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A Decision Model of Choice of Investment Variants for an Industrial Branch*

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A Decision Model of Choice of Investment Variants for an Industrial Branch*

Presenting a model of choice of investment variants the author emphasizes its superiority over traditional calculations of investment effectiveness. The model differs from others of the same type by giving broader consideration to the interdependencies between decision variables. The model was used in constructing an investment programme for the Polish sugar industry for 1971—1975. The programme provided a basis for investment activities in that industry over those years.

The commonly used methods in analyzing the effectiveness of investments compare the outlays and the effects of each variant under consideration and select the one that is most effective.

To choose investment variants within the whole branch, it is necessary, in my opinion, to use optimizing decision models, for they enable us to consider various interrelationships between competing investment variants more fully than the methods used so far. They also enable us to include various limitations directly into our analysis, both for all variants under consideration and for their certain groups.

When a model approach is applied to the problem of choice of investment variants, it is possible to simplify the decision-making situation and to disregard relationships of secondary importance. There are so many diverse relationships within an industrial branch that, with the present state of knowledge, a detailed mathematical identification of the model is practically impossible.

Whole number optimizing models have been presented in various studies[1]. The basic difference between the model presented later in this work

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* The text is based on the article published in "Ekonomista" 1971 No. 3 pp. 405—419.

[1] Among better known studies in which models were used to choose optimal investment variants the following may be mentioned: A. G. Aganbegian, D. M. Kozakiewicz, *Optimalnoye terytoryalno-proisvodstvyennoye planyrovanye*, Novosybirsk 1969, Nauka, pp. 29—39; *Optymalny plan ostrasly*, ed. by I. J. Birman, Moskva 1970, Ekonomika, pp. 144—405; B. M. Khumawala, An Efficient Branch and Bound. Algorithm for the Warehouse Location Problem, "Management Science" 1972 No. 12, p. 718.

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and the models in the studies cited is that the interdependencies between decision variables are taken into consideration more extensively in the former than in the latter. I would especially like to emphasize the condition of implication disregarded in decision models. This condition should be taken into consideration when the following relation between the particular investment variants holds: if we implement variant *A* then we also have to implement another investment variant, eg. *B*. We are at times faced with more complex relations of this type, such as: if we realize variants A_1 and A_2 then we have to realize variant *B*; or there may be a chain of implicating relationships such as: if we realize *A* then we have to realize *B*, and if *B* then *C* etc.

The implication relationship, which is not a passing relationship here, complicates the problem solving method, but is extremely significant from the point of view of constructing an overall, comprehensive investment programme. In an industrial branch decisions concerning particular investment variants are closely tied to each other. These diverse relationships must be taken into consideration in designing an optimal programme.

The model may be used not only for the construction of an optimal investment programme, but also for the simulation "what for", i.e. what will happen if a change occurs in the particular elements of the model, such as the organization conditions, sets of feasible investment variants, and the characteristics of the particular variants. I have presented these possibilities in the model described here and have made a calculation which has enabled me to list the economic effects derived from the departure from an optimal solution owing, for instance, to the need of taking into consideration the postulates resulting from a specific social situation.

Apart from the programme, designed with the help of an optimization model, an investment programme has been outlined on the basis of the same input information by calculating the recoupment period. That means that the chosen variants were characterized by the lowest ratio of investment outlays to profits earned in the plant built in consequence of implementation of a given investment variant. Some variants are both in the set determined by the calculation of the recoupment period and in the set determined by the optimizing model. On the whole, however, there is a considerable difference between both sets of variants. An analysis of the second set showed that the investment programme of the branch determined by calculating the recoupment period is unrealistic because it exceeds the limitations imposed on the branch. If, therefore, the second set were to be taken as the basis for investment activities in the branch then it would have to be corrected intuitively. The aim of this correction is to eliminate those variants from the set which use up a relatively great amount of scarce means and to introduce other variants requiring a relatively small amount of these means. It is understandable that, even with expert help, such an intuitive correction could be optimal only by chance. On the whole, higher effectiveness is the characteristic of an investment programme for a branch determined by an optimizing model.

