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Investment Strategy for an Industry*

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Investment Strategy for an Industry*

The paper gives an outline of the procedure for choosing the development strategy for a branch of industry and presents synthetic results obtained while the procedure was applied to draw up the investment plan 1975—1980 for the sugar industry. The procedure enabled to determine development directions which included decisions on the construction of new plants and modernization or extension of plants in operation, taking into consideration preferences voiced by various economic subjects.

1. Problem formulation

The use of computer based information systems in the process of taking decisions concerning development allows for the application of comprehensive models. The procedure outlined below has been tested in the elaboration of the investment plan 1975—1980 for the sugar industry. With the aid of this procedure we had to find out where and to what extent it is necessary to develop the sugar industry in order (1) to secure a target output of sugar for 1980, (2) to implement this task taking into consideration such criteria as optimum of costs and effects. The primary goal was to secure the attainment of the prescribed volume of future output for the internal market and for exports. Constraints regarding scarcity of resources had to be taken into consideration in choosing the strategy. Some difficulties arose from the fact that at the time the exercise was carried out information on the magnitude of available resources for the development program could not be precisely established. This fact caused some difficulties. For this reason a procedure was applied which enabled to consider a number of different situations which could have obtained in the future. The situations varied according i.a. to the level of demand, the magnitude of resources allocated, etc. It was assumed that the maximum level of resources available for the program would be equal

* This is a translation of the revised version of Chapter 4 of the book *System informatyczny programowania rozwoju gałęzi przemysłu* Warszawa 1976, Państwowe Wydawnictwo Ekonomiczne.

to the requirements put forward by the industry. These requirements were based on the development program worked out by the industry. The industry elaborated program contained proposals to modernize all existing establishments and to build a number of new plants. Since it was realized that it is impossible to modernize the whole industry by 1980, certain procedures were used which allowed to find out priorities in the implementation of particular projects and to reflect changes in the investment strategy changing in relation to the availability of resources. Besides overall constraints there were also some local limitations, resulting from regional considerations. The latter concerned infrastructural constraints as well as limited local availability of raw material and labour force.

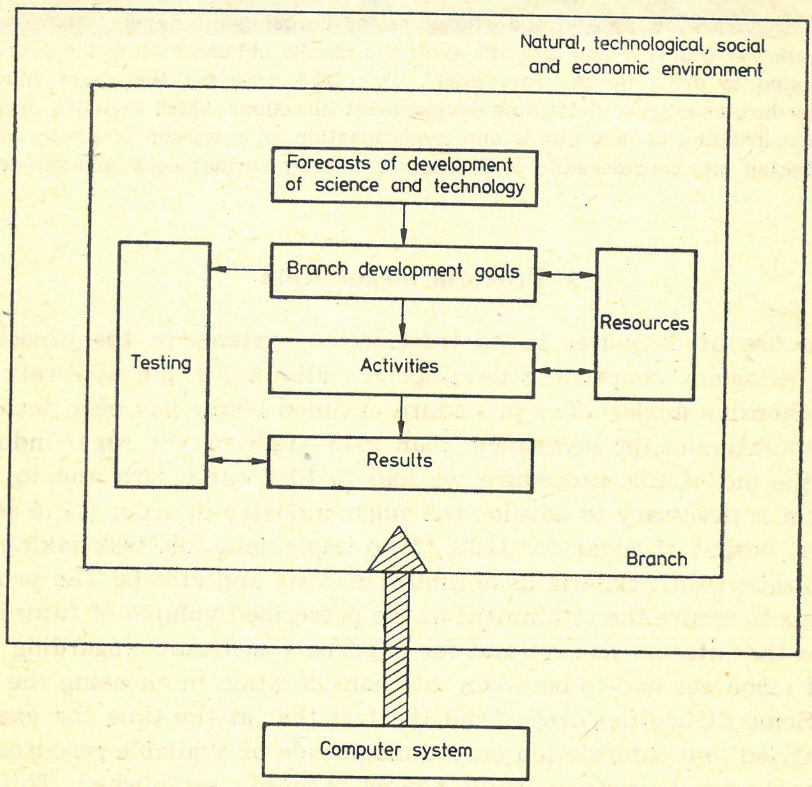

Fig. 1 *Interconnections of modules participating in the construction of the program*

The general procedure is presented in Fig. 1. The branch of industry is conceived as a system against the background of the natural, technological and socio-economic environment. The development of the branch depends on the influence of the environment, i.e. the whole of the national economy connected with the economies of other CMEA countries and the world. The external factors set certain targets for the branch.

