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ScienceDirect

Procedia - Social and Behavioral Sciences 210 (2015) 348 – 357

Procedia
Social and Behavioral Sciences

4th International Conference on Leadership, Technology, Innovation and Business Management

CPM, PERT and Project Management With Fuzzy Logic Technique and Implementation On A Business

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Abstract

As a result of increased competition environment, it has been obligatory to complete the projects in the foresighted time and with the specified sources. An effective project management is necessary to finish the projects without delay and with the available qualifications identified beforehand. The project planning techniques are utilized to satisfy these necessities.

In this study, classic PERT and CPM, which are project management techniques, fuzzy PERT and fuzzy CPM, which are used in the fuzzy project management, will be used to improve an online internet branch and to plan the project of an online internet branch. At the end of the study, the results will be analyzed. In the study, certain and fuzzy activity times of three different firms are used. With certain activity times, classic CPM and PERT optimization and with using triangular fuzzy numbers for fuzzy data, CPM and PERT optimization are analyzed.

Keywords: Project Management, Fuzzy Logic, PERT, CPM, Fuzzy PERT, Fuzzy CPM

1. Introduction

Fuzzy Set Theory, proposed in 1965 by LA Zadeh, is not only interested in well-defined and precise data, but also in uncertain and fuzzy data (MathWorks, 1995). This theory provided the real world to be expressed mathematically, thus the exact boundaries created by classical mathematics have been removed, and uncertainty took place in the decision-making processes (Steyn, Stokar, 2014). In almost every field of science and technology, the widespread use of fuzzy set theory with the new perspectives supplied to decision-making in industrial systems to the subject of the classic operations research studies have expanded the domain(Aziz,2013). This theory widely used in game theory and network problems in operations research, linear programming, nonlinear programming, goal programming, dynamic programming, transportation models (Junior, Carvalho, 2013).

2. Literature Review And Hypotheses

2.1. Fuzzy Set Theory

Triangular fuzzy numbers are shown as (a1, a2, a3) (Pillay ve Wang,2003). Here a2 is a number indicating the size is certainly. A1 and A3 size and upper and bottom limit shows the acceptable values**.**

Elements Of U, with "x" is defined as shown a universal set. Which is conventional for a subset of the membership function characteristic represented by μ, and {0, 1} as the following ranges of: (Ross,1995)

$$\mu A(x) = \begin{cases} 1 & \text{İf } x \, \varepsilon A \\ 0 & \text{Otherwise} \end{cases}$$

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doi:10.1016/j.sbspro.2015.11.378

If value set is allowed to be in the range of [0, 1], A is Fuzzy set. μ A (x), x in the set of "degree of membership" and to μ (x) for values of x close to 1 set of membership increases. A fuzzy set, is characterized by a set of regular binary (Yakhchali, 2012).

$A=\{(x,\mu_A(x))\ x\varepsilon X\}$

Zadeh, in the form as proposed here also has the following representation. A fuzzy set X is a finite set {x1, x2, x3, ... xn} is indicated in the form.

That's a lot of uncertainty and competition in today's activity life, Triangular Fuzzy Numbers made using a CPM / PERT much more flexible and gives accurate results (Madhuri, Saradhi, Shankar, 2014).

A = (x1, x2, x3) and B = (Y1, Y2, Y3) in the form of two triangular fuzzy numbers;

• Equality: equality of fuzzy numbers A and B, shows the mutual equality of all members. This can be explained as follows:

If A = B (x1, x2, x3) = (Y1, Y2, Y3) if x1 = y1, x2 = y2, x3 = Y3 is.

• Gathering : A (+) and B = (x1 + y1, x2 + y2, x3 + y3) is expressed as.

• Subtraction : A (-) B = (x 1-y3, x2-y2, x3-y1) is shown as. Result is again a triangular fuzzy number.

• The symmetric triangular fuzzy numbers: A = (x1, x2, x3) if taken as triangular fuzzy number, that number will be as symmetrical - (A) = (-x1,-x2,-x3)

Multiplication and division operations are defined only on positive fuzzy numbers. The number of positive fuzzy numbers is the lower limit value is positive (Klir ve Yuan, 1995).

• Multiplication: A ⊗ B = (x1.y1, x2.y2, x3.y3) are shown in the form.

Division

$$A : B = \left(\frac{x_1}{y_3}, \frac{x_2}{y_2}, \frac{x_3}{y_1}\right)$$

This process results in the resulting number is a triangular fuzzy number (Sadjadi, Pourmoayed ve Aryanezhad, 2012).

t; increasing flexibility and innovation; making major changes in processes, products, or services; and gaining commitment to the changes (Yukl, 2002). Specific types of change-oriented behaviors can be classified as (1) influencing organizational culture, (2), developing a vision, (3) implementing change, (4) increasing innovation and learning (Yukl, 2002).

