

# An overview of critical path applied to project management with WinQSB software

M. A. Gurau and L. V. Melnic

**Abstract**—Planning of transportation projects is vital as it involves huge costs and large periods of implementation. Numerous tools and techniques have been developed and put in use by different firms. Starting with an introduction discussion about the CPM method and PERT method, this paper introduces some aspects about the advantages and disadvantages of the PERT/CPM module and of using it in a project. Modern management strategies aim for the maximum reduction of projects duration. One of the techniques usually used, applied to activities on the critical path of course, is the Crashing, consists in allocating more resources on a activity to make it end before; in this case the total project cost will increase. The case study presents a real situation of a furniture manufacturing company that wish to expand their opportunities for sale, on the internet. The project, should be carried out in a shortest time and with a lower cost, therefore, the analysis of critical path was done using PERT/CPM module, of the WINQSB decision analysis software.

**Keywords**—Critical path, PERT/CPM, Project management, WinQSB software.

## I. INTRODUCTION

IN the current work of the organizations, institutions, and state enterprises, private firms, and companies run diversified activities and actions, both from the point of complexity view and of their repeatability's. The projects are unique activities geared toward objective, with a high degree of novelty and a complex workload. These are limited in time and in terms of human and material resources, needs an interdisciplinary collaboration usually within a specific organizational structure, involving specific risks. The objective is to create a new entity (product, service, and layout) [1].

The importance of projects is overwhelming in nowadays, and it will continue to grow in the future. It must be stated that not all companies have production, but all companies (or organizations) have projects [2].

Basically, the project term is used for packaged or interdisciplinary activities, in which more people and areas of

activity are involved. This interdepartmental collaboration is common in daily practice of organizations [1].

The ability of an enterprise (or system), for doing what should be done, depends on its elements and their interdependencies. When the number of interdependencies increases, the variability also increases. However, the number of elements that control the performance of the enterprise is extremely small, and it is call constraints. In order to improve the system performance under the restriction effects, it is necessary to apply the following rule “more is better”, meaning that: if it were possible to increase the production rate of the constraint element, then the total output will be higher. In order to improve the system performance under non-restrictions, it is necessary to apply the reverse rule to non-constraints: “more is worse”, working at full capacity the resource will produce excess inventory that will choke the constraint resource, increasing the lead times.

The main constrains that, should be taken into considerations, in a project are [3]:

- scientifically constrains: the necessary knowledge can be not available;
- temporal constrains: time is a critical resource;
- budgetary constrains: the budget is approved at the project beginning and usually aren't modified, funds being limited; due to this fact should be treated with great attention during whole project.

The ability to reach at a correct decision in the framework of a project, as a final point of engineering economic analysis, depends on unavoidable conceptual understanding of the environment, in which decision is taking. A decision is an adopted solution, taken following an order up to a problem, a situation. From the viewpoint of engineering economic analysis, a decision is, at the same time, an allocation of resources [4]. It is like with writing a payment order and sending the money to the beneficiary. It is irrevocable, except the situation in which later it has adopted another decision contrary to first. A decision-maker can perform a decisional analysis, which is defining as a structured way of thinking on how the current decision will lead to a result.

In the decision analysis process of analysis are building models, logical and mathematical representations of relationships within and between these three components of a decision-making situation. The models allow assessing further possible implications of each possible course of actions, which

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M. A. Gurau is with the Engineering and Technological Systems Management Department, Polytechnics University, Bucharest, 060042 Romania (phone: +40727 804 893; e-mail: andreigurau@yahoo.com).

L. V. Melnic is with Industrial Engineering and Management Department, Ovidius University, Constanta, 900527 Romania (e-mail: lmelnic@univ-ovidius.ro).

it undertakes, and so the decision-maker can better understand the bindings of its objectives and actions [4].

In the last decades, many studies were made to identify lacking of efficiency in project management. Usually they fall in one of two categories: focus on PERT/CPM techniques of project planning or focus on the human resources management. Both areas claim that project failure is due to problems regarding their subject study [1], [2].