The branch in turn draws up development goals on the basis of information about the future state of the environment. The consecutive steps consist in determining:

— "activities" which should be undertaken to implement the future dewelopment goals,
— "results" which would have been obtained after the realization of these actions,
— "resources" allocated for the branch development.

The final step is — "verification" in order to compare the overall results with the goals which were set.

For a smooth realization of the procedure just outlined a computer system is needed which would enable the establishment and use of the data bank as well as the carrying out the required number of computation runs.

2. The procedure of choosing directions of investment

The procedure used in working out the program of development of the sugar industry is presented in Fig. 2. It is general in the sense that it can be adapted to other branches as the basic procedure. It falls into five phases.

Phase I. Problem formulation.

In this phase two steps are carried out:

Step 1. Defining the desired state of the system at the end of the time interval considered.

The desired state is such a state in which the system is able to reach the goals set [1], i.e. first of all to ensure that the demand is met while various technological, organizational and economic constraints are taken into account. The explicit treatment of these conditions is connected with the problem of efficiency. In case they are disregarded, the requirements of the national economy would be met at an excessive social cost. Defining the future state of the system is a task requiring cooperation among the Planning Commission, the Ministry, Headquarters of the branch, local authorities and research units. The most important information needed for the selection of the development strategy is the future demand. It requires a comprehensive and dynamic approach encompassing the economic and social policy of the country.

Step 2. Determining the activity set.

[1] For building the so-called tree of goals the PATTERN method was used. This method is used mainly in medium- and long-term planning of complex projects. PATTERN enables to analyze and to group elements of complex systems according to their degree of importance.