I. The Model

Solution of the problem posed in the model is intended to lead to a choice of investment variants within the whole branch which when implemented within the assumed period of time will with the use of the available financial and material means designated for this purpose make it possible to attain the desired state of the branch. If the allocated means do not lead to the desired state, then the solution will show that the target cannot be reached.

The model presented here was designed for the purpose of selecting the directions of investment in the sugar industry in 1971—1975. The numerical data in the model pertain to this branch.

In designing the model, the following information was available: (a) the existing state of the branch: (b) the target state which the branch should achieve after a specified length of time; (c) different investment possibilities in the particular plants of that branch, i.e. on investment variants; (d) the available material and financial resources.

Since we have assumed that our information is reliable, we have therefore defined it as a deterministic decision model. The assumption of the deterministic nature of information simplifies the problem. In the model designed by us we have limited the time horizon to five years. If a longer period of time were taken then the assumption of the deterministic nature of information would in most cases be wrong; and it would have to be a stochastic model.

The model has the following objective function:

$$\sum_{i=1}^{n} z_i x_i = \max \quad i = 1, 2, \ldots, n \ldots \tag{1}$$

The model contains the following limiting conditions for decision variables:

Limitation resulting from the indivisibility of investment variants:

$$x_i = \begin{cases} 1 \\ 0 \end{cases} \tag{2}$$

Limitation related to the mutual exclusion of certain investment variants that belong to the subset of variants $S_k \subset S$

$$\sum_{i \in S_k} x_i \leqslant 1 \quad \text{for } k = 1, 2, \ldots p, \tag{3}$$

Limitation resulting from the need to realize one of the investment variants that belongs to the given subset of variants $S_m \subset S$.

$$\sum_{i \in S_m} x_i = 1 \quad \text{for } m = 1,2, \ldots r \tag{4}$$

Limitation related to the implication condition

$$x \leqslant x_{ji} \quad \text{for } i \neq j \tag{5}$$

In addition to the limitations on decision variables resulting from the specific relationships between them, the model also contains limitations related to the available

$$\sum_{i=1}^{n} a_{if} x_i \leqslant A_f \quad \text{for } f = 1, 2. \tag{6}$$

$$\sum_{i=1}^{n} b_{iw} x_i \leqslant B_w \quad \text{for } w = 1, 2, 3. \tag{7}$$

and limitations related to the need to increase production at least to level *D*,

$$\sum_{i=1}^{n} d_i x_i \geqslant D \tag{8}$$

The notations are as follows:

x_i — the decision variable indicating whether the i-th investment variant will be realized, then $x_1 = 1$; if the solution of the model does not envisage the realization of i-th investment variant, then $x_i = 0$;

i — elements of set S to which all possible investment variants belong; in our case the model contains 100 investment variants, i.e. $n = 100$;

z_i — average annual profit earned in consequence of implementation of the i-th investment variant; profit is calculated as the difference between the factory price, on the one hand, and the total production cost and the transportation cost of the raw materials on the other. It is given in millions of zlotys;

S_k — subsets singled out from the set of possible investment variants S;

j_i — the number of the j-th variant necessary because of the implementation of the i-th variant; it is obvious that element $j_i \in S$;

a_{if} — the total amount of the f-th financial resource needed for the realization of the i-th variant;

A_f — the maximum value of the f-th financial resource which may be earmarked in the 5-year plan for investment needs for the whole branch (In our model they were total investment outlays in the amount of 3100 million zlotys available for total investment outlays and 1.27 million zlotys for construction works);

b_{iw} — the total amount of the w-th material resource needed for the implementation of the i-th variant;

B_w — the maximum amount of the w-th material resource available in the 5-th year plan that may be allocated to the whole branch; for the sugar industry limited material resources were: 16 ORS — 16 boilers, 7 OR-32 boilers and 6 TP5 turbines;

d_i — the average annual increase in the productive capacity obtained in consequence of the realization of the i-th investment variant; in the case of the sugar industry, the object was to use up the whole quantity of the raw material earmarked for sugar production; the duration of the sugar campaign in Poland exceeds the period recognized as optimal and in this connection there are considerable losses of sugar toward the end of the sugar campaign and an increase in the marginal production cost;

D — the postulated incrase in the productive capacity of the sugar factories toward the end of the 5-year plan amounting to 10 470 tons of sugar beets per day.