## II. CRITICAL PATH METHOD

The Critical Path method is a heuristic one based on the graphs theory, containing some process of readjustment and estimation of activities length, as well as on the knowledge of advanced techniques that it can analyze in terms of the development phase in time. The complex process consists in a set activities which their sequence logic form an organized system, represented by a deterministic mathematical model, outlined through a graphical network which tracks the chronological sequence of the facts by oriented arcs [5], [6], [10].

Critical Path method identifies activities that influence in a striking character that process time duration, the sequence of these critical activities making the "critical path". The attention of the analyst must be directing to the activities included in the critical path, the reduction of the entire duration process can be achieving only through technical and organizational measures, which target the activities duration and their temporal interdependence [5].

The graph parameters are the following [3]:

- Final term  $T_p$  – is established function the beneficiary requirements (in the contract), or is calculated;
- Initial term  $T_i$  – is determined by calculus taking in account the critical path duration and respecting  $T_p$ , or is imposed.
- The even terms – represents the moment when all the activities converge towards an event are realized and the activities that starts from the event.

For the events that are not on the critical path an interval comprised between a minimum and a maximum term is established.

In a strictly mathematical definition the graph represents a pair  $(x, y)$ ,  $x$  is a nonempty lot and  $y$  is an application of  $x$  in it positions lot, the elements of  $x$  being the nodes graph and ordered pairs  $(Z, Z')$  are the arcs graph, where  $Z$  belongs to  $x$  and  $Z'$  belongs to  $y(Z)$ . The  $(Z, Z')$  arc is incident in  $Z$  or  $Z'$  node and  $Z$  will be called initial extremity, and  $Z'$  will be the final extremity of the  $(Z, Z')$  arc. A path of graph  $(x, y)$  is a succession of arches so that the final extremity of one to be the initial extremity of another [7].

In the case of PERT/CPM methods, these abstract notions are accurate: nodes graph represent the events, distinct and significant moments in the development process, and arcs represent the activities, actions based on a specific resource consumption and time, leading at the development process modification. Some activities requires only time, they are

called expectations and are technological stages which are not consume resources (drying, cooling, natural aging). The event represented by circles, does not consume resources, time, and are numerated for identification so that the math processing of processes to be possible, and each activity to be characterized by events, which delineates it, thus [5], [7], [9]:

- "i" represents the number of initial event of activity;
- "j" represents the number of final event of activity.

The numbering starts with the initial event of the graph with a zero in the meaning of arrows in the order of natural numbers, from left to right.

There are a number of rules, which comply in the construction phase of a graph:

- The graph must represent correct the chronological sequence in time and interdependence of the various activities;
- The arcs must not be represented at the scale, in accordance with time duration of activities;
- Each activity cannot start than from an event and ends in another event;
- Two events must not be linked between them by more than one activity.

There are a number of fictitious activities, represented by a line cut, which does not consume any resources, neither time. These warn that the next succeeding activity cannot start until the previous one is finished being on another path of the graph and influencing the realization of the respective event.

Peaks arrows, which are directing in a specific node, indicate the activities that must be completed in the event before it could start any other activity that starts from that node. Although mathematically is possible, a graph of the CPM method application in managerial problems has no circuits, it mean it's impossible that starting from an event and following a series of activities that consume time to get back to the initial event, temporal returning being illogical. To develop a program optimized by critical path method are following the steps [5]:

- Analysis of the structure of complex process;
- Graph network construction based on adopted process;
- Calculation of the graph parameters: event and activities dates, execution time, time reserves;
- Critical path fixing;
- Analysis and initial program optimization;

All the measures adopted will have to take into consideration a series of well-defined criteria: time, cost, and resource. Optimizing the execution duration follow the reduction of the process realization target by removing some initial activities, the judicious distribution of human and material resources, and development of some activities in parallel or delayed. The duration's estimate of all the activities in the context of the rationale and systematic use of resources can reduce the durations of critical activities. Periodical reconsideration of product documentation and improvement of fabrication process should not be neglect, to avoid the miss of internal and external resources to specific operations [7], [8].

CPM method is a fundamental analyzing method of the critical path and a process analysis in which the only analyzed parameter is time.