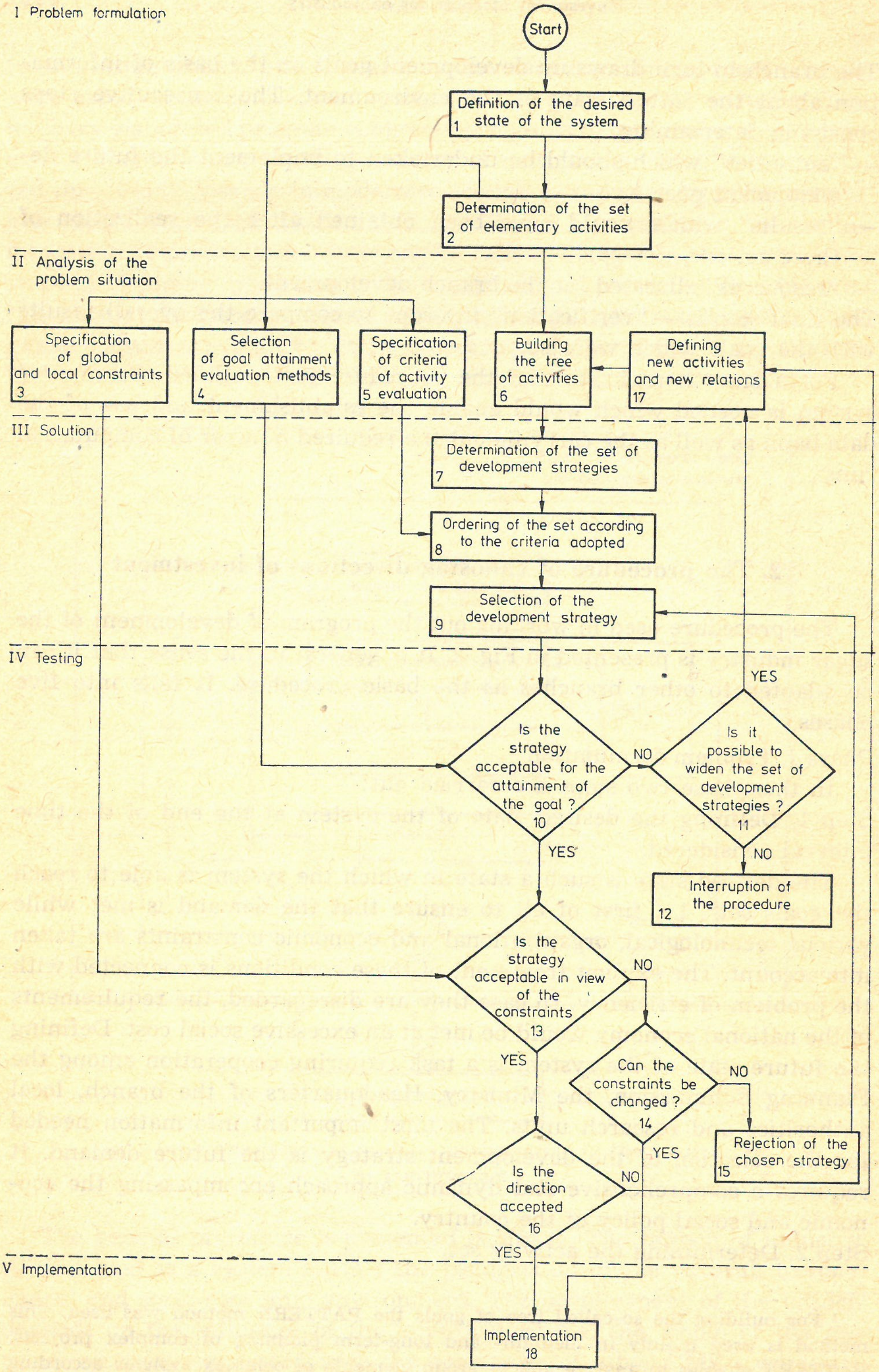

Fig. 2 *Procedure for development strategy selection*

The stipulated increase of production is to be carried out by means of activities[2] such as the construction of new establishments or development and modernization of existing plants. The increase of output depends not only on capital-consuming projects but also on non-investment progress which is not discussed here, as we make the simplifying assumption that non-investment progress is autonomous and thus it does not require inclusion in the overall program. Another assumption concerns the indivisibility of activities which means that a given single activity can either be accepted or rejected.

The determination of the set of possible activities constitutes an important step of the procedure. The more exhaustive is this set, the higher the chance to select the optimal strategy. The participation of research units and design offices of the industry is important, particularly in working out new projects and their locational variants. The activity defined as single direction of development is thus the basic element in the task of development programming. Indicators and coefficients such as profits, costs, output, interest rate, constitute aggregate characteristics of particular directions of development and of the whole program.

Phase II. Analysis of the problem situation.

In phase two there are four steps:

Step 3. Identification of constraints.

We can devote a finite amount of resources of the national economy for industrial development. The available resources are divided among branches of industry directly or via economic instruments such as price and rate of interest. In our procedure we took into consideration only those limited resources which were directly allocated to the branch. Constraints affecting all possible directions of development in the whole industry were regarded as global limitations. There also were local limitations which concerned exclusively certain subsets of directions of development. These local constraints pertained in principle to the possibilities of building a new or extending an existing plant up to a certain size with respect to: available labour force, raw materials, plot area, transport, etc. The results of inter-branch coordination agreements and linkages between regional and branch plans were taken into account in this step. Since the value of constraints varied and assumed different levels one could simulate the decision making process with respect to consequences of different allocations of resources and random changes of the external variables.

Step 4. Selection of a method to assess the degree of goals attainment.

