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Athens, 29 November - 20 December 1967
Provisional agenda, Item 3(b)

PRINCIPLES AND MODELS OF INDUSTRIAL LOCATION

SUMMARY

Submitted by
The Government of the Union of Soviet Socialist Republics

* This is a summary of a paper issued under the same title, as document ID/CONF.1/G.38.

GE. 67-18882

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

1. The question of location of industrial enterprises in developing countries has been reviewed in several United Nations documents and at the United Nations Inter-regional Symposium on Industrial Project Evaluation.

2. The report ID/CONF.1/65 of which this is a summary reviews factors that should be taken into consideration in order to find the optimum variant of location for industrial enterprises.

3. The problem of optimization is a complicated one and concerns industry, transportation and practically all branches of the national economy. The report, however, deals only with the problem of location of industrial enterprises for selected branches of industry.

4. One of the important criteria to be considered in the calculation of optimum variant of location is profit. If the goal is to gain maximum profit, it should only be calculated after all proper conditions for operation are fulfilled. The criteria of maximum profit is appropriate in those cases in which future prices can be forecast more exactly than can future needs.

5. Another method for industrial location planning is based on the criterion of minimum expenses for production of a particular product. This method should be used when the forecast of future prices is less dependable than the forecast for need, or when the need for goods should be satisfied unconditionally.

6. The coefficient of effectiveness of the criteria of optimization is considered in the report. This coefficient should be calculated integrally, i.e. for the whole period of planning.

7. The report discusses a number of limitations which influence the expediency of various variants in the development plans.

8. Calculation difficulties as well as a lack of basic information and experience in calculating variants of industrial locations call for the use of a simplified system when plans are carried out.

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9. To compare basic techno-economic information related to various years of development, another coefficient can be used that is called "norm of efficacy". Various formulas in the report illustrate how this coefficient is calculated.

10. A model of a problem illustrates optimum perspective planning for development and location of a specific branch of industry. Basic assumptions are suggested and necessary mathematical apparatus is given.

11. In the Union of Soviet Socialist Republics the work on optimization of development and location plans for various branches of the State economy, especially certain branches of industry, is one of the basic subjects for research and practice in planning the State economy. There are many studies made on this subject as well as many studies on calculation methods and techniques. Many practical problems have been solved successfully. Starting in 1966, calculations for optimization of development and location plans have been made for more than twenty industrial branches of the USSR, using capital investments amounting to more than half of all USSR capital investments in this field. The calculations for optimization are used not only for the plans for development and location of industrial branches, but also for development of economic regions and complexes, especially in newly developed industrial regions of the USSR.

12. Besides dealing with industrial complexes, many studies and experimental work are undertaken in connexion with the optimization of the plans for development and location on a state-wide scale: that is, for the whole economy and industry of the Soviet Union.

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ID/CONF. 1/G.38

USSR ACADEMY OF SCIENCES

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PRINCIPLES AND MODELS FOR THE LOCATION OF INDUSTRY

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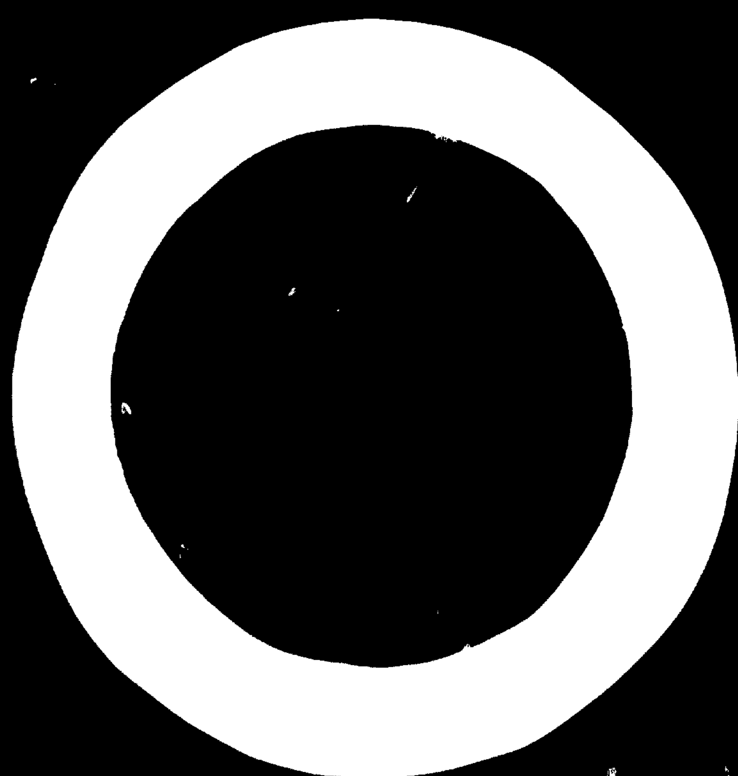
MOSCOW 1967



