning mill is justified. The synthetic index of an old spinning mill is now computed, assuming that major repairs are performed. The period of exploitation was established for:

old spinning mill: 15 years,

modernized spinning mill: 20 years,

with the help of a special formula for estimating the effectiveness of essential repair outlays. The effectiveness of investment outlays on the modernization is computed according to the following formula:

$$E_m = \frac{\frac{1}{6} \cdot I_m (1 + 0.15 \times 1.2) - R_o (1 + 0.15 \times 0.25) + \Delta C_m}{\Delta P_m}$$

where:

I_m = investment outlays on modernization;

R_o = value of the first essential repair, which can be avoided if the old spinning mill is modernized;

$\Delta C_m = C_m Y_m - C_{st} Y_{st}$;

$\Delta P_m = P_m Z_m - P_{st} Z_{st}$;

n_m = 20 years; n_{st} = 15 years (therefore: $Y_m = 1.0$; $Y_{st} = 0.8022$; $Z_m = 1.0$; $Z_{st} = 0.8597$).

The subscript m means modernized spinning mill; st means old spinning mill. Transformation costs (C_m, C_{st}) include essential repairs.

Outlays on essential repairs (in millions of zlotys):

	Spinning mill	
	Old	Modernized
In the first year	63.4	—
After 5 years	50.1	12.6
After 10 years	63.4	33.1
After 15 years	—	35.7
Total	113.5	81.4

It follows that the average annual outlays on essential repairs would be (in millions of zlotys):

In old spinning mill: $113.5 \div 15 = 7.6$

In modernized spinning mill: $81.4 \div 20 = 4.1$

Inserting into the synthetic formula above the following data:

I_m = 160 million zlotys

R_o = 63.4 million zlotys

$C_m = 5{,}850 \times (9{,}800 + 2{,}260) + 4{,}100{,}000$

$C_{st} = 6{,}720 \times 9{,}800 + 7{,}600{,}000$

$\Delta C_m = 1.0\ C_m - 0.8022\ C_{st} = 16.4$ million zlotys

$\Delta P_m = (9{,}800 + 2{,}260) - 0.8597 \times 9{,}800 = 3{,}635$ tons.

The effectiveness of the modernization of the old mill is:

$E_m = 10{,}151$ zlotys per ton.

Since this value is lower than E_h (1,349 zlotys per ton), it follows that the modernization of the existing mill is more effective than the construction of a new mill; however, the effectiveness of this modernization is not high enough to unjustify the sustained operation of the old mill without modernization ($E_{st} = 5{,}195$ zlotys per ton).

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[c] The difference in material input between the old and new spinning mills was taken into account.

5. Optimal duration of the sugar production season

In an industry using agricultural raw materials, the duration of production season influences the final amount of output because of quantitative and qualitative losses of raw materials in storage. The duration can be shortened and output increased by means of installation of additional capacities. This implies, however, additional investment outlays.

It is possible to estimate, on the basis of the behaviour of the main techno-economic parameters, levels of operating costs, investment outlays and finally synthetic indices as a function of the length of production season.

Table 7 presents relevant data under the assumptions that the planned sugar beet crop is 11 million tons, and the duration of production season is shortened from 100 to 50 days.

Table 7

Data for estimating optimal duration of sugar production season

Duration of production season (days)	Sugar beets actually processed (millions of tons) B_p[a]	Capacity (thousands of tons per 24 hours) Z[b]	Fixed productive assets (billions of zlotys) M[c]	Sugar output (thousands of tons) P[d]	Operating costs (billions of zlotys) C[e]
100	10.65	106.5	11.18	1,473	8.87
98	10.66	108.8	11.42	1,483	8.88
95	10.67	112.3	11.79	1,498	8.88
93	10.67	114.8	12.05	1,508	8.89
91	10.68	117.4	12.32	1,518	8.90
90	10.68	118.7	12.46	1,523	8.90
89	10.69	120.0	12.60	1,527	8.90
87	10.69	122.9	12.91	1,535	8.91
85	10.70	125.9	13.22	1,542	8.92
83	10.71	129.0	13.54	1,550	8.93
80	10.72	133.9	14.06	1,561	8.94
75	10.73	143.1	15.02	1,577	8.96
70	10.75	153.5	16.12	1,592	8.98
65	10.76	165.6	17.39	1,604	9.03
60	10.78	179.7	18.86	1,615	9.07
50	10.81	216.2	22.70	1,633	9.17

[a] B_p is computed taking into account losses in the storage of 11 million tons of sugar beets.

[b] $Z = B_p / n$.

[c] $M = Z \cdot C$ where C is a constant capital/capacity ratio (=1.05 million zlotys per ton).

[d] P depends on n.

[e] C does not include operating costs of by-products.

Synthetic indices of effectiveness for each interval (for example, 100–98 days) have been computed, assuming the period of immobilization $n_2 = 2$ years.

Table 8

Increase of marginal capital output ratio and synthetic indices of effectiveness (E)

Interval days	$\Delta M = I$ (millions of zlotys)	ΔC (millions of zlotys)	ΔP (thousands of tons)	$E = \frac{\frac{1}{6} I(1+q_2 n_2) + \Delta C}{\Delta P}$ (thousands of zlotys per ton)
100–98	236.3	5.1	9.9	5.69
98–95	371.7	6.9	15.0	5.83
95–93	258.3	5.4	9.9	6.20
93–91	273.0	6.0	9.9	6.59
91–90	140.7	3.0	5.0	6.70
90–89	136.5	3.7	3.9	8.76
89–87	304.5	6.9	7.6	9.59
87–85	311.8	8.1	7.6	9.96
85–83	326.6	7.7	7.6	10.33
83–80	519.7	12.5	11.4	10.97
80–75	959.7	26.0	15.4	15.19
75–70	1,097.3	30.3	15.3	17.52
70–65	1,257.3	34.1	12.3	25.10
65–60	1,475.3	40.8	11.0	32.76
60–50	3,839.8	103.3	18.0	51.96

In order to determine an optimal shortening of the production season, these indices of effectiveness (E) are compared with the indices of alternative solutions (E_A). The purchase of an additional amount of sugar beets, instead of "saving" by means of shortening the duration of production season, has been assumed in the alternative solutions.

The limit of shortening the production season is determined at the point where E becomes larger than E_A. From the computation shown in table 9, it is clear that the optimal duration in this case is equal to ninety days. The analysis may be further elaborated by changing the assumptions with regard to prices of the additional purchase of sugar beets, and also by introducing other alternative solutions—for example, modernization of the existing plant.

Table 9

INDICES OF ALTERNATIVE SOLUTIONS (E_A) AND COMPARISON OF E_A AND E

[illegible] n	ΔP [illegible]	ΔB_P[a] [illegible]	ΔZ_A[b] [illegible]	E_A [illegible]	ΔZ[c] [illegible]	E_A [illegible] ΔP	E [illegible]
100–98	9.9	71.6	0.72	75.6	53.5	7.06	5.69
98–95	15.0	107.8	1.10	115.5	80.5	7.03	5.83
95–93	9.9	70.5	0.74	77.7	52.7	7.02	6.20
93–91	9.9	70.1	0.75	78.8	52.3	7.01	6.59
91–90	5.0	35.2	0.39	41.0	26.2	7.02	6.70
90–89	3.9	27.4	0.30	31.5	20.4	6.97	8.76
89–87	7.6	53.2	0.60	63.0	39.7	7.03	9.59
87–85	7.6	53.0	0.61	64.1	39.6	7.04	9.96
85–83	7.6	52.7	0.62	65.1	39.5	7.05	10.33
83–80	11.4	78.8	0.95	95.8	58.8	7.05	10.97
80–75	15.4	105.7	1.32	138.6	78.9	7.07	15.19
75–70	15.3	104.1	1.39	146.0	77.9	7.16	17.52
70–65	12.3	83.0	1.19	125.0	62.3	7.27	25.10
65–60	11.0	73.8	1.14	119.7	55.4	7.39	32.76
60–50	18.0	120.1	2.00	210.0	90.5	7.56	51.96

[a] $\Delta B_P = \Delta P/W$ where W = sugar produced per unit of sugar beet.
[b] $\Delta Z_A = \Delta B_P/n$.
[c] C_4 does not include operating cost of by-products.

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The Dual Nature of Industrial Development in Japan

THE ARTICLE BELOW *is one in a series of studies published in the* Bulletin *on different aspects of the industrial structure and industrial development in Japan. A first article, by Mr. Toyoroku Ando, contained in the second issue (Sales No.: 59.II.B.1), discussed the interrelations between large and small industrial enterprises in Japan, with special reference to subcontracting arrangements. Another article in the same issue presented the conclusions and recommendations of a group of experts on the organization and operation of cottage and small industries, on the basis of a survey made during a visit to that country. A third article, on choice of techniques, by Mr. Saburo Okita, published in the fourth issue (Sales No.: 60.II.B.2), analysed the approach adopted in Japan to make the best use of its endowment in capital and labour in developing agriculture, transportation and manufacturing, and its implications for the developing countries.*

The present article examines a particular aspect of the industrial growth in Japan, namely, the economic coexistence of highly capital-intensive large-scale industries and of a highly developed small-scale industry sector using labour-intensive processes and employing vast amounts of labour at wage rates substantially lower than those in large-scale industries.

The article is a revised version of a paper presented to the Seminar on Industrial Development Programming in the Latin American Region, held in São Paulo, Brazil, from 4 to 15 March 1963.

IN CERTAIN DEVELOPING and certain recently industrialized countries, the economic structure may present a dual aspect: one which emerges from inherited factors in the economy, and another which arises as a result of the process of industrialization. The first type is dependent upon historical conditions in individual countries and may not, therefore, be a universal feature of all developing countries. It is reflected in a significant contrast of attitudes and ways of living between the few highly "westernized" citizens, often educated in the universities of Europe or North America and generally employed in governmental and semi-governmental agencies and a few modern business corporations, and the great masses of people whose patterns of life correspond to and are shaped by pre-industrial societies. This situation was prevalent in Japan during the nineteenth century and right up to the period preceding the Second World War and might be ascribed to the almost complete absence of international relations for three hundred years prior to 1870. The principal economic feature of this type of dualism is the existence of an abundant labour force with a completely different mode of living from that of the "westernized" group. It might be recalled that in 1900, a year characteristic of the pre-industrialization period, the share of primary industry in the total national income of Japan was more than 50 per cent, while about 70 per cent of the labour force was occupied in this sector.

The chief characteristic of the second type of dualism is the existence of income differentials, more specifically wage differentials, between firms, industries, regions, and so on.[1] These wage differentials were the pronounced feature of the process of industrialization in Japan until the nineteen fifties. As can be seen from the data in table 1 in the appendix, there have been no drastic changes in inter-industry wage differentials, particularly since 1929.

[1] The interdependence between these two types of dualism is an important consideration, but it cannot be explicitly discussed in the present article.

ELASTIC SUPPLY OF LABOUR AND TECHNOLOGICAL PROGRESS

THE FIRST ISSUE to be examined is the relationship between the existence of an abundant labour force and the pattern of industrial development. To avoid confusion, the existence of an abundant labour force is defined as the elastic supply of labour under the existing wage rate (6).[2] The data on wage rates and their changing pattern among various occupations from 1885 to 1910 in Japan, as shown in appendix table 2, indicate the general validity of the assumption of the elastic supply of labour. During this period, one of the most active industries which absorbed agricultural labour was the textile industry. As indicated in columns (2), (3) and (4) in table 2, there were almost no differences between the wage rates of female workers in the textile industry and those in agriculture. This shows that if new labour in industry was needed there were almost no obstacles to obtaining it. Even after 1910, it could be said that this favourable situation regarding labour supply in manufacturing industry continued for some time. For example, in 1935, the ratio of the wage rate in the textile industry to that in agriculture, for female workers, was still 1.2. Between 1885 and 1910, the number of gainfully employed persons in manufacturing industry rose by 140 per cent, while the number of those in agriculture remained almost constant.[3]

The elastic supply of labour can become a favourable factor for industrial expansion if there is an adequate effective demand for industrial products and if labour-intensive techniques are optimal. However, these two conditions may not be fulfilled in most of the developing countries. An extensive use of labour-intensive techniques may adversely affect industrial expansion, giving rise to more or less chronic deficits in the balance of payments, owing to the generally weak trend of the demand for labour-intensive goods. On the other hand, a rapid introduction of capital-intensive techniques may intensify social problems such as unemployment and may also lead to acute foreign exchange shortages.

An example of the way to handle this paradoxical situation may be found in the pattern of industrial growth in Japan. A detailed study by Chenery-Shishido-Watanabe shows that "the process of industrialization in Japan from 1914 to 1954,[4] during which period its economy was transformed from that of a typically underdeveloped country to that of an advanced society, can be traced mostly in terms of changes in supply conditions, including substitution of domestic manufactures for both imported manufactures and primary products and also technological changes". (2) The nature of technological changes—that is, whether they were labour-using or capital-using—was not, however, explicitly examined in that paper.

Technological changes have been examined in several interesting studies, among others Solow (12) and a report by the European Economic Community (17). Most of those studies, however, are based almost exclusively on the assumption of "neutral" technological changes. To identify the nature of technological changes—labour-saving, capital-saving and neutral—requires the introduction of a formulation which is different from those used in the studies mentioned and can be done by using a concept analogous to the "substitution term" in the consumer theory.[5] The application of this formulation to the

Packing cans of crab meat in a Japanese canning boat

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

[3] The ratio of new inflow from the agricultural sector to total net increases of labour in the non-agricultural sector was 85 per cent in 1880, 58 per cent in 1920 and 71 per cent in 1953. *See* Umemura (13).

[4] The reason for singling out 1914 specifically was that (i) around 1910, there had been rather drastic structural changes, that is, the rapid industrialization of Japan began at that period, and (ii) a variety of statistical information was systematically made available in 1914. For example, Professor Ohkawa advanced the hypothesis whereby he characterized the early period, from 1870 to 1910, as having a "labour growth dominant pattern" and the later period as having a "productivity growth dominant pattern". *See* Ohkawa (6).

[5] In order to identify the nature of technological changes, the following scheme can be introduced. Assume a general type of production function which satisfies all the neo-classical conditions, namely, the production function $(v_1, \ldots, v_n)$, where v_i represents the i th factor of production at a given state of technology, is twice differentiable for all positive v_i, and the isoquants are all smooth and strictly convex towards the origin. The production function may be assumed to be subject to constant returns to scale.

Technological changes will be called: i-saving if $S_{i\tau} < 0$, i-neutral if $S_{i\tau} = 0$, and i-dissaving if $S_{i\tau} > 0$; the substitution terms ($S_{i\tau}$) are obtained as:

$$S_{i\tau} = (1 - r_i)(\delta v_i / \delta\tau) + \psi_\tau \quad (i = 1, \ldots, n),$$

where $\psi_\tau = \delta\psi / \delta\tau$. It is easily proved that the weighted sum of $S_{i\tau}$ is equal to zero, that is, $\sum_i r_i S_i = 0$, where r_i is the relative share of factor i. This relation implies a method of measuring ψ_τ: such as $\psi_\tau = -\sum_i r_i [(1 - r_i)(\delta v_i / \delta\tau)]$.

