

# Usage of Modern Information Technologies of Solving the Optimal Allocation Problem Investments in the Enterprise

Anna Ignatenko, Leonid Scherbak

**Abstract**— This work concerns the present-day problems of modern information technologies usage in solving the optimal allocation problem investments in economics.

**Keywords**— method, solution, enterprise, technology, investments, efficiency.

## I. INTRODUCTION

The development of various enterprises, the accumulation and use of capital investments have been urgent problems of the economy of different countries of the world for the last, almost three centuries. Today these problems are solved with the use of modern information technologies. Over the past period, a considerable number of methods of solving economic problems have been introduced, so when creating the appropriate information technology, there is always a question, and accordingly a task, on the basis of which method to implement the relevant information technology.

One of these tasks this work is dedicated.

## II. LITERATURE REVIEW

This work is based on three main types of literature: modeling in economics (Kartaev F.S. Econometrics, Baldin K.V. Mathematical Methods and Models in Economics, Markin Y.P. Economic Analysis, Karaseva R.B. Mathematical Enhancement student's competence in introducing research problems into the learning process), the use of MS excel in economic tasks (Internet tutorials in Excel, Microsoft Excel user manual, Guseva O.L. Mironova N.N. Excel for Windows), as well as programming of economic processes (Karaseva R. B. Tend of Modern, Mathematical Education, I.L. Akulich, Mathematical Programming in Examples and Problems, M.G. Zaitsev (Methods of Management Optimization for Managers).

## III. THE PURPOSE OF THE WORK

### A. Problem statement

Based on the analysis of the results of the use of three known methods: search; search for a solution; dynamic programming to justify the choice of one of them to solve the problem of optimal distribution of investments in the development of the enterprise.

In this way, you can form the purpose, object, subject and methods of research of this work.

### B. The purpose of the work.

Based on the results of the analysis of the use of the three methods of solving the optimal problem, it is reasonable to use one of them to create the appropriate information technology.

Object of research. The process of optimizing the efficiency of investment in the development of each enterprise.

### C. The subject of research.

Results of efficiency of use of capital investments by the enterprise.

## IV. RESEARCH METHODS

1. The search method
2. Solution Finder
3. Programming method.

This work was done based on MS Excel.

### A. Task

- Exploring different methods of finding the most profitable investment
- Identify opportunities for using modern technologies
- Investigation of the most rational method for individual tasks

For the development of three enterprises allocated 5 million UAH. The known efficiency of investments in each enterprise, given by the values of nonlinear functions  $g1(X_j)$  presented in the table below:

$X_j$	$g1(x)$	$g2(x)$	$g3(x)$
0	0,0	0,0	0,0
1	2,2	2,0	2,8
2	3,0	3,2	5,4
3	4,1	4,8	6,4
4	5,2	6,2	6,6
5	5,9	6,4	6,9

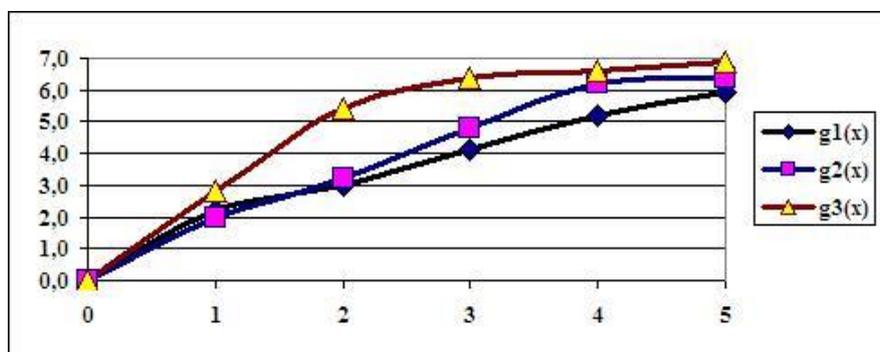


Fig. 1 Graphical representations of performance features

The calculations will be made on the assumption that the distribution of funds is made in integers  $X_j = \{0,1,2,3,4,5\}$  million UAH.