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PRINCIPLES AND MODELS FOR THE LOCATION OF INDUSTRY

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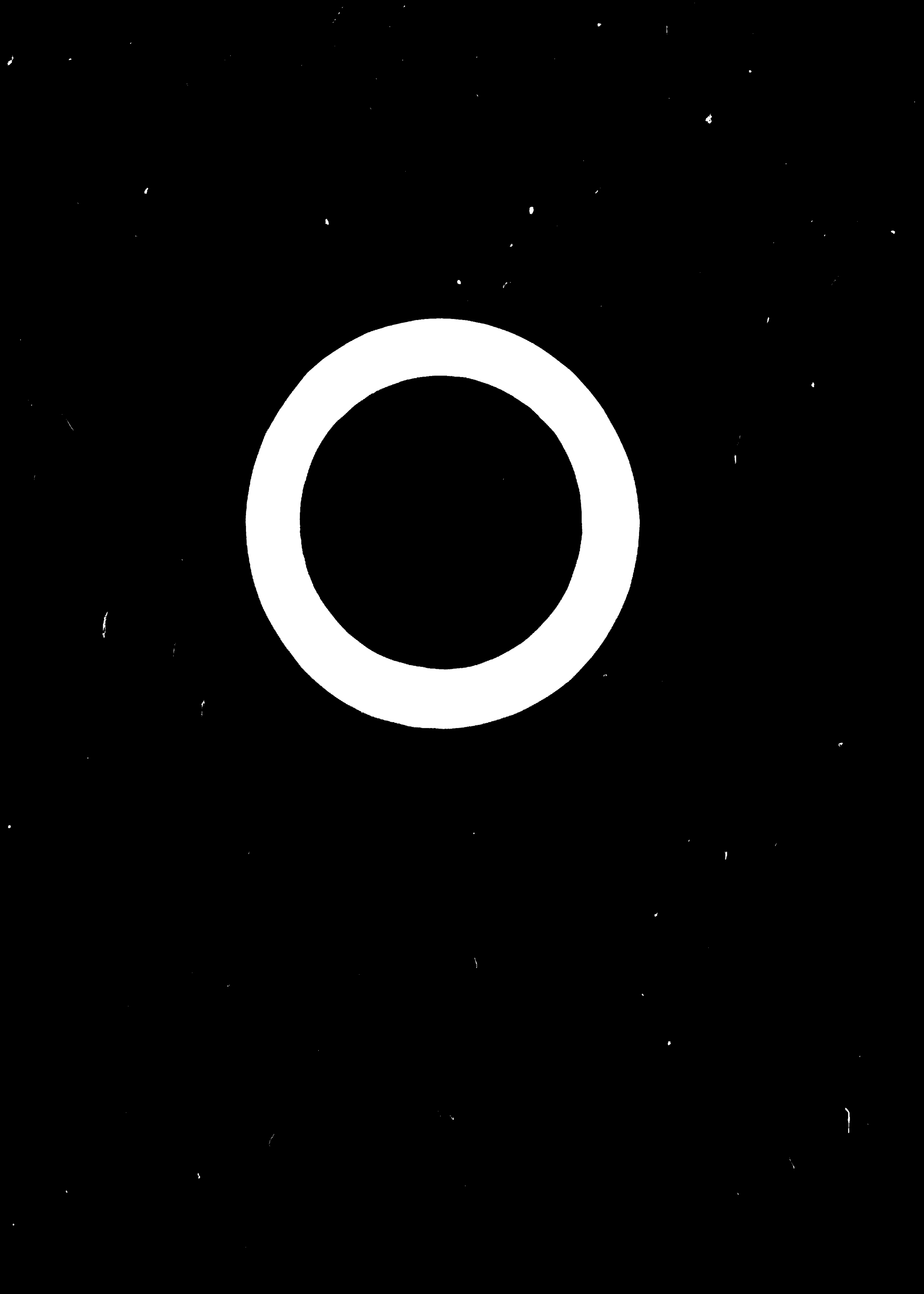