For details of the mathematical formulation, *see* Uzawa-Watanabe (14).

historical time series data on capital, labour and their relative shares compiled by the Hitotsubashi Economic Research Institute, Tokyo, for the period preceding the Second World War in Japan (*see* appendix table 3) reveals that during the period 1904-1933 about one-fourth of the increase in labour productivity (which was about 4.5 per cent per year) could be accounted for by technological changes if the latter were assumed to be "neutral", and also that the use of labour-saving (or capital-using) techniques was predominant.

These findings are consistent with the one derived by Chenery-Shishido-Watanabe: that (i) technological changes played an important role in the industrial development of Japan, and (ii) in spite of the existence of an abundant labour force, Japanese industry continued its efforts to introduce capital-using techniques.

An application of the same analytical tool to the time series data for agriculture is shown in appendix table 4.[6] The pattern of technological changes in agriculture appears to be different from that in manufacturing industry. There was no continuity in the nature of technological changes, and neither labour-saving techniques nor capital-saving techniques were dominant; it does not follow, however, that technological changes were neutral. The share of technological changes in the total increase in labour productivity in agriculture was, on the average, about 70 per cent during the period 1887-1936. The increase in labour productivity between 1887 and 1910 was 2.7 per cent per year, but it declined to 2.4 per cent per year during the period 1910-1936. However, the share of technological changes in the increase in labour productivity was identical in both periods.[7]

The paradoxical pattern of industrial growth in Japan

Hemming towels in a small Japanese factory

—that is, the coexistence of an abundant labour force and a utilization of labour-saving techniques—can be ascribed to the following factors. First, the aggressive use of "borrowed technology" from advanced countries was combined with the adequate supply of a reasonably educated labour force at the existing wage rate.[8] The use of capital-intensive techniques in conjunction with the more or less low and constant wage rate yielded relatively high rates of savings over a long period.[9] For example, the savings accounted for 19 per cent of the national income over the period 1913-1935 (8). Secondly, the structure of relative prices, especially the maintenance of lower prices of rice, together with the absence of the unionization of labour, were among the key factors which kept wage rates from increasing. Finally, the socio-economic viability of agricultural and service industries enabled these industries to support the abundant (surplus) labour force without a drastic impact on the traditional levels of living.

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[6] In this computation of technological changes, capital stock, including land, was investigated independently. The results of this assumption, however, showed almost the same pattern as mentioned above.

[7] As investigated by Professor H. Rosovsky, the ratio of government investment to gross national product in Japan was considerably higher and some part of this investment went to agriculture, for example, in irrigation projects. Also, continuous efforts were made during the pre-war period to improve the seeds of rice—efforts mostly undertaken by governmental institutes—and to intensify the use of chemical fertilizer. Those three policies may have enabled agriculture in Japan to adopt labour-saving techniques. More detailed discussion regarding this problem is found in Ohkawa (5).

[8]

EDUCATIONAL BACKGROUND OF LABOUR FORCE, SELECTED YEARS
(Thousands of persons; per cent of total)

	Total labour force	*Higher education*	*Middle education*	*Elementary education*	*No education*
1910	23,639	118 (0.5%)	306 (1.3%)	8,936 (37.8%)	14,279 (60.4%)
1930	27,991	590 (2.1%)	1,446 (5.2%)	20,256 (72.4%)	5,669 (20.3%)
1960	43,691	2,968 (6.8%)	11,696 (26.8%)	28,620 (65.5%)	403 (0.9%)

The headings "Higher education", "Middle education" and "Elementary education" apply to graduates of colleges and universities, of high schools (senior and junior) and of elementary schools (compulsory), repectively.

[9] It may be said that the absolute value of saving ratio in Japan during the pre-war period, which was 19 per cent on the average, was not unexpectedly high, compared to the estimates made by C. Clark and S. Kuznets for Germany, the United Kingdom and the United States:

	Percentage
Germany (1879-1909)	17.3
United Kingdom (1860)	17.7
United States (1884-1898)	16.2

The important point to be emphasized is the fact that the ratio continued to be high over a longer period in Japan.

DUAL STRUCTURE AND INDUSTRIAL GROWTH STRATEGY

THE PERIOD 1910-1936 witnessed remarkable progress in the industrial growth of Japan. This is apparent from a comparison of the rates of growth of the major sectors of the economy during this period with those in the period from 1872-1882 to 1908-1912.

Sectors	*Annual growth rates*	
	1872-1882 to 1908-1912 *(percentage)*	*1910-1936*
Factory production	7.8	18.0
Handicraft production	4.5	4.0
Services	5.4	6.0
Agriculture	2.7	1.5
Economy as a whole	4.2	5.0

See Ohkawa (5) and (7) for methods of estimation and detailed analysis.

It is apparent from these data that the major drive for accelerated industrial development took place during the period 1910-1936. The remaining portion of this article is devoted to the explanation of this rapid industrialization with special reference to its dual nature.

It should be pointed out that the labour force of Japan during this period had an adequate capacity to utilize "borrowed technology", that is, to build and operate industrial plants on the basis of technology developed in foreign advanced countries. But Japan did not then possess the capacity to develop new technology on its own account. It is hardly possible to say that Japan has either adequately developed or organized this type of capacity even as of the present time. However, the borrowed technology was developed in advanced countries with a view to substituting capital for labour. Thus, Japan was compelled to use capital-intensive techniques in important branches of the industrial sector.

As noted earlier, Japan had high rates of saving which provided enough resources to finance a considerable proportion of capital requirements for industries. It must be emphasized that the appropriate selection of industries to be financed by the Government and entrepreneurs should be worked out in advance. For example, several industries such as iron and steel, shipbuilding and transportation equipment were largely financed by the Government in Japan, while the textile industry was financed mostly by private sources.

The borrowed technology was mostly employed in large establishments in the industrial sector. Several policies were implemented by the Government to assure reasonable degrees of productivity increases in small establishments in all sectors of the economy.[10] Important among them were the selection of products or production processes which were specifically relevant to small firms (for example, production of toys or household utensils), active use of economies of scale, especially in agriculture (official assistance for irrigation projects, use of fertilizers, and the like), and aggressive transfers into small firms of the part of capital assets which were deemed to be inefficient in large establishments employing modern technology. The use of second-hand capital assets was probably the most important for the non-agricultural sectors; it considerably reduced the capital costs of small firms, and together with the elastic supply of labour at low wage rates, assured rates of profit comparable to those in larger firms (*see* appendix table 5).

The maintenance of the lower and stable level of prices for key consumer goods played a crucial role in the continued elastic supply of labour at the existing low wage rates which were adequate for traditional ways of living. The retail price of rice was the kingpin in this price structure. A comparison between the price of rice and the consumer's general price index is given in appendix table 6, which shows the relative constancy of prices except for the years 1918 to 1920 which witnessed the big rice riot.[11]

[10] Government measures touching this problem were generally not active in the pre-war as compared to the post-war period, except in agriculture.

[11] Since the Meiji restoration, there had been almost no other rice riots, which is an indication of political stability during this period.

DUAL STRUCTURE IN POST-WAR DEVELOPMENT

JAPAN HAS UNDERGONE drastic changes in almost every aspect of its society since the Second World War. The major changes from the viewpoint of economic development were: (i) transformation of industrial structures from military to peace-time uses; (ii) changes in major foreign markets, especially losses of mainland China and Manchuria; (iii) changes in the ways of living, that is, transformation from traditional to "westernized" patterns of consumption, and (iv) creation of powerful trade unions. It was believed by those responsible for decisions on economic policies that accelerated industrialization with special emphasis on heavy manufacturing industries was the only way to overcome difficulties associated with these new structural changes.[12]

[12] The shift of the industrial structure during the post-war period from light industry, such as textiles, to heavy industry, such as machinery, was given a strong impetus by changes in the foreign export markets. Even as of the time of writing, in 1962, one of the most urgent problems for economic planning in Japan is to ascertain the relationship between the structure of industrial production and that of exports.

Workmen assembling a section of the hull of a 45,000-ton ore carrier under construction at the Yokohama Shipyard and Engine Works

During the past ten years the average rate of economic growth has jumped to about 10 per cent; it was about 5 per cent in the pre-war period (1910-1936). More specifically, the contribution of neutral technological changes in manufacturing industry has risen sharply: half the increases in labour productivity are attributable to technological changes, which are twice their pre-war magnitude. Also, the share of heavy industry has reached a much higher level (*see* appendix table 7).

In order to accomplish such a high rate of economic growth, additional policy measures were taken in the post-war period: (i) increased government intervention, especially in financing new capital requirements (creation of semi-governmental financial institutions, such as the Development Bank of Japan, the Export-Import Bank, the Long-term Credit Bank, and so on); (ii) explicit formulation of economic plans as a target of governmental and private activities; (iii) governmental regulation of the price of rice to consumers and producers; (iv) adoption of a land reform policy, the major purposes of which were the creation of land-owning farmers and the replacement of rent in kind by a controlled low-cash payment, and (v) special procedures to accelerate depreciation in manufacturing industries.

These policy measures had a considerable impact on industrialization and also on changes in the nature of dualism. First of all, as expected, the pattern of technological changes in the post-war period in Japan was again capital-using (*see* appendix table 8). This was true especially in industries such as electronics, petrochemicals, plastics and synthetic fibres, and also in large plants producing iron and steel, electrical equipment, machinery, and the like.[13] These technological changes were mostly accelerated by the devices listed under (i), (ii) and (v) above—financial assistance by government, economic planning, especially the "Income Doubling Plan" (9, 16), and the special procedure for depreciation.[14]

At the same time, these measures created a new type of dualism, inter-firm wage differentials. In general, wage differentials are understood to arise out of differences in productivity among industries and in the skills of labour employed. In the case of the Japanese economy, however, special attention must be paid to differentials among firms; inter-industry wage differentials have not changed significantly from the historical point of view (*see* appendix table 1), and have not been particularly large in an

[13] As compared with the situation in the pre-war period, these tendencies were supported by a high mass consumption of consumer durables rather than by military preparation.

[14] According to the special procedure introduced by the Government in 1957, eligible machinery and equipment (which covers most capital assets in newly developed industries, export industries and some basic industries such as machine tools and industrial machinery) may be replaced within four years, if it is desirable.

Assembly line in the Toyota Motor Company at Toyoda, Aichi Prefecture, Japan

international comparison (*see* table 9).[15] Some characteristics of the inter-firm wage differentials are shown in table 10. The widening of the inter-firm wage differentials in recent years can be explained by (i) the particular structure of trade unionism (there are almost no trade unions by occupations; practically all unions are organized on the basis of the firm), (ii) the peculiar system of wage contract (in most large firms employment involves a lifetime commitment), and (iii) the absence of a legal guarantee of minimum wage rates.

Under the conditions of rapid industrialization and the widening of wage differentials, it was found necessary to introduce policies which could help to raise the general standard of living in real terms, and to maintain, to some degree, a balanced growth between the rapidly developing sectors of the economy and the residuals, especially agriculture. For these purposes, the policy devices mentioned under (iii) and (iv) have proved quite useful.

Land reform, referred to under (iv), which was originally introduced by the United States Occupation Forces in co-operation with the Government, has played an unexpectedly important role in accelerating mechanization and technical progress in agricultural production. The creation of the spirit of entrepreneurship was extensively observed among farmers after the reform. This is reflected in the replacement of human and animal traction by mechanized traction,[16] greater use of chemical fertilizers and insecticides, and diversification of agriculture (for instance, the expansion of the live-stock industry), among others. These developments, in combination with large-scale irrigation and reclamation projects executed by the Government, resulted in a significant increase in the income of farmers and enabled them to increase both consumption and investment.

The relative position of the farming to the non-agricultural sector, especially to the rapidly growing manufacturing industry, was also partially improved by policy device (iv), control of the price of rice. This policy had two purposes: (i) to maintain the retail price at a reasonable level and (ii) to guarantee a reasonable income to producers (farmers). The price of rice was controlled by means of two procedures: (i) regulating the producer's price at a level sufficiently high to compensate for the major part of production cost,[17] and (ii) fixing the consumer's price at a relatively lower level. As a result of this artificial price discrimination between producer and consumer, a considerable amount has been paid by the Government for rice subsidies. In fact, these subsidies came to about 1.5 per cent of the total 1961 budget.

This policy has effectively maintained a stable consumer's price, especially for foods, until very recently. The average annual increases in consumer's prices by major items between 1951 and 1961 were as follows: 2.4 per cent for food, 7.1 per cent for housing, 3.9 per cent for fuel and light, 4.1 per cent for miscellaneous items and 2.7 per cent for all items. However, clothing recorded a decline of 1.9 per cent per year during this period.[18] The nominal wage rate rose by about 20 per cent per year during the same period. This shows a great improvement in the living standard of the people between 1951 and 1961.

This period also witnessed the growth of large as well as small firms and a noticeable increase in labour productivity in both types of firms. For example, during

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[15] Although inter-industry wage differentials vary considerably from one country to another, as can be seen in table 9, the variation of V_w can be explained systematically in the following way:

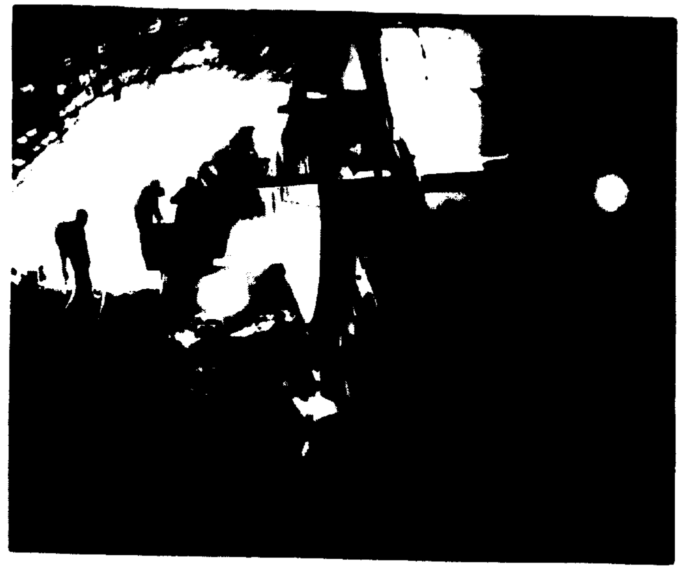
$$V_w = 45.00 - 9.97 \log w + 0.06 V_e$$
$$(0.944) \qquad (0.025)$$
$$R^2 = .78$$

where w is the over-all average wage rate in manufacturing industries and V_e represents the variation of the size of establishment in terms of the coefficient of variation defined by the same formula as that of the wage differentials, V_w. The wage differentials in Japan are not extremely large in comparison with what is "normal" in terms of the above described relationship.

[16] For example, the ratio of chemical fertilizer used to output of rice was (2): in 1914, .015; in 1935, .029, and in 1954, .051; while the number of motor-cultivators or tractors in use was in 1935, 211; in 1950, 13,240, and in 1960, 517,000.

[17] For example, as a result of this price fixing, in 1958 the producer's price for Italian rice was about half the corresponding Japanese price, namely, 3,480 yen and 7,660 yen per 100 kilogrammes, respectively.