**B. The search method.**

The application of this method is justified by the fact that the problem is solved in integers with a small range of values of variables. In this case, the three variables  $x_1$ ,  $x_2$  and  $x_3$  take one of the six possible values of  $X_j$ . So there are  $6^3 = 216$  combinations of variables in total. However, only those with  $x_1 + x_2 + x_3 = 5$  should be considered for consideration

The output is recorded in the MS Excel worksheet as shown in Figure 2.

	B	C	D	E
2	$X_i$	$g_1$	$g_2$	$g_3$
3	0	0,0	0,0	0,0
4	1	2,2	2,0	2,8
5	2	3,0	3,2	5,4
6	3	4,1	4,8	6,4
7	4	5,2	6,2	6,6
8	5	5,9	6,4	6,9

Fig. 2 Organization of output data on a worksheet

To systematically search all combinations, it is rational to translate decimal numbers in the range from 0 to 215 in a six-point system of calculus. Separate bits of the hex representation and will be the values of the variables sought.

A possible variant of translation of decimal numbers of combinations in the digits of hex code is presented in Fig. 3.

	A	B	C	D
12	Дес экв	$x_1$	$x_2$	$x_3$
13				
14	0	0	0	0
15	1	=ЕС.ИИ(И(C14=5;D14=5);ЕС.ИИ(B14+1=6;0;B14+1);B14)	=ЕС.ИИ(D14=5;ЕС.ИИ(C14+1=6;0;C14+1);C14)	=ЕС.ИИ(D14+1=6;0;D14+1)
16	2	=ЕС.ИИ(И(C15=5;D15=5);ЕС.ИИ(B15+1=6;0;B15+1);B15)	=ЕС.ИИ(D15=5;ЕС.ИИ(C15+1=6;0;C15+1);C15)	=ЕС.ИИ(D15+1=6;0;D15+1)
17	3	=ЕС.ИИ(И(C16=5;D16=5);ЕС.ИИ(B16+1=6;0;B16+1);B16)	=ЕС.ИИ(D16=5;ЕС.ИИ(C16+1=6;0;C16+1);C16)	=ЕС.ИИ(D16+1=6;0;D16+1)

Fig. 3 Formulas for translating decimal combinations numbers into hex codes

The calculation of the investment performance is made in the column  $g_1 + g_2 + g_3$ . To do this, enter the formula E14: = IF (B14 + C14 + D14 = 5; VIEW (B14; \$ B \$ 3: \$ B \$ 8; \$ C \$ 3: \$ C \$ 8) + VIEW (C14; \$ B \$ 3: \$ B \$ 8; \$ D \$ 3: \$ D \$ 8) + VIEW (D14; \$ B \$ 3: \$ B \$ 8; \$ E \$ 3: \$ E \$ 8); 0), which is then extended (extended) to the bottom of the table (Fig. 4).

	E
12	$g_1 + g_2 + g_3$
13	
14	=ЕС.ИИ(B14+C14+D14=5;ИПОСМОТП(B14;SBS3:SBS8;SC3:SC8)+ИПОСМОТП(C14;SBS3:SBS8;SD3:SD8)+ИПОСМОТП(D14;SBS3:SBS8;SE3:SE8);0)
15	=ЕС.ИИ(B15+C15+D15=5;ИПОСМОТП(B15;SBS3:SBS8;SC3:SC8)+ИПОСМОТП(C15;SBS3:SBS8;SD3:SD8)+ИПОСМОТП(D15;SBS3:SBS8;SE3:SE8);0)
16	=ЕС.ИИ(B16+C16+D16=5;ИПОСМОТП(B16;SBS3:SBS8;SC3:SC8)+ИПОСМОТП(C16;SBS3:SBS8;SD3:SD8)+ИПОСМОТП(D16;SBS3:SBS8;SE3:SE8);0)

Fig. 4 Formulas for calculating overall performance with constraints on variables  $x_1$ ,  $x_2$  and  $x_3$

To select the optimal solution in the cell F14, the formula for selecting the maximum value from the whole range of variants is introduced, and the cells G14, H14, and I14 enter formulas for choosing from the range of the combinations  $x_1$ ,  $x_2$ , and  $x_3$  at which this maximum is reached (Fig. 5).