(f) the considerable share of imported components in the cost of production of many goods;

(g) the possibility of undertaking simultaneous construction of a limited number only of new enterprises, and the fact that there are few regions and places where these can reasonably be located.

2. In these circumstances it would seem practicable in some cases to pose the problem of optimal economic development as a complex one in time and space either of the economy of the country as a whole or of its complexes, where they are large enough, taken either on a territorial or on an industrial basis. Both the national economy and its larger links are usually a complex embracing the production and consumption of many products, a transport system, etc. When the economy is considered as a whole, however, the choice of criteria of optimum development is complicated. The present paper examines only local optimization problems, i.e. those of the development and location of the various separate units. For uniformity of description any of these units will be referred to as an "optimised system", or simply as a "system".

3. Work on optimal planning of the development and location of any economic system is carried out in stages, as follows:

(a) a criterion of the optimum is established to enable the effectiveness of different development variants of the system to be evaluated and compared;

(b) the conditions and interconnections for practicable functioning of the whole system under review, and its individual components, are formulated; these conditions and interconnections are described in the form of a mathematical economic model, allowing variants of the system as a whole to be constructed on the basis of the given set of the possible development variants of the individual components;

(c) the initial information determining the numerical magnitudes of the parameters for the model and of the criterion of optimal development is compiled or worked out;

(d) the extremum problems arising, of finding the best variant for the development of the system, are solved either by simple comparison of variants, if their number is small, or (when planning large and complex systems) by utilising mathematical programming and an electronic computer. The solutions obtained are tested and corrected by modifying the initial data and by using the methods of econometric analysis.

4. We shall first consider the problem of the criterion of optimal development.

The most general synthetic index of the effectiveness of the variants of the functioning of the local system being examined is obviously the profit, measured as the difference between the income from sale of the goods produced and the outlay on their production.

When maximum profit is sought, the optimal variant for the development and location of a branch of industry is taken as that variant of the construction of new production units, and extension or modernization of existing ones, of choice of volume and mix of output produced and sold and of technological production processes used, as well as of organization of transport between units and of utilization of the products by individual units (including ultimate consumers), in which the required operating conditions of the industry are maintained throughout the planning period and in which the profit from the output and its realisation is maximum.

Reference to profit allows any versions of activity to be compared, including those that differ in volume and dynamics of output. In the special case, of an equal volume of output, and consequently of an equal income from sales, the efficiency of the variants being compared is evaluated according to the outlay involved.

Where minimum outlay is postulated the dynamics of the general development of the optimized system (e.g., the dynamics and territorial distribution of final consumption of its products) are taken as known for the planning period. The optimal plan of development is then considered to be that plan (as above but given interchangeability of products) in which the required development of the system (e.g., full satisfaction of the final consumers at any moment during the planning period) and maintenance of all other postulated operating conditions are ensured, and in which outlay on the production, transport, and utilization of the product is minimal.

These criteria may be modified for the special conditions of developing countries, primarily to take account of the lack of foreign exchange for the needs of national development and the necessity of increasing employment.

Thus, where a significant share of the goods produced by the optimized system is meant for export in order to increase the country's receipt of exchange, a criterion of maximum foreign exchange profit may be postulated as the aim of optimal development of the system.

Since unskilled workers are paid in the national currency, such a modification of the criterion in some measure favours the use of technological processes promoting employment of the local population.

A more detailed description of the various forms of criteria is given in reference (1).

5. It is advisable to postulate maxi-

mum profit (or foreign exchange profit) as a target primarily in cases where the forecasting of market prices is more reliable than the forecasting of levels of demand. We may take two main cases of this type, as follows.