The advantages of the models with CPM networks are [5], [8]:

- Require a detailed analysis of the logical structure of the project;
- Explicitly outlines the logical links between activities, determining the real project duration, outlines the critical activities and those non-critical, allowing certain time reserves with the possibility to distribute to critical activities;
- The made graph keeps configuration even if changes occur duration or deadlines;
- Allow projects optimization depending on time.

Detailed planning in the form of a network, allows the management team to streamline everything must be carried out in a comprehensive manner in order to achieve the objective of the project on time.

However, CPM representation reduces the possibility of taking decisions at the level of senior management and requires time consuming for details leading to an absence of a history on the costs.

### III. PERT METHOD

PERT method allows the calculation of the average time needed for completion of a project, identification of critical activities and estimations of probabilities of achieving the planned deadlines. Because in practice, activities duration are insufficiently known or uncertain by consideration of statistical concepts, the activities duration are considered random variable characterized by it media and dispersal [5], [12].

PERT method uses three times associated with each activity (the optimist - a, probable - m, and the pessimist - b), forming an average duration, which represents the anticipated duration of the project:

- The optimist duration of an activity “ $i$ ”, ( $a_i$ ), is considered the minimum duration of activity execution, in general normal conditions;
- The probable duration of an activity “ $i$ ”, ( $m_i$ ), as estimation with the greatest chance of achieving project under normal conditions;
- The pessimist duration of an activity “ $i$ ”, ( $b_i$ ) is considered the maximum length of activity execution, when there is the most unfavorable conditions for the realization of the project.

So the time of execution of a project is calculated based on the theory of probabilities. PERT is a probabilistic method based on beta distribution for each time of activities and on a normal distribution (Gauss) for the estimated amount of time, allowing the planning and control of the execution time of the entire project [8], [13]. PERT network is a CPM network in representation and each activity is characterized by three types of durations (a, m, b).

The average duration of execution ( $\bar{t}$ ) (hope math) of an activity, “ $i$ ” is the expression (1):

$$\bar{t} = \frac{a + 4 \cdot m + b}{6}. \quad (1)$$

Dispersion of the duration execution ( $\sigma^2(i)$ ) of an activity “ $i$ ”, characterized as a measure of the insecurity degree in estimating activity, is calculating with the expression [5], [11]:

$$\sigma^2(i) = \left( \frac{b-a}{6} \right)^2. \quad (2)$$

The total duration of the project is a random variable with a normal distribution with average and dispersion:

$$T = \sum_{i \in D_{crit}} \bar{t}(i). \quad (3)$$

$$\sigma^2 = \sum_{i \in D_{crit}} \sigma^2(i). \quad (4)$$

where,  $D_{crit}$  represents the set of all activities that are on the critical path.

The probability of achieving the planned duration of a project  $T_{plan}$ , is determined calculating the probability factor  $Z$ , and then is deducted from the values table of Laplace function, the probability  $p(T \leq T_{plan})$ .

$$Z = \frac{T_{plan} - T}{\sqrt{\sigma^2}}. \quad (5)$$

*PERT algorithm for determining the probability of completing a project at the planned time* [8], [12]:

*Step 1:* Calculate the average duration of each activity from PERT network, using the relation (1);

*Step 2:* Calculate the PERT network time activities;

*Step 3:* Calculate the duration dispersion of each activity, using the relation (2);

*Step 4:* Calculate the execution duration of the entire project ( $T$ ) and the dispersion ( $\sigma^2$ ), with the relations (3) and (4);

*Step 5:* Determine the probability of achieving the project planned duration, using the relation (5);

*Step 6:* Analysis of the project made according to the execution probabilities of the duration of the project:

- if  $p \leq 25\%$ , shows a very high risk that the project was not carried out at the planned time and requires revision of terms of activities execution, in terms of the expedite them;

- if  $p \approx 50\%$ , planning activities is correct and may apply to;
- if  $p \geq 60\%$ , comply with the time limit but there was a planned waste of resources.