On the basis of available information we have assumed that 100 different investment variants are possible within the whole sugar industry. These included: modernization of plants not connected with increase in production; expansion of plants and their modernization; simple replacement of the used up fixed capital goods, construction of new plants. It might be possible in this model to treat the replacement of the particular machines and equipment as separate investment directions, but this idea was given up because it would then be necessary to analyze a very big model. It would not have been possible to find a solution to such a model with the computers available to the author at the time.

Information concerning investment variants was received from the individual sugar plants. The data, verified and occasionally supplemented by the enterprises and by the Sugar Industry Association[2], are presented in Table 1. In the model we have assumed that investment variants are indivisible. Decision variable x_i may then assume the values 0 or 1.

If decision variable for direction $x_{33} = 0$, that means that the given investment variant should not be put into effect. If we obtain $x_i = 1$ from the model that would mean that the realization of the i-th variant is desirable from the point of view of the adopted objective function.

We may now look at other constraints on the model. The separate investment variants in a certain subset S_k may exclude each other. That means that if one of the variants is chosen for realization, the other variants in the subset would have to be rejected. The condition is written as constraint (3). For example: three investment variants may be implemented in sugar plant LXII: i_{97} consisting in the replacement of macinery; x_{98} consisting in the modernization of the whole technological line with a relatively slight increase in production; and x_{99} consisting in a considerable expansion with-

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[2] In the sugar industry tere are twelve multi-plant enterprises; some have 1—13 sugar plants, and some only one plant.

Table 1.

Basic Data on Investment Variants

No of variant (i)	Average annual profit earned through realization of the variant in million zlotys (z_i)	Investment outlays on implementation of variant in million zl.		Amount and kind of new equipment needed in units			Average annual increase in the productive capacity of the plant in tons of sugar beet per day (d_i)	Optimal solution (x_i)	Description of variant
		total (a_{i1})	of which: construction work (a_{i2})	TP-5 turbines (b_{i1})	ORS-16 boilers (b_{i2})	OR-32 boilers (b_{i3})			
1	2	3	4	5	6	7	8	9	10
1	24.9	33.3	16.9	—	—	1	—	1	Replacement of production equipment in plant I
2	1.0	5.0	1.5	—	—	—	—	0	Partial replacement of production equipment in plant II
3	12.6	15.0	5.0	—	—	1	310	1	Expansion of plant II
4	4.2	19.5	11.2	—	—	—	—	0	Partial modernization of plant III
5	8.4	34.6	18.7	—	1	—	—	0	Modernization of plant IV
6	6.3	22.0	10.7	—	1	—	170	1	Expansion of plant IV
7	48.9	51.2	34.7	—	—	—	—	1	Modernization of plant V
8	3.0	40.0	24.0	—	—	—	—	0	Partial modernization of plant VI
9	14.2	72.0	50.0	—	—	—	300	0	Expansion and modernization of plant VI
10	8.6	42.0	17.0	—	1	—	230	0	Expansion of plant VII
11	24.0	97.0	59.0	—	—	—	640	0	Major expansion of plant VII
12	10.0	48.0	20.0	1	—	1	—	0	Modernization of plant VIII
13	18.7	60.0	20.0	1	—	1	200	1	Expansion and modernization of plant VIII
14	2.0	20.0	12.0	—	—	—	—	0	Replacement of productive equipment in plant IX
15	8.7	12.0	8.0	—	—	—	200	1	Expansion of plant IX
16	5.0	50.0	20.0	—	1	—	—	0	Modernization of plant X
17	10.0	66.5	48.8	1	—	—	—	0	Modernization of plant XI
18	21.3	150.0	45.5	—	1	—	680	0	Major expansion and modernization of plant XII
19	10.9	127.0	28.0	—	—	—	350	0	Expansion and modernization of plant XII