(a) the product supplied by the optimized system is in great demand on the home and foreign markets, but the foreign exchange or other resources allocated for development of the system are inadequate to raise output to the level at which the needs of all prospective consumers are completely satisfied. This failure to expand the production of the optimised system will either hold back development of the country's exports or of other branches of its economy, compel it to consume other more expensive goods or commodities in short supply, or, finally, will not allow it to make full use of certain potential opportunities (such as raising yields by increasing the use of mineral fertilisers, for example). In this situation the problem arises of the selection of the range of goods to be produced by the system, as well as of consumer choice and the extent to which demand is to be met.

(b) the final product of the optimized system is in the form of consumer goods that have a very elastic demand - the demand for a certain product, for example, rises significantly with a reduction of its selling price. Thus the possibility must be considered not only of a functional relation between the selling price of a commodity and the corresponding demand for it, but also between the selling prices of similar, interchangeable products and the total demand for all these commodities, etc.

Postulation of minimum outlay as the criterion for optimal development and location is advisable when studying systems producing a commodity with a very inelastic demand, this demand being liable to unconditional satisfactions and also where the selling prices of the output of the system are not known or are not considered as sufficiently reliable (are less reliable than forecasts of demand).

6. The indices of effectiveness (or coefficients of the criterion of optimal development) must be computed integrally, i.e. for the whole period that decisions relating to the activity of individual industrial units (objects) are operative.

This period, which we will provisionally call the account period, includes both the period of construction and exploitation of the object.

7. The optimal variant is selected from the feasible versions, i.e. those that comply with the limits established for the system for the utilization of scarce resources, such as raw materials and semi-finished goods, certain types of equipment, natural and labour resources, foreign exchange, etc. The postulate of minimum outlay also requires restrictions on the production of industries subject to unconditional satisfaction. The period for which these restrictions are in force, we will refer to as the planning period. Its length is usually recommended at ten to 15 years.

8. The system of restrictions determining the acceptability of the development plan variants being considered must include the following:

(a) the initial state of the system (the production capacity of existing enterprises, the existing infra-structure, etc.);

(b) the rates of expenditure of raw materials, fuel, and other materials, equipment, skilled and unskilled labour, and of other resources, by the technology actually, in use and anticipated, in production;

(c) the existence, or possibility of obtaining, scarce resources, including skilled labour and foreign exchange;

(d) the character of the inner connections of the system;

(e) the conditions for transport of raw materials and semi-finished and finished goods;

(f) the conditions of sale of products (their interchangeability, the size of the foreign and home markets at various price levels and of the demand for products that is to be unconditionally satisfied, etc.).

Limitations are established both for the separate years of the planning period and for the period as a whole.

9. With a dynamic formulation of the problem, the validity of the plan is checked for several selected moments of time (years) during the planning period;

the optimal variant is adopted according to the complete, integral effect for the account period. In addition to the relations between the different units of the system, attention is also paid to the relations between the different successive states of the same unit.

10. The data-collecting and computing difficulties linked with a dynamic postulate, the determining of the length of the account period, and the calculation of the effect of the plan during this period make it necessary to simplify the formulation of the practical problems. The following simplifications are those most commonly used:

(a) a static formulation in which the state of the system is considered for the conditions of a certain fixed year and can be taken as constant in time. The mutually independent solutions of a number of static problems for several moments of time serve as a method of approximate representation of the dynamic development of the system. Such a solution can be considered satisfactory if the optimal variants obtained are not contradictory. Where they are contradictory the means to eliminate the contradictions depends on their nature and importance. With really significant contradictions, it is necessary to formulate and solve a dynamic problem - either for that part of the optimized system where contradictory solutions have been obtained, provided it can be isolated or alternatively for the system as a whole;

(b) the substitution of annual indices for the integral indices in the static formulation of the problem. The annual indices are either those for the account year, or for an intermediate year considered typical for the period under review; weighted mean values calculated from the anticipated dynamic of volumes and prices. The use of weighted mean indices is preferable when the economic parameters and volume of activity of the unit are subject to significant annual changes. They may be determined for a finite period equal to the expected lifetime of the economic unit, for a period less than this lifetime, or for an indefinite period; in the last case it is assumed that the unit is restored after physical wear to its original state with exactly the same technological process and at the same outlay.