Analysis based on PERT network graphs is currently considering indispensable for large and complex projects. Two qualities do represent a useful tool for planning and tracking projects of any size and nature [8], [10], [11]:

- The activities are representing graphically in sequential order and it can observe the entire network of the project, what activities must end before others start;
- We can calculate the minimum and maximum periods start and end of the activities of the project.

Using the network graph, it can work directly with the activities of the network and change easy the relations between them. Specific techniques for network graphs analysis propose to calculate [5], [10]:

- The total duration of the project based on the each activity duration in part, on the required links to make them and on these interdependence relations;
- Critical path or execution sequence of activities which cannot be delayed for any reason, any delay of these leading to lateness of the entire project;
- Time reserves, during which activities can drag without affecting the total duration of the project, are calculated.

In the elaboration of PERT graph, the following steps are performing:

- Listing of project activities based on the hierarchical decomposition of the project previously established;
- Definition for each activity of the following information: code, description, duration;
- The definition of logical sequence of activities by indicating the activities conditioned by the current activity and those who influencing the current activity;
- The last step is definition of external links or restrictions of contractual terms.

The disadvantages of using PERT method are:

- Lack of historical data for the estimate of costs;
- Great effort in terms of work and time required for their application;
- Reduce the possibility of taking decisions at the level of senior management.

The PERT method allows specification of realization probabilities at terms, in advance or delays of the projects.

#### IV. WINQSB SOFTWARE MENU PRESENTATION

WinQsb represents a software with windows interface and with small limitations on the size of the problems to solve. It is very easy to import data in other programs and offer options to control the appearance of printed pages. In addition, it has implemented modules for almost all operational research problems: Decision Analysis, Dynamic Programming, Forecasting, Job Scheduling, Linear and Integer Programming, Markov Process, Network Modeling, Nonlinear Programming,

PERT/CPM, Quadratic Programming, Quality Control Chart, etc.

The main menu of this software includes the following features:

1. File - creating a new issue, a problem loading, saving, or printing out existing problems, setting print parameters;
2. Edit – text edit (cut, copy, paste), changing the name of a problem;
3. Format - formatting the display mode of numbers (Number) and text (Font), align mode, define the dimensions for the rows and columns;
4. Solve and analyze - options related to the ways in which a problem is solving; this menu will change depending on the type of problem;
5. Result – the display mode of results;
6. Utility - the product offers several utilities, such as:
  - Scientific calculator, or standard;
  - Watch, analog or digital;
  - Graphics - draws some graphics of the following types: surface, vertical bars 2D, vertical bars 3D, columns 2D, columns 3D, lines, pie 2D, pie 3D, cloud of points.
7. Window - the display mode of various windows open at a time;
8. WinQSB - allow navigation between modules of the product, i.e. the selection of a particular type of problem; Some of the submenus of the menu change its main available options, depending on the type of the problem selected.

#### V. CRITICAL PATH ANALYZE (PERT/CPM) USING WINQSB SOFTWARE

This module provide ordering activities or operations of a project using CPM (Critical Path Method) or PERT (Program Evaluation and Review Technique) of critical analysis of the path.

##### A. Problem formulation

It is considering the case of a furniture manufacturing company, S.C Logy Bic S.R.L, who wishes to improve the services, realizing a very complex website that will enable a new way of selling the products via the internet.

The economists' engineers along with the marketing director have made a list of primary activities to be undertaken.

Table I presenting the activities, their durations and activities directly preceding. The society director wants to know the critical path, cost and duration of it, minimum duration of the project end, so that all the activities to be completed, using WinQSB software.

Nr.	Activity Code	Activity name	Activities directly preceding	Durati-on (days)
1	A	Selection of staff	-	2

2	B	Realization of advertising materials	-	4
3	C	Warehouse staff allocation	A	1
4	D	Allocation website staff , advertising campaigns	A	4
5	E	Advertising campaigns on the internet	B, D	2
6	F	Advertising TV campaigns	B, D	3
7	G	Making a poll about campaigns efficiency	E, F	3
8	H	Creating the website site and loading with materials	D	4
9	I	Fill the warehouse with products	C	5
10	J	Website launch and receipt the first orders	H, I	5