1	2	3	4	5	6	7	8	9	10
20	22.9	113.0	62.2	—	—	—	730	0	Expansion and modernization of plant XIII
21	12.0	78.0	40.0	1	—	1	—	0	Modernization of plant XIV
22	24.0	100.0	60.0	1	—	—	500	0	Expansion of plant XIV
23	18.0	70.0	30.0	—	—	1	—	1	Partial modernization of plant XV
24	0.4	26.0	2.3	—	—	—	—	0	Replacement of production equipment in plant XVI
25	160.0	800.0	340.0	—	—	—	5000	1	New plant A
26	40.6	298.0	162.0	—	—	—	1100	0	Major expansion of plant XVII
27	33.2	219.0	115.0	—	—	—	900	0	Medium expansion of plant XVII
28	11.1	20.0	9.0	—	—	—	300	1	Minor expansion of plant XVII
29	6.3	10.0	4.0	—	—	—	—	1	Partial expansion of plant XVIII
30	8.5	38.5	18.7	—	—	—	—	0	Replacement of production equipment in plant XIX
31	28.4	51.5	26.0	—	—	—	540	1	Expansion of plant XIX
32	10.0	55.0	42.0	—	—	—	—	0	Modernization of plant XX
33	39.6	120.0	80.0	—	1	—	800	0	Expansion of plant XX
34	2.0	15.0	4.0	—	—	—	—	0	Partial modernization of plant XXI
35	8.0	19.5	5.0	—	—	1	150	1	Expansion of plant XXI
36	6.4	35.0	7.5	—	—	—	160	1	Expansion of plant XXII
37	9.0	46.0	18.0	—	—	—	—	0	Modernization of plant XXIII
38	3.9	45.0	31.5	—	—	—	100	0	Modernization of plant XXIV
39	10.6	116.0	46.0	—	—	1	450	0	Expansion of plant XXV
40	14.2	124.0	48.0	—	—	1	600	0	Major expansion of plant XXV
41	14.0	84.0	60.0	—	—	1	—	0	Modernization of plant XXVI
42	4.1	23.8	10.2	—	—	—	70	0	Modernization of plant XXVII
43	1.7	7.6	2.6	—	—	—	—	0	Replacement of production equipment in plant XXVII
44	7.5	34.8	19.9	—	—	1	—	0	Modernization of plant XXVIII
45	12.5	64.0	22.0	1	—	1	210	1	Expansion of plant XXVIII
46	3.5	22.5	14.0	—	—	—	—	0	Replacement of production equipment in plant XXIX

