Applying the CPA Method in Order to Solve Ordering Problems

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Abstract— **The duration for carrying out a complex action varies between two moments imposed by certain technical and/or economical considerations, namely from one high tide to one low tide moment. As the duration of the project has numerous implications on the cost, it is very important to determine the duration of a complex action corresponding to a minim cost. Thus, the paper presents a modality in which WinQSB software can be used in solving such types of problems, namely the critical path analysis (CPA), the efficiency of the method being illustrated by three analyses.**

Keywords- CPM methods; CPM/COST methods; critical path; normal time; crash time; crashing analysis.

I. INTRODUCTION

An ordering problem consists in the establishing of an order for carrying out the activities of a project, so as the interdependencies of that activities are respected within the available resources and the total duration of action are minimal.

Practical situations that require solving of an ordering problem are quite varied and the most used managerial tool in programming and monitoring the projects is the *critical path analysis* (CPA).

The method consists in dividing complex actions in component parts (activities) at a level which permits their logical and technological correlation [1].

The first operation demanded by the CPA methodology is the definition of the list of activities by the specialist, who, on the basis of the gathered experience, settle the immediate following activities (conditionings) as well as the duration of each activity that may have a determined, probable or simulated character [2].

The module PERT/CPM of the WinQSB software realizes the ordering of activities or operations for a project using the CPM method (Critical Path Method) or PERT (Program Evaluation and Review Technique) in the analysis of the critical path [6].

In this paper we shall present the CPM method (Critical Path Method), one of the most often used procedures for analyzing the critical path, in which the only parameter used is time and in the graphical representation of the network one bears in mind the following conventions [3]:

- To each activity an oriented segment is associated, named arch, defined by its ends, thus each activity being identified by an arch;

- To each arch an equal value to the period of time of the representing activity is associated;
- Conditioning of two activities is represented by the succession of two adjacent arches.

The nodes of the graphic will represent the characteristic moments of the project, stages of realizing the activities (namely, finishing one or several of them and/ or beginning one or several other activities).

II. THE CPM METHOD

In order to create a new product, a firm has to carry out a project that contains 21 activities (fig.1), noted A to V.

The minimum duration for completing the project is determined, so as all other activities can be concluded.

Activity Number	Activity Name	Immediate Predecessor [list number/name, separated by ',']	Normal Time
1	A		3
2	B		1
3	C		2
4	D	A	4
5	E	B	2
6	F	C	4
7	G	D	2
8	H	E	3
9	I	E	2
10	J	F	2
11	K	F	3
12	L	G,H	1
13	M	G,H	5
14	N	G,H	3
15	O	I,J,L,P	7
16	P	K	2
17	Q	K	1
18	R	K	6
19	S	M	2
20	T	S	4
21	U	N,O,R,T	8

Figure 1. The data of the project in a matrix form

The project will be completed in 28 weeks, according to the table bellow.

In the last column of the table from fig. 2 on can see the delay that is admissible for each activity, so as the whole time for completing the project is not affected. Activities for which the "Slack" (difference) is zero are critical ones. Thus, the critical road of this project is the following: A-D-G-M-S-T-U.

In practice we are required to take several times interest in the activities, concerning the stage of their completion, more than the events. Lastly we are interested in the critical activities (thus situated along the critical path), they having to be carried out at the computed dates. These activities do

not have a time reserve, thus they have to start and end at the computed dates, in order not to surpass the day for completing the project. The other activities can be postponed with their time reserves, but their usage makes the project to become rigid.