Table I. The project activities

Activity Number	Activity Name	Immediate Predecessor (list number/name, separated by ',')	Normal Time	Crash Time	Normal Cost	Crash Cost
1	A		2	1	100	80
2	B		4	2	500	300
3	C	A	1	1	200	150
4	D	A	4	3	500	350
5	E	B,D	2	1	100	50
6	F	B,D	3	2	450	200
7	G	E,F	3	2	120	30
8	H	D	4	3	300	270
9	I	C	5	4	5000	3800
10	J	H,I	5	3	1000	800

Fig. 2 Representation of activities and costs

*B. Problem solution*

In the dialog window that appears behind *New* option from *File* menu is specifying a title for the problem, the number of activities, the unit of measurement for the duration of the activities, the type of problem (PERT or CPM), input data format (matrix or graphic). For deterministic problems (CPM) will specify the existing data (normal length, normal cost, crash, effectively cost and the percentage of completion).

We introduce the following data, in the PERT/CPM module of WinQSB:

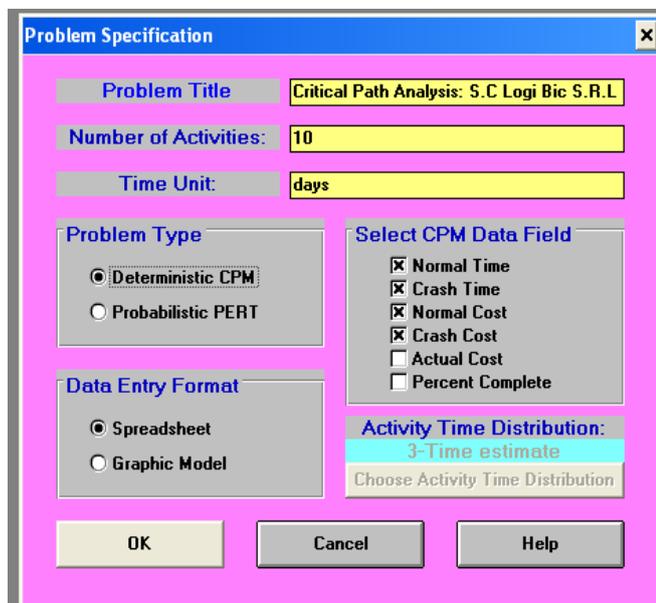


Fig. 1 Data entry

For our problem, data is entering in the matrix form, as can be seen in fig. 2.

If we want to represent the activities on graphic, we do the operation from WinQSB: *Format – Switch to Graphic Model*.

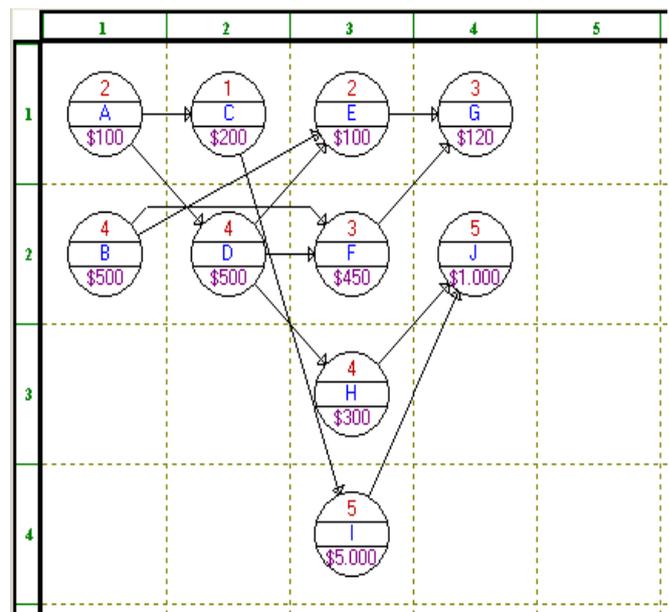


Fig. 3 Graphic representation of activities

Now we have the possibility to solve the problem using the normal durations (Solve Critical Path - Using the Normal Time), or the crash (Solve Critical Path - Using Crash Time) and perform sensitivity analyses.