[18] The stability of consumer's prices has been quite significantly disturbed for the past year (June 1961-May 1962). Within the year, the following increases were noted: food, 10.4 per cent, housing, 4.2 per cent, fuel and light, 2.9 per cent, clothing, 5 per cent, miscellaneous, 14 per cent, and total, 7.5 per cent.

Construction of the Nagoya-Kobe Expressway. Left: Work in progress on one of the shoulders of the highway, along a side of Mount Osaka. In the background is a section of Route 1 of Japan's old National Highway; Right: Construction of the Torimot Tunnel as part of the Expressway

1950 to 1955, increases in labour productivity, by size of firm, were as follows:[19]

Number of persons engaged	*Annual rate of expansion in labour productivity (percentage)*
4-29	1.63
30-49	1.60
50-99	1.62
100-199	1.71
over 200	1.81

One of the explanations for this parallel growth in labour productivity between large and small firms was the extensive use of second-hand capital assets. Although this factor was significant in the pre-war period, it has been given added importance in the post-war years.[20]

Although it is hardly possible to forecast the future pattern of dualism in Japan quantitatively, several possibilities may be indicated:

(i) The inherited type of dualism, *the elastic supply of labour under traditional ways of living*, will disappear in the near future. Indeed, the Second World War gave very strong stimuli to changes in ways of living, economically and psychologically. The elastic supply of labour itself will gradually be transformed into a labour shortage. In the latest Japanese economic plan, the "Income Doubling Plan", it is anticipated that a labour shortage will develop during the latter half of the nineteen seventies.

(ii) The induced type of dualism will disappear much faster than the former one. In the manufacturing industry, the inter-firm wage differentials have been reduced very recently. For example, the wage rate in firms which employ less than thirty but more than five persons is now (1962) 58.2 per cent of the wage rate in firms which employ more than five hundred persons, while it was around 40 per cent in 1956.

(iii) The institutional background of the dual nature of the Japanese economy—the lifetime commitment system in the employment contract, the family system and similar established practices—will correspondingly be gradually weakened.

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[19] This series was estimated by Professor M. Shinohara (10).

[20] According to the figures in the Japanese Census of Manufactures, the proportion of second-hand assets in total newly added capital assets was estimated as follows:

Size of firm (number of persons engaged)	*1955*	*1956 (percentage)*	*1957*
4-9	40.2	34.3	—
10-19	40.8	29.9	—
20-29	34.3	28.7	—
30-49	28.9	26.1	26.8
50-99	22.0	22.3	21.9
100-199	16.3	16.8	14.5
200-299	9.1	9.9	9.3
300-499	10.1	9.1	7.4
500-999	5.2	4.2	4.6
Over 1,000	4.1	4.9	3.3
TOTAL average	14.3	12.3	—

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Appendix

Table 1

WAGE DIFFERENTIALS BETWEEN INDUSTRIES

Year	Average wage[a] (all manufacturing per day or month)	Ratio of maximum to minimum wage rate (Percentage)	Coefficient of variation[b]
1909	42	2.21	22.3
1914	47	2.28	22.8
1919	144	1.89	17.5
1920	147	2.06	19.4
1921	156	2.03	20.7
1922	158	2.22	22.4
1923	161	2.25	22.1
1924	163	2.18	21.4
1925	162	2.17	21.4
1926	158	2.25	22.0
1927	156	2.23	21.9
1928	156	2.26	22.5
1929	44.0	2.57	30.4
1930	38.3	2.86	31.9
1931	35.5	2.79	32.5
1932	36.0	3.18	33.8
1933	36.3	3.24	35.6
1934	37.5	3.10	35.6
1935	36.4	2.87	33.6
1936	36.5	2.81	33.0
1937	37.6	2.70	31.4
1938	40.1	2.73	31.0
1939	45.8	2.62	30.2
1940	48.9	2.38	26.1
1941	55.6	2.53	26.9
1942	60.1	2.58	26.7
1946	524	2.38	27.2
1947	1,411	2.03	21.5
1948	3,579	2.65	24.5
1949	6,439	2.77	27.1
1950	6,808	2.96	28.3
1951	8,837	3.22	29.7
1952	9,854	3.02	28.6
1953	11,213	3.03	28.1
1954	12,114	2.94	27.6
1955	12,362	2.80	26.7
1956	13,776	3.26	30.2

Source: Historical Examination of Wage Structures in Japan, Shiseido Publishing Company, Ltd. (Tokyo, 1960).

[a] In sen per day up to 1929; in yen per month in following years (sen = 1/100 yen).

[b] Defined as follows:

$$\text{Coefficient of variation} = \sqrt{\frac{\Sigma (X_i - \bar{X})^2}{n}} \Big/ \bar{X}$$

where

$\bar{X}$ = average wage rate for all manufacturing industries,

X_i = the wage rate in the i-th industry, and

n = the number of industries. (Up to 1947, $n = 9$; 1948-1953, $n = 19$; in following years, $n = 20$).

Table 2

WAGE RATE BY OCCUPATIONS
(Sen per day)

Year	*Farming (male)* (1)	*Farming (female)* (2)	*Spinning (female)* (3)	*Weaving (female)* (4)	*Casting (male)* (5)	*Smithery (male)* (6)	*Carpentry* (7)
1885	15	10	11	8	—	21	23
1886	13	8	11	7	—	21	23
1887	14	8	—	7	—	22	22
1888	—	—	—	—	—	—	—
1889	—	—	—	—	—	—	—
1890	—	—	—	—	—	—	—
1891	—	—	—	—	—	—	—
1892	16	9	13	9	—	25	27
1893	—	—	—	—	—	—	—
1894	17	11	13	11	30	29	30
1895	19	11	13	12	30	29	32
1896	21	13	15	13	33	33	38
1897	25	16	18	15	39	39	44
1898	28	18	20	19	43	41	47
1899	26	17	22	19	42	45	51
1900	30	19	20	20	47	48	54
1901	32	20	20	19	50	49	59
1902	31	19	20	20	54	52	58
1903	31	10	20	19	53	52	59
1904	33	20	21	17	51	55	59
1905	32	20	22	13	53	55	60
1906	34	20	23	21	55	57	65
1907	36	22	27	24	62	65	75
1908	39	23	25	24	66	68	81
1909	38	23	27	26	67	67	80
1910	39	24	31	27	69	69	80

Source: Employment and Unemployment, Showa Dojinkai (Tokyo, 1957).

Table 3

TECHNOLOGICAL CHANGES IN MANUFACTURING INDUSTRY

Year	*With respect to use of labour* (1)	*With respect to use of capital* (2)	*Assuming neutrality* (3)
1905	—0.0988	0.0472	0.0312
1906	—0.0699	0.0341	0.0241
1907	—0.0465	0.0235	—0.1305
1908	—0.0477	0.0234	—0.0727
1909	—0.0444	0.0226	0.0456
1910	—0.0027	0.0013	—0.0077
1911	—0.0357	0.0173	0.0363
1912	—0.0611	0.0289	—0.0181
1913	—0.0446	0.0204	—0.1206
1914	—0.0173	0.0077	0.1517
1915	—0.0322	0.0138	0.1608
1916	—0.0389	0.0161	0.0861
1917	—0.0518	0.0162	—0.0788
1918	—0.1030	0.0480	—0.0180
1919	—0.0427	0.0243	0.0593
1920	—0.0493	0.0337	—0.2143
1921	—0.0162	0.0260	—0.1680
1922	—0.0162	0.0138	0.0408
1923	—0.0117	0.0103	0.0753
1924	—0.0110	0.0090	0.0690
1925	—0.0152	0.0118	0.0648
1926	—0.0092	0.0068	0.0018
1927	—0.0210	0.0160	—0.0340
1928	—0.0225	0.0185	0.0625
1929	—0.0392	0.0338	0.0638
1930	0.0011	—0.0009	—0.0279
1931	—0.0549	0.0411	—0.0469
1932	—0.0017	0.0013	0.1353
1933	0.0030	—0.0020	0.0790

Source: Basic data for capital, "Interim Report on Estimation of Long-run Capital Stock Series in Pre-war Japan", Economic Research Institute, Hitotsubashi University, Tokyo, Japan (unpublished); for labour, reference (7); for relative shares, reference (13).

Note: Minus sign (—) represents negative values, implying the "saving" of the factor considered.

Table 4

TECHNOLOGICAL CHANGES IN AGRICULTURE

Year	With respect to use of labour (1)	With respect to use of capital (2)	Assuming neutrality (3)	Year	With respect to use of labour (1)	With respect to use of capital (2)	Assuming neutrality (3)
1887	0.053	—0.033	—0.117	1912	—0.061	0.056	0.056
1888	0.141	—0.085	—0.029	1913	0.006	—0.006	0.019
1889	—0.015	0.009	0.046	1914	0.071	—0.061	—0.055
1890	—0.349	0.218	0.248	1915	0.080	—0.064	—0.064
1891	0.099	—0.060	—0.043	1916	—0.056	0.041	0.047
1892	0.044	—0.029	0.045	1917	—0.026	0.018	0.085
1893	0.023	—0.015	—0.010	1918	—0.115	0.078	0.099
1894	—0.184	0.130	0.116	1919	—0.166	0.110	0.103
1895	0.054	—0.041	—0.046	1920	0.184	—0.124	—0.124
1896	0.071	—0.062	—0.067	1921	0.024	—0.016	—0.042
1897	—0.037	0.031	0.011	1922	0.048	—0.030	—0.086
1898	—0.229	0.217	0.232	1923	—0.090	0.065	0.053
1899	0.160	—0.147	—0.089	1924	—0.055	0.041	0.054
1900	—0.025	0.023	0.034	1925	—0.081	0.061	0.074
1901	—0.051	0.047	0.031	1926	0.080	—0.066	—0.047
1902	0.104	—0.102	—0.053	1927	0.059	—0.050	—0.024
1903	—0.129	0.126	0.104	1928	—0.017	0.013	0.020
1904	—0.013	0.011	0	1929	—0.047	0.038	0.018
1905	0.153	—0.146	—0.096	1930	0.142	—0.114	—0.114
1906	—0.105	0.100	0.135	1931	0.072	—0.066	—0.053
1907	—0.060	0.055	0.055	1932	—0.122	0.109	0.096
1908	—0.014	0.013	0.031	1933	—0.109	0.098	0.079
1909	0.062	—0.059	—0.041	1934	0.070	—0.073	—0.040
1910	0.060	—0.059	—0.047	1935	—0.072	0.074	0.094
1911	—0.123	0.115	0.115	1936	—0.052	0.052	0.059

Source: Basic data for capital, Umemura, M. and Yamada, S., "The Estimates of Agricultural Capital Stock", *Quarterly Journal of Agricultural Economics*, vol. 16, No. 4, 1962; for labour, reference (7); for relative shares, reference (13).

Table 5

RATE OF PROFIT ON TOTAL CAPITAL, 1953

Size of firms[a] (thousands of yen)	Rate of profit (Percentage)	Size of firms[a] (thousands of yen)	Rate of profit (Percentage)
Under 2,000	15.2	50,000-99,999	11.3
2,000-4,999	8.9	Over 100,000	13.8
5,000-9,999	12.3	TOTAL average	13.6
10,000-49,999	12.7		

Source: Statistics of Corporations, Ministry of Finance, Government of Japan (Tokyo, 1953).
[a] Measured by amounts of total capital.

Table 6

VARIOUS INDICES OF CONSUMER'S PRICES: GENERAL, RICE, FOOD AND CLOTHING

Year	General price (1)[a]	Rice (2)[a]	(2)/(1)	General price (3)[b]	Food (4)[b]	Clothing (5)[b]	(4)/(3)	(5)/(3)
1879	100.0	100.0	100.0	24.5	28.6	38.1	116.7	155.5
1880	114.9	127.7	111.1	28.2	34.8	44.7	123.4	158.5
1881	125.1	129.1	103.2	30.7	36.6	61.8	119.2	201.3
1882	117.8	107.1	90.9	28.9	32.8	52.8	113.5	182.7
1883	105.0	81.1	77.2	25.7	26.3	39.6	102.3	154.1
1884	97.3	72.3	74.3	23.9	22.7	36.8	95.0	154.0
1885	102.8	89.8	87.4	25.2	25.2	38.6	100.0	153.2
1886	96.4	73.4	76.1	23.6	21.7	34.8	91.9	147.5
1887	96.2	66.1	68.7	23.6	21.6	38.1	91.5	161.4
1888	95.3	65.2	68.4	23.4	21.2	38.4	90.6	164.1

Table 6 (continued)

Year	*General price (1)*[a]	*Rice (2)*[a]	(2)/(1)	*General price (3)*[b]	*Food (4)*[b]	*Clothing (5)*[b]	(4)/(3)	(5)/(3)
1889	102.0	73.9	72.5	25.0	23.7	37.0	94.8	148.0
1890	112.4	114.2	101.6	27.6	29.6	33.7	107.2	122.1
1891	109.4	93.1	85.1	26.8	26.8	30.9	100.0	115.3
1892	100.0	100.0	100.0	27.2	27.8	30.8	102.2	113.2
1893	102.0	102.0	100.0	27.7	27.8	32.8	100.4	118.4
1894	105.9	121.1	114.4	28.8	29.4	33.5	102.1	116.3
1895	115.3	122.2	106.0	31.4	30.6	35.6	97.5	113.4
1896	124.0	131.0	105.6	33.7	33.0	37.8	97.9	112.2
1897	144.1	163.5	113.5	39.2	39.9	39.1	101.8	99.7
1898	154.7	197.7	127.8	42.1	46.1	38.2	109.5	90.7
1899	144.1	132.8	92.2	39.2	39.0	43.2	99.5	110.2
1900	162.5	165.6	101.9	44.2	43.2	48.3	97.7	109.3
1901	159.6	169.7	106.3	43.4	42.9	45.3	98.8	104.4
1902	166.2	174.0	104.7	45.2	46.3	43.9	102.4	97.1
1903	175.5	198.8	113.3	47.7	49.2	45.0	103.1	94.3
1904	180.0	187.2	104.0	49.0	51.7	47.0	105.5	95.9
1905	100.0	100.0	100.0	50.4	52.8	50.2	104.8	99.6
1906	104.1	115.3	110.8	52.2	54.4	53.3	103.6	101.5
1907	111.8	125.8	112.5	56.4	59.3	56.8	105.1	100.7
1908	107.7	116.6	108.3	54.3	55.6	52.1	102.4	95.9
1909	105.9	98.7	93.2	53.4	55.4	50.5	103.7	94.6
1910	106.8	96.0	89.9	53.9	55.2	56.0	102.4	103.9
1911	114.6	126.8	110.6	57.8	60.9	58.0	105.4	100.3
1912	122.0	148.6	121.8	61.5	67.8	57.7	110.2	93.8
1913	126.1	160.0	126.9	63.6	70.6	58.4	111.0	91.8
1914	100.0	100.0	100.0	57.3	61.7	57.2	107.7	99.8
1915	94.3	78.3	83.0	54.0	54.3	54.3	100.6	100.6
1916	101.6	82.3	81.0	58.2	57.4	65.7	98.6	112.9
1917	122.1	117.7	96.4	70.0	74.5	87.8	106.4	125.4
1918	161.3	184.4	114.3	92.4	109.0	118.5	118.0	128.2
1919	213.2	263.8	123.7	122.0	151.8	155.8	124.4	127.7
1920	224.4	267.7	119.3	128.6	158.1	147.8	108.3	103.9
1921	209.8	191.3	91.3	120.0	129.9	124.7	108.3	103.9
1922	209.8	217.7	103.8	120.1	134.2	127.9	111.7	106.5
1923	101.3	91.1	89.9	117.9	130.0	133.6	110.3	113.3
1924	101.9	97.8	96.0	118.5	135.2	133.2	114.1	112.4
1925	103.7	106.7	102.9	120.6	137.5	131.6	114.0	109.1
1926	100.0	100.0	100.0	116.3	129.3	107.8	111.2	92.7
1927	99.5	93.3	93.8	115.7	125.2	101.7	108.2	87.9
1928	96.6	82.2	85.1	112.4	118.2	98.9	105.2	88.0
1929	94.4	75.6	80.1	109.8	114.6	95.6	104.4	87.1
1930	85.7	68.9	80.4	99.7	101.5	77.8	101.8	78.0
1931	91.0	68.0	74.7	91.0	84.5	86.3	92.9	94.8
1932	91.8	74.2	80.8	91.8	87.9	85.4	95.8	93.0
1933	95.8	77.3	80.7	95.8	91.0	97.0	95.0	101.3
1934	98.2	89.7	91.3	98.2	96.1	100.4	97.9	102.2
1935	99.7	102.1	102.4	99.7	99.3	101.3	99.6	101.6
1936	102.1	108.2	106.0	102.1	102.7	103.4	100.6	101.3
1937	110.6	114.4	103.4	110.6	110.3	114.9	99.7	103.9
1938	122.6	123.7	100.9	122.6	120.3	144.5	98.1	117.9

Source: Yamada, S. and Ando, Y., "Cost of Living Index from early Meiji Era to World War II (1879-1938)" (unpublished).

