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INFORMATION PROCESSING SYSTEMS FOR DEVELOPMENT STRATEGY OF SUGAR INDUSTRY

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The paper presents same theoretical and practical problems of the Information Processing Systems for selecting the development strategy for a industry sector. In particular procedures and their results as applied for the 5-year development plan for the sugar industry in Poland are describend. This will be followed by a description of the further research work aiming at the improvement of the decision algorithms.

INTRODUCTION

A short model of Development Strategy for a sector of industry may by represented in the following manner;

$$\left\{ C^t, D^t, R^t \right\}$$

where: t - time period,

C^t - set of objectives which we would like to obtain in the analyses time period,

D^t - set of decisions which allow the set of objectives to be met in the analysed time period,

R^t - set of resurces which are necessery meeting the stated objectives in the analysed time period.

Element of set D^t cause transformation of the set resurces R^t into the set of objectives.

$$\text{hence} \quad R^t \xrightarrow{D^t} C^t$$

The set D^t in the point of the decision thory mey be defined as the set of decisions D^* of the real development strategy for an industry D^* is limited by C^t and R^t. The set D^t included all the possibility elementary of decision in the analysed industry. The problem will by discribed in the subsequent part of this paper presenting the procedure for development strategy selection. The solution of the development strategy requires building Information Processing Systems /IPS/.

Such on IPS should include:

1. Data Base with DBSM / Data Base Management System/ A Data Base includes information about: national, economic, industry, for casting of global and local development and so an. The Structure of the Date Base is presented in Fig. 1.

2. A mathematical model for generation of different investment strategies for the sugar industry.
3. Procedures /algorithms for building programme development of the sugar industry. Procedure is presented in Fig. 2.

The system has been developed on an IBM 370/148.

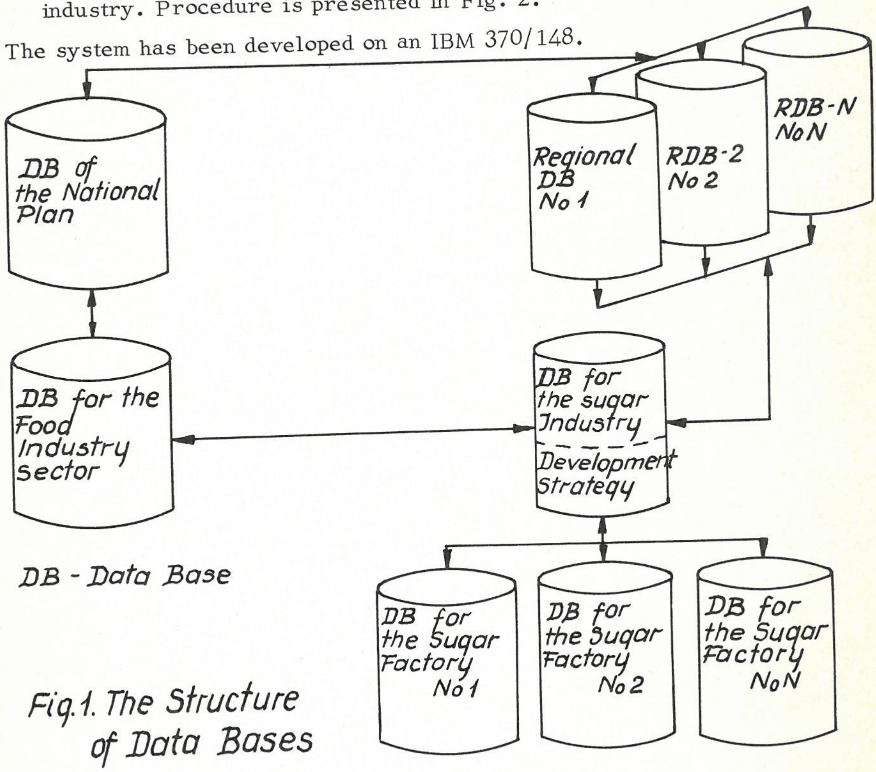

Fig. 1. The Structure of Data Bases

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 contraints are taken into account. The explicit

[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.