In order to assess whether the chosen strategy of development would allow to reach the future goal, a method had to be devised. The assessment

[2] Here we use T. C. Koopmans' notion of activity referred to any project aimed at improving the efficiency of a single plant or the whole organization (ed.note).

should indicate the difference between the expected results of the given strategy and the goal which was set. This had to be done not only with respect to the main goal, but also with respect to partial objectives arrived at by means of the decision tree decomposition. As a result of such an assessment it was possible to determine to what extent the desired goal had been attained, and also to design appropriate corrective actions. Step 5. Selection of criteria of evaluation of elementary activities.

In actual practice the following criteria of assessment are most commonly encountered: minimization of outlays, maximization of profit or value added, maximization of final output, or maximization of foreign currency revenue. The analysis of these criteria goes beyond the frame of this article. I would like to point to the fact that in the cost/benefit analysis which constitutes the core of all allocative activities, identical pricing principles have to be applied for each branch and each product. The importance of this condition is also emphasized by J. Kornai in his study on the method of industrial planning [3]. This does not mean, however, that only one criterion should be used. In working out the investment plan for the sugar industry various criteria of assessment were applied, such as: profits, costs, output, and differences in the programs arrived at were analyzed. In such a way the degree of sensitivity of the plan to different

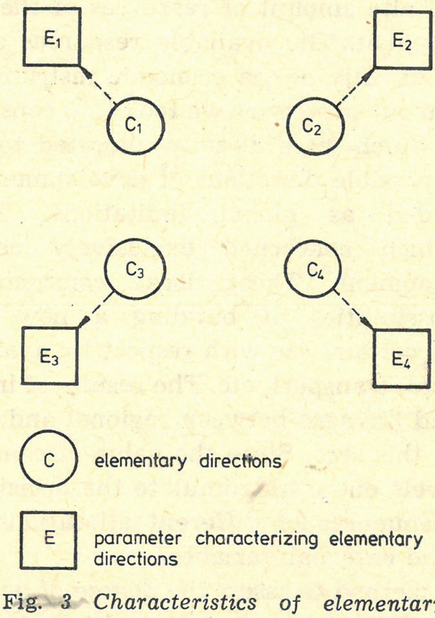

Fig. 3 *Characteristics of elementary directions considered separately, i.e. without interactions*

[3] J. Kornai, *Zastosowanie programowania w planowaniu*, Warszawa 1969, Państwowe Wydawnictwo Naukowe.

criteria of assessment was tested. (Parallelly with steps 3, 4 and 5 step 6 is executed).

Step 6. Constructing the tree of development strategies.

This model facilitates the determination of all possible strategies. It is presented in Fig. 3. To clarify the procedure only four elementary activities were considered.

It is generally accepted that it is sufficient to know the internal characteristics of each elementary activity (the volume of output, investment outlays, transportation costs, etc.) to be able to make the choice. The question arises whether it is so in actual practice. By constructing a given plant we usually influence other establishments of the same branch. This leads to overall changes in outlays and effects. As it is shown graphically in Fig. 4, before making decisions we ought to have information