08-23-2010 15:50:36	Activity Name	On Critical Path	Activity Time	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack (LS-ES)
1	A	Yes	3	0	3	0	3	0
2	B	no	1	0	1	3	4	3
3	C	no	2	0	2	2	4	2
4	D	Yes	4	3	7	3	7	0
5	E	no	2	1	3	4	6	3
6	F	no	4	2	6	4	8	2
7	G	Yes	2	7	9	7	9	0
8	H	no	3	3	6	6	9	3
9	I	no	2	3	5	11	13	8
10	J	no	2	6	8	11	13	5
11	K	no	3	6	9	8	11	2
12	L	no	1	9	10	12	13	3
13	M	Yes	5	9	14	9	14	0
14	N	no	3	9	12	17	20	8
15	O	no	7	11	18	13	20	2
16	P	no	2	9	11	11	13	2
17	Q	no	1	9	10	27	28	18
18	R	no	6	9	15	14	20	5
19	S	Yes	2	14	16	14	16	0
20	T	Yes	4	16	20	16	20	0
21	U	Yes	8	20	28	20	28	0
	Project	Completion	Time	=	28	weeks		
	Number of	Critical	Path(s)	=	1			

Figure 2. The activities analysis

The program builds automatically the graphic belonging to the problem, presented in figure 3. The critical path is presented in red [5].
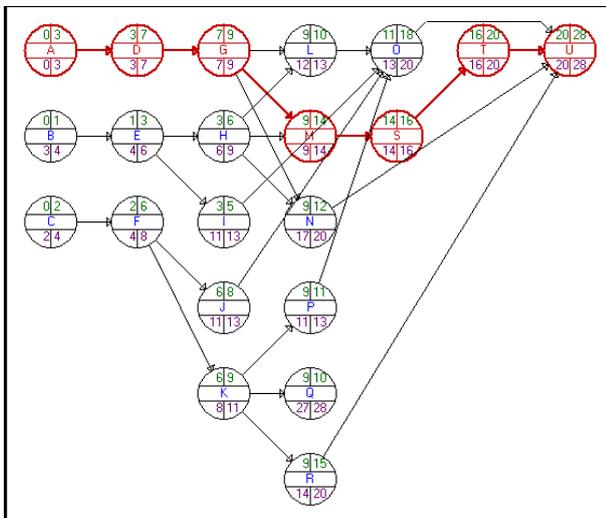

Figure 3. The project's graphic

A highly used instrument in the analysis of the critical path is the timetable graphic of the Gantt type, that appeared at the beginning of the century. If it is created after a thorough analysis, the Gantt graphic offers rich information and extremely suggestive presented, regarding the carrying out the work, as well as a series of derived information, concerning the staging of resources (work force, raw materials, instruments, funds).
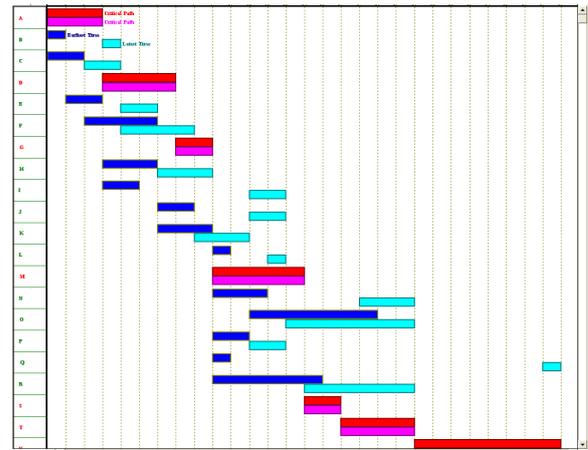

Figure 4. The Garrett graphic associated to the project

In order to build the Gantt graphic adherent to the problem, the Gantt chart is available, also in the Results menu. The graphic can be saved in a .bmp file, as all as any other graphic built by WinQSB (the option Save As in the File menu) and it is used for the time parameters which are the earliest and the latest. The critical path is rendered with red for the earliest time parameters and pink for the latest ones, for the non critical activities dark blue is used, with dark blue as well for the earliest times and light blue for the latest times [4].

For the allotted problem, the Gantt graphic is presented in Figure 4.

III. THE CPM/COST METHOD

The analysis form the point of view of duration can be completed with costs associated to the activities.