1	2	3	4	5	6	7	8	9	10
47	4.7	31.5	15.6	—	—	—	50	0	Modernization of plant XXIX
48	9.4	136.5	64.1	1	—	—	400	0	Expansion of plant XXX
49	3.0	66.3	20.0	1	—	1	—	0	Modernization of plant XXXI
50	13.0	48.9	15.0	—	—	—	—	1	Modernization of plant XXXII
51	21.0	115.0	27.0	—	—	—	340	0	Expansion of plant XXXII
52	7.0	22.0	9.0	—	1	—	300	1	Expansion of plant XXXIII
53	5.0	71.0	21.5	—	—	1	—	0	Modernization of plant XXXIV
54	6.6	52.6	11.3	—	—	—	80	1	Minor modernization of plant XXXIV
55	5.0	55.0	24.0	1	—	—	—	0	Modernization of plant XXXV
56	1.6	10.0	2.0	1	—	—	50	1	Partial elimination of bottleneck in plant XXXV
57	3.2	25.0	8.0	1	—	—	100	0	Elimination of bottleneck on plant XXXV
58	4.8	30.0	11.0	1	—	—	150	0	Partial modernization of plant XXXV
59	4.5	16.3	5.0	—	—	—	—	0	Modernization of plant XXXVI
60	12.8	14.7	4.0	—	—	—	400	1	Expansion of plant XXXVI
61	6.9	31.3	12.5	1	—	1	—	0	Modernization of plant XXXVII
62	26.4	48.0	25.5	—	—	—	—	1	Modernization of plant XXXVIII
63	30.6	148.0	82.0	—	—	—	270	0	Expansion of plant XXXIX
64	34.2	176.0	103.0	—	—	—	500	0	Major expansion of plant XXXIX
65	1.8	48.0	22.0	—	—	1	—	0	Replacement of production equipment in plant XL
66	6.5	70.0	30.0	—	—	1	—	0	Modernization of plant XL
67	2.9	21.3	11.8	—	—	—	—	0	Replacement of production equipment in plant XLI
68	32.3	68.0	21.7	—	—	—	—	1	Modernization of plant XLII
69	6.3	127.3	78.6	—	—	1	400	0	Expansion of plant XLIII
70	15.0	85.9	51.5	—	—	—	—	0	Modernization of plant XLIV
71	14.7	54.0	32.0	1	—	1	940	0	Expansion of plant XLIV
72	35.0	90.0	18.0	1	—	—	—	1	Replacement of production equipment in plant XLV
73	36.9	100.0	23.0	—	—	1	120	0	Minor expansion of plant XLV
74	39.5	180.0	37.0	1	—	1	200	0	Expansion and modernization of plant XLV*

1	2	3	4	5	6	7	8	9	10
75	0.5	8.8	4.0	—	—	—	—	0	Replacement of production equipment in plant XLVI
76	2.1	20.1	11.0	—	1	—	100	0	Minor expansion of plant XLVI
77	9.0	77.0	34.0	1	—	—	400	0	Expansion of plant XLVII
78	6.3	16.0	8.0	—	—	—	—	1	Replacement of production equipment in plant XLVII
79	1.0	16.0	13.0	—	—	—	—	0	Modernization of plant XLVIII (partial)
80	4.5	51.0	22.0	1	—	1	—	0	Modernization of plant XLIX
81	7.5	27.3	9.7	—	—	—	300	1	Expansion of plant L
82	13.0	30.0	8.0	—	—	—	—	1	Modernization of plant LI
83	3.8	37.9	18.5	—	—	1	—	0	Modernization of plant LII
84	1.2	20.0	5.5	—	1	1	—	0	Replacement of production equipment in plant LIII
85	11.7	53.2	32.0	—	1	—	420	0	Expansion of plant LIII
86	7.4	32.4	17.6	—	1	—	250	0	Medium expansion of plant LIII
87	6.2	23.7	12.3	—	1	—	200	0	Minor expansion of plant LIII
88	26.0	94.0	68.0	—	—	—	—	0	Modernization of plant LIV
89	6.0	4.0	2.2	—	1	—	—	1	Partial modernization of plant LV
90	10.2	16.5	12.7	—	—	—	170	0	Expansion of plant LV
91	9.4	15.0	10.0	—	—	—	380	1	Expansion of plant LVI
92	6.7	37.5	9.0	—	—	—	270	1	Expansion of plant LVII
93	0.1	8.8	1.1	—	—	—	—	0	Replacement of production equipment in plant LVIII
94	10.0	29.0	13.5	—	—	—	—	1	Modernization of plant LIX
95	8.8	52.3	17.4	—	—	—	630	0	Expansion pf plant LX
96	5.9	22.9	10.5	—	—	—	290	1	Expansion of plant LXI
97	8.8	184.0	92.0	—	—	1	—	0	Replacement of production equipment in plant LXII
98	41.9	350.5	161.7	1	—	1	1520	1	Expansion of plant LXII
99	57.2	513.0	313.4	1	—	1	2400	0	Major expansion of plant LXII
100	174.9	847.3	392.0	—	—	—	5280	1	New plant B

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* In most cases an expansion of a plant also implies its partial modernization. The description of the variant is then very general.

in specified limits, combined with the modernization of the whole plant. The choice of investment variant x_{98} automatically determines that variants x_{97} and x_{99} cannot be realized.