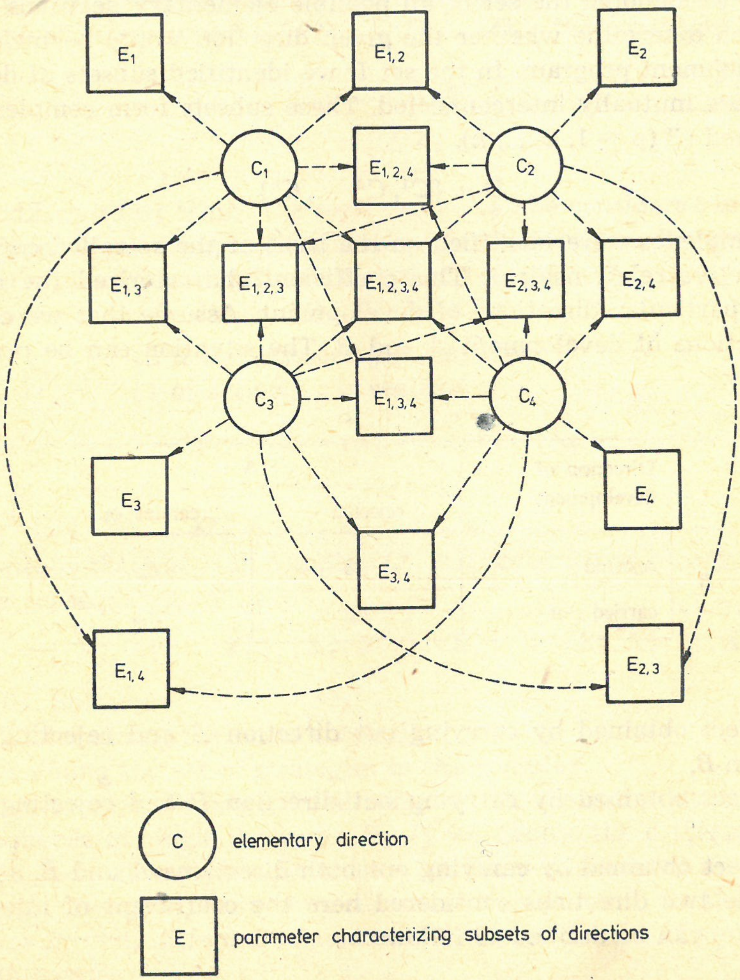

Fig. 4 *Characteristics of the set of directions while interections are accounted for*

characterizing each of the possible development strategy. With four interconnected elementary activities there are 15 different possible development strategies ($2^4 - 1$). For instance the joint effect of constructing plants 1 and 2 does not always equal the sum of effects obtained when the construction of plant 1 is considered independently of constructing plant 2. In this case, depending on the situation, the per unit effects may decrease or increase.

The subset of elementary activities which are mutually interconnected in one way or another, forms the so-called complex of activities. Individual activities belong to the same complex if there are certain directly indentifiable relations between them. In our exercise the complex was made up of those activities, which could be carried out in a single region. The size of the complex depended on specific economic conditions.

By D we denoted the set of all possible elementary decisions (yes or not) which determine whether the given direction would be included in the development program. In the set D we identified subsets of decisions which were mutually interconnected. These subsets form complexes and are denoted C^p $(p = 1, 2, ..., k)$.

$$D = \{C^1, C^2, ..., C^k\}$$

These complexes were identified on the basis of the so-called coefficient of interactive relationship λ. This coefficient characterized the relation between particular directions of development. Assume that we consider two directions of development A and B. The situation can be presented as follows:

	Direction of development	A	
		rejected	carried out
B	rejected	Ø	E_a
	carried out	E_b	E_{ab}

where

E_a — effect obtained by carrying out direction A and rejecting direction B,

E_b — effect obtained by carrying out direction B and rejecting direction A,

E_{ab} — effect obtained by carrying out both directions A and B.

For the two directions considered here the coefficient of interactive relationship can be defined as follows:

$$\lambda = \frac{E_{ab}}{E_a + E_b}$$

The coefficient λ takes values from the interval $[0, \infty]$. If this coefficient

a. $\lambda = 1$, then both directions of development are mutually independent,

b. $\lambda < 1$, then both directions are in a "negative" interaction, which means that each of these direction has a negative influence on the other by diminishing its effects,

c. $\lambda > 1$, then the interaction relation is "positive" i.e. the realization of both directions of development simultaneously improves the effects.

In the example outlined above we considered effects to be maximized. If we analyze parameters of a different character, e.g. costs, the "negative" and "positive" meaning of the coefficient λ is to be interpreted in a different way: if $\lambda > 1$ then the interaction is "negative", and if $\lambda < 1$ then the interaction is "positive".

If the analysis of interactive relationships concerns larger blocks of directions of development ($D_1, D_2, \ldots, D_j, \ldots, D_n$), the coefficient λ equals

$$\lambda = \frac{E_{(1,2,\ldots,n)}}{\sum_{j=1}^{n} E_j}$$

The condition under which the coefficient λ can be considered to be significant depends on the specific situation. In this analysis it was assumed that the value of λ is significant if $0{,}95 < \lambda < 1{,}05$.

