PROBLEMS OF CREATING SCIENTIFIC IDEAS ABOUT WORLD DEVELOPMENT

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CHOICE OF A MACHINE-BUILDING ENTERPRISE CLIENT WITH LIMITED PRODUCTION CAPACITIES

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The limitation of production resources with a significant portfolio of orders forces manufacturers to choose the most profitable among all orders.

Let's consider the solution of this problem for a machine-building enterprise that manufactures large-sized structures.

For this, statistics were collected from 80 orders that were previously fulfilled by this enterprise on nine factors, indicating their conventional designations:

1) client - the name of the legal client encrypted with a number according to the value of the client for the enterprise (x_1);

2) production terms - the period of time necessary for the complete completion of the order is expressed in calendar days (x_2);

3) the cost of materials - the cost of materials needed to fulfill the order (x_3);

4) basic W/P - wages paid to workers for order fulfillment (x_4);

5) general production costs - all types of costs that occur during production, for example, costs of production management, depreciation of intangible assets, costs of maintenance of the production process, costs of labor protection, etc. (but EXCEPT costs of maintenance and operation of equipment and administrative costs) (x_5);

6) expenses for the maintenance and operation of the equipment - expenses for maintaining the equipment in working condition and technical care (x_6);

7) administrative expenses are expenses for communication services (postal, telegraphic, telephone, fax, etc.), for depreciation of intangible assets of general economic purpose and other (x_7);

8) sales expenses - these are expenses for packaging materials and repair of containers, for delivery, for sales department employees' business trips, etc. (x_8);

9) planned profit - the amount of profit that will be received after the execution of the order (y).

The names of the customers of the engineering company are numbered from less important to more important in order of increasing importance from 1 to 14.

All data in monetary terms are adjusted to take into account the current galloping inflation. A fragment of the results is given in table. 1.

Table 1
Input factors

Client	Deadlines production, days	Cost of materials, UAH	Main S/P, UAH	General production costs, UAH	Maintenance expenses and equipment operation, UAH	Administrative expenses, UAH	Selling expenses, UAH	Planned profit, UAH	The total cost, UAH
1	60	12 000,71	5 464,07	3 835,95	2 397,47	2 234,44	1 917,98	3 196,63	31 047,25
1	70	64 787,85	29 077,03	20 413,02	12 758,14	11 890,58	10 206,51	25 516,27	174 649,40
3	30	57143,485	7862,69	3 324,28	798,07	2 405,21	1 616,14	11 776,04	84 925,90
4	50	573987,59	86859,86	35 559,34	8 992,09	23 739,26	16 875,17	127 508,29	873 521,60
9	20	6052,925	900,45	357,58	92,65	253,94	183,29	1 488,68	9 329,50
9	30	45991,05	8581,7	2 868,28	806,57	2 404,71	1 474,14	10 724,55	72 851,00
9	20	6708,685	1022,49	413,00	110,75	321,25	210,50	1 768,24	10 554,90
9	30	21098,24	3722,96	1 264,58	318,90	945,69	735,79	5 294,44	33 380,60
10	30	15314,34	2375,36	906,74	210,44	683,31	509,87	3 830,54	23 830,60
14	55	84040,95	12626,3	5 100,92	1 430,23	4 355,69	2 772,46	20 868,45	131 195,00
13	20	7233,81	963,74	436,90	108,47	333,42	214,95	1 398,11	10 689,40

Taking into account the fact that these data refer to different types of orders, we consider it necessary to divide all orders into homogeneous groups using the method of cluster analysis[1] by the STATISTICA 12 program.

The system suggested 6 clusters as the best option. The clustering error is 12.4%. For this type of clustering, an error size of less than 20% is acceptable. In the table 2 shows the content of the clusters.

The task of classification, that is, assigning new orders to a certain cluster, is performed by the method of creating linear separable functions [1].