In contrast to constraint (3), constraint (4) concerns the situation where one variant should be selected from the given subsets of investment variants S_m, i.e. we cannot decide not to realize an investment variant of subset S_m. The sugar plant may be in such a technical condition that, for instance, the failure to implement at least one variant in the given plant is tantamount to a decision to close the plant. This may be impossible for various, such as social, reasons. Constraint (4) ensures that the model will select one of the variants belonging to subset S_m. We wish to draw attention to the fact that the adoption of this type of condition makes the whole model more "rigid" and consequently in comparison with the model in which there is no such condition reduces the value of the objective function.

Constraint (5) concerns a situation in which the implementation of one variant necessitates the implementation of another investment variant. This dependence is called an implicating relationship between variants. To give an example, a variant which provides for the automation of the technological process requires the implementation of a variant in which the periodic diffusion apparatus is replaced by constant diffusion equipment. If, however, the decision is that we realize the variant providing for the substitution of permanent diffusion with periodic diffusion, we may, although we do not have to, implement the variant involving the automation of the whole technological process.

Constraint (6) is related to the fact that the industry is limited not only by the amount of financial means earmarked for investments, but also by the amount of the means available for construction work. The limitation of the means for construction work is meant to limit the scope of construction work in view of difficulties connected with finding a construction contractor in Poland.

Constraint (7) concerns scarce investment goods. In our case the limitation would concern two kinds of boilers (b_{i2} and b_{i3}) and a certain type of turbine (b_{i1}).

The choice of the objective function is very important. This decision stands higher in the hierarchy than the choice of the optimal decision with a given objective function.[3] In our model the objective function is so constructed that all decision variables and profit are its components. The purpose of this function is to determine the relationships between the specific decisions and their economic effects. A specific value of the function is a measure of the quality of the investment programme. One reason

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[3] Cf. Z. Czerwiński, *Matematyka na usługach ekonomii*, 3rd ed., Warszawa 1972, Państwowe Wydawnictwo Naukowe, p. 143.

why profits should be included in the objective function is because it is a measure with a wide range of reception, i.e. the amount and kind of phenomena registered by it are considerable.[4] A decision that is inconsistent with the maximization of the objective function enables the calculation of opportunity cost.

The model's time horizon is five years and its data (plants, effects, the future state of industry) were accepted without a division into shorter periods of time because no information was available concerning the desirable distribution of data over time. Moreover, a model with 500 decision variables ($x_i \cdot t$) would pose difficulties in solving the problem. Another weakness of the model is that we have narrowed the potential of building new plants to two investment variants, namely: the sugar plants of Łapy, Białystok voievodship, processing 5280 tons of sugar beet daily, and the sugar plant Krasnystaw, Lublin voievodship, processing 5000 tons of sugar beet daily. The choice of location variants and of the desired size of the plant has been made earlier, outside of the model.

The sugar beet campaign lasts only about three months; expansion and modernization of a sugar plant does not mean that it is shut down. There is therefore no such situation where a plant under expansion ceases to produce, thus reducing the output of the whole branch.

II. Analysis of the Results

The stages by which the solution is reached are shown in Fig. 1. It can be seen that the model is solved by the iteration procedure.

Among the effective investment variants the solution includes the construction of two big modern plants (x_{25} and x_{100}) and the modernization combined with only a slight expansion of the 36 existing plants.

The basic feature of the optimal solution is that without exceeding the limit set for the resources it yields an increase of 16 710 tons of sugar beets per day in the plant's productive capacity, while the five year plan envisaged an increase of only up to 10 470 tons of sugar beets per day. The substantial expansion of the plant's productive capacity, provided for by the optimal solution and exceeding the intentions of the five year plan in this field by 6240 tons of sugar beet per day, makes it possible to close down several obsolete plants or to shorten considerably the sugar campaign.