Activity Number	Activity Name	Immediate Predecessor (list number/name, separated by ',')	Normal Time	Crash Time	Normal Cost	Crash Cost
1	A		3	2	100	200
2	B		1	1	50	50
3	C		2	2	150	150
4	D	A	4	3	260	390
5	E	B	2	1	140	295
6	F	C	4	3	330	400
7	G	D	2	2	80	80
8	H	E	3	3	500	500
9	I	E	2	2	190	190
10	J	F	2	1	160	400
11	K	F	3	2	440	600
12	L	G,H	1	1	95	95
13	M	G,H	5	3	590	800
14	N	G,H	3	3	500	500
15	O	I,J,L,P	7	5	1100	1400
16	P	K	2	2	220	220
17	Q	K	1	1	150	150
18	R	K	6	4	810	1200
19	S	M	2	2	100	100
20	T	S	4	4	360	360
21	U	N,O,R,T	8	5	1500	2200

Figure 5. Data of the project in a matrix form

If the type of the problem is CPM/COST, after taking over the above mentioned data, the menu of the window will be modified and a new box will be opened, in which information related to the duration, (normal and crash) as well as related to cost (normal and crash). Every effort of expediting the affair is considered to be accompanied by the increase in expenses.

08-25-2010 15:05:51	Activity Name	On Critical Path	Activity Time	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack (LS-ES)
1	A	Yes	3	0	3	0	3	0
2	B	no	1	0	1	3	4	3
3	C	no	2	0	2	2	4	2
4	D	Yes	4	3	7	3	7	0
5	E	no	2	1	3	4	6	3
6	F	no	4	2	6	4	8	2
7	G	Yes	2	7	9	7	9	0
8	H	no	3	3	6	6	9	3
9	I	no	2	3	5	11	13	8
10	J	no	2	6	8	11	13	5
11	K	no	3	6	9	8	11	2
12	L	no	1	9	10	12	13	3
13	M	Yes	5	9	14	9	14	0
14	N	no	3	9	12	17	20	8
15	O	no	7	11	18	13	20	2
16	P	no	2	9	11	11	13	2
17	R	no	6	9	15	14	20	5
18	S	Yes	2	14	16	14	16	0
19	T	Yes	4	16	20	16	20	0
20	U	Yes	8	20	28	20	28	0
	Project	Completion	Time	=	28	weeks		
	Total	Cost of	Project	=	$7.675	(Cost on	CP =	$2.990)
	Number of	Critical	Path(s)	=	1			

Figure 6.   The activities analysis in a normal environment

In figure 6, one may notice that the project in a normal environment, can be completed in 28 weeks, the cost of the project is 7675m.u. and there is only one critical path, the same as in the previous case, with a cost of 2990m.u.

The total duration of the project in a crash environment is of 21 weeks (fig.7), the cost of the project is 10130m.u. and the one of the critical path 4130u.m., the critical activities being the same as in the case of the normal environment.

08-25-2010 15:14:32	Activity Name	On Critical Path	Activity Time	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack (LS-ES)
1	A	Yes	2	0	2	0	2	0
2	B	no	1	0	1	2	3	2
3	C	no	2	0	2	2	4	2
4	D	Yes	3	2	5	2	5	0
5	E	no	1	1	2	3	4	2
6	F	no	3	2	5	4	7	2
7	G	Yes	2	5	7	5	7	0
8	H	no	3	2	5	4	7	2
9	I	no	2	2	4	9	11	7
10	J	no	1	5	6	10	11	5
11	K	no	2	5	7	7	9	2
12	L	no	1	7	8	10	11	3
13	M	Yes	3	7	10	7	10	0
14	N	no	3	7	10	13	16	6
15	O	no	5	9	14	11	16	2
16	P	no	2	7	9	9	11	2
17	R	no	4	7	11	12	16	5
18	S	Yes	2	10	12	10	12	0
19	T	Yes	4	12	16	12	16	0
20	U	Yes	5	16	21	16	21	0
	Project	Completion	Time	=	21	weeks		
	Total	Cost of	Project	=	$10.130	(Cost on	CP =	$4.130)
	Number of	Critical	Path(s)	=	1			

Figure 7.   Activities analysis in a crash environment

The module permits the carrying out of an analysis of the involved costs in realizing the project, in a table or graphical form. The options in the menu that allow this thing are Results → PERT/Cost-Table, respective Results → PERT/Cost–Graph. The results of such an analysis carried out for normal time parameters are presented as follow [4].