Performing the Solve Critical Path operation for normal time, we obtained the following matrix form:

02-21-2012 11:46:19	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	4	0	4	5	9	5
3	C	no	1	2	3	4	5	2
4	D	Yes	4	2	6	2	6	0
5	E	no	2	6	8	10	12	4
6	F	no	3	6	9	9	12	3
7	G	no	3	9	12	12	15	3
8	H	Yes	4	6	10	6	10	0
9	I	no	5	3	8	5	10	2
10	J	Yes	5	10	15	10	15	0
Project Completion Time =				15	days			
Total Cost of Project =				\$8.270	(Cost on CP =		\$1.900)	
Number of Critical Path(s) =				1				

Fig. 4 Project data (normal time)

In the table above, the first column represents the number allocated to the activity. YES/NO on the second column says if the activity is on the critical path found, or not. In the third column are presented the activities duration, and the next two columns present the earliest time at which the activity can start and the earliest time at which it ends (CMD/CMT). Similarly, in the following columns are present the latest beginning and later ended for the considered activities. The last column contains the difference between the latest and the earlier start time of the activity.

On the last three rows are specified the number of days in which the project can be realized (15), the total costs (8270) and the number of critical paths found, in this case only one.

If we want to go more in details, and to be displayed the activities and the order in which are realized on the critical path found, we do the operation Results->Show Critical Path:

02-21-2012	Critical Path 1
1	A
2	D
3	H
4	J
<b>Completion Time</b>	<b>15</b>

Fig. 5 Critical path

For the construction of Gantt chart of related problem (fig. 6) is available option *Gantt Chart*, in the *Results* menu. The graph can be saved as .bmp file, and is built for both those

earlier times and later times. The critical path is render in red for those earlier times and with pink for the later times, and for the non-critical activities is use dark blue for those earlier times, and light blue for later times.

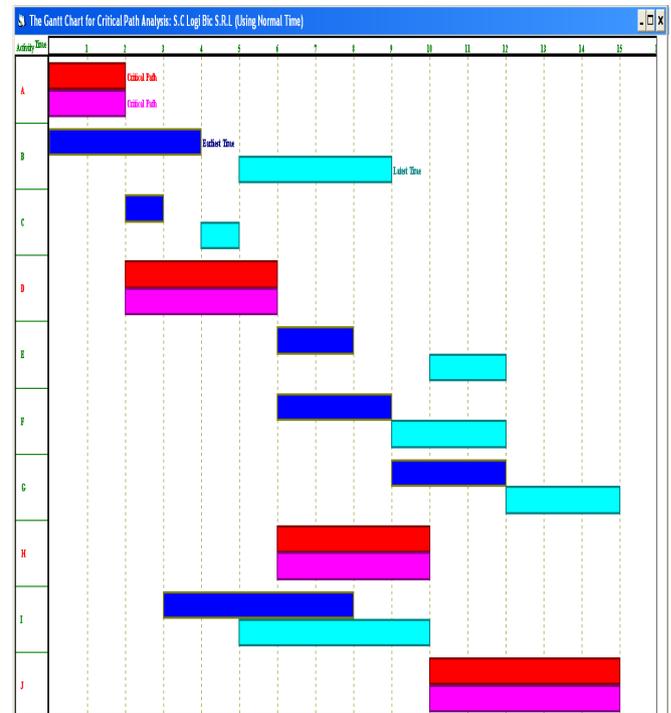


Fig. 6 Gantt graphic

For shorter durations, the matrix will be next and will have the same interpretation as the previous (crash time).

02-21-2012 11:52:59	Activity Name	On Critical Path	Activity Time	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack (LS-ES)
1	A	Yes	1	0	1	0	1	0
2	B	no	2	0	2	4	6	4
3	C	no	1	1	2	2	3	1
4	D	Yes	3	1	4	1	4	0
5	E	no	1	4	5	7	8	3
6	F	no	2	4	6	6	8	2
7	G	no	2	6	8	8	10	2
8	H	Yes	3	4	7	4	7	0
9	I	no	4	2	6	3	7	1
10	J	Yes	3	7	10	7	10	0
Project Completion Time =				10	days			
Total Cost of Project =				\$6.030	(Cost on CP =		\$1.500)	
Number of Critical Path(s) =				1				

Fig. 7 Project data (crash time)

Sensitivity analyses allow the application of restrictions regarding the project duration or budget and determine the distribution of costs so that the total cost to be low.