	F	G	H	I
12	Решение			
13	Max	x1	x2	x3
14	=МАКС(E14:E229)	=ИНДЕКС(B14:B229;ПОИСКПОЗ(SF14;SE14:SE229;0);1)	=ИНДЕКС(C14:C229;ПОИСКПОЗ(SF14;SE14:SE229;0);1)	=ИНДЕКС(D14:D229;ПОИСКПОЗ(SF14;SE14:SE229;0);1)

Figure 5. Choosing the best solution formulas

To facilitate the visual search for the best solution, a column with cumulative performance can be formally conditionally formatted to equal the maximum cumulative efficiency value. A fragment of the letter showing the final decision is presented in Fig. 6.

	A	B	C	D	E	F	G	H	I
12	Дес экв	x1	x2	x3	g1+g2+g3	Решение			
13						Max	x1	x2	x3
14	0	0	0	0	0	10,8	1	2	2
15	1	0	0	1	0				
16	2	0	0	2	0				
64	50	1	2	2	10,8				
65	51	1	2	3	0				
66	52	1	2	4	0				
67	53	1	2	5	0				
68	54	1	3	0	0				
69	55	1	3	1	9,8				

Figure 6. The final results of the decision by the search method.

C. "Finding a Solution".

Solution Finder allows you to limit the number of variables. Therefore, this problem can be solved with this tool.

Figure 7 shows the possible organization of the worksheet, and Figure 8 - setting options options "Search for a solution."

	B	C	D	E
2	x1	g1	g2	g3
3	0	0	0	
4	1	2,2	2	2,8
5	2	3	3,2	5,4
6	3	4,1	4,8	6,4
7	4	5,2	6,2	6,6
8	5	5,9	6,4	6,9
9				
10				
11	x1	x2	x3	x1+x2+x3
12				=B12+C12+D12
13				
14	Целевая функция			
15	=ПРОСМОТР(B12;SB\$3:SB\$8;SC\$3:SC\$8;ПРОСМОТР(C12;SB\$3:SB\$8;SD\$3:SD\$8;ПРОСМОТР(D12;SB\$3:SB\$8;SE\$3:SE\$8))			

Fig. 7. Organizing your worksheet when using the Solution Finder tool

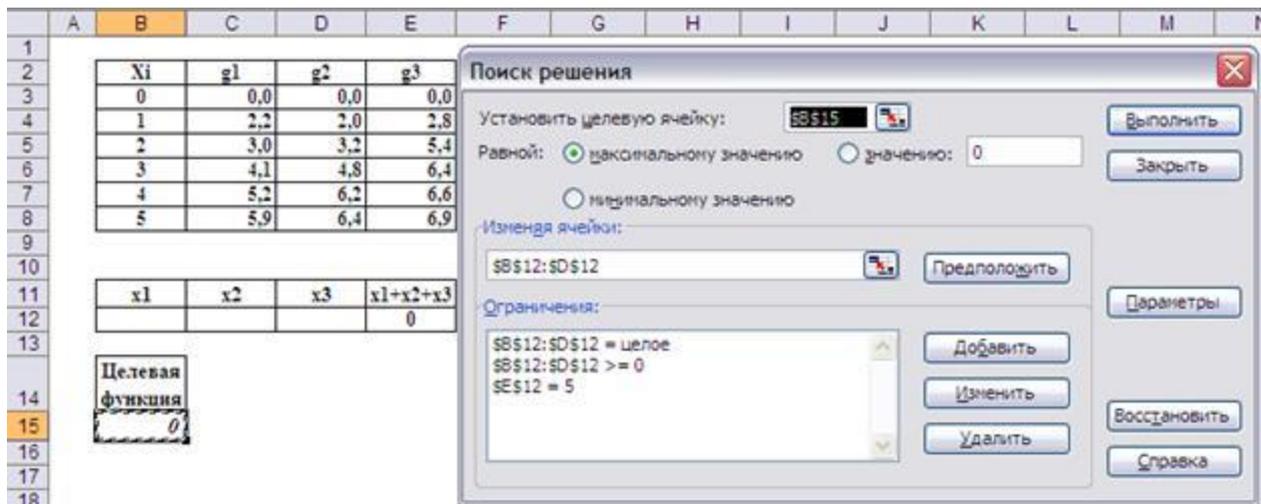


Fig. 8. Setting options for Solution Finder

The results of the decision (Fig. 9) coincide with the results obtained by the search method.