[a] The indices in columns (1) and (2) are discontinuous as among the following six periods: 1879-1891 (1879 = 100); 1892-1904 (1892 = 100); 1905-1913 (1905 = 100); 1914-1922 (1914 = 100); 1923-1930 (1926 = 100); 1931-1938 (1934 = 100).

[b] All indices in columns (3), (4) and (5) are based on 1934-36 = 100.

Table 7

COMPOSITION OF OUTPUT IN MANUFACTURING INDUSTRY[a]
(Percentages)

Year	*Light industry*	*Heavy industry*	*Year*	*Light industry*	*Heavy industry*
1909	81.3	18.7	1959	45.6	54.4
1934	55.8	44.2	1961	36.7	63.3
1950	67.2	32.8	United Kingdom (1955)	41.2	58.8
1955	43.9	56.1	Germany, Federal Republic of (1956)	43.9	56.1
1956	43.9	56.1			

Source: Census of Manufactures.

[a] Heavy industries are defined as metal products, machinery and equipment, and chemicals; light industries comprise the remainder.

Table 8

TECHNOLOGICAL CHANGES, 1953-1958

Year	*With respect to use of labour (1)*	*With respect to use of capital (2)*	*Assuming neutrality (3)*	*Year*	*With respect to use of labour (1)*	*With respect to use of capital (2)*	*Assuming neutrality (3)*
1953	−0.052	0.034	0.025	1956	−0.043	0.025	0.000
1954	−0.014	0.009	0.056	1957	−0.090	0.055	−0.024
1955	0.039	−0.024	0.075	1958	−0.006	0.003	0.060

Source: Census of Manufactures 1953-1958; and *Capital Stock and Economic Growth*, Economic Research Series, Economic Planning Agency, Government of Japan (Tokyo, 1963) (in Japanese).

Table 9

INTER-INDUSTRY WAGE DIFFERENTIALS[a] AMONG COUNTRIES

Country	*Wage differential* (V_w)	*Country*	*Wage differential* (V_w)	*Country*	*Wage differential* (V_w)	*Country*	*Wage differential* (V_w)	*Country*	*Wage differential* (V_w)
Argentina	18.71	China (Taiwan)	25.80	India	24.84	Nicaragua	27.78	Sweden	15.13
Australia	10.37	Colombia	30.62	Iraq	34.18	Norway	12.21	Turkey	24.17
Austria	22.47	Costa Rica	28.70	Ireland	17.41	Pakistan	27.95	United Arab Republic	22.88
Brazil	22.34	Denmark	3.13	Israel	7.87	Paraguay	27.86	United Kingdom	14.00
Burma	33.18	Finland	13.24	Japan	31.00	Peru	24.38	United States	13.61
Canada	17.50	France	22.94	Kenya	32.71	Philippines	27.58		
Ceylon	27.10	Honduras	35.15	Lebanon	27.72	Puerto Rico	23.72		
Chile	24.41	Iceland	12.96	New Zealand	13.54	South Africa	25.06		

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

[a] Defined as: $V_w = \sqrt{\sum_i k_i (w_i - \bar{w})^2} / \bar{w}$ (%)

where w_i and $\bar{w}$ represent the average wage rate in the ith industry and the over-all average wage rate in total manufacturing industries respectively, and k_i is a normalized distribution of number of persons engaged.

Table 10

INTER-FIRM WAGE DIFFERENTIALS
(Indices: wage rate in firms employing over 1,000 persons = 100)

<table>
<tr><th rowspan="2">Size of firm (number of persons engaged)</th><th colspan="4">Japan</th><th>United Kingdom</th><th>United States</th></tr>
<tr><th>1909</th><th>1914</th><th>1951</th><th>1955</th><th>(1949)</th><th>(1947)</th></tr>
<tr><td>5-9</td><td>100</td><td>91</td><td>37</td><td>40</td><td>—</td><td>73</td></tr>
<tr><td>10-19</td><td rowspan="2">97</td><td rowspan="2">84</td><td>43</td><td rowspan="2">43</td><td rowspan="2">84</td><td rowspan="2">79</td></tr>
<tr><td>20-29</td><td>47</td></tr>
<tr><td>30-49</td><td>94</td><td>81</td><td>51</td><td>47</td><td>83</td><td>84</td></tr>
<tr><td>50-99</td><td>94</td><td>84</td><td>56</td><td>53</td><td>84</td><td>86</td></tr>
<tr><td>100-199</td><td rowspan="2">97</td><td rowspan="2">84</td><td>64</td><td>59</td><td>85</td><td>86</td></tr>
<tr><td>200-499</td><td>75</td><td>69</td><td>86</td><td>88</td></tr>
<tr><td>500-999</td><td>94</td><td>91</td><td>89</td><td>79</td><td>89</td><td>90</td></tr>
</table>

Source: Census of Manufactures.

Plant Size and Economies of Scale

The question of size of industrial plant in the developing countries has been dealt with, in some aspects, in two studies published by the United Nations. The first study, which appeared in the second issue of the Bulletin *(Sales No.: 59.II.B.1) under the title "Problems of size of Plant in Industry in Under developed Countries", analysed changes in costs and in investment outlays in relation to capacity of output in two industries, ammonia fertilizers and glass containers. The second study*—Cement—Nitrogenous Fertilizers Based on Natural Gas—*published in* Studies in Economics of Industry, No. 1 *(Sales No.: 63.II.B.3), referred to the subject in connexion with economies of scale and production costs in these two industries.*

In the present article, the relationship between plant size and economies of scale is studied with reference to a certain number of industries, including those discussed in the above-mentioned studies. Two main types of economies of scale —technical and organizational—are distinguished, and their relative importance in the cost structure is analysed. Attention is drawn, in particular, to the fact that the economies derived from production organization are independent from the size of plant and that even small-scale industrial enterprises can benefit from them, with the assistance, as necessary, of appropriate servicing institutions.

The article is a revised version of a paper submitted to the Seminar on Industrial Development Programming in the Latin American Region, held in São Paulo, Brazil, from 4 to 15 March 1963.

One of the problems which has been widely and frequently discussed in the recent literature on economic development, both at the macro-economic and the micro-economic level, is the question of economies of scale and size of plants. The question relates to techniques and forms of production organization which can be utilized in a plant or industry.[1] In developed countries the problem has been mostly discussed as relating to monopoly and strategy under oligopoly, whereas in newly industrializing countries it has concerned the selection of industry or the establishment and operation of new plants. This article will be confined mainly to discussion of size of plants as related to developing countries.

As is well known, the cost of industrial product is generally lower in a large-scale plant than in a small-scale plant, the main reason being that the costs of equipment and construction and land, the amount of labour required and sometimes the amount of raw materials do not vary in proportion to changes in the size of production. A large-scale production may also require less overhead cost per unit of output.

However, the economies of scale may not always be entirely relevant for the choice of industry, especially in under-developed countries, when one takes into account

[1] The term "economies (or diseconomies) of scale" has been vaguely used. One of the distinctions is between external and internal economies, the other between those which are pecuniary or technological. Internal economies are those within the firm, external economies are external to the firm but available to all firms in the industry. Pecuniary economies arise from the change in the price of a factor or intermediate good, or a cost of marketing, while technological economies are realized when a larger scale of output permits a lesser input per unit of output to be realized in physical terms.

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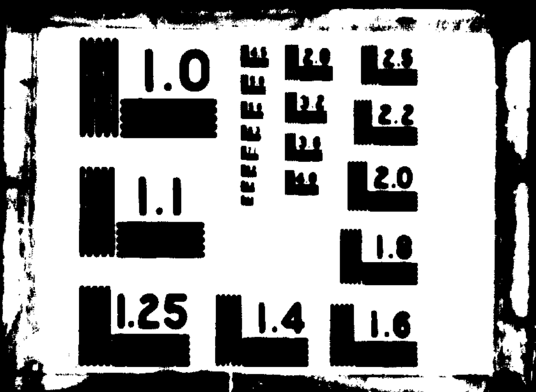

local conditions in their factor proportions, the prices of competitive goods, the size of market, the location of plant, the technology involved, and the like.

This article deals briefly with the cost of production in relation to the scale of production and forms of production organization, and the effect of such factors as market, transportation and technology on the scale of production.

COST-SIZE RELATIONSHIP

A DECREASE IN unit production cost with increase in size of plant is a well-known characteristic of many industries.

This relationship can be expressed for various components of production cost, including investment or capital charges, labour, raw materials, maintenance and other inputs, by formulation of appropriate equations. The relationship between investment and scale of production, for example, has been presented in the following formula:

$$\left(\frac{K_1}{K_2}\right) = \left(\frac{X_1}{X_2}\right)^{\beta}$$

where K_1 and K_2 stand for capital requirements of plants 1 and 2, and X_1 and X_2 are the corresponding output levels. β is an empirical exponential coefficient which varies from one industry to another and which would hold true only within a certain range beyond which it would also tend to vary.

Each component of production cost shows a different variation in relation to the scale of capacity and output. In general, the amounts of raw materials consumed vary in about the same proportion to output, whereas labour and equipment requirements increase less rapidly than the rise in production. The costs for sales and distribution, although they are not included in the direct cost, also increase less proportionately.

A few studies on the subject of economies of scale have been undertaken by the Centre for Industrial Development at United Nations Headquarters and the United Nations Economic Commission for Latin America. For example, a study on this subject, analysing changes in costs and in investment outlays in relation to capacity of output in two industries—ammonia fertilizers and glass containers—appeared in the *Industrialization and Productivity Bulletin*.[2] The Economic Commission for Latin America made a similar study on the steel industry, which also offers an extensive example for the case.[3] Some other papers on programming data for such industries as cement, fertilizers based on natural gas and aluminium, prepared by the Centre for Industrial Development, provide similar examples.[4] The following table shows some of the conclusions drawn from a number of the above-mentioned studies and from a recent study undertaken by the Productivity Center of Japan on four industries—ball-bearings, tar, benzol and aluminium plate (for details, *see* the appendix to the present article).

Since each item has been calculated on different assumptions, table 1 does not serve for the purpose of comparison among various industries. It shows, however, as a first approximation, that the production cost in industry is normally lower in large-scale production than in small-scale production.[5]

It should be noted that the cost of production is affected differently by the scale of capacity and by the scale of output or actual operation. In a plant of a given capacity, the higher the degree of capacity utilization, the lower will be the unit cost of production because the fixed costs will be spread out over larger output. In examining the factors affecting economies of scale, it is assumed that the degree of operation or capacity utilization remains constant.

The advantage of large-scale over small-scale production with respect to unit costs as revealed by the data cited arises from two distinct sources—technological economies of scale and facilities for economic "overheads". Technological economies of scale are generally made possible by the division of labour, the integration of processes by unifying a number of them formerly performed in a series so that they may be performed simultaneously, and the physical or mechanical advantage of large size for some types of equipment and machinery (blast, steel and glass furnaces, ships and aeroplanes, for example).

In many industries, however, there are limitations on the technological economies of scale. For example, in cotton spinning and cotton weaving, the sequence of processes has long been divided into the greatest number of technically possible operations, and a further subdivision seems to be impossible. Similarly, the integration of processes is restricted where the economic scale of operation of one specific process diverges widely from that of other processes in the industry. In such cases, the specific process is separated from the main industry and is performed by a specialist firm. Finishing stages of the textile industry and the manufacture of various components such as radiators, wings, chassis, electrical parts, and so on in the automobile industry furnish examples of such developments.

It is therefore quite likely that the large part of technical economies of scale are obtained in several industries by relatively modest size. At the other extreme, significant diseconomies of scale may be found only after a

[2] "Problems of Size of Plant in Industry in Under-developed Countries", *Industrialization and Productivity Bulletin*, No. 2.

[3] Economic Commission for Latin America, *A Study of the Iron and Steel Industry in Latin America* (Sales No.: 54.II.G.3, Vol. I), pages 112-116.

[4] *See* United Nations, *Cement-Nitrogenous Fertilizers based on Natural Gas* (Sales No.: 63.II.B.3).

[5] *See* appendix tables I to VIII for the break-down of the cost data into different components for these products.

Table 1

VARIATION IN PRODUCTION COST IN RELATION TO DIFFERENT SCALES OF OUTPUT IN SELECTED INDUSTRIES

Product, capacity and cost	*Unit*	*Variation in capacity and production cost*			
Steel					
Capacity	Thousands of tons per year	50	250	500	1,000
Cost per ton	1948 U.S. dollars	209.4	158.8	137.5	127.2
Cement					
Capacity	Thousands of tons per year	100	450	900	1,800
Cost per ton	1959 U.S. dollars	26.0	19.8	16.4	13.9
Ammonium nitrate					
Capacity	Short tons per day	50	100	150	300
Cost per ton	1957 U. S. dollars	190.4	145.1	125.6	101.5
Beer bottles					
Capacity	Number of moulding machines	1	2	6	12
Cost per gross	1957 U.S. dollars	8.51	7.25	6.13	5.69
Glass containers					
Capacity	Number of moulding machines	1	2	6	12
Cost per gross	1957 U.S. dollars	8.66	7.77	6.78	6.33
Radial ball-bearings					
Capacity	Production index (1961 = 1)	1	2	3	
Cost per thousand	1961 yen	79,800	67,100	63,100	
Tar					
Capacity	Tons per day	100	200	300	400
Cost per ton	Thousands of 1961 yen	10.5	9.6	9.2	8.9
Benzol					
Capacity	Tons per day	50	100	200	300
Cost per ton	Thousands of 1961 yen	29.2	27.1	25.9	25.4
Aluminium plate					
Capacity	Tons per year	200	1,200	3,000	5,000
Cost per ton	Thousands of 1960 yen	276.8	272.2	269.1	263.5

Source: For steel, Economic Commission for Latin America, *A Study of the Iron and Steel Industry in Latin America*, op. cit.; for cement, Economic Commission for Asia and the Far East, *Formulating Industrial Development Programmes* (Sales No.: 61.II.F.7); for fertilizers and glass containers, "Problems of Size of Plant in Under-developed Countries", *Industrialization and Productivity Bulletin*, op. cit.; for other products, Productivity Center of Japan, *A Research Project in the Size of Plants* (Tokyo, 1961) (mimeographed).

fairly large plant size has been reached. In such industries, there may be a plateau of almost constant costs extending over a fairly wide range of plant sizes.[6] This might be at least a partial explanation of the continued existence and survival of firms varying in plant size and in effective competition with each other in a number of industries.