Table way – there is a weekly and total planning of costs, based on the earliest and latest time parameters (fig.8).

09-06-2010	Project Time in week	Cost Schedule Based on ES	Cost Schedule Based on LS	Total Cost Based on ES	Total Cost Based on LS
1	1	158,33 lei	33,33 lei	158,33 lei	33,33 lei
2	2	178,33 lei	33,33 lei	336,67 lei	66,67 lei
3	3	185,83 lei	108,33 lei	522,50 lei	$175
4	4	409,17 lei	$190	931,67 lei	$365
5	5	409,17 lei	217,50 lei	1.340,83 lei	582,50 lei
6	6	314,17 lei	217,50 lei	$1.655	$800
7	7	291,67 lei	314,17 lei	1.946,67 lei	1.114,17 lei
8	8	266,67 lei	289,17 lei	2.213,33 lei	1.403,33 lei
9	9	186,67 lei	353,33 lei	2.400,00 lei	1.756,67 lei
10	10	624,67 lei	264,67 lei	3.024,67 lei	2.021,33 lei
11	11	529,67 lei	264,67 lei	3.554,33 lei	2.286,00 lei
12	12	576,81 lei	$403	4.131,14 lei	2.689,00 lei
13	13	410,14 lei	$498	4.541,29 lei	3.187,00 lei
14	14	410,14 lei	275,14 lei	4.951,43 lei	3.462,14 lei
15	15	342,14 lei	342,14 lei	5.293,57 lei	3.804,29 lei
16	16	207,14 lei	342,14 lei	5.500,72 lei	4.146,43 lei
17	17	247,14 lei	382,14 lei	5.747,86 lei	4.528,57 lei
18	18	247,14 lei	548,81 lei	5.995,00 lei	5.077,38 lei
19	19	$90	548,81 lei	6.085,00 lei	5.626,19 lei
20	20	$90	548,81 lei	6.175,00 lei	6.175,00 lei
21	21	187,50 lei	187,50 lei	6.362,50 lei	6.362,50 lei
22	22	187,50 lei	187,50 lei	6.550,00 lei	6.550,00 lei
23	23	187,50 lei	187,50 lei	6.737,50 lei	6.737,50 lei
24	24	187,50 lei	187,50 lei	6.925,00 lei	6.925,00 lei
25	25	187,50 lei	187,50 lei	7.112,50 lei	7.112,50 lei
26	26	187,50 lei	187,50 lei	7.300,00 lei	7.300,00 lei
27	27	187,50 lei	187,50 lei	7.487,50 lei	7.487,50 lei
28	28	187,50 lei	187,50 lei	7.675,00 lei	7.675,00 lei

Figure 8.   The PERT/Cost Table for normal time parameters

The costs analysis using expedited time frames leads to the obtaining of the following results in a matrix form (fig.9).

09-06-2010	Project Time in week	Cost Schedule Based on ES	Cost Schedule Based on LS	Total Cost Based on ES	Total Cost Based on LS
1	1	$225	$100	$225	$100
2	2	$470	$100	$695	$200
3	3	$525	$255	$1.220	$455
4	4	$525	$500	$1.745	$955
5	5	$430	$430	$2.175	$1.385
6	6	$740	$340	$2.915	$1.725
7	7	$340	$340	$3.255	$2.065
8	8	938,33 lei	566,67 lei	4.193,33 lei	2.631,67 lei
9	9	843,33 lei	566,67 lei	5.036,67 lei	3.198,33 lei
10	10	1.013,33 lei	471,67 lei	6.050,00 lei	3.670,00 lei
11	11	$630	$750	6.680,00 lei	$4.420
12	12	$330	$330	7.010,00 lei	$4.750
13	13	$370	$670	7.380,00 lei	$5.420
14	14	$370	836,67 lei	7.750,00 lei	6.256,67 lei
15	15	$90	836,67 lei	7.840,00 lei	7.093,33 lei
16	16	$90	836,67 lei	7.930,00 lei	7.930,00 lei
17	17	$440	$440	$8.370	$8.370
18	18	$440	$440	$8.810	$8.810
19	19	$440	$440	$9.250	$9.250
20	20	$440	$440	$9.690	$9.690
21	21	$440	$440	$10.130	$10.130