	A	B	C	D	E
1					
2		<b>Xi</b>	<b>g1</b>	<b>g2</b>	<b>g3</b>
3		0	0,0	0,0	0,0
4		1	2,2	2,0	2,8
5		2	3,0	3,2	5,4
6		3	4,1	4,8	6,4
7		4	5,2	6,2	6,6
8		5	5,9	6,4	6,9
9					
10					
11		<b>x1</b>	<b>x2</b>	<b>x3</b>	<b>x1+x2+x3</b>
12		1	2	2	5
13					
14		<b>Целевая функция</b>			
15					10,8

Figure 9. The final results of the solution using the Find Solution

Dynamic programming method. The above methods of decision are rationally applied at small dimensions of the problem. In the case of a large number of enterprises and a large amount of investment, the dynamic programming method is used.

According to the idea of the method of the problem is solved in two stages .:

Stage 1 Conditional optimization (k = 3, 2, 1).

Step 1:  $k = 3$ . It is assumed that all funds in the amount of  $x_3 = \text{UAH } 5$  million. dedicated to a third company. In this case, the maximum revenue, as can be seen from the output table and the table for the Bellman function  $F_3(c_3) = g_3(x_3)$  will be  $g_3(x_3) = \text{UAH } 6.9$  million.

$c_3 \backslash x_3$	0	1	2	3	4	5	$F_3(c_3)$	$x_3^*$
0	0,0	-	-	-	-	-	0,0	0
1	-	2,8	-	-	-	-	2,8	1
2	-	-	5,4	-	-	-	5,4	2
3	-	-	-	6,4	-	-	6,4	3
4	-	-	-	-	6,6	-	6,6	4
5	-	-	-	-	-	6,9	6,9	5

Step 2:  $k = 2$ . Determine the optimal strategy for allocating funds between the second and third companies. In this case, the Bellman recurrence relation has the form:  $F_2(c_2) = \max \{g_2(x_2) + F_3(c_2 - x_2)\}$

Based on the last relation, a table is constructed for the Bellman function  $F_2(c_2)$

$c_2 \backslash x_2$	0	1	2	3	4	5	$F_2(c_2)$	$x_2^*$
0	0+0	-	-	-	-	-	0,0	0
1	0+2,8	2,0+0	-	-	-	-	2,8	0
2	0+5,4	2,0+2,8	3,2+0	-	-	-	5,4	0
3	0+6,4	2,0+5,4	3,2+2,8	4,8+0	-	-	7,4	1
4	0+6,6	2,0+6,4	3,2+5,4	4,8+2,8	6,2+0	-	8,6	2
5	0+6,9	2,0+6,6	3,2+6,4	4,8+5,4	6,2+2,8	6,4+0	10,2	3

Stage II:  $k = 1$ . Determine the optimal strategy for allocating funds between the first and two other enterprises, using the formula for calculating total income:  $F_1(c_1) = \max \{g_1(x_1) + F_2(c_1 - x_1)\}$ , on the basis of which compiled table for Bellman function  $F_1(c_1)$

$c_1 \backslash x_1$	0	1	2	3	4	5	$F_1(c_1)$	$x_1^*$
0	0+0,0	-	-	-	-	-	0,0	0
1	0+2,8	2,2+0	-	-	-	-	2,8	0
2	0+5,4	2,2+2,8	3,0+0	-	-	-	5,4	0
3	0+7,4	2,2+5,4	3,0+2,8	4,1+0	-	-	7,6	1
4	0+8,6	2,2+7,4	3,0+5,4	4,1+2,8	5,2+0	-	9,6	1
5	0+10,2	2,2+8,6	3,0+7,4	4,1+5,4	5,2+2,8	5,9+0	10,8	1

Stage 2 Unconditional optimization ( $k = 1, 2, 3$ ).

We determine the trajectory of the optimal strategy.

Step 1:  $k = 1$ . According to the table for the Bellman function  $F1(c1)$ , the optimal plan for the distribution of 5 million UAH. between the three enterprises is:  $c1 = 5$   $F1(5) = 10.8$ . In this case, the first enterprise should be allocated  $x1 = 1$  million UAH.