11. In calculating both integral and weighted mean indices of the criterion of optimal development the values of the initial economic indices for individual years of the account period must be determined on the assumption that the prices of the resources used and the output produced change with time. However, since reliable data on the character of these price changes are not available, the economic indices (income, outlay, profit) for different years are usually referred to time by means of an approximate index - the effectiveness rate E.

The value of this rate may vary with time; in that case its magnitude for the year t is indicated by E_t.

When this rate is used, the economic indices applying for different years are multiplied by "remoteness factors" B_t correcting them to a common moment of time. These factors are calculated from formulae (1) or (2) depending on whether the rate is considered time constant or time variable:

$$B_t = \frac{1}{(1+E)^{t-1}} \tag{1}$$

or

$$B_t = \frac{1}{\prod_{\tau=1}^{t-1}(1+E_\tau)}, \tag{2}$$

where:[1] B_t is the "remoteness factor" or the coefficient to correct the economic indices for the year t under consideration to the first year of the planning period[2]

E or E_t is the rate of effectiveness.

12. The introduction of the effectiveness rate into the economic calculations makes possible an approximate reflection of the circumstance that the input and output of resources and products usually have greater significance for society the earlier the moment in time to which they are related. A dynamic evaluation somewhat simplified may be obtained by adopting a certain value of the rate of

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1) $\prod_{r=1}^{R} a_r$ is a mathematical symbol designating the product of R multipliers a_r.

2) When the economic indices are corrected to a certain reference year θ, all the remoteness factors are multiplied by a constant equal to $(1+E)^{\theta-1}$ if B_t is calculated from formula (1), or to $\prod_{\tau=1}^{\theta-1}(1+E_\tau)$ if formula (2) is employed. The correction moment adopted for reference does not affect the results of comparing different plan variants, thus making it sufficient to determine B_t from formulas (1) and (2).

effectiveness. However, these rates are not necessarily equal for all resources and products.

13. The role of the effectiveness rate in the long-term optimal calculations made at present is not exhausted by this consideration.

When formulas (1) and (2) are used, the further the year under consideration is from the beginning of the plan period the less the economic indices of the different years affect the decisions adopted at present. Thus, according to formula (1) with $E = 0.15$ $B_{11} = 0.2472$; this means that at a remoteness of ten years from the base year the influence of economic differences between versions is reduced to less than 25 per cent.

Any long-term planning, however, is actually undertaken under conditions of uncertainty due to the following principal reasons:

(a) the impossibility of exactly predicting the scope and pace of future scientific and technical progress and, consequently, the dates of introduction of new technological processes, the degree to which the parameters of existing processes may change, and the extension of possibilities of utilizing natural resources, etc.;

(b) the lack of sufficiently exact information on the dynamic and territorial aspects of the long-term development of the economy as a whole and, therefore, of other economic systems (for example, other branches of industry) supplying materials and equipment to the system under consideration, or consuming its products, and also of systems competing with it to utilize natural and labour resources or for customers;

(c) the uncertainty of the market in probable volume and conditions of sale of consumer goods;

(d) the uncertainty of natural conditions (for example, of the weather).

This uncertainty grows with remoteness in time. Consequently the rate of effectiveness reduces the influence of the economic indices not only of the more remote periods but also of those marked by the greatest degree of uncertainty. This implies that the rate can reflect our evaluation of the quality of the initial information and our confidence in the validity of the hypotheses of future operational conditions.

In view of this, and according to the reliability of long-term predictions of conditions of activity and of potential dates for the industrial application of major discoveries and inventions, it is possible to raise the effectiveness rate in 8-10-15 years. Both the moment and the degree of increase of the rate may be different for different branches and districts for the following reason: the greater the degree of uncertainty (the faster the pace of scientific and technical progress, the quicker the changes in market conditions, etc.) the sooner and the greater the increase in the rate of effectiveness.