Denoting a single decision by X_r^p we have:

$$D = X_r^p : X_r^p = \begin{cases} 0 \text{ if the complex p is rejected} \\ 1 \text{ of activity r is realized} \end{cases}$$

$$(p = 1, 2, \ldots, k; \ r = 1, 2, \ldots, i_p)$$

and then

$$C^p = \{X_1^p, X_2^p, \ldots, X^p\} \ p = 1, 2, \ldots, k$$

which means that the p-th complex C^p is a sequence of binary decisions.

As a consequence we have

$$D = \left|\{X_1^1, X_2^1, \ldots, X_{i_1}^1\}, \{X_1^2, X_2^2, \ldots, X_{i_2}^2\}, \ldots, \{X_1^k, X_2^k, \ldots, X_{ik}^k\}\right|$$

Phase III. Solution

Step 7. Determining the set of strategies.

a) Determining the set of strategies in the complex.

Let us consider in more detail complex C^p. We call a strategy a specific sequence of single decisions. By I_d^p we denote the d-th strategy realized in the p-th complex. Strategies for the p-th complex are given by sequences of length i_p containing zeros and ones. In total, for this complex there are $2^{i_p} = n_p$ different sequences. Let S^p be the set of strategies for the p-th complex

$$S^p = \{I_d^p\} \quad d = 1, 2, \ldots, n_p$$

The set of strategies in the complex p can be presented as follows:

$$I_1^p = \{0, 0, 0, 0, .., 0\}$$
$$I_2^p = \{1, 0, 0, 0, ..., 0\}$$
$$I_3^p = \{0, 1, 0, 0, ..., 0\}$$
$$\cdots\cdots\cdots\cdots\cdots\cdots$$
$$I_d^p = \{0, 1, 0, 1, ..., 0\}$$
$$\cdots\cdots\cdots\cdots\cdots\cdots$$
$$I_{n_p}^p = \{1, 1, 1, 1, ..., 1\}$$

Since in a given complex the strategies are exhaustive and mutually exclusive only one can be included in the development program.

b) Determining the set of strategies for the entire branch.

Having determined sets of strategies in a single complex, we could determine the set of strategies for the entire branch. The full set of strategies can be presented in the form of the following table.

Complexes p / Strategies $d_p = 1, 2, ..., n_p$	$p = 1$	$p = 2$	...	p	...	$p = k$
$d = 1$	I_1^1	I_1^2	...	I_1^p	...	I_1^k
$d = 2$	I_2^1	I_2^2	...	I_2^p	...	I_2^k
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
d	I_d^1	I_d^2	...		...	$I_{n_k}^k$
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
$d = n-1$	I_{n-1}^1	I_{n-1}^2	...		...	
$d = n$		I_{n-2}^2	...		...	

Next we had to form the set of all possible global strategies (which concern the whole branch). If there are k complexes in the branch, then a global strategy consists of an ordered sequence of elementary strategies containing k elements.

Let us take an example: assume that the set of possible directions at the scale of the entire branch encompasses four complexes, the first one containing three possible strategies, the second — four, the third — six, and the fourth — three; it follows that there are 216 different strategies: $n_1 \times n_2 \times n_3 \times n_4 = 3 \times 4 \times 6 \times 3 = 216$.

In actual practice we had to deal with a much greater number of complexes of development directions and with more strategies within a single complex. Such a calculation could only be performed with the help of appropriate computer system.

For a branch with k complexes and n_p strategies in the p-th complex is thus possible to define T different global strategies:

$$T = \prod_{p=1}^{k} n_p$$

hence $S = \{S_1, S_2 ..., S_t, ..., S_T\}$
and $S_t = \{I^1_{d_1}(t), I^3_{d_2}(t), ..., I^p_{d_p}(t), ..., I^k_{d_k}(t)\}$
Step 8. Set ordering.