Step 2:  $k = 2$ . Determine the amount of cash remaining in the shares of the second and third companies:  $c2 = c1 - x1 = 5 - 1 = \text{UAH } 4$  million.

According to the table for the Bellman function  $F2(c2)$  we find that the optimal variant of the distribution of funds in the amount of 4 million UAH. between the second and third enterprises is:  $F2(4) = 8.6$  when allocating the second enterprise  $x2 = 2$  million UAH.

Step 3:  $k = 3$ . Determine the amount of cash remaining in the share of the third enterprise:  $c3 = c2 - x2 = 4 - 2 = 2$  million UAH.

According to the table for the Bellman function we find:  $F3(2) = 5.4$ ;  $x3 = \text{UAH } 2$  million

The trajectory of the steps of the second stage is clearly illustrated in Fig. 10.

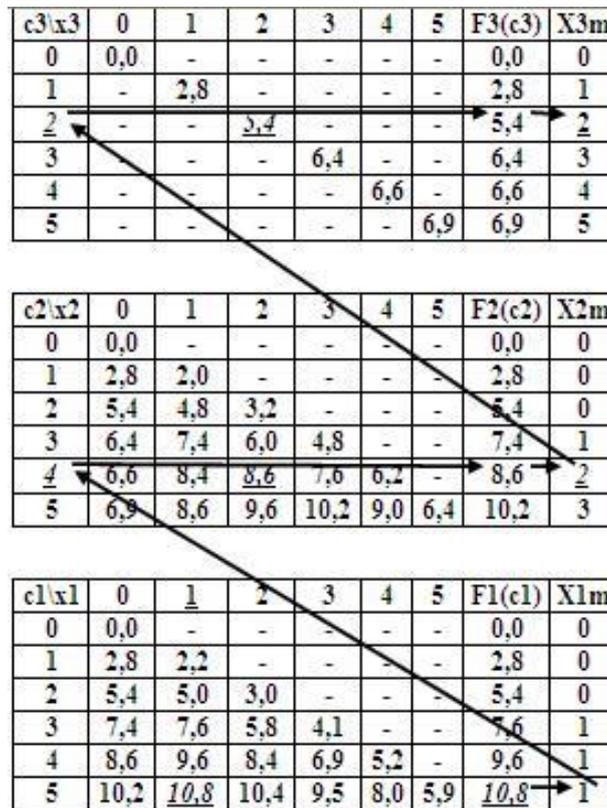


Figure 10. The trajectory of the steps of the second stage of optimization by the method of dynamic programming

Thus, the optimal enterprise investment plan:  $x1 = 1$ ,  $x2 = 2$ ,  $x3 = 2$ , which provides a maximum return equal to  $F1(5) = g1(1) + g2(2) + g3(2) = 10.8$  million UAH

Figure 11 shows a possible organization of tables on a sheet of MS Excel application.

	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1														
2	<b>Xi</b>	<b>g1</b>	<b>g2</b>	<b>g3</b>		<b>c3\X3</b>	0	1	2	3	4	5	<b>F3(c3)</b>	<b>X3m</b>
3	0	0,0	0,0	0,0		0	0,0	-	-	-	-	-	0,0	0
4	1	2,2	2,0	2,8		1	-	2,8	-	-	-	-	2,8	1
5	2	3,0	3,2	5,4		2	-	-	5,4	-	-	-	5,4	2
6	3	4,1	4,8	6,4		3	-	-	-	6,4	-	-	6,4	3
7	4	5,2	6,2	6,6		4	-	-	-	-	6,6	-	6,6	4
8	5	5,9	6,4	6,9		5	-	-	-	-	-	6,9	6,9	5
9														
10														
11														
12						<b>c2\X2</b>	0	1	2	3	4	5	<b>F2(c2)</b>	<b>X2m</b>
13						0	0,0	-	-	-	-	-	0,0	0
14						1	2,8	2,0	-	-	-	-	2,8	0
15						2	5,4	4,8	3,2	-	-	-	5,4	0
16						3	6,4	7,4	6,0	4,8	-	-	7,4	1
17						4	6,6	8,4	8,6	7,6	6,2	-	8,6	2
18						5	6,9	8,6	9,6	10,2	9,0	6,4	10,2	3
19														
20														
21														
22						<b>c1\X1</b>	0	1	2	3	4	5	<b>F1(c1)</b>	<b>X1m</b>
23						0	0,0	-	-	-	-	-	0,0	0
24						1	2,8	2,2	-	-	-	-	2,8	0
25						2	5,4	5,0	3,0	-	-	-	5,4	0
26						3	7,4	7,6	5,8	4,1	-	-	7,6	1
27						4	8,6	9,6	8,4	6,9	5,2	-	9,6	1
28						5	10,2	10,8	10,4	9,5	8,0	5,9	10,8	1