14. Let us take a model of the problem of optimal long-term planning of the development and location of a certain local complex of the economy, based on the following assumptions:

(a) the decision to adopt one development plan variant or another is made by the State authorities of the country, taking account of the interests of the economy as a whole;

(b) the model is a static one; the operating conditions of the system are checked with reference to the state of the year T of the planning period; data on capital expenditure for (T-1) years and current outlay for year T are utilized to obtain indices of the criterion of optimal development;

(c) the infrastructure is taken as given, and problems of its expansion (in particular, extension of the transport system) are not considered;

(d) the enterprises making up the optimized system can turn out several products and there is no inter-consumption of manufactured products by enterprises, a certain set of possible operational variants with fixed volumes of output of each product and a fixed level of outlay is stipulated in advance for each enterprise so that optimition is confined to choosing between these variants;

(e) the system meets the needs of both the home and foreign markets; maximum current foreign exchange profit of the system, taking into account current outlay of foreign exchange (payment for purchases and deliveries of imported goods, payments to foreign specialists, etc.) is adopted as the criterion of optimal development; a definite limitation is put on the total of foreign exchange allocated for capital construction of enterprises for the system over (T-1) years (acquisition of equipment, etc.);

(f) for the sake of simplicity it is assumed that the prices of goods sold and of resources utilized are stable (do not depend upon the volume of sales) both on the home and foreign markets within the range of activity of the optimized system; the capacity of the market for each product is limited;

(g) all enterprises of the optimized system employ a limited number of qualified specialists (for simplicity it is assumed that this limitation applies only to a single speciality; but an extension of the limitation to a number of specialities does not complicate the structure of the problem).

15. The method used to account for incomes and expenditure in the national currency in the problem depends on the state of the economy of the country and its monetary system:

(a) for countries with a readily available and conditionally convertible stable currency, the economic indices can be converted from local to foreign currencies using a certain fixed rate of exchange;

(b) for countries with an incovertible currency, the plan providing for maximum exchange profit may be adopted initially; if there are several plans with identical profit, that with the best economic indices (minimum outlay or maximum profit) in the national currency is selected;

(c) finally, for countries with strict financial controls, limitations may be imposed on the volume of permissible outlay or on the size of the balance of payments deficit.

16. The following symbols are adopted for econometric models complying with the preconditions of Section 14 and sub-sections "a" to "c" of Section 15:

m - number of possible points of location of enterprises;

n - number of markets including "n_1", foreign and $(n-n_1)$ home markets;

P - number of products;

Q_r - number of variants considered for the development and operation of enterprises at point "r";

X_r^{qj} - output of product "j" at point "r" for the "q" variant of development (in units);

D_s^j - capacity of market "S" for product "j" (in units);

P_s^j - selling price of a unit of product "j" on market "S" (for $S = 1, 2, \ldots n_1$, i.e. for foreign markets, P_s^j is expressed in units of the adopted foreign currency, and foreign exchange expenditures on the delivery of the product being excluded from its selling price. With $S = n_1 + 1$, $n_1 + 2, \ldots\ldots n$, i.e. for the internal market, P_s^j is expressed in units of the national currency);

$\bar{Z}_r^q$ - current foreign exchange expenditures due to development at point "r" according to variant "q" (including payment for imported materials and their importation, foreign exchange payments to specialists, etc.), in units of foreign currency;

$\bar{Z}_r^q$ - outlay (capital and current) in the national currency due to development at point "r" according to variant "q";

Z_{rs}^j - transport outlay in the national currency for the carriage of a unit of product "j" from production point "r" to market "S" (or to the respective frontier station of the country);

K_r^q - foreign exchange investments due to development at point "r" according to variant "q", in units of foreign currency;

K - total limit of foreign exchange investments for the system for (T-1) years (in units of foreign currency);

G_r^q - number of specialists required for development at point "r" according to variant "q" (number of persons);

G - total limit of specialists for the system (persons);

L - rate of exchange for hard foreign currency into the national currency, in units of foreign currency/units of national currency;

C - permissible balance of payments deficit in national currency.

In addition we adopt the following symbols for variables:

X_r^q - variables indicating whether the "q" variant of development at point "r" is included in the plan; if so, $X_r^q = 1$; if not $X_r^q = 0$;

Y_s^j - volume of sale of product "j" on market "s", in units;

X_{rs}^j - volume of delivery of product "j" from production point "r" to market "s".