If we want to realize the project in an exact number of days between the minimum and maximum value (10 - 15), we can use the option *Solve and Analyze -> Perform Crashing Analysis*. In case the project is complete fastest, you can offer a bonus per day (*Early reward per day*), and in the case of lateness, they may penalize (*Late penalty per day*). In our case are not taken into account any bonuses or penalties.

In corresponding window (fig. 8), we complete as follows:

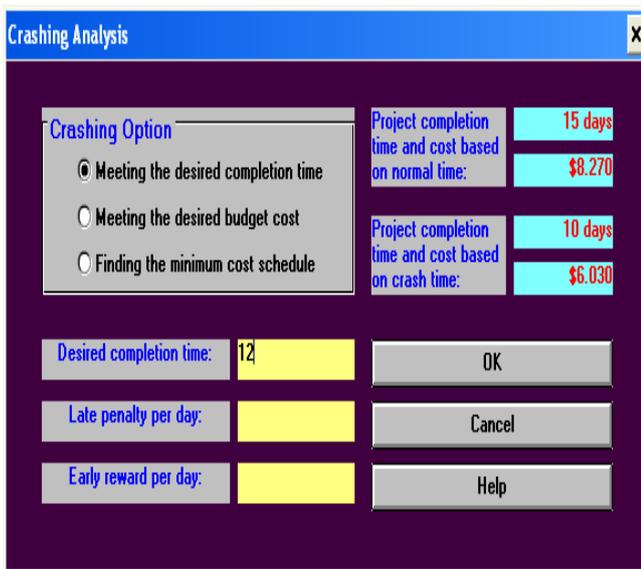


Fig. 8 Crashing analysis

02-21-2012 11:55:37	Activity Name	Critical Path	Normal Time	Crash Time	Suggested Time	Additional Cost	Normal Cost	Suggested Cost
1	A	Yes	2	1	1	0	\$100	\$100
2	B	no	4	2	4	0	\$500	\$500
3	C	Yes	1	1	1	0	\$200	\$200
4	D	Yes	4	3	3	0	\$500	\$500
5	E	no	2	1	2	0	\$100	\$100
6	F	no	3	2	2	0	\$450	\$450
7	G	no	3	2	3	0	\$120	\$120
8	H	Yes	4	3	3	0	\$300	\$300
9	I	Yes	5	4	5	0	\$5.000	\$5.000
10	J	Yes	5	3	5	0	\$1.000	\$1.000
	Overall Project:				12	0	\$8.270	\$8.270

Fig. 9 Project conclusions

It will obtain a table in which are specified the activity durations and costs for the entire project to be completed in the period imposed by us, properly 12 days (fig. 9).

In conclusion, we note that for 12 days all costs are 8.270, as for 15 days, which leads us to the conclusion that it is desirable to realize the project in a shorter amount of time than initial value considered (15 days).

VI. CONCLUSION

In the projects field, path represents a sequence of adjacent activities between milestones; it is mark by a series of lines that have their origin in the start of the project and it clears in the end.

A number of critical activities, which must be completed according to schedule, so the project to be completed in the initial date set, determines the critical path. The need for providing an increased attention of these activities by studying the risks that can occur, involves a critical path management.

In general, the costs grow along with reducing the period of project execution, in this way reaching the limits of its decrease determined by maximum expenditure might be. So the problem of planning activities consists in finding an optimal compromise between shortening the total length of the process and the corresponding variation of costs.

This article presents the decision-making process in business of the enterprises and the use of informatics systems for decision support. Solving the case study using the module PERT/CPM of WinQSB software offers a new vision of assisting decision and choosing the right economic strategy from many for an enterprise.

The results of the article can be put into practice exactly in the mode that have been, or can be modified according to the needs of the project. The software used provides a wide range of application in practice.