Facilities of economic "overheads" include industrial research, bulk buying of raw materials, marketing of finished products, facilities for tooling and repairs, specialized staff for the maintenance of machinery and equipment, advertising, standardization of products, cheaper and easier credit facilities, highly specialized and functional management and supervision of production, among others. Just one example will suffice to indicate the magnitude of reduction in unit costs achieved by these facilities. The costs of production per metric ton of tar were found to be 10,504 yen and 8,919 yen in two different plants in Japan, one with a capacity of 100 metric tons per day and the other with a capacity of 400 metric tons per day. The costs of "administration" in the two plants were 1,300 yen and 736 yen per metric ton respectively. Thus, the reduction in the unit cost of administration contributed 564 yen, or more than one-third of the total reduction of 1,585 yen.[7] It appears highly probable that economies of scale realized through facilities for economic overheads seem to be at least as important as technological economies of scale in a large number of industries.

Most of the economies of scale derived from the facilities of economic overheads are independent and irrespective of the size of the plant and can be provided to small plants by surrounding them with appropriate agencies which can take over the functions of economic overheads and perform them as common services to small production units. An industrial extension service can impart technical and managerial skills and can help small units to introduce quality control and standardization. It can render effective assistance in solving production problems and in raising the productivity of labour. It can also furnish general marketing services to help management to determine major distribution centres, to establish contacts with important wholesale and retail dealers, and to obtain the reaction of dealers and consumers as to price, quality and design of products.

[6] E. A. G. Robinson, *The Structure of Competitive Industry*, Cambridge University Handbooks, revised edition, 1953, pages 182 and 183.

[7] *See* table V in the appendix.

Finally, it can provide tooling and repair facilities in its own workshops. Technological research institutes can undertake the tasks of improving the production and design of products and developing new processes and products.

The government can take several measures to increase the flow of credit to small units and reduce its cost. Long-term and medium-term financing for small industrial units can be provided directly through the relevant government departments or indirectly through government sponsored finance corporations. Such corporations may also supply machinery on a hire-purchase basis. Similarly, short-term credit can be provided by industrial credit co-operatives or through commercial banks on the basis of liberalized standards of credit-worthiness. In the latter case, the government should extend the credit to commercial banks through the central bank and guarantee the losses arising out of a possible default. Sale and purchase co-operatives may take over the bulk buying of raw materials and marketing and advertising of the manufactured products.[5]

Special studies to distinguish and determine the relative contributions of technical and other economies will help considerably in determining the proper size of plants in different industries. They will also help to correct the not infrequent and unjustifiable emphasis on and bias in favour of large-sized plants found among technicians and engineers. The importance of such studies for countries with comparatively small national markets hardly needs to be emphasized.

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[5] Most of the measures described above have been implemented in some of the developing countries.

COSTS OF MAJOR INPUTS

It will be useful to examine the available data on costs of important inputs in relation to the scale of output. These data, however, do not clearly distinguish the relative contributions of technical economies of scale and other economies, especially those arising in the economic overheads facilities. For the sake of simplicity, total production cost may be divided into the following four groups:

(i) Cost of raw materials and supplies, including all current purchases made by the factory and excluding supplies for maintenance;

(ii) Cost of power and fuels, wherever such distinction can be made;

(iii) Labour cost, including all wages and related payments, other than the wages of maintenance workers;

(iv) Cost relating to capital investment, including depreciation, labour and materials for maintenance and the normal remuneration of capital and miscellaneous charges, such as short-term interest and insurance charges.

Cost of raw materials and supplies

Raw materials requirements in physical terms are, in most industries, virtually independent of the size of operation and change in almost direct proportion with the scale of production. Unit cost of raw materials, however, often decreases with the possibility of lower cost in bulk purchasing and shipping, and of reduced waste in handling. Only the latter arises from technical economies of scale.

In the cases mentioned above, no change in the unit cost of raw materials and supplies was assumed for ammonium nitrate, beer bottles, tar, benzol and cement, although raw materials cost may, in practice, change slightly, as is seen in other cases. Certain savings in raw material inputs were shown for aluminium plate and finished steel, mainly because of the lower cost of bulk purchasing and partly owing to better handling and operating methods, which are technologically feasible only in large-scale plants.

Cost of power and fuels

In general, physical inputs of fuel and power change slightly with changes in the size of operation, but the magnitude of this change is likely to be insignificant in most cases. Any contribution to total savings of savings in power and fuel input is, therefore, rather small. This is especially true in industries where the costs of power and fuel constitute a small proportion of total costs. For example, in ball-bearing plants (where the power cost is only 1.1 to 1.6 per cent of total costs) and in plants fabricating aluminium products (where the corresponding cost is 3.5 per cent of the total), the contribution of saving of power to total decrease is only one per cent and 8.9 per cent respectively, with a four times increase in the scale of production in the case of ball-bearings and an increase from 1,200 tons to 5,000 tons in the case of aluminium fabrication.

In industries requiring a high consumption of fuel or power, such as in the manufacture of ammonium nitrate where the share of unit cost of fuels and power in the total cost is large, the size factor may affect total production cost to some extent, owing to the technology involved in the process. The size factor is, however, a minor factor in determining the cost of product, since the unit cost of fuels and power is in general rather independent of size.

Cost of labour

An increase in the size of plant would require a lesser number of workers to engage in its operation. Unit cost of labour shows a remarkable decrease in all of the cases given above: for example, 41.1 per cent in the case of ball-bearings, 56.7 per cent in that of tar, 59.7 per cent for benzol and 33.5 per cent for aluminium plate.

In general, a part of labour inputs is independent of size and remains unchanged even if the size increases, while the remaining part changes proportionately with an increase in the scale of output. The proportion between these two parts, fixed and variable, of the labour inputs varies from one industry (or plant) to the other, depending on the technology involved. In such industries as metal and chemical processing industries, especially in modernized plants with continuous process and automated machines, where the labour is more or less of a supervising type, the fixed part is proportionately larger than the other. The scale effect is greater in this item of cost. However, in more labour-intensive types of plants, the fixed labour is relatively small, and, accordingly, the labour cost decreases very slowly with an increase in size of operation. In the case of glass containers, for example, it is considered that total labour requirements tend to follow more closely the increase in scale of output than in the case of the production of fertilizer. It can be stated in general that the more capital-intensive a production process, the greater will be the savings in labour costs arising out of technical economies of scale.

It should be noted that in the cases mentioned marginal labour costs, both wage rates and productivity, are assumed to be constant. In reality, however, they may not be constant.

Cost relating to capital

Costs relating to capital investment include such items as depreciation, labour and materials for maintenance and the normal remuneration of capital and miscellaneous charges, such as short-term interest and insurance charges. Some of these are variable and some are fixed, in relation to changes in the scale of capacity. The effect of the scale of output on the unit cost of capital is generally considerable, and varies from one industry or plant to the other depending on the cost structure and the marginal price of capital.

Big corporations with large plants are associated in the investor's mind with stability and growth while small firms with small plants are generally regarded as somewhat unstable and stagnant enterprises. Investments in the latter are, therefore, considered more risky than in the former. This phenomenon has several consequences. Small firms have to offer and assure higher returns on investment than large firms to compensate for the greater degree of the supposed risk. This, in turn, adversely affects reinvestment of retained profits. Secondly, small firms find it difficult to persuade issue houses and underwriting firms to float and underwrite their securities on the stock exchange and have to pay higher costs for these services than large firms. Finally, small firms have to pay higher costs for borrowing short term and long term funds and for ensuring plants and other property than large firms. The consequent lower capital costs of large firms, which arise from facilities of economic overheads and "prestige" associated with them, are independent of technical economies of scale.

Large plants commanding specialized maintenance staff and equipped with tooling and repairing facilities have longer life-spans and a higher degree of capacity utilization compared with small plants lacking in such facilities. This results in relatively lower costs of depreciation and spreading of fixed costs over larger output in large plants. In addition, large plants frequently enjoy the benefits of research and development which are incorporated in processes of production and also in the design of the product. All these advantages can be secured for small plants with the help of government-sponsored institutions and arrangements, as already noted.

Nonetheless, substantial technical economies of scale in costs relating to capital are obtained in large-sized plants. In certain industries such as steel and shipbuilding, total cost of plant per flow of unit output falls with an increase in scale. On the other hand, such cost tends to rise with an increase in scale where the integration of processes and extended division of labour are incorporated in the design of the large plant. But this increase in total capital cost is compensated by a proportionately far greater reduction in labour costs in operating the plant.

According to the studies referred to above, total capital cost in the case of ammonium nitrate increases proportionally with the 0.6th power of capacity and in the case of glass containers increases approximately with the 0.75th power of capacity. In the case of ball-bearings, the unit cost of capital increases as the scale of production increases, the reason being that the enlargement of the scale of production requires additional installation of new machines and equipment which are taken to be more expensive than the original. The increase in capital costs in this case, however, is offset to an even greater extent by the savings in labour inputs resulting from the application of new machines and equipment.

FACTORS AFFECTING THE SCALE OF PRODUCTION OR CAPACITY

Although the cost of production of manufacturing goods is, as was mentioned above, lower—in many cases much lower—in large-scale plants than in small-scale ones, the size of plants (measured by volume of production or by capacity) is affected by a number of factors, such as (*a*) type of technology involved, (*b*) price of competitive imports, (*c*) size of prospective market and its anticipated growth, and (*d*) distribution costs of product.

Technological factors

In the cases mentioned earlier, it has been assumed that the quantitative composition of main production factors—labour and capital—in the process of producing goods remains the same; in other words, unchanged technology is assumed. In practice, however, alternative processes, which involve different relative amounts of capital and labour, seem to be technologically feasible. The factor mix in industrial processes is adjusted to the relative costs of labour and capital. The problem has been known as a choice between capital-intensive and labour-intensive processes of production.

Real cost of capital is much higher and that of labour much lower in the under-developed economies than in the developed countries.[9] The process of production which yields the least unit costs is, therefore, relatively more labour-intensive or less capital-intensive in the developing countries than in the advanced countries. This factor tends to lower the appropriate scale of capacity in the developing countries because the scale of output varies directly with the capital intensity and indirectly with the labour intensity. However, substitution of labour for machinery and equipment in the core of the industrial process may be technologically limited in some of the modern industries. In such cases, various levels of mechanization are possible in a number of ancillary operations such as unloading, conveying and mixing raw materials and handling finished products. The Centre for Industrial Development has conducted several studies on this subject of choice of technology.[10]

The size of market[11] is one of the important factors limiting the scale of capacity, but account should be taken not only of the present volume of demand but also of the future growth of the market. The optimum scale in a growing economy is, however, very difficult to determine. This problem of "anticipated market" is particularly important in the case of industries whose increases in capacity of output proceed by substantial "jumps", each involving a considerable additional investment outlay.

If a plant is installed on the basis of present level of demand and the actual demand grows rapidly, the plant will have to be expanded frequently; thus, a considerable amount of capital as well as time will be wasted. On the contrary, if a plant is designed for the anticipated market in the future, it may begin to operate at a level below its capacity, and the return on investment in the early years will be fairly low.

The optimum scale is set at the point where the discounted value of production over time exceeds the discounted costs (including depreciation) by the greatest amount. The rate of discount used should represent the social return to capital in alternative uses, which is measured by its accounting price. A high discount rate will therefore lead to the construction of smaller plants, and a low discount rate to the construction of larger ones.

Minimum capacity

Minimum scale of capacity is generally determined by the price at which the same product is available as an import. In other words, such capacity should result in a production cost on the basis of which the price of the locally manufactured product would be equal to that of the imported product; operation below this capacity would result in the import price being lower than the price at which the locally manufactured product could be sold. Minimum scale is thus distinguished from optimum capacity. The two would coincide only if the anticipated market, including the external market, for the locally manufactured product over the period of years corresponding to the useful life of the equipment were met by output at the minimum capacity. If market studies indicate that the market is too small to sustain the minimum capacity, it would be cheaper to meet local needs through imports.

In this connexion, the cost of transporting both inputs and outputs becomes an important factor in determining the level of capacity. This factor is of particular importance when and where transportation cost is high relative to production cost. In establishing a cement plant in a South East Asian country, for example, the cost of production in a proposed 300,000-ton plant at a specified location was estimated to be $US13 per ton. Railway freight charges to two major markets located some 100 miles and 600 miles respectively from that plant were estimated to be $US2.60 and $US10 per ton, or 20 and 70 per cent of production cost. By virtue of this location problem, plants may be operated at levels well below the optimum scale and yet have a competitive advantage over large plants which are located farther from the market.[12]

The petroleum refining industry is another example of the case. A refinery with a crude oil throughput of 120,000 barrels a day is generally considered the optimum scale of plant in the United States. This is so, however, on the assumption that the refinery can transport its products to the market by ship or that it is located in close proximity to a very dense market so that transport by road or rail entails only short hauls. In the inland areas of the country, on the other hand, there are a number of refineries with much smaller capacities.[13]

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[9] Market prices of production factors in developing countries do not precisely reflect their relative scarcities; if factors are valued at prices reflecting relative scarcities, the pattern of relative costs may differ even more from that prevailing in industrialized countries. The costs of raw material will also have to be adjusted when indigenous materials may be available only in poor quality or irregularly.

[10] *See*, for example, the following articles published in various issues of the *Industrialization and Productivity Bulletin*: "Choice of Technology in Industrial Planning", by Jan Tinbergen, and "Capital Intensity in Industry in Under-developed Countries" in *Bulletin* No. 1; "Choice of Industrial Technology: The Case of Wood-working", by G. K. Boon, in *Bulletin* No. 3; "Choice of Techniques", by Saburo Okita, in *Bulletin* No. 4; and "Choice of Capital Intensity in Industrial Planning" in *Bulletin* No. 7.

[11] It is assumed here that the market is sufficient to absorb the whole production of at least one firm of optimum size, and that the market is competitive enough not to create monopolistic prices. This assumption, however, may not always be true.

[12] In other cases, where transport cost may not be high relative to production cost, inadequate distribution facilities may be another limiting factor. Inadequate services such as irregular deliveries may be partly resolved by, among other things, the use of motor transport and the establishment of transit stores at appropriate locations, as well as the installation of relatively small-scale plants.

[13] Joe S. Bain, *Barriers to New Competition* (Harvard University Press, Cambridge, 1956).