Figure 11. Organize data on a worksheet.

Fig. 12 shows a fragment of the worksheet in the display of formulas. The cells H3, H13, and H23 correspond to the upper left corners of the Bellman function tables ,, respectively. Addressing cells in formulas provides automatic filling of all tables when spreading formulas throughout the field of tables.

	G	H
1		
2	c3\*3	0
3	0	=FC.ТН(HS2=SG3;ΠΠOCMOTP(SG3;SBS3;SBS8;SES3;SES8);"-")
4	1	=FC.ТН(HS2=SG4;ΠΠOCMOTP(SG4;SBS3;SBS8;SES3;SES8);"-")
11		
12	c2\*2	0
13	0	=FC.ТН(HS12<=SG13;ΠΠOCMOTP(HS12;SBS3;SBS8;SDS3;SDS8)+ΠΠOCMOTP(SG13-HS12;SGS3;SGS8;SNS3;SNS8);"-")
14	1	=FC.ТН(HS12<=SG14;ΠΠOCMOTP(HS12;SBS3;SBS8;SDS3;SDS8)+ΠΠOCMOTP(SG14-HS12;SGS3;SGS8;SNS3;SNS8);"-")
21		
22	c1\*1	0
23	0	=FC.ТН(HS22<=SG23;ΠΠOCMOTP(HS22;SBS3;SBS8;SCS3;SCS8)+ΠΠOCMOTP(SG23-HS22;SGS13;SGS18;SNS13;SNS18);"-")
24	1	=FC.ТН(HS22<=SG24;ΠΠOCMOTP(HS22;SBS3;SBS8;SCS3;SCS8)+ΠΠOCMOTP(SG24-HS22;SGS13;SGS18;SNS13;SNS18);"-")

Fig. 12. Introducing formulas into the cells of a worksheet to populate the main fields of the Bellman function tables

Calculation of maximum values of functions and finding of corresponding values of arguments is carried out by means of functions MAX () and SEARCH () (Fig.13).

	N	O
1		
2	F3(c3)	X3m
3	=МАКС(H3:M3)	=ΠΠOCMOTP(N3;H3:M3;0)-1
4	=МАКС(H4:M4)	=ΠΠOCMOTP(N4;H4:M4;0)-1
11		
12	F2(c2)	X2m
13	=МАКС(H13:M13)	=ΠΠOCMOTP(N13;H13:M13;0)-1
14	=МАКС(H14:M14)	=ΠΠOCMOTP(N14;H14:M14;0)-1
21		
22	F1(c1)	X1m
23	=МАКС(H23:M23)	=ΠΠOCMOTP(N23;H23:M23;0)-1
24	=МАКС(H24:M24)	=ΠΠOCMOTP(N24;H24:M24;0)-1

Fig. 13. Entering formulas into cells of a worksheet finding maximum values of functions and finding appropriate arguments.

### V. CONCLUSION

In this paper, we have explored the use of modern technology, as exemplified by the most optimal capital allocation.

We managed to solve the problem of optimal distribution of investments between the three enterprises. All of them gave the same result, which confirms their effectiveness and reliability.

Thus, we can draw the following conclusions: in small dimensions, it is easier to solve by the search method or by using the Solution Search tool. These methods are easy to understand and implement. However, for large dimensions, it is rational to use a dynamic programming algorithm. It is stable in solution and the most fast-acting.

Mastering the method requires some mental effort. The above solution is considered by this method "manually". To solve similar problems with other source data, it is rational to automate the process of compiling Bellman function tables.

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