Each strategy I^p_d can be assessed by means of certain fixed criteria and assigned a definite economic effect. We denote this effect by E^p_d. It is a measure of utility of the d-th strategy in the p-th complex and is a function of the strategy:

$$E^p_d = f(I^p_d)$$

For each $S_t \in S$ we have:

$$E_{s_t} = \sum_{p=1}^{k} f[I^p_{d_p}(t)]$$

we are looking for such a global strategy $S_t \in S$, for which

$$E = \max_{S_t \in S} E_{s_t};$$

Let H_m ($m = 1, 2, ..., s$) be the state of the outside world that might obtain during the realization of any strategy S_t. The results expected from the realization of a given strategy corresponding to various states of the outside world can be listed in the form of a matrix presented below.

Strategies	States of the environment which are independent of the decision-maker				
	H_1	H_2	.	H_m	.	H_s
S_1	a_{11}	a_{12}	.	a_{1m}	.	a_{1s}
S_2	a_{21}	a_{22}	.	a_{2m}	.	a_{2s}
.	.	.	.	.	.	.
S_t	a_{t1}	a_{t2}	.	a_{tm}	.	a_{ts}
.	.	.	.	.	.	.
S_T	a_{T1}	a_{T2}	.	a_{Tm}	.	a_{Ts}

If our information is more complete and we know the probability distribution of occurence of particular states of the outside world $P(H_m) = p_m$, then we want to determine the value of the game

$$V = \max \sum_{m=1}^{S} a_{tm} \cdot p_m$$

In cases in which it is possible to form a payoff matrix, the theory of games should be applied.

Step 9. Choice of the strategy of development

From the set of strategies, we choose that one, for which the value of the criterion function is maximized.

Phase IV. Testing

The verification of the selected strategy precedes the elaboration of the development plan. Such a testing is based on the following considerations: 1) does the strategy ensure the attainment of the perspective goals set for the industry, 2) are the resource constraints fulfilled, 3) is it in accordance with the actual social and economic policy? It is very difficult to develop computer packages for this phase, as each problem requires individual treatment.

The flow diagram of fig. 2 presents the most essential steps of the procedure. The steps of phase IV are as follows.

In step 10 on the basis of information derived in steps 4 and 9 it is checked whether the chosen strategy allows us to reach the desired goal. In case the desired goal can not be attained we pass to step 11, in which we analyze the possibility of extending the set of strategies. If it is possible to add new strategies we go back to phase II, i.e. to the analysis of the problem situation (step 17) in which we determine new feasible directions. The necessity of extending the set of directions follows from the fact, that none of the strategies developed so far allows to reach the desired goal. If in step 11 it comes out that the set of directions can be extended, then we interrupt the procedure. In such a case it is necessary to state the goal in different terms, i.e. to start the problem once again.

Let us, however, return to step 10 and assume that the first part of the testing gives a positive result. We proceed then to step 13, i.e. we answer the question whether the strategy can be accepted in view of the existing constraints. If the analysis of constraints yields a positive result, we proceed to step 16, in which we find out whether the elements of the strategy (i.e. directions) can be accepted. In case the answer is in the affirmative the selected strategy is passed over to the Decision Centre (Branch Headquarters or the Ministry). In the case of a negative outcome of step 13 we proceed to step 14, which involves the analysis of constraints. If the Decision Centre allows for such a change of constraints, that enables the implementation of the program determined by the strategy, it is then accepted in block 16. If constraints can not be changed, then in step 15 we drop the strategy chosen and return to phase III step 9, i.e. to the selection of another strategy from the set. In block 16 the strategy is finally evaluated by the Decision Centre. If it is accepted, then its implementation follows (Phase V, step 18), and if not, the strategy is rejected and through step 17 the procedure returns to step 6 — which is: constructing the activity tree.

Phase V. Implementation.

This phase is marked on the flow diagram only, as its content goes beyond the main line of reasoning of this paper.

3. Practical example and ways of generalizing the procedure

The above outlined procedure was applied for the selection of investment alternatives for the period 1975—80, the exercise being carried out for plants grouped in the Union of Sugar Industry. The information was supplied by sugar factories and by the Industry Headquarters and Design Office. The data were checked before use. Some difficulties were encountered while gathering information on:

a) the size of financial means which could be allocated for development of the industry, (upper limits concerning expenditure on global investment program and its items, e.g. site development, construction etc.,

b) the expected running costs for certain directions, this caused difficulties in evaluating the effects of carrying out some strategies.