REFERENCES

- [1] M. Mocanu, and C. Shuster, *Management of projects*. Bucharest: All Beck, 2004, pp. 33-93.
- [2] F. Correia, and A. Abreu. (2011, August). An overview of critical chain applied to project management. *Recent Advances in Manufacturing Engineering*. [Online]. pp. 261-267. Available: <http://www.wseas.us/e-library/conferences/2011/Barcelona/MEQAPS/MEQAPS-45.pdf>
- [3] M. Sohaci, I. Csaki, S. Velicu, and C. Predescu. (2010, July). Project management – a useful tool for SME’s. *Latest Trends on ENGINEERING EDUCATION*. [Online]. pp. 163-167. Available: <http://www.wseas.us/e-library/conferences/2010/Corfu/EDUCATION/EDUCATION-27.pdf>
- [4] C. Doicin, *Analysis of investment projects in engineering*. Bucharest: Bren, 2009, pp. 45-120.
- [5] L. Melnic, R. Zagan, and M. Chircor, *Operational Researches*. Bucharest: Bren, 2007, pp. 3-10.
- [6] S. Sharma. (2011, August). Transportation project planning and modeling. *Recent Researches in Circuits, Systems, Mechanics and Transportation Systems*. [Online]. pp. 35-39. Available: <http://www.wseas.us/e-library/conferences/2011/Montreux/MECHICSE/MECHICSE-05.pdf>
- [7] F. Filip, *Support systems for decision*. Iasi: Technical, 2004, ch. 2.
- [8] C. Neagu, E. Nitu and M. Catana, *Engineering and production Management*. Bucharest: Pedagogical, 2005, pp. 503-582.

- [9] R. G. Hoffman, "Economic scenarios for project evaluation," *Journal of Business Strategy*, vol. 5, no. 4, 2008, pp. 66-82.
- [10] Z. Gherasim, D. Fusaru, and M. Andronic, *Informatics systems for assisting the economic decision*. Bucharest: Romania Foundation, 2008, ch. 3.
- [11] P. Jovanovici, "Application of sensitivity analysis in investment project evaluation under uncertainty and risk," *International Journal of Project Management*, vol. 17, no. 4, 1999, pp. 217-222.
- [12] N. Krivulin. (2012, March). Algebraic solutions to scheduling problems in project management. *Recent Researches in Communications, Electronics, Signal Processing and Automatic Control*. [Online]. pp. 161-166. Available: <http://www.wseas.us/e-library/conferences/2012/CambridgeUK/NAISEH/NAISEH-25.pdf>
- [13] D. Fierro, G. Giorleo, and P. Zoppoli. (2008, June). Decision support system for risk management in robust fast tracking projects. *Proceedings of the 7th WSEAS International Conference on SYSTEM SCIENCE and SIMULATION in ENGINEERING (ICOSSE '08)*. [Online]. pp. 266-271. Available: <http://www.wseas.us/e-library/conferences/2008/venice/icosse/icosse44.pdf>

**M. A. Gurau** (M'2012) was born in Medgidia town, Romania, in 18'10'1985.

- *Diplomat Engineer*, Faculty of Mechanical, Industrial and Maritime Engineering (Specialization: Economical Engineering in the Mechanical Field), Ovidius University, Constanta, Romania, 2004-2009.

- *Economist Engineer*, Faculty of Mechanical, Industrial and Maritime Engineering (Masters: Engineering and Business Management), Ovidius University, Constanta, Romania, 2009-2011.

- *PhD*, Faculty of Technology Systems Engineering and Management (Industrial Engineering), Polytechnic University, Bucharest, Romania, 2010-present.

He works in this moment as ASSISTANT PROFESSOR at Ovidius University, Constanta, Romania; EXPERT ASSISTANT PROJECT MANAGER at Ovidius University in an European Project (SOP-HRD); ENGINEER ECONOMIST at S.C Logi Bic S.R.L, Constanta, Romania.

Mr. Gurau is member of the Romanian Association economical engineering (ARIE) since 2010. Also he has a Book-Keeper Diploma obtained in 2009, approved by the Ministry of Labor and Ministry of Education.