Figure 9.   PERT/Cost Table for urgent time parameters

IV.   SENSITIVITY ANALYSES

These analyses allow us to apply some restrictions referring to the duration or budget of the project and to determine the repartition of costs so that the total cost is minimal [5].

The informatics product WinQSB allows the carrying out of the following analyses:

A.   Meeting the desired completion time

For our project we desire its finalizing in 25 weeks. In the case of an earlier completion a bonus of 200m.u. is offered weekly, whereas in the case of delays a penalty of 50m.u. is imposed on the same weekly basis. The results presented in figure 10 are obtained. In this case one may note an increase of the total cost by 380m.u.

08-25-2010 15:35:19	Activity Name	Critical Path	Normal Time	Crash Time	Suggested Time	Additional Cost	Normal Cost	Suggested Cost
1	A	Yes	3	2	2	$100	$100	$200
2	B	no	1	1	1	0	$50	$50
3	C	Yes	2	2	2	0	$150	$150
4	D	Yes	4	3	4	0	$260	$260
5	E	no	2	1	2	0	$140	$140
6	F	Yes	4	3	3	$70	$330	$400
7	G	Yes	2	2	2	0	$80	$80
8	H	no	3	3	3	0	$500	$500
9	I	no	2	2	2	0	$190	$190
10	J	no	2	1	2	0	$160	$160
11	K	Yes	3	2	3	0	$440	$440
12	L	no	1	1	1	0	$95	$95
13	M	Yes	5	3	3	$210	$590	$800
14	N	no	3	3	3	0	$500	$500
15	O	Yes	7	5	7	0	$1.100	$1.100
16	P	Yes	2	2	2	0	$220	$220
17	R	no	6	4	6	0	$810	$810
18	S	Yes	2	2	2	0	$100	$100
19	T	Yes	4	4	4	0	$360	$360
20	U	Yes	8	5	8	0	$1.500	$1.500
	Penalty/	Reward:						0
	Overall	Project:			25	$380	$7.675	$8.055

Figure 10. The results of the analysis in the case of completing the project in 25 weeks

One may notice an expediting of activities A, F and M. Activity A, for example, which usually lasts for 3 weeks, has been changed to 2 weeks, and the normal cost of 100m.u. has been increased to 200u.m., due to the that imposed change.

08-25-2010 15:34:27	Activity Name	Critical Path	Normal Time	Crash Time	Suggested Time	Additional Cost	Normal Cost	Suggested Cost
1	A	Yes	3	2	2	$100	$100	$200
2	B	no	1	1	1	0	$50	$50
3	C	Yes	2	2	2	0	$150	$150
4	D	Yes	4	3	3	$130	$260	$390
5	E	no	2	1	2	0	$140	$140
6	F	Yes	4	3	3	$70	$330	$400
7	G	Yes	2	2	2	0	$80	$80
8	H	no	3	3	3	0	$500	$500
9	I	no	2	2	2	0	$190	$190
10	J	no	2	1	2	0	$160	$160
11	K	Yes	3	2	3	0	$440	$440
12	L	no	1	1	1	0	$95	$95
13	M	Yes	5	3	3	$210	$590	$800
14	N	no	3	3	3	0	$500	$500
15	O	Yes	7	5	6	$150	$1.100	$1.250
16	P	Yes	2	2	2	0	$220	$220
17	R	no	6	4	6	0	$810	$810
18	S	Yes	2	2	2	0	$100	$100
19	T	Yes	4	4	4	0	$360	$360
20	U	Yes	8	5	5	$700	$1.500	$2.200
	Late	Penalty:						$50
	Overall	Project:			21	$1.360	$7.675	$9.085

Figure 11. The results of the analysis in the case of completing the project in 20 weeks

If the completion of the project is desired in 20 weeks, with the incentives and the penalties remaining the same, it is obvious that this is not possible, (figure 11), the minimal time span being 21 weeks, with a supplementary cost of 1360m.u. The penalty appears to be 50m.u., the equivalent of one week of delay.