With the elimination of obsolete plants, it would be possible to close down small plants that process less than 1200 tons of sugar beet per day.

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[4] An analysis of using profit for verifying the production methods with respect to the range of reception of the indicator has been made by J. Więckowski, *Rola zysku w kierowaniu produkcją*, Państwowe Wydawnictwo Naukowe, Warszawa 1965, p 392.

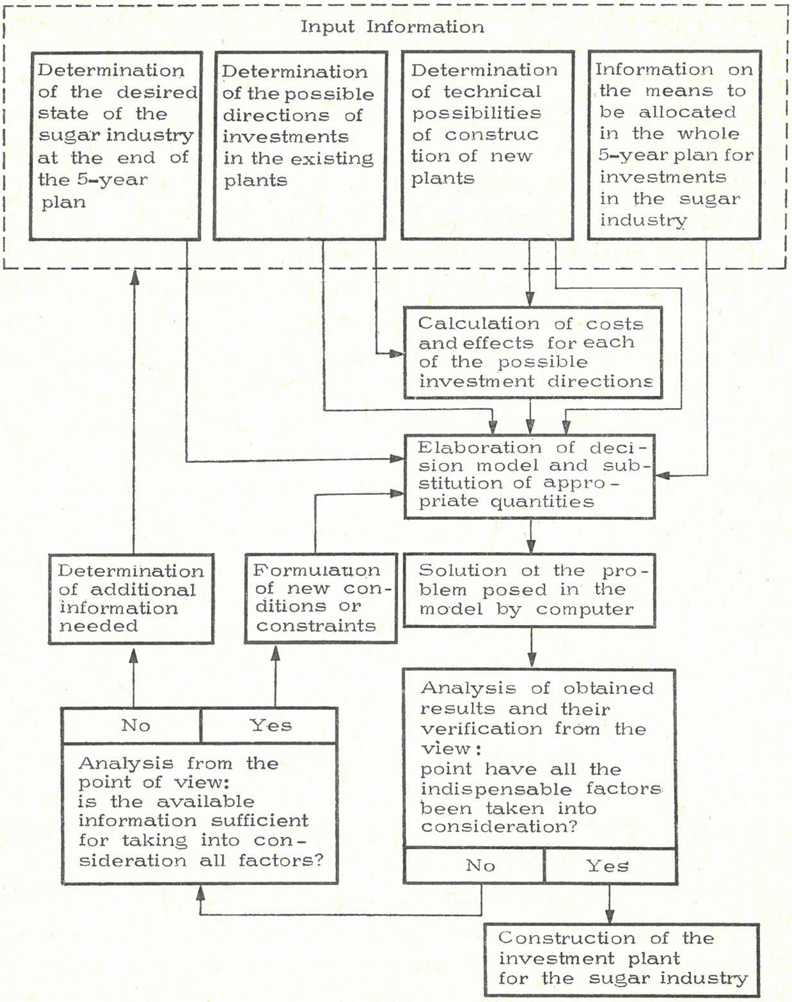

Fig. 1. *Stages in determining the most effective directions of investment for the sugar industry*

Although these plants lie within a relatively small radius of raw material sources, they usually produce at the highest cost and have the worse technical parameters. About 20 per cent of the total number of sugar plants in Poland now have an average processing capacity of less than 1200 tons of sugar beet per day. The shortening of the sugar campaign would primarily affect those sugar plants where sugar production is relatively expensive, especially toward the end of the campaign when marginal costs increase considerably. The more the sugar campaign exceeds the optimal duration of the campaign, the higher the costs increase.