17. With the preconditions stipulated in Sections 14 and 15a, the econometric model of the problem of optimal development and location of the separate units is formulated as follows: find the plan, i.e. the set of values of the variables, that maximizes the system profit

$$L = \left[\sum_{s=1}^{n_1} \sum_{j=1}^{F} P_s^j y_s^j + \alpha \sum_{s=n_1+1}^{n} \sum_{j=1}^{F} P_s^j y_s^j\right] - \left[\sum_{r=1}^{m} \sum_{q=1}^{Q_r} (Z_r^q + \alpha \bar{Z}_r^q) x_r^q + \right. \quad (3)$$

$$\left. + \alpha \sum_{r=1}^{m} \sum_{s=1}^{n} \sum_{j=1}^{F} \bar{Z}_{rs}^j x_{rs}^j \right]$$

while satisfying conditions (4) - (11):

$$y_s^j \leq D_s^j \qquad \begin{pmatrix} j = 1, 2, \ldots, F \\ s = 1, 2, \ldots, n \end{pmatrix} \qquad (4)$$

$$\sum_{q=1}^{Q_r} M_r^{qj} x_r^q > \sum_{s=1}^{n} x_{rs}^j \qquad \begin{pmatrix} j=1,2,\ldots,F \\ r=1,2,\ldots,m \end{pmatrix} \tag{5}$$

$$\sum_{r=1}^{m} x_{rs}^j > Y_s^j \qquad \begin{pmatrix} j=1,2,\ldots,F \\ s=1,2,\ldots,n \end{pmatrix} \tag{6}$$

$$\sum_{r=1}^{m} \sum_{q=1}^{Q_r} k_r^q x_r^q < K \tag{7}$$

$$\sum_{r=1}^{m} \sum_{q=1}^{Q_r} g_r^q x_r^q < G \tag{8}$$

$$\sum_{q=1}^{Q_r} x_r^q < 1 \qquad (r=1,2,\ldots,m) \tag{9}$$

$$y_s^j, x_{rs}^j > 0 \qquad \begin{pmatrix} j=1,2,\ldots,F \\ r=1,2,\ldots,m \\ s=1,2,\ldots,n \end{pmatrix} \tag{10}$$

$$X_r^q = 0 \text{ or } 1 \qquad \begin{pmatrix} r=1,2,\ldots,m \\ q=1,2,\ldots,Q_r \end{pmatrix} \tag{11}$$

18. In accordance with Section 14, the limitations imposed on the model have the following meanings:

inequality (4) indicates the capacity limitations of each market;

inequality (5) indicates the need to provide sufficient resources of product "j" at point "r" to ensure a volume of deliveries equal to X^j_{rs};

inequality (6) stipulates the availability of deliveries ensuring a volume of sales equal to Y^j_s;

inequalities (7) and (8) indicate the limitations imposed on foreign exchange (for investment) and on specialists;

inequality (9) stipulates that development at point "r" is not feasible according to more than one variant.

Formula (3) represents the system profit as converted into hard foreign currency[3].

19. Where the formulation of the problem complies with the condition stated

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[3] Formula (3) does not take foreign exchange investment into account. Such a formulation is expedient provided limitation (7) is very substantial, and it can be considered that limit K is fully utilis-

in sub-section 15b, it is necessary first to solve the problem with limitations (4) to (11) for maximum "L" where "L" is determined from the following formula:

$$L=\sum_{s=1}^{n_1}\sum_{j=1}^{F} P_s^j y_s^j - \sum_{r=1}^{m}\sum_{q=1}^{Q_r} Z_r^q x_r^q \qquad (12)$$

Then the plan with the lowest value of "W" is selected from the plans providing the largest values for "L":

$$W=\left(\sum_{r=1}^{m}\sum_{q=1}^{Q_r} \bar{Z}_r^q X_r^q+\sum_{r=1}^{m}\sum_{s=1}^{n}\sum_{j=1}^{F} \bar{Z}_{rs}^j X_{rs}^j\right)- \qquad (13)$$

$$-\sum_{s=h_1+1}^{n}\sum_{j=1}^{F} P_s^j y_s^j$$

20. When the formulation of the problem complies with the condition stated in sub-section 15c, the problem is solved with the criterion of optimal development (12), and conditions (4) to (11) and (14):

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ed at any variant of development. Otherwise capital outlay in foreign currency has to be taken into account in one or another way, as well as current expenditures, when calculating the profit. Analogous considerations apply also to the modified models described in Sections 19 and 20.