The following technique was used to construct linear separable functions:

1) a column of an additional variable was created, which was called the cluster separation function (Y*);

2) when calculating the linear regression for the i-th cluster, the value of Y* was assigned the number 1000 only for the data of this cluster (Table 3);

3) for other clusters Y* = 0;

4) after that, linear regression dependences of Y* on the input factors were constructed. An example is given in table 3.5;

5) repeat the previous procedure for all clusters, thus obtaining 5 dependencies;

6) checking the quality of cluster separation for these functions is performed according to the table of calculated Y* values. If the value of Y* for the corresponding cluster exceeds the value of Y* for the other clusters, then the function is acceptable.

Table 2.
List of orders of each cluster

Cluster number	Order number
1	1;2;3
2	7;15;17;20
3	32;33;34;35;36;37;38;39;40;41;42;43;44;45;46;47;48;49;50; 51;52;53;54;55;56;57;58;59;60;61;62;63;81
4	64;65;66;67;68;82;83;84;85;86;87;88;89;90; 91;92;93;94;95;96;97;98;99;100
5	4;5;8;9;10;11;12;13;14;16;18;19;21;22;23;24;25;26;27;28; 29;30;31;69;70;71;72;73;74;75;76;77;78;79;80
6	6

We use the obtained data, divided into clusters and ordered data, to construct separate functions.

Table 3.
Data for constructing separable functions

x_i	C laster	Clien	Deadlines productio n, days	Cost of materials, UAH	Main S/P, UAH	General production costs, UAH	Maintenance expenses and equipment operation, UAH	Administrativ e expenses, UAH	Selling expenses, UAH	Planned profit, UAH	Y*
1	1	1	60	12 000,71	5 464,07	3 835,95	2 397,47	2 234,44	1 917,98	3 196,63	1000
2	1	1	70	64 787,85	29 077,03	20 413,02	12 758,14	11 890,58	10 206,51	25 516,27	1000
3	1	1	90	83 512,33	42 497,20	29 834,41	18 646,51	17 378,55	14 917,21	37 293,00	1000
7	2	1	45	498199,8	12186,6	11026,0	10004,3	16539,0	6383,5	29015,7	0
…											
79	5	5	30	21731,0	3647,8	1254,3	310,6	1039,8	750,2	5260,8	0
80	5	5	30	44015,9	5900,5	2532,6	698,2	1795,5	1146,3	10123,3	0
6	6	2	100	722558,8	289023,5	231218,8	144511,8	134877,7	115609,4	289023,5	0

To obtain the dependence of profit on other factors, we will use the method of regression analysis [2], implemented in the Microsoft Excel program, Regression application.

Equations of linear separable functions for each cluster are given in formulas (1) – (5):

$$Y_1^* = -149{,}560312939845 - 7{,}09068385470914x_1 + 8{,}55694422389997x_2 - 0{,}0010770767528679x_3 + 0{,}0678413864889972x_4 + 0{,}0350170017499101x_5 + 0{,}0290135580007626x_6 + 0{,}10742725104577x_7 - 0{,}313245729560543x_8 ; \quad (1)$$

$$Y_2^* = 95{,}522815611928 - 1{,}13728709806489x_1 - 4{,}69099852289208x_2 + 0{,}00252519403870347x_3 + 0{,}0483490570323496x_4 + 0{,}0394352564458389x_5 + 0{,}0933677749343886x_6 + 0{,}0088758189384828 6x_7 - 0{,}299740950783223x_8 ; \quad (2)$$

$$Y_3^* = -47{,}5216834409601 + 23{,}9212438708728x_1 + 7{,}86930264674164x_2 - 0{,}000563503512678159x_3 - 0{,}0568865746457246x_4 + 0{,}211182540978628x_5 - 0{,}219689141899767x_6 + 0{,}0843717753182541x_7 - 0{,}0823407894840514x_8 ; \quad (3)$$

$$Y_4^* = -348{,}611420093822 + 77{,}9693909678877x_1 - 0{,}713000303145708x_2 + 0{,}000450316663141703x_3 + 0{,}0287352487310771x_4 - 0{,}173182883354813x_5 + 0{,}276231977169644x_6 + -0{,}123800605570664x_7 - 0{,}00307431813846626x_8 ; \quad (4)$$

$$Y_5^* = 1434{,}9329837623 - 94{,}1321883224578x_1 - 10{,}2415136122854x_2 - 0{,}0012592112307783x_3 - 0{,}0796663582345305x_4 - 0{,}122503664851109x_5 - 0{,}16373275794641x_6 - 0{,}0775190120632026x_7 + 0{,}671965009657603x_8 ; \quad (5)$$