The set of elementary directions was subdivided into complexes on the basis of the analysis of interaction coefficients. Economic effects for each strategy within a complex were determined. These effects were

Table 1

Strategy S_t $(t = A, B)$	Elements of S_t	Evaluation criteria	Elementary strategy i_p	Financial constraints of the global investment program ,000 zł	
				Total	of which site preparation and construction
S_A	Set of all elementary directions	Quantity of raw material processed per day	1	14,200	7,020
			2	12,780	7,020
			3	11,360	5,616
			4	9,940	4,914
			5	1,278	710
S_B	Subset of elementary directions which yield a considerable increase of output in existing plants or construction of new plants.	Expected economic effects	1	7,900	4,400
			2	7,000	4,000
			3	6,000	3,500
			4	4,000	2,500

computed as economic gains resulting from simultaneous implementation of activities related to construction, extension or modernization of two or more plants belonging to the same complex. It was assumed that there is a constant quantity of raw material in the given complex and that the decision problem consists in deciding to which factory it should be assigned to.

The global effect was the sum of the following elements:

— reduction of the raw material transportation costs (elimination of long--distance transports of sugar beet),

— reduction of production costs resulting from cutting the duration of sugar beet processing.

Table 2

Synthetic Results Characterizing Particular Development Strategies

Strategy S_t $(t = A, B)$	Elementary strategy i_p	Investment resources required to carry out the strategy, 000 zł		Expected effects	
		total	of which site preparation and construction	increase of quantity of sugar beet processed, tons per day*	average effect per annum ,000 zł
S_A	1	12,306	6,832	182,250	not available
	2	12,306	6,832	182,250	,,
	3	10,340	5,564	174,180	,
	4	8,708	4,822	169,380	,,
	5	1,272	709	37,030	,,
S_B	1	7,290	4,020	25,070	1.622
	2	6,905	3,846	24,970	1.602
	3	5,959	3,279	20,270	1.334
	4	3,605	2,046	12,970	966

* The effect is calculated as the throughput capacity planned for 1980.

On the basis of input data two feasible sets of activities were determined, which were next tested with respect to the constraints alternatives. The main characteristics of these two sets are presented in Table 1.

Table 2 contains synthetic results characterizing basic development strategies. Strategy S_A differs from strategy S_B as to the number of activities considered and to criterion of evaluation.

On the basis of the results obtained it was suggested to implement the strategy of development of the sugar industry in three successive stages:

Stage I — Small modernization projects carried out in existing plants enabling them to continue production (this concerned some 20 plants),

Stage II — Building new sugar beet processing plants and considerable extension of those which already exist,
Stage III — Execution of the remaining projects.

*

The procedure outlined here can be used for selection of a development strategy aimed at various goals, while different constraints and criteria of evaluation are adopted. It has been tested for the sugar industry; its application in other industrial branches needs some modification. It is particularly important to construct the strategy tree, which forms the characteristic step of the procedure. In order to chose a development strategy it is necessary to analyze all posible elementary strategies. Only then we can assume, with a high degree of certainty, that the strategy chosen for realization is optimal with respect to the criteria adopted. The generation, and subsequent analysis of development strategies requires the use of computer systems equipped with specialized software for simulation methods. The author is familiar with the use of simulation techniques for the programming of regional development, viz. the study conducted by teams of the UK Scientific Centre, IBM United Kingdom Limited and cooperating institutions [4]. The use of simulation techniques is facilitated by the fact that there already exist many simulation languages. The main shortcoming of many problem oriented simulation languages is their low degree of flexibility. If we want to use this tool we must first check, whether it pays to adapt packages already existing or to devise our own programs. (*ev*)

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[4] See IBM reports, e.g. E. Brookbons et al., *A Dynamic Simulation Model for Regional Planning*, A Case Study of the Northern Region UKSC 1973; K. Telford et al., *A. Dynamic Macroeconomic Model of the Northern Economic Planning Region*, UKSC 1974.

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