Likewise, in equating import prices to local production costs to determine the minimum capacity, the resulting scale will be much lower in under-developed countries than the average capacity of a corresponding plant operating at optimum level in an industrialized country, because transportation cost accounts for a considerable part of the import prices of competitive products. Thus, in under-developed countries the minimum size is often less than the average size of plants in the older industrialized countries.[14]

It is important to state explicitly that the domestic or local production costs refer to the costs of production at a mature stage of the industry and not to the costs of "infant industries", which would be higher than the import price for some time and which need to be protected in the initial phases of development. In addition, the criterion of equating local production costs with the import price to determine the minimum scale of capacity needs to be modified in developing countries which are deficient in the social and economic infrastructure and managerial and technical experience. This amounts to examining the criteria of protecting an industry whose production costs are higher than the import price, which is beyond the scope of this article.

[14] The minimum size of plant would be further reduced if the rate of domestic taxation applicable to the products were smaller than the rate applicable to the competing foreign products in their own countries; it follows that exemption from domestic taxation would bring about an even greater reduction in the minimum size of plant. A further reduction—of a scope varying from one industry to the other—would be obtained through devaluation or through imposition of customs duties on the competing imported products.

CONCLUDING REMARKS

The problem of economies of scale and size of plants is too complicated to allow of its presentation in a general formula. The data used in this article indicate only orders of magnitude and explain only some aspects of the whole problem. Increased effort would be required for assembling a systematic and coherent documentation on the cost of a large number of industrial products and on the variation of costs in relation to the size of plant, with special reference to savings in production costs arising from technical economies of scale and from facilities for economic overheads. The chief advantages of a large plant lie in specialization of work, integration of processes, continuous flow of materials, utilization of by-products and reduction in waste through mechanical handling. As noted before, several other advantages associated with and often attributed to large-scale production arise out of the facilities for economic overheads (which are generally commanded by large firms) and can be made available to small plants by appropriate institutional arrangements.

It should be emphasized that industrialization does not consist solely or chiefly in the creation of large-scale plants. First, as was mentioned earlier, the large part of technical economies of scale are obtained in many cases by a relatively modest size of plant. Secondly, the small size of the national market may justify small-scale production in many countries. Thirdly, abundance of cheap labour in developing countries may make employment of small-scale methods of production profitable in several industries with relatively labour-intensive production processes. Fourthly, local availability of raw materials and the conditions of infrastructure, such as water and power supply and housing, may also justify the installation of small plants. Finally, the small scale of plant often reduces the risk arising out of obsolescence due to technical progress or change of tastes and business fluctuations.

Decisions as to the scale of industries or plants thus depend on a number of technological, economic, social and political factors, such as the supply of inputs, geographical distribution of markets, distribution cost, anticipated pattern of growth of the industry, government policy and measures, and so on. In other words, the decision of scale coincides not only with the firm's interest but also with the regional and national plan.

Appendix

Table 1

Production cost of ammonium nitrate for different scales of production, United States
(1957 United States dollars per short ton of ammonia content)

Components of cost	*Scale of capacity in short tons per day*			
	50	*100*	*150*	*300*
Raw materials and supplies	27.0	27.0	27.0	27.0
Labour	46.0	28.8	23.0	17.2
Cost relating to capital	117.4	89.3	75.6	57.3
Total	190.4	145.1	125.6	101.5

Source: "Problems of Size of Plant in Industry in Under-developed Countries", *Industrialization and Productivity Bulletin*, No. 2, page 12.

Table II

PRODUCTION COST OF BEER BOTTLES FOR DIFFERENT SCALES OF PRODUCTION, UNITED STATES
(1957 United States dollars, per gross, packed)

Components of cost	*Number of bottle-moulding machines* 1	2	4	6	12
Raw materials	2.40	2.40	2.40	2.40	2.40
Labour	3.09	2.31	1.93	1.80	1.67
Cost relating to capital	3.02	2.54	2.13	1.93	1.62
TOTAL	8.51	7.25	6.46	6.13	5.69

Source: See source for table I, page 13.

Table III

PRODUCTION COST OF RADIAL BALL-BEARINGS[a] FOR DIFFERENT SCALES OF PRODUCTION, JAPAN
(Yen per thousand units)

Components of cost	*Scale of production*		
	Present production level	*Double scale*	*Four-times scale*
Raw materials	44,600	41,200	39,200
Labour	17,700	10,400	8,600
Supplies from outside	8,100	5,000	4,700
Taxation	300	800	800
Depreciation	3,200	4,900	5,100
Power	1,100	1,200	1,200
Others	4,700	3,600	3,600
TOTAL	79,800	67,000	63,100

Source: Japan Productivity Center, *A Study on the Size of Firms* (Tokyo, 1961) (mimeographed).
[a] Size of bearing being between 10 and 20 millimetres.

Table IV

PRODUCTION COST OF TAPER ROLLER-BEARINGS[a] FOR DIFFERENT SCALES OF PRODUCTION, JAPAN
(Yen per thousand units)

Components of cost	*Scale of production*	
	Present production level	*Double scale*
Raw materials	165,800	149,000
Labour	57,000	41,600
Sub-contract	26,900	16,900
Depreciation	12,600	16,000
Taxation	1,100	2,100
Power	4,600	5,100
Others	12,300	11,200
TOTAL	280,300	241,900

Source: See source for table III.
[a] Size of bearing being between 20 and 50 millimetres.

Table V

PRODUCTION COST OF TAR FOR DIFFERENT SCALES OF PRODUCTION, JAPAN
(Yen per metric ton)

Components of cost	*Scale of production (Metric tons per day)* 100	200	300	400
Raw materials	6,500	6,500	6,500	6,500
Auxiliary sector	1,328	1,195	1,072	955
Labour	473	300	242	205
Equipment	1,053	841	734	673
Administration	1,300	953	809	736
By-product and others	(—)150	(—)150	(—)150	(—)150
TOTAL	10,504	9,639	9,207	8,919

Source: See source for table III.

Table VI

PRODUCTION COST OF BENZOL FOR DIFFERENT SCALES OF PRODUCTION, JAPAN
(Yen per metric ton)

Components of cost	*Scale of production* 50	100 (*Metric tons per day*)	200	300
Raw materials	20,725	20,725	20,725	20,725
Auxiliary sector	2,904	2,519	2,464	2,437
Labour	655	400	264	218
Equipment	3,659	2,854	2,280	1,991
Administration	1,610	1,194	1,766	623
Others	(—)357	(—)597	(—)597	(—)597
TOTAL	29,196	27,095	25,902	25,397

Source: See source for table III.

Table VII

PRODUCTION COST OF CEMENT FOR DIFFERENT SCALES OF PRODUCTION

Input and investment per thousand tons	*Capacity of plant* 35	50	100	230 (*Thousands of metric tons*)	450	900	1,800
Labour input (man-years)	1.43	1.20	1.00	0.80	0.75	0.65	0.50
Capital investment (thousands of United States dollars)	50	46	43	40	35	23	22
Cost per ton (United States dollars)							
Operating cost[a]	16.2	15.5	15.2	14.7	11.0	9.4	8.4
Capital charges[b]	12.5	11.5	10.8	10.0	8.8	7.0	5.5
TOTAL cost	28.7	27.0	26.0	24.7	19.8	16.4	13.9

Source: United Nations Economic Commission for Asia and the Far East, *Formulating Industrial Development Programmes* (Sales No.: 61.II.F.7), page 46.

[a] Raw materials inputs are assumed to be constant. Fuel and power decrease with scale.

[b] Charges for depreciation and returns to capital are calculated at 25 per cent of capital stock.

Note: Estimates are based on United States International Cooperation Administration publications and Soviet Union programming norms. Similar data can be obtained from the United Nations publication, *Cement—Nitrogenous Fertilizers based on Natural Gas* (Sales No.: 63.II.B.3).

Table VIII

PRODUCTION COST OF FINISHED STEEL FOR DIFFERENT SCALES OF PRODUCTION, LATIN AMERICA
(1948 United States dollars)

Components of cost per ton[a]	*Capacity of plant* 50	250 (*Thousands of metric tons per year*)	500	1,000
Raw materials	33.84	31.26	31.26	25.68
Labour	32.00	15.20	8.57	6.60
Capital charges	122.93	101.20	87.10	85.05
Maintenance and miscellaneous	20.59	11.11	10.57	9.83
TOTAL cost	209.36	158.77	137.50	127.16
TOTAL investment per ton	492	405	348	340

Source: United Nations Economic Commission for Asia and the Far East, *Formulating Industrial Development Programmes*, page 44.

[a] The costs are taken from engineering calculations for hypothetical integrated plants of different sizes located in the eastern part of the United States. Labour costs are taken here at 50 per cent of the United States costs and charges for depreciation and profit at 25 per cent of the capital invested to reflect Latin American conditions.

Table IX

PRODUCTION COST OF ALUMINIUM PLATE FOR DIFFERENT SCALES OF PRODUCTION, JAPAN
(Yen per ton)

Components of cost	*Scale of production* 50	200	1,200 (*Metric tons per year*)	3,000	5,000
Raw materials	230,220	225,300	229,220	223,880	223,120
Labour	20,940	16,050	10,120	6,730	5,250
Power	12,400	11,800	9,590	9,160	8,770
Depreciation	7,880	14,150	12,800	18,780	16,380
Others	7,350	8,780	11,040	10,560	9,610
TOTAL	278,790	276,080	272,770	269,110	263,530

Source: See source for table III.

Aspects of the Design of Machinery Production During Economic Development

By SEYMOUR MELMAN

IN THE DEVELOPED countries, machinery production has characteristically taken place in industries that are grouped by product lines. Printing machinery, paper-making machinery and machine tools, for example, are produced in factories that are separately organized and located. This grouping of production has come about as a result of the early growth pattern of these machinery-producing industries, which were set up in connexion with the using industries they serve.

Under modern conditions, it is evident that many classes of machinery can be most efficiently produced on the same premises, which permits integration in the design of products and the fabrication of components that go through similar operations. In the important machine tool field, for example, integrated design and production of the mechanical and control elements of fabricating machinery afford major advantages.

The purpose of this article is to call attention to a series of factors which should facilitate the design of new machinery-producing industries in developing areas by taking advantage of up-to-date developments in production engineering and engineering economy.

BEGINNINGS OF MACHINERY PRODUCTION

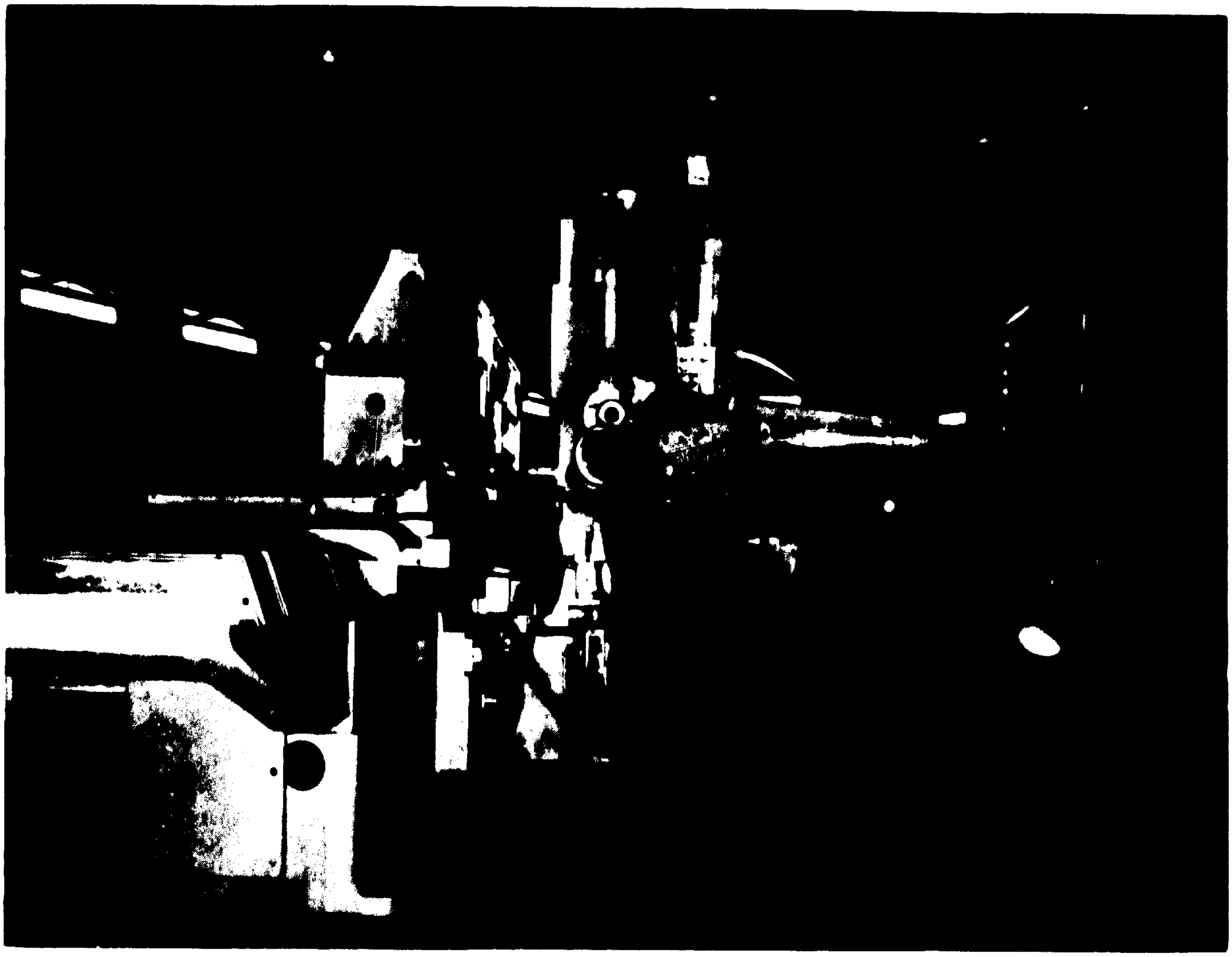
THE MANUFACTURE OF machinery in developing countries usually starts with the production of replacement parts for widely used classes of machinery—such as trucks, tractor cars, buses and agricultural machinery. Even at this early stage of machinery production, it is possible to ensure efficiency of operation and to prepare the way for optimal conditions under which large-scale manufacture can be undertaken at a later stage.

A characteristic circumstance in developing countries is the early proliferation of vehicle types. In the smallest countries, one finds representative products from almost every motor vehicle factory in the world. This situation automatically imposes not only high prices for initial purchases, but also high costs for replacement parts and excessive down-time for repairs because of the unavailability of parts when needed. A large saving could be effected by limiting the variety of brands and classes of vehicles which enter a developing country.[1] This would mean a reduction in unit prices and in the cost of vehicle maintenance, and would achieve a considerable saving in foreign exchange. Concomitantly, there would be a substantially enlarged market for replacement vehicle components, since reduced variety in vehicle types makes possible greater standardization in the replacement parts field and this, in turn, opens up opportunities for quantity production of spare parts. In this case, and in others to be discussed, standardization signifies systematic variety, not uniformity.