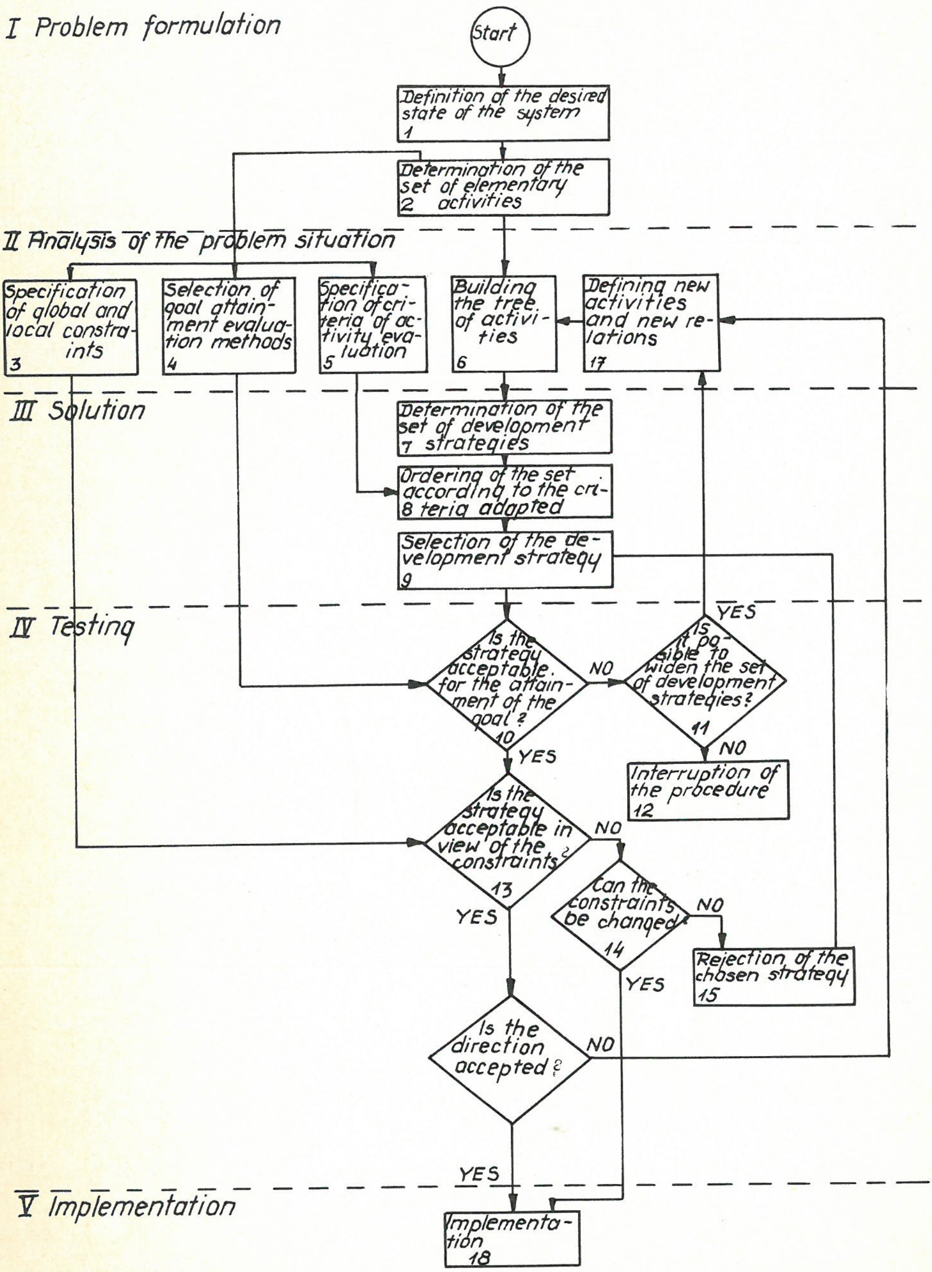

Fig. 2. Procedure for development strategy selection

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.

The stipulated increase of production is to be carried out by means of activities 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 contraints.

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 limitation 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 a account in this step. Since the value of contraints 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 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, maximi zation of final output, or maximization of foreign currency revenue. The analysis of these criteria goes beyond the frame of this article. 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 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.

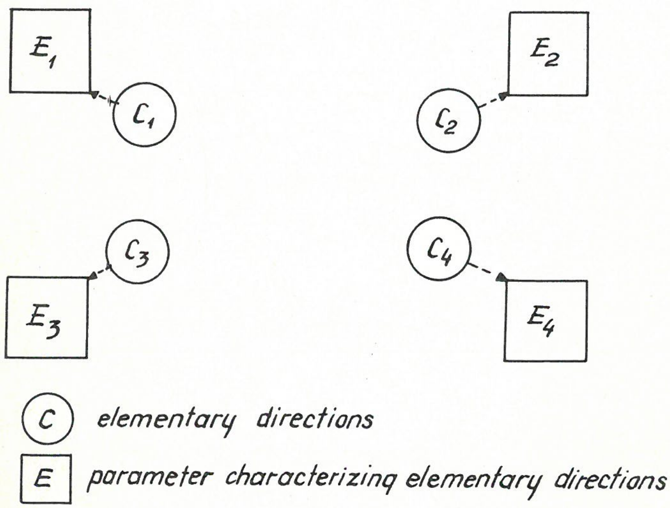

Fig. 3. Characteristics of elementary directions considered separately, i.e. without interactions

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 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.