$$\left(\sum_{r=1}^{m}\sum_{q=1}^{Q_r}\bar{Z}_r^q X_r^q+\sum_{r=1}^{m}\sum_{s=1}^{n}\sum_{j=1}^{F}\bar{Z}_{rs}^j X_{rs}^j\right)- \tag{14}$$

$$-\sum_{s=n_1+1}^{n}\sum_{j=1}^{F} P_s^j\, y_s^j < C$$

21. The problems of optimal development described by models (3) to (14) are problems of mixed integer programming. At small sizes they can be solved by corresponding exact methods (4, 5, 6 and 7) and at large sizes - by approximation (8).

The solution of any of these problems enables us to determine the following:

(a) the location, size and specialisation of enterprises;

(b) the rates of development of the system and of its individual units;

(c) the production technology to be chosen;

(d) the range of output and the volume for each product;

(e) the volume of imports and exports;

(f) satisfaction of the demand of various consumers;

(g) transport connections;

(h) the system of evaluation of output;

(i) the system of rent evaluation for resources utilized natural and labour resources, means of production, etc.

22. The present report describes main principles and models for optimal planning of industrial development and location, which illustrate only the general approach to formulating and solving the problem. Naturally, no single or universal procedure or method can be proposed since a great variety of specific features of the economics of developing countries have to be taken into account in each concrete case.

23. It is evident that the possibilities of formulating and resolving the problems of planning for developing countries depend in essence on the general level of the theoretical elaboration and practical utilization of mathematical models and

methods of optimal planning. Research in this field is being carried out at present in various countries.

24. In the Soviet Union one of the main trends in the theory and practice of optimal planning is work on the optimal development and location of separate units of the economy and, especially, of individual branches of industry. Much research has been done in this field, numerous computing methods have been developed, and dozens of practical problems have been solved; and a number of large research groups and computer centres are working on the problem. Many of the results obtained are being utilised in the work of planning bodies and design institutions. Since 1966 optimation calculations on the development and location of more than twenty large branches of industry, with a capital investment amounting to more than half of the total investment in the economy, have been undertaken.

Such calculations are being performed not only for planning the development of branches of industry but also for planning the development of economic regions and territorial industrial complexes, in particular of districts being newly developed.

The basic trends in the theoretical study of these problems are as follows:

(a) theoretical substantiation of the criterion of optimal development ensuring full agreement of the interests of local complexes with those of the economy as a whole;

(b) introduction of the uncertainty of technical and economical parameters;

(c) introduction of the dynamics of development.

25. Together with the formulation and solution of particular problems, work is also being carried out on problems of the optimal development and location of the productive forces on a national scale, i.e. development of the economy by industries and regions. Experimental calculations for this very complex and immense problem are being made at the present time. Even a very simplified and aggregated solution of the problem will give a general picture of the possibilities and directions of development of social production for a limited long-term period, and will also allow a system of economic evaluation of basic resources and products to be defined.

Bibliography

1. Criteria for Location of Industrial Plants (Changes and Problems). United Nations, New York (1967).
2. Industrial Location in Development Planning and Policies of Industrial Location. United Nations, CID.
3. Choice of Location in Industrial Projects Evaluation. United Nations, CID/IPE/B, 42, Inter-Regional Symposium on Industrial Project Evaluation.
4. Gomory R.E. An Algoritm for the Mixed Integer Problems. RAND Corporation, P-1885 (1960).
5. Гольштейн Е.Г., Юдин Д.Б. Новые направления в линейном программировании. Изд-во "Советское радио", Москва (1966).
6. Черенин В.П., Хачатуров В.Р. Решение методом последовательных расчетов одного класса задач о размещении производства. Сб. "Экономико-математические методы", вып.2. Изд-во "Наука", Москва (1965).

7. Финкельштейн Ю.Ю. Алгоритм для решения задач целочисленного программирования с булевыми переменными. "Экономика и математические методы", т. I, № 5 (1965).

8. Гольштейн Е.Г. Транспортная задача и ее обобщения. Сборник "Методы и алгоритмы решения транспортной задачи". Изд-во "Госстатиздат", Москва (1963).

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