In terms of geographic size and population, it goes without saying that the larger the area over which given standards prevail, the larger will be the potential market to be served in the replacement field. It is not implied that the requirement here is to overstep political boundaries; nevertheless, it may make a difference if the organizers of economic development from the outset keep

MR. MELMAN, *professor of industrial engineering at Columbia University, New York, has acted as a consultant to governments and industry on problems of industrial productivity. He participated in the meeting of an Expert Working Group on Industrial Development Programming Data, held at United Nations Head quarters in May 1961, and was a member of the Advisory Committee of Experts on the Industrial Development Activities of the United Nations System, which met at Headquarters in March 1963. His article is a revised edition of a paper which he submitted to the United Nations Seminar on Industrial Development Programming in the Latin American Region, held in São Paulo, Brazil, in March 1963.*

[1] An analysis of this problem, with special reference to Venezuela, has been made by Mr. Frank Senior in a paper entitled *Alternatives for Organizing a Motor Vehicle Industry During Industrialization* (Engineering Library, Columbia University, New York), 63 pages.



Jig-mill automatically boring a gear-case cover under the direction of a three-axis numerical tape control. The machine works to an accuracy of 0.0001 inch with average time savings of 25 to 75 per cent over conventional boring methods, depending on particular job

in view the considerable economic gains to be derived from following up these considerations.

Similar criteria can be applied to a range of allied machinery products, like agricultural machinery, electrical machinery, and the various types of equipment used for public utilities. In each of these branches, there are advantages to be gained from early attention to the possibilities of standardization.

ORGANIZATION OF MACHINERY PRODUCTION

Countries entering upon industrialism in the middle of the twentieth century should be able to take advantage of opportunities in the organization of their machinery-producing industries that did not exist one hundred years ago. A survey of many classes of machinery discloses that component parts tend to be produced by common manufacturing processes. This entails the possibility of using—for manufacturing a wide variety of machine elements—factories already equipped to handle the main metal-fabricating processes. In so doing, developmental research and functional design would be separately pursued for particular classes of machinery and would be specialized according to the end-use of machinery products, that is, with separate sections for laundry machines, for food-processing machines, and so on. Similarly, the assembly operations for classes of machinery would be specialized. Marketing and maintenance would also have to be treated separately.

Using common manufacturing facilities to produce machinery creates possibilities for high-capacity, stable operation of such industrial plants—thereby at minimum cost. Where high-capacity utilization can be anticipated, this will make economic more mechanized forms of equipment for particular unit operations.

Integrated production of machinery components alters the condition under which manufacturing facilities must be restricted by the marketing estimate for a particular class of machinery products. Instead, the market is broadened to include servicing a range of machinery products which enter diverse fields. This has the immediate effect of minimizing the risk that may be incurred owing to incorrect market forecasting in any particular machinery area. The cumulative error in market forecasting is bound to be smaller than the largest error in any one of the component machinery classes serviced by common manufacturing facilities.

Integrated machinery production also makes possible the effective use of production and design engineering skills, for the employment of highly paid technical talent is justified by the range of products to which the technique can be applied.

The necessarily larger size of integrated manufacturing facilities compared with that of individual plants operated on the traditional pattern also permits a fresh approach to the important problem of training industrial workers and technicians. Occupational training for workers and technicians must be regarded as a capital outlay during industrialization. The larger the plant, the greater is the opportunity for utilizing the services of specially skilled training technicians, and for providing a variety of auxiliary aids to accelerate technical training.

Furthermore, integrated manufacturing facilities of this sort will be in a favourable position to increase the productivity of their own operations by taking advantage of new manufacturing equipment and production engineering techniques.

Special attention may be called to the fact that this form of machinery manufacturing organization is facilitated by newer developments in the design of basic metal-working machines. In the machine tool field, the most important development is probably that involving the numerical control of machine tools by electronic equipment, which takes the place of human machine operators. This development has brought about a further opportunity for the use of general-purpose machine tools. The latter can now be utilized with an intensity heretofore reserved for specialized machine tools having a limited range of capability. For example, manufacturing experience indicates that in a general-purpose machine shop, the characteristic metal-working machines tend to be utilized about 20 per cent of the available working time because of the time required by a human operator to manipulate a machine, change tools, and change the position of the work-piece. With numerically controlled equipment it has been possible to sustain metal removal for 85 per cent of the available working time, while a wide variety of operations are performed that require extensive changes in tools and repositioning of the work-piece. Automatic control of both tools and work-piece makes this possible. Such high-capacity utilization of general-purpose machine tools suggests the importance of examining this class of numerically controlled equipment as one of the classes of machines eligible for use in integrated manufacturing facilities. There are, of course, attendant problems, such as providing for the adequate maintenance of intricate types of production equipment. This, however, is mitigated by the opportunity to make use of a considerable number of such machines. When that stage is reached, it then becomes economic to train specialized maintenance personnel.

The availability of an integrated fabricating system for machinery components will undoubtedly affect the design of machines: for example, in pressure towards the restriction of unnecessary variety where standardized components are functionally adequate. In the assembly function, it may be expected that highly specialized personnel could be employed to assure reliable performance and a satisfactory finished product.

The integrated approach to machinery production opens up new possibilities for the developing countries. Rather than a multiplicity of functionally disparate machinery-producing units, a combined effort based on the conception of integration affords greater strength to such a beginning industry. This should lead to early attainment of a tradition of reliability of machinery product under conditions of acceptable productivity, cost and price. The reasoning that favours an integrated manufacturing complex for varied machinery production does not exclude the use of limited-purpose equipment for large quantity manufacture of particular machines or components. The usefulness of this mode of operation is entirely a function of the cost-quantity conditions in the particular situation.

STRATEGIC ASPECTS OF MACHINERY PRODUCTION

In the tradition of western industrialism, machinery production has been mainly organized on a small quantity basis, with notable exceptions as in some heavy earth-moving equipment, small electric motors, and motor vehicles. The fact that unstable production rates are characteristic of small quantity production has detracted attention from the conditions under which optimum production may be attained.

Many machinery-producing industries in the West have relied upon the accumulated knowledge of science and technology, without formally establishing research and development departments to keep up with technological advances. Skilled and talented draftsmen and others innovated changes in design which were incorporated in a firm's products. Enterprises also leaned heavily on the general community of "inventors" for innovation in their product fields. While there is much to be said for a dispersed innovating movement, this means of developing new technology, under modern conditions, is no match for institutional research and development groups which can bring new benefits of science and technology to bear on a firm's products. Modern experience in applied science underscores the productive value of research and development—especially that carried on in technological institutes—with respect to the manufacture of machinery. The integrated machinery production complex is far better equipped than any of the classically organized machinery-producing industries to sponsor this activity, since, by the size of its capital investment and the range of its interest over a gamut of machinery manufacture, it is in the most advantageous position to utilize the diverse results of formal research and development organizations.

It is hardly possible to overstate the importance of standardization as a thoroughgoing technique to be applied even at the very early stages of machinery manufacture. Standardization, again, does not mean uniformity, or all-of-one-kind. Standardization means the systematization of variety in particular characteristics. The evidence available from the analysis of about twenty machinery-producing industries in the United States and western Europe is that major economies in production costs are made possible by the standardization of component elements in machinery construction. Standardization of components begins with the use of an ordered range of sizes for elements like electric motors, ball and roller bearings, gears and the like. The standardized elements are prepared in series of sizes agreed upon by design and manufacturing engineers so as to minimize the range of products that may be constructed from them. Thereafter, design engineers are required to make maximum use of the standardized range of components in their own work.

One of the crucial aspects of standardization is how to organize efficiently the formulation of standards programmes and their subsequent acceptance. Standardization negotiations are apt to drag on for many years. This is the inevitable result of conflicting traditions and of the effort of various groups to defend their own pattern of operation as the "one best way". It is essential and possible to break out of deadlocks of this sort by establishing impartial boards for the review of standards recommendations on the basis of formally specified criteria. It should be possible to estimate both the advantages and disadvantages to various participants that would ensue from standardization of particular elements and, on the basis of such estimates, for an impartial board to make a final determination. A standardization programme must be made a workable one, which in turn requires that standards be determined expeditiously. Where five years of negotiation are required to set a standard, the whole activity is frustrated. Five months would seem a reasonable outside limit for decision on formulated standards once there is agreement on the criteria which should determine preferred practice.

The same considerations which apply to standardization of component elements in machine manufacture apply to the principle of modular design of machinery sections. A "module" may be defined as a section of a machine which can be utilized in varied combinations with other machinery sections for the construction of diverse machine types.

In the machine tool field, for example, modules may consist of elements like power heads, tool holders, work positioning devices, major bases and slides, and control devices for positioning machine elements. Analysis has disclosed that where a family of machines is conceived as being composed of a set of integrated modules, then small quantity requirements for particular machines become transformed into large quantity requirements for the modules which comprise them.

The modular approach to machine design has an important bearing on "special *v.* general-purpose" machines. The ability to utilize standardized modules even for machines that have a limited range of application alters the "special" character of the particular equipment. Where the unique features of a machine constitute a minor proportion of its components, a new conception is opened up, both in design and construction of special, limited-purpose machines.

Machines can be rationally designed for capability according to the functional requirements of users. Recent studies at the machine tool laboratory of the Technische Hochschule at Aachen, West Germany, have disclosed that entire classes of machine tools have been regularly constructed with a range of work capability (like sizes of work-pieces) far in excess of user requirements. Thus, when it is determined that 80 per cent of the work done on a particular class of lathes requires only two feet of space for the length of the work-piece, there is clearly little point in constructing the same class of machines with a six-foot bed so as to accommodate, in each instance, the maximum conceivable size of work piece. By shortening the bed for most machines, major economies are scored in construction, with important effect on price to the users.

Frequently the managements of machinery-producing enterprises have failed to make use of appropriate methods for determining the economically preferred technique in their own production operations. Although cost-estimating techniques are widely available, they are restricted in application, since managements prefer to rely on their own ability to forecast their markets and thus the degree of utilization of their manufacturing equipment. From this standpoint, the integrated manufacturing facility should be better able to make reasonable forecasts of activity and hence of economically preferred operating methods.

ECONOMIC CRITERIA FOR DESIGN OF PRODUCTION FACILITIES

A CHARACTERISTIC FEATURE of industrial technologies is that they provide an array of alternative methods for doing given work in virtually every type of industrial operation. In addition to alternative methods of work, there is a varying proportional mix of labour and machinery.[2] Consequently, the problem of the design of industrial operations is the systematic selection from among an available array of alternative methods, capital intensities and costs.

In the mechanical manufacturing industries, the critical alternative input factors are labour as against machinery. This means that for given work, the array of alternative available technologies may be described in terms of different proportional combinations of these two factors. In the processing industries (including steam power plants), however, the major alternative factors for design of production operations have been recently defined as raw materials costs as against machinery costs.[3]

Within certain countries, each of these classes of industries has been characterized by the more rapid rise in the cost per unit of labour (or fuel) compared to machinery. In the United States, for example, the cost of man-hours of work to management, has, during the twentieth century, persistently increased at a more rapid rate than the prices of various classes of machinery.[4] Thus, in 1940 industrial management in the United States could purchase 0.93 hours of work by a fork-lift truck for the price of an average hour of industrial labour. By 1950, owing to the more rapid rise in the wages of workers as compared to the prices of materials handling and other machinery, the cost of a man-hour of work could be used to buy 1.74 machine hours, almost twice as many as in 1940. The same type of development was observed in the United Kingdom. In both cases, analysis showed that, as a result, managements were pressed to increase mechanization of operations in order to operate at minimum cost.

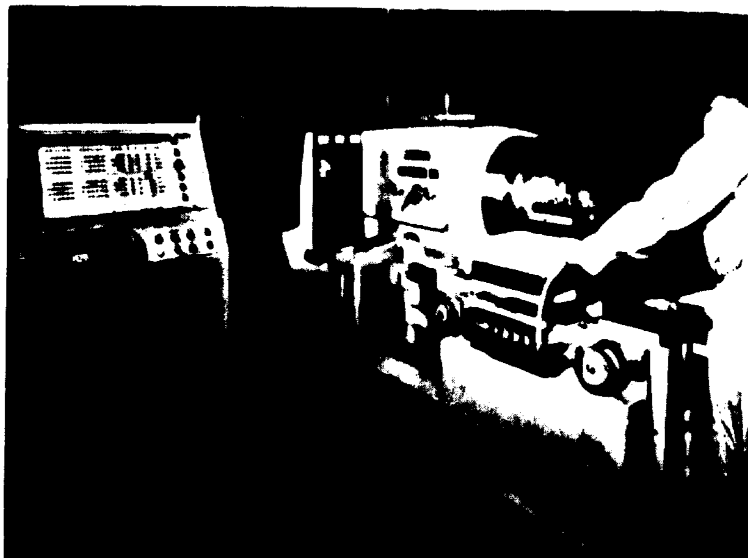
It is important to note that the same differences found ***through*** time within a country have been found at *single* ***times*** among countries. In 1950, for example, a man-hour of labour in the United States could purchase twice as many machine hours as a man-hour of labour in the United Kingdom. This difference in industrial cost factors was paralleled by major differences in mechanization.

In the field of process industries, parallel types of alternative cost development have been observed. Mr. George Watkins, in a study of central-station boilers in the United States and Europe, found similar increases in the relevant cost of fuel to machinery within the United States and within European countries. Furthermore, the international comparison of the relative cost of fuel to machinery showed a pattern similar to that of labour to machinery in the mechanical manufacturing industries.[5] Here again, the mechanization of operations was the result of the relatively lesser cost of machinery.

Other data—contained in a range of studies on many manufacturing operations, including international comparisons of the costs of labour and electric power and alternative cost analyses specifically oriented to problems of countries undergoing industrialization—tend to support these general hypotheses on the effect of relative costs of labour (or fuel) to machinery as controlling elements in the mechanization of production.

During the past ten years, graduate students who have studied industrial economics with this writer have prepared, as a regular exercise in their course, independent analyses of alternative costs in industrial operations of their own choice. Altogether, about one hundred such detailed analyses are available for a variety of industrial operations in many industries. These analyses, based on data compiled from many sources, confirm the general relationship of the growth in the cost of labour (or fuel) as against that of machinery. Certain of these data have been published in the *Journal of Industrial Economics*.[6]

Another indicator of the growth in the cost of labour units *versus* machinery is found in the trend of the hourly cost to industrial management of labour in relation to electric power. In the United States, over the last half-century, the average cost of a kilowatt-hour of elec-



Numerically controlled engine lathe turns, faces and bores a 250-pound cast-iron housing in a single fully automatic cycle. Punched tape is used to programme eighteen speed changes, the indexing of a four-position turret, and all feed changes and cross-slide motions

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[2] S. Melman, *Dynamic Factors in Industrial Productivity* (Oxford, Basil Blackwell, 1956), chapter 1.

[3] G. Watkins, *Cost Determinants of Process Plant Design*, doctoral dissertation (Columbia University, New York, 1957).

[4] S. Melman, op. cit., chapter 19.

[5] G. Watkins, op. cit., chapters 7 and 10.

[6] S. Melman, A. Calderaro, and J. Suridis, "Selected Studies in Alternative Manpower Costs", *Journal of Industrial Economics*, vol. 5, No. 3, July 1957, pages 225 ff.

tricity to industrial users has been remarkably stable, or declining. Indeed, from 1909 to 1950 the cost of electricity to industrial users declined in price (measured in current dollars) from 2.2 cents per kilowatt-hour in 1909 to 0.93 cents per kilowatt-hour by 1950. A similar development is observed in the United Kingdom from 1924 to 1950.[7] During the same period, the cost of labour to management increased several times over.