In this case we may notice the expediting of some other activities, as in the case of completing the project in 25 weeks.

B. Meeting the desired budget cost

In the case of an available budget of 8500 u.m., the project can be completed in 23.09 weeks, the original cost being 825m.u. and the expedited activities being: A, F, M.

08-27-2010 01:14:03	Activity Name	Critical Path	Normal Time	Crash Time	Suggested Time	Additional Cost	Normal Cost	Suggested Cost
1	A	Yes	3	2	2	$100	$100	$200
2	B	no	1	1	1	0	$50	$50
3	C	Yes	2	2	2	0	$150	$150
4	D	Yes	4	3	4	0	$260	$260
5	E	no	2	1	2	0	$140	$140
6	F	Yes	4	3	3	$70	$330	$400
7	G	Yes	2	2	2	0	$80	$80
8	H	no	3	3	3	0	$500	$500
9	I	no	2	2	2	0	$190	$190
10	J	no	2	1	2	0	$160	$160
11	K	Yes	3	2	3	0	$440	$440
12	L	no	1	1	1	0	$95	$95
13	M	Yes	5	3	3	$210	$590	$800
14	N	no	3	3	3	0	$500	$500
15	O	Yes	7	5	7	0	$1.100	$1.100
16	P	Yes	2	2	2	0	$220	$220
17	R	no	6	4	6	0	$810	$810
18	S	Yes	2	2	2	0	$100	$100
19	T	Yes	4	4	4	0	$360	$360
20	U	Yes	8	5	6,0929	445,00 lei	$1.500	1.945,00 lei
	Overall	Project:			23,09	825,00 lei	$7.675	8.500,00 lei

Figure 12. The results of the analysis in the case of an available budget of 8500m.u.

08-27-2010 01:21:44	Activity Name	Critical Path	Normal Time	Crash Time	Suggested Time	Additional Cost	Normal Cost	Suggested Cost
1	A	Yes	3	2	2	$100	$100	$200
2	B	no	1	1	1	0	$50	$50
3	C	Yes	2	2	2	0	$150	$150
4	D	Yes	4	3	3	$130	$260	$390
5	E	no	2	1	2	0	$140	$140
6	F	Yes	4	3	3	$70	$330	$400
7	G	Yes	2	2	2	0	$80	$80
8	H	no	3	3	3	0	$500	$500
9	I	no	2	2	2	0	$190	$190
10	J	no	2	1	2	0	$160	$160
11	K	Yes	3	2	3	0	$440	$440
12	L	no	1	1	1	0	$95	$95
13	M	Yes	5	3	3	$210	$590	$800
14	N	no	3	3	3	0	$500	$500
15	O	Yes	7	5	6	$150	$1.100	$1.250
16	P	Yes	2	2	2	0	$220	$220
17	R	no	6	4	6	0	$810	$810
18	S	Yes	2	2	2	0	$100	$100
19	T	Yes	4	4	4	0	$360	$360
20	U	Yes	8	5	5	$700	$1.500	$2.200
	Overall	Project:			21	$1.360	$7.675	$9.035

Figure 13. The results of the analysis in the case of an optimal cost

C. Finding the minimum cost program

By specifying this option, an expedited optimal cost of 9035m.u. is obtained, adherent to the minimal duration of 21 weeks and the expedited activities are: A, D, F, F, and M, O, U.

The degree of completion of the project can be verified in any moment of action, comparing the real state with the planned one. For this analysis the option „Project Completion Analysis" is used.