After making sure that the clusters are chosen correctly, we calculate the regression dependence of profit on 8 variable factors for each cluster separately.

The obtained regression models (6) - (10) are acceptable, because R^2 is close to one, and the standard error is relatively small.

$$Y_1 = -1950{,}90052644474 + x_1 + x_2 + 0{,}080556382542458x_3 + 0{,}765143334712704x_4 + x_5 + x_6 + x_7 + x_8 ; \quad (6)$$

$$Y_2 = -1359{,}87577854601 + x_1 + x_2 - 0{,}0688575542775755x_3 + 1{,}08915537890526x_4 + x_5 + x_6 + 3{,}10825484442974x_7 + x_8 ; \quad (7)$$

$$Y_3 = 955{,}988217306248 - 42{,}9361820680878x_1 - 20{,}3639638570665x_2 + 0{,}0704084932487456x_3 + 0{,}372275745834202x_4 + 1{,}69497354707548x_5 - 7{,}88754821059287x_6 + 1{,}91241925216224x_7 + 1{,}0518035075457x_8 ; \quad (8)$$

$$\begin{aligned} Y_4 = {} & -157{,}937254874147 + 34{,}4828931140938x_1 - 16{,}89761042695x_2 \\ & - 0{,}0148641008706581x_3 - 0{,}402367560254512x_4 \\ & + 1{,}69518315771836x_5 + 0{,}812333688491075x_6 \\ & + 2{,}90254485840924x_7 + 1{,}91209077114898x_8 ; \end{aligned} \quad (9)$$

$$\begin{aligned} Y_5 = {} & 546{,}895069714055 - 15{,}1727018624788x_1 - 25{,}7387129775071x_2 \\ & + 0{,}0802086853955735x_3 + 0{,}414101015798951x_4 \\ & + 1{,}92242345974274x_5 - 2{,}34029827292609x_6 \\ & + 1{,}35534393016702x_7 - 1{,}50539839889764x_8 ; \end{aligned} \quad (10)$$

To obtain the dependence of profit on other factors, we will use the method of regression analysis [2], implemented in the Microsoft Excel program, Regression application. Thus, profit forecast functions for each cluster were obtained.

Now it is necessary to formulate restrictions for optimization x calculations on a computer:

1) profit tends to the maximum value
$$Y_i \rightarrow max \ ;$$
2) the daily load in monetary terms must be less than the calculated average daily load from the execution of all orders (the order with the optimal production load was selected)
$$\frac{\sum_{i=3}^{6} \boldsymbol{x_i}}{\boldsymbol{x_2}} \leq \mathbf{2956,17}\ грн \ ;$$

3) there is only one value in the sixth cluster, and a model cannot be created for it. Then, for such rare and large orders, we will introduce conditions: if the cost of the order is more than UAH 1,300,000, then the profit is 10% of it:

$$\sum_{i=3}^{6} x_i > 1300000 грн., мод i\ Y_j = 0{,}1 \sum_{i=3}^{6} x_i \ ; \quad (11)$$

4) all entered parameters must be greater than or equal to zero
$\boldsymbol{x_i \geq 0}$.

Thus, the mathematical model has the following form given in formula (12):

To test the performance and efficiency of the IS, let's take 10 new orders and process them with the help of the program. The characteristics of the orders are given in table. 4.

The calculation of the optimal choice of orders is performed by the simplex method [2] in two stages.