Again, international analysis discloses the same degree of contrast in the relative costs of labour and power as can be observed within a given country over a long period of time. Thus, in selected countries in recent years, the following numbers of kilowatt-hours could be purchased at the cost to industrial management of a man-hour of labour:

United States	157.5 (1950)
Sweden	116.0 (1949)
United Kingdom	35.6 (1950)
USSR	15.8 (1948)

These large differences in the relative costs of labour and electric power appear to be important indicators of the variation in mechanization, and hence, of productivity, among countries.[8]

A more recent view of these relative costs is found in data developed by this writer for the United Kingdom, the United States and Yugoslavia. This information is especially interesting because it is possible to parallel the relative costs of labour and electric power with measurements of the productivity of labour in similar operations. For 1954, this writer developed an analysis of labour productivity in the assembly of agricultural tractors in Detroit and Coventry, England. Early in 1960, similar operations were observed in Belgrade, Yugoslavia.

In 1954, industrial management in Detroit could buy about 200 kilowatt-hours of electricity at the price of an hour of labour. In the United Kingdom, this figure was ninety at that time. In 1960, the Yugoslav management could purchase nine kilowatt-hours of electricity at the cost of an hour of labour. Clearly, in the case of Yugoslavia, the wages of workers relative to the cost of electric power were drastically lower than the levels obtaining in the United States or the United Kingdom.

Among factories in these countries doing the work of assembling tractors of similar design, the differences in labour productivity paralleled the differences in alternative cost. Taking the output per man-hour of work in the Detroit factory in 1954 as 100, productivity in the British factory in the same year was 85, while productivity in the Yugoslav factory in 1960 was between 25 and 35 per cent of the Detroit level.

This writer had the opportunity of examining production operations in each of these plants. There is no question but that the mechanization of operations was most intensive in the Detroit factory, closely followed by the factory doing comparable work in Coventry, England. The contrast between the Belgrade factory and these two was indicated by the utilization of hand labour for many assembly operations which were mechanized in the United States and British factories. Materials handling and finishing work of many kinds was done manually in the Belgrade factory. These differences, apart from factors of organization which of course contribute to variations in productivity, undoubtedly account for the greater part of the discrepancies in productivity level among these factories.[9]

In countries undergoing industrialization, these alternative cost factors are important determinants as to which of the array of technologies for doing given work is indeed the least cost method. Mr. Alberto Calderaro has made a detailed diagnosis of the cost of performing certain painting operations according to a set of alternative

Operator examines finished work-piece produced on engine lathe at left under fully automatic control of numerical sequence programmer. Separate electronic control cabinet and control panel of programmer may be seen at right, behind operator

methods in the United States and in Argentina. In each country, an examination was made of the effect on operating costs of three methods varying in degree of mechanization. The most highly mechanized method available was conclusively the cheapest one in the United States. At the same time, owing to the relatively higher

[7] S. Melman, op. cit., page 206.

[8] S. Melman, op. cit., chapter 16.

[9] It should be added that there are considerable differences in the quantity of output among these factories: thus, the output capacity of the Detroit and Coventry factories is about ten times that of the Belgrade plant. Nevertheless, this is another way of saying that if a plant in the United States or the United Kingdom attempted to produce tractors in as small a quantity as the Belgrade plant, it could not continue operation with the degree of mechanization used in the latter, for that would spell very high fixed charges per unit of product and, therefore, unacceptably high prices. Conversely, a high price would result in the United Kingdom and the United States if this work were done with a high labour component. In other words, the relatively high cost of labour compared to machinery in the United Kingdom and the United States presses for the mechanization of work and the utilization of large plants. Both these effects, for the time being at least, can be avoided in the case of Yugoslavia.

cost of machinery as compared to labour in Argentina, a less mechanized method was the cheapest one there. It was demonstrated, however, that in each country developments over time have again favoured the increased mechanization of work owing to the rise in the wages of labour relative to the prices of machinery.[10]

In all of the data reviewed here, one feature is consistent: workers' wages or raw materials prices have been driven upwards at a more rapid rate than machinery prices. The result has been that managers and engineers in industrial firms have been compelled to utilize more machinery input factors as a necessary step for countering the rise in the alternative labour or materials factors.

Therefore the average unit cost of product in many manufacturing industries has not risen at the same rate as labour costs. The rise in workers' wages has been absorbed in improved productivity of operations, which has been made possible by the increased intensity of mechanization.

[10] A. Calderaro, *Design of Industrial Plants in Countries Undergoing the Process of Industrialization*, Master's thesis (School of Engineering, Columbia University, New York, 1957).

THE COST OF LABOUR DURING INDUSTRIALIZATION

THE ANALYSIS OF alternative costs of labour compared to machinery, and their effect on mechanization, calls attention to the importance of wages as the crucial accelerating factor in the growth of the alternative cost ratio (L/M). For the selection of manufacturing equipment to be used in production, it is essential to have a basis for predicting the magnitude of labour *versus* machinery costs, in order to make a rational choice from among an array of alternative production methods.

The problems of forecasting labour costs (average hourly earnings of workers) are especially awkward. There is no general theory of wages which covers this. In industrialized countries it has been possible to view this matter empirically—estimating future wage costs by extrapolation based on the regular development of workers' wages in particular industries. Such extrapolation involves the assumption that the same set of factors which have been operative during the observation period will continue to determine wage levels during the forecast period. This is not an unreasonable assumption, taking for granted the continued existence of trade unions and the continued stability of economic institutions. But it is precisely the conditions prerequisite to a stable structure which are often lacking in the developing countries. Therefore the problems of forecasting workers' wages must be treated in a special way.

In 1956 Mr. Moshe Kelman completed a study on "The Behavior of Wages as an Industrial Cost in Countries Undergoing Industrial Development".[11] Mr. Kelman found that during the industrialization process wages follow a regular pattern as a function of degree of industrialization. His studies suggested strongly that the appropriate indicator of degree of industrialization is the number of kilowatt-hours produced per person per year in a country. This measures the amount of electric power used both for production and consumption. Analysis of economic development in India, Israel, Puerto Rico and the Soviet Union disclosed common features in the development of wages as a function of electric power produced per person. The relationship is illustrated in figure 1.

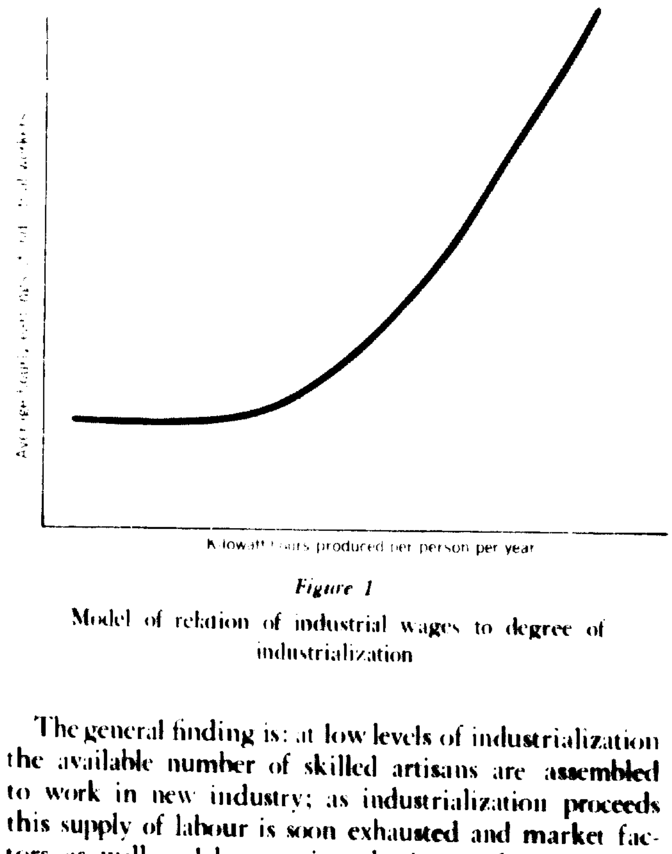

Figure 1

Model of relation of industrial wages to degree of industrialization

The general finding is: at low levels of industrialization the available number of skilled artisans are assembled to work in new industry; as industrialization proceeds this supply of labour is soon exhausted and market factors as well as labour unions begin to play a role in boosting the wages of workers; the wages of workers rise, at first slowly and then at an accelerating tempo, as the industrialization process proceeds. This mode of analysis is of special interest, for the output of electric power per person can be reasonably forecast since the production of electric power requires long-range planning of investment in large-scale facilities.[12]

Such methods for diagnosing the future costs of wages

[11] Doctoral dissertation (Columbia University, New York), 237 pages.

[12] In his study of the development of alternative costs in Argentina as contrasted with the United States, Mr. Calderaro (*see* foot note *10*) made use of this mode of analysis to good effect.

during economic development, while empirical, are nevertheless superior to guess-work. The Kelman method affords a means for avoiding the two principal sources of error in the design of industrial facilities during economic development: under-investment in mechanization by the purchase of ostensibly low-priced second-hand machinery; or over-investment in mechanization by the purchase of the "latest" equipment which is produced in industrialized countries, but which is unsuited to the cost conditions of early industrialization.

A forecast of workers' wages can therefore be used as a rational approach to the selection of production equipment. Figure 2 portrays this problem. If current wages are used as a basis for selecting preferred equipment, then the wages to be paid during the life of equipment tend to be underestimated, and this depresses the estimate of required intensity of mechanization. On the other hand, it is possible to estimate the growth of wages during the life of equipment. This generates a preference for a larger capital investment per worker and a higher intensity of mechanization, and safeguards the enterprise against finding itself operating with methods that have become high-cost within a few years owing to rising wage costs.

In developed countries the cost of training workers is not a major item of cost in the operation of an industrial enterprise. Workers come to the enterprise already schooled and reasonably well trained in the understanding of the physical relationships that underlie industrial work. In developing countries, however, the cost of training a work force must be taken into account as a *capital* item in the operation of an enterprise. The cost

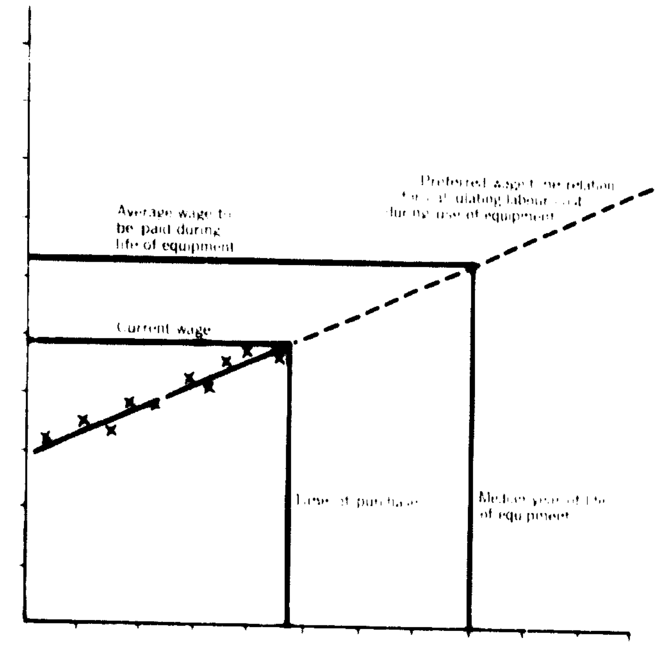

Figure 2

Model illustrating effect of using a future wage level for calculating justified intensity of capital investment, relative to labour cost to management. The forecast wage is based upon ten years of observations

of training a skilled worker, which is borne in an industrialized country by the society as a whole as a social cost, must, in the developing country, be borne by the single enterprise. In such a case, it therefore appears more reasonable to regard this sort of expenditure as a capital outlay rather than as an item of current labour expense.

PROBLEMS OF MACHINERY PRICES DURING INDUSTRIALIZATION

ALL OF THE reasoning reviewed above involves the assumption that workers' wages tend to rise more rapidly than prices of machinery, thereby creating a preference for increased intensity of mechanization. However, in developing countries machinery prices have sometimes increased more rapidly than wages. Where this situation has occurred, it has often been due to a sharp inflation of the domestic currency with the major result that machinery, when imported, has risen in price relatively to the wages of domestic labour. This development has a counter-productivity effect. It depresses the process which gives sustained importance to increased mechanization of work.

This consideration underscores the importance of the main proposals advanced in this article for the design of machinery production even in the early stages of economic development. By these means, developing countries can economize in the capital outlay for machinery, whether purchased abroad or produced at home. This restricts the depressing effect of domestic currency inflation on the cost of labour relative to that of machinery.

NATURE OF MASS PRODUCTION

FROM THE VERY outset it is important—and possible—for the designers of machinery production in developing countries to take advantage of the economies of mass production. The usual conception of the nature of mass production is that it involves large-quantity output of identical goods and utilizes specialized, limited-purpose equipment and methods. Manufacturing conditions in the industrialized countries demonstrate that this is a faulty conception. Indeed, in the classic demonstration of mass production—the automobile industry—there is great diversity of product characteristics even in particular plants, and relatively small-quantity output of individual unit products—identified by a special combination of engine, size, colours, number of doors, interior finish, transmission type and the like.

The essential characteristic of mass production is the stable operation of a production system. Mass production is a characteristic, not of the product, but rather of the production system, especially its mode of operation.

Stability in a production system still implies variation in the rate of output within acceptable and predictable limits. This does not impose a quantity requirement with respect to a unit product. Accordingly, it is not only conceivable but feasible to operate by mass production methods with lot sizes of one for the product. This is made practical by the sort of manufacturing equipment that is now increasingly available for metal-working—the numerically controlled equipment described above. The movement and selection of tools are controlled by information punched on tape. Highly varied work-pieces can be processed by such equipment under conditions of great stability of utilization.

Stability of operation of production facilities can be attained with any given set of operations or degree of mechanization of production equipment. Stability in a production system maximizes the productivity of manual work, for such work tends to be most efficiently performed at an even work pace. The same criterion applies to maximum productivity of machine work, for the operation of machines is optimized by stable utilization of the equipment. Thus, the quantity of fuel consumed by engines is minimized by stability of utilization of the engine. The length of life of steel rolls in rolling mills is maximized by a stable rate of utilization of these rolls. The length of life of furnace linings is extended by stable control of furnace heat. Stability in production maximizes the productivity of capital and of labour.

The enterprise operated under stable production conditions also realizes economies from minimization of the stock of materials required for a given output rate, and from minimization of scrap in the course of manufacturing operations.

* * *

This article has attempted to indicate the range of opportunities for maximizing productivity in machinery production which are within reach by countries undergoing economic development. The design of machinery production is a subject worth consideration owing to the accelerating effects on productivity in all other industries—and therefore on the entire process of economic development—which stem from the availability of good machinery at low prices. This condition is an incentive to the purchase and use of new manufacturing equipment throughout an industrial and agricultural system.

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Printed in U.S.A.
11479—December 1964—4,400

Price: $U.S. 0.75
(or equivalent in other currencies)

United Nations Publication
Sales No.: 64.II.B.6

74. 10. 10