Another important characteristic of the optimal solution is that it has zeroed out a considerable part of investment variants providing for modernization and expansion while including both variants providing for the construction of big new plants with a greater productive capacity than has ever been known in Poland. The solution contradicts the commonly held view that it is most advantageous to expand an operating plan. This occurs when we have unsynchronized production lines. In that event investment in some elements only gives fuller utilization of the whole line. With the passage of time, however, bottlenecks are eliminated. In Poland cheap modernization and expansion of sugar plants have actually been completed. At present the effective variants call for the construction of new plants or the modernization of the existing one, this with substantial outlays. This is related to the fact that the capital-output ratio of new plants is basically lower than the capital-output ratio of modernization and expansion of old plants. It is probable that if there were found more then two investment variants in the model providing for the construction of new big sugar plants then more then two new plants would be included in the optimal solution.

The obtained value of the objective function could be considerably increased if the constraint on the model by equation (4) were dropped. We may take here the examples of the variants concerning minor expansion (x_{98}), major expansion (x_{99}), or only the replacement of production equipment (x_{97}) in the sugar plant at Przeworsk. The Przeworsk plant is the only one in Przemyśl voievodship to have a considerable surplus of sugar beets. In the opinion of experts, if one of the investment variants mentioned above were not realized, the plant in Przeworsk would have to be closed down because of its technical condition. Generally, however, this would be undesirable because the elimination of the sugar plant in this region would in turn cause a cutback in sugar beet cultivation contracts and therefore a decline in cultivation and in farmers' incomes in that region. The constraint laid upon the model, calling for the choice of one of the investment variants for the sugar factory of Przeworsk, introduced variant x_{98} into the optimal solution and in effect lowered the value of the objective function by about 40 milion zlotys, precluding choice of other, more effective investment variants. Taking the interest of the region into consideration has turned out to be relatively costly.

By solving the dual problem we have obtained dual prices[5] for scarce factors (limited resources). Outlays for construction work obtained the highest dual price. One zloty's worth of this work obtained the dual price equal to 0.44 zlotys; one zloty's worth of investment outlays — 0.005 zlotys; one zloty's worth of OR 32 boilers — 0.003 zlotys and the dual price of ORS 16 boilers and turbines equalled O. We know that the dual price in-

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[5] Since the optimization model belongs to the class of whole number models, these are not strictly speaking dual prices, but quasi dual prices. They have been obtained by the parametrization of constraints.

dicates how much the objective function changes if a limited resource is increased by one unit.

The investment programme determined by the model presented here has been and is a basis for the investment policy pursued by the Polish sugar industry in 1971—1975. Most variants determined by the optimization model have already been realized or are being realized. The construction of the new plant of Łapy is completed and the sugar plant of Krasnystaw is in the final stage of construction. The suggestion that small sugar plants should be eliminated has not been put into effect, however, even though this was indicated by the solution of the model and was advisable from the economic point of view. This, however, proved impracticable for social reasons. It was in the interest of these regions to keep the sugar plants in operation for they ensured seasonal work and sponsored the development of cultural activities (cinemas, day rooms etc.). Even though small sugar plants have not been eliminated in most cases, they have, nevertheless, been expanded. Small sugar plants whose daily processing is below 1200 tons of sugar beets per day represent only 10 per cent in 1975, as compared with the 20 per cent of the total sugar plants in operation.

With the implementation of the investment programme, it was possible to reduce to a certain degree the disproportion between the big productive capacity of the sugar plants of western Poland, with their relative shortage of raw material, and the relatively small productive capacity of the sugar plants of the central and south-eastern regions which traditionally are the areas of the greatest sugar beet cultivation.

The practical usefulness of the model prompted the sugar industry to decide to use it again with certain adaptations for developing the investment programme for 1976—1980.

The obtained results clearly indicate the advantages of choosing investment variants on the basis of a decision model, over the traditional analysis of outlays and effects. The traditional analysis of the effectiveness of investments cannot take into account such basic elements of choice as, eg. the limited availability of certain economic resources. It seems advisable, therefore, to make greater use of decision models in analyzing the effectiveness of investments.

The model presented here was prepared for a specific branch and its application to other branches will require appropriate modifications and development. It should be remembered, however, that every development of the model brings it closer to reality, although it also makes the possibility of solving it more remote. (*js*)

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