One may notice in fig. 14 that the activities A-M and P, S have been carried out in proportion of 100%, after 15 weeks since the project began. Activity N has been realized in proportion of 33.33%, activity T in proportion of 50%, activity R in proportion of 66.66%, and activities O-U in proportion of 71.43%. Thus after 15 weeks the project has been completed to a proportion of 60%.

08-27-2010 01:54:06	Activity Name	On Critical Path	Activity Time	Latest Start	Latest Finish	Planned % Completion
1	A	Yes	2	0	2	100
2	B	no	1	2	3	100
3	C	Yes	2	0	2	100
4	D	Yes	4	2	6	100
5	E	no	2	3	5	100
6	F	Yes	3	2	5	100
7	G	Yes	2	6	8	100
8	H	no	3	5	8	100
9	I	no	2	8	10	100
10	J	no	2	8	10	100
11	K	Yes	3	5	8	100
12	L	no	1	9	10	100
13	M	Yes	3	8	11	100
14	N	no	3	14	17	33,3333
15	O	Yes	7	10	17	71,4286
16	P	Yes	2	8	10	100
17	R	no	6	11	17	66,6667
18	S	Yes	2	11	13	100
19	T	Yes	4	13	17	50
20	U	Yes	8	17	25	0
	Overall	Project:		0	25	60

Figure 14. Analysis of the realization degree of the project

V. CONCLUSIONS

In a normal environment, the project can be completed in 28 weeks, with a total cost of 7675m.u. The critical project activities in this case were: A, D, G, M, S, T and U, and the cost are the critical path 2990m.u.

The urgent completion of the project is carried out after 21 weeks, at a cost of 10130m.u. The critical path remains the same as in the normal regime, but its cost is 4130m.u.

The following analyses were carried out afterwards:

1. We have tried to achieve project completion in 25 weeks and 20 weeks, setting is a bonus of 200m.u. / week for early project completion and a penalty of 50m.u. / week for delay.

In the first case, the project cost increased to 1410m.u., of which 50m.u. are penalized for a week of delay, which means that the project can be completed sooner than 21 weeks.

2. If the budget reaches the level of 8500m.u., the project can finish in 23.09 weeks, the additional cost is 825m.u., and the emergent activities are: A, F and M.

3. The optimal total cost is 9035m.u., for the minimum period of 21 weeks and the expedited activities are: A, D, F, and M, O and U.

In the last part of the paper the degree of completion of the project was verified after 15 weeks from the moment of the beginning.

REFERENCES

[1] C. Rațiu-Suciu, F. Luban, D. Hîncu, N. Ene, „Applied Economical Modelling", Ed. Economică, București, 2002, pp.172-181

[2] C. Rațiu-Suciu, „Modelling & Simulation of Economical Processes. Theory and Practice", Ed. Economică, București, 2003, pp.194-195

[3] O.I. Amariei, „Aplications of WinQSB software in production systems simulation", Eftimie Murgu Press, Reșița, 2009, pp. 108-133

[4] R. Mihalca and C. Fabian, „Using the software products - Word, Excel, PMT, WinQSB, Systat", Ed. ASE Bucuresti, 2003. Article in journal:

[5] O.I. Amariei, D. Fourmaux, D. Papageorgiou, D. Baclesanu, „Using the WinQSB software in Critical Path Analysis", Analele UEM Reșița, Fascicola I, Facultatea de Inginerie, anul XV, nr.1/2008, pg.43-50 http://ideas.repec.org/a/uem/journl/v1y2008ixvp43-50.html Article in conference proceedings:

[6] O.I. Amariei, D. Frunzăverde, G. Popovici, C.O. Hamat, „WinQSB Simulation Software - A Tool for Professional Development", World Conference on Education Sciences, 04-07 feb. 2009, Nicosia, Cyprus, Procedia - Social and Behavioural Sciences Volume 1, Issue 1, 2009, pp. 2786-2790 doi: 10.1016/j.sbspro.2009.01.494