At the first stage, the order data is entered into separate functions (1) - (5), which determine the number of the class to which this order belongs.

At the second stage, the appropriate profit function is chosen and, taking into account the restrictions, the possible profit from this order is found.

After calculating the possible profits for all orders in this way, those that give the highest profit in this set of orders are chosen among them.

$$
\begin{aligned}
&Y_1 = -1950{,}90052644474 + x_1 + x_2 + 0{,}080556382542458x_3 \\
&\qquad + 0{,}765143334712704x_4 + x_5 + x_6 + x_7 + x_8 ; \\
&Y_2 = -1359{,}87577854601 + x_1 + x_2 - 0{,}0688575542775755x_3 \\
&\qquad + 1{,}08915537890526x_4 + x_5 + x_6 + 3{,}10825484442974x_7 + x_8 ; \\
&Y_3 = 955{,}988217306248 - 42{,}9361820680878x_1 - 20{,}3639638570665x_2 \\
&\qquad + 0{,}0704084932487456x_3 + 0{,}372275745834202x_4 \\
&\qquad + 1{,}69497354707548x_5 - 7{,}88754821059287x_6 \\
&\qquad + 1{,}91241925216224x_7 + 1{,}0518035075457x_8 ; \\
&Y_4 = -157{,}937254874147 + 34{,}4828931140938x_1 - 16{,}89761042695x_2 \\
&\qquad - 0{,}0148641008706581x_3 - 0{,}402367560254512x_4 \\
&\qquad + 1{,}69518315771836x_5 + 0{,}812333688491075x_6 \\
&\qquad + 2{,}90254485840924x_7 + 1{,}91209077114898x_8 ; \\
&Y_5 = 546{,}895069714055 - 15{,}1727018624788x_1 - 25{,}7387129775071x_2 \\
&\qquad + 0{,}0802086853955735x_3 + 0{,}414101015798951x_4 \\
&\qquad + 1{,}92242345974274x_5 - 2{,}34029827292609x_6 \\
&\qquad + 1{,}35534393016702x_7 - 1{,}50539839889764x_8 ; \\
&\boldsymbol{Y_j \rightarrow max} \ ; \\
&\frac{\sum_{i=3}^{6} x_i}{x_2} \leq \frac{\sum_{i=3}^{6}\sum_{j=1}^{100} x_{ij}}{\sum_{j=1}^{100} x_{2j}} \ ; \\
&\sum_{i=3}^{6} x_i > 1300000 \text{грн.}, \text{моді } Y = 0{,}1\sum_{i=3}^{6} x_i \ ; \\
&x_i \geq 0 \ .
\end{aligned}
\tag{12}
$$

The results of the calculations of the estimated profit from orders based on the integer simplex method [2], which are placed in descending order of priority, are shown in green in the table. 4.

The optimal package of orders (indicated in green) is also indicated in the table. 4.

Table 4.
Characteristics of new orders

№	Name of the order	Clien	Deadlines production, days	Cost of materials, UAH	Main S/P, UAH	General production costs, UAH	Maintenance expenses and equipment operation, UAH	Administrative expenses, UAH	Selling expenses, UAH
1	Smoke pipe (brand G1)	1	30	12 385	1 905	762	191	572	381
2	Smoke pipe (brand G2)	3	30	55 969	8 611	3 444	861	2 583	1 722
3	Smoke pipe (brand G3)	2	30	24 693	3 799	1 520	380	1 140	760
4	Limestone bunker	11	40	42 717	6 572	2 629	657	1 972	1 314
5	Gypsum bunker	14	30	14 404	2 216	886	222	665	443
6	Slag hopper	6	35	53 226	8 189	3 275	819	2 457	1 638
7	Iron ore bunker	4	20	131 117	20 172	8 069	2 017	6 052	4 034
8	Dust chute	7	15	2 234	344	137	34	103	69
9	Chute 1	8	20	18 843	2 899	1 160	290	870	580
10	Chute 2	9	30	24 824	3 819	1 528	382	1 146	764

References:

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