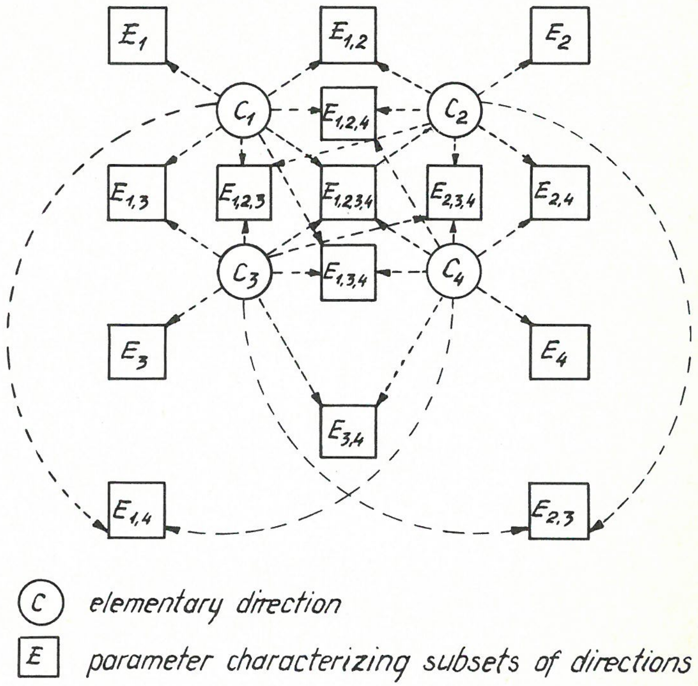

Fig. 4. Characteristics of the set of directions while interections are accounted for

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/.

$$D = \left\{C^1, C^2, \ldots, C^k\right\}$$

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	O	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 takes valueas 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 directions 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 $>$ 1 then the interaction is "negative", and if $<$ 1 then the interaction is "positive".

If the analysis of interactive relationships concerns larger blocks of directions of development $/D_1, D_2, \ldots, D_n/$, 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:

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

$$/p = 1,2, \ldots, k; \quad r = 1,2, \ldots, i_p/$$

and then

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

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

As a consequence we have

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

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 lengzh 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 ^{p}

$$S_p = \left\{I_d^p\right\} \qquad d = 1,2, \ldots, n_p$$

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

$$I_1^p = \{0, 0, 0, 0, \ldots, 0\}$$

$$I_2^p = \{1, 0, 0, 0, \ldots, 0\}$$

$$I_3^p = \{0, 1, 0, 0, \ldots, 0\}$$

....

$$I_{n_p}^p = \{1, 1, 1, 1, \ldots, 1\}$$

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.

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.

Complexes p / Strategies $d_p = 1, 2, \dots, n_p$	p = 1	p = 1	...	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	...		...	$I^k_{n_k}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮
d = n - 1	I_{n-1}^1	I_{n-1}^2	...		...	
d = n		I_{n-2}^2	...		...	

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

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

hence $S = \left\{ S_1, S_2 \dots, S_t, \dots, S_T \right\}$

and $S_t = \left\{ I_{d_1}^1(t), I_{d_2}^3(t), \dots, I_{d_p}^p(t), \dots, I_{d_k}^k(t) \right\}$

A calculation could only be performed with the help of appropriate computer system.

Step 8. Set ordering.

Each strategy I_d^p can be assessed by means of certain fixed criteria and assigned of utility of the d-th strategy in the p-th complex and is a function of the strategy:

$$E_d^p = f\left(I_d^p\right)$$

For each $S_t \in S$ we have:

$$E_{s_t} = \sum_{p=1}^{k} f\left[I_{d_p}^p(t)\right]$$

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 oudside 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 pf 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. direction/ 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.

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 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-distan-

ce transports of sugar beet/,
- reduction of production costs resulting from cutting the duration of sugar beet processing.

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 2 3 4	14,200 12,780 11,360 9,940 1,278	7,020 7,020 5,616 4,914 710
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 2 3 4	7,900 7,000 6,000 4,000	4,400 4,000 3,500 2,500

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 basis 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 tjose which already exist,

Stage III - Execution of the remaining projects.

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[x]	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 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 charaterisctic step of the procedure. In order to chose a development strategy it is necessary to analyze all possible 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 use of simulation techniques is facilitated by the fact that three 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.