2.2. Fuzzy Critical Path Method (FCPM)

CPM (Critical Path Method) network planning is a technique used in the analysis. This technique "of the work done towards the realization of a project, when to start, and what bits work as well as when and what to do with the" grid presents visual information to the manager (Mccahon and Lee,1989). CPM, the duration of activity is assumed to be constant when the deterministic method (Meyer, Loch, Pich, 2014). In this study, the problem of CPM subjective interest based merging method is used with the membership functions. In this method, the formula of triangular fuzzy numbers,

$$\left(\frac{a+2b+c}{4}\right)$$

each with a designated representative values and values that are greater among themselves pessimistic, optimistic median optimal value was considered as the lowest value were calculated CPM (Baykasoglu, Gokcen, 2012).

2.3. Fuzzy PERT Method (FPERT)

In this study, known as the method of FPERT benchmarking method is used in this method assumes that each job is known of fuzzy time (Chanas Zielinski, 2001). Benchmarking method to find the time to complete the project in the early start-to-finish in a blur in transition forward and backward pass, pass a blur start-to-finish time is calculated in the following way.

$$\widetilde{ES}_i = \max_{v_j \in P_i} \left[\widetilde{ES}_j \ (+) \ \widetilde{A}_j\right]$$

$$\widetilde{EF}_i = \widetilde{ES}_i \ (+) \widetilde{A}_i$$

$$\widetilde{LF}_i = \min_{v_j \in S_i} \left[\widetilde{LF}_j \ (-) \ \widetilde{A}_j\right]$$

$$\widetilde{LS}_i = \widetilde{LF}_i \ (-) \widetilde{A}_i$$

3. Methodology

3.1. Research Goal

In this study, classic PERT and CPM, which are project management techniques, fuzzy PERT and fuzzy CPM, which are used in the fuzzy project management, will be used to improve an online internet branch and to plan the project of an online internet branch.

3.2. Sample and Data Collection

Although there are many methods used in project management methods, PERT and CPM are most popular methods (Kim, Kang, Hwang, 2013). In this study, the classical PERT and CPM in project management used in project management with a fuzzy fuzzy PERT (FPERT) and fuzzy CPM (FCPM) techniques to be used, and the results will be analyzed.

All analysis and observations are made in a new online internet branch project. For these project project activities and activities time are obtained by X, Y and Z consulting firm's project team. The results are Table 1 .

Table 1

Activity Code	Previous Activity	Definition of activity
A	-	The creation of the project plan and team
B	A	Determination of user needs / survey, focus group
C	B	Benchmark studies and determination of proper layout
D	C	Get the determination of the companies to offer
E	D	Evaluation of tenders
F	C	Evaluation of Contract and maintenance conditions
G	C	Consulting Services decision
H	C	The creation of new content and approval
I	G,H	Preparation of visual and template design
J	I	Tests
K	F	Launch

In phase I, the logical relationship between these activities and times WINQSB program was initiated, entered and analyzed.

Activity Name	Immediate Predecessor (list number/name, separated by ',')	Normal Time
A		7
B	A	90
C	B	15
D	C	7
E	D	7
F	C	15
G	C	7
H	C	3
I	G,H	3
J	I	7
K	F	7

Figure 1 Precise Time in the WINQSB Screen Display

In Figure 1, the first column (activity name) related activity, while the second column (immediate predecessor) related activities should take place before the activity, the activity will take place the third column is the precise time (in normal conditions) shows. Precise time of activities were analyzed with using WinQSB program.

Activity Name	On Critical Path	Activity Time	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack (LS-ES)
A	Yes	7	0	7	0	7	0
B	Yes	90	7	97	7	97	0
C	Yes	15	97	112	97	112	0
D	no	7	112	119	120	127	8
E	no	7	119	126	127	134	8
F	Yes	15	112	127	112	127	0
G	no	7	112	119	117	124	5
H	no	3	112	115	121	124	9
I	no	3	119	122	124	127	5
J	no	7	122	129	127	134	5
K	Yes	7	127	134	127	134	0
Project	Completion	Time	=	134	days		
Number of	Critical	Path(s)	=	1			

Figure 2 Precise Time and Project Completion Time For Calculation of WINQSB

WinQSB calculated completion time 134 days and critical path A-B-C-F.

This situation is shown in Figure 2 and Figure 3.

05-10-2014	Critical Path 1
1	A
2	B
3	C
4	F
5	K
Completion Time	134

Figure 3 Expected Completion of the Critical Path

WinQSB's graphical solution shown in Figure 4.

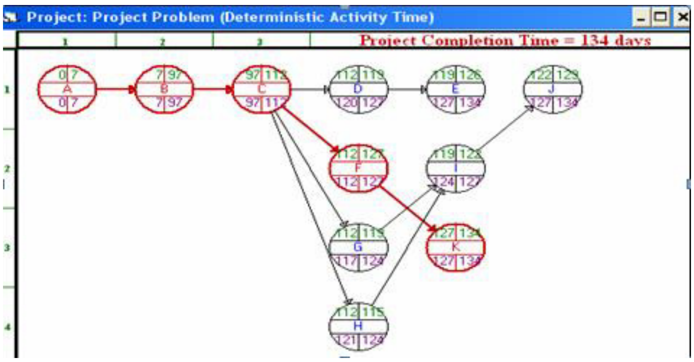

Figure 4 Graphical CPM Solution.

3.3. Analyses and Results

Table 3, X, Y and Z taken from firms operating time has been considered as triangular fuzzy numbers, and these numbers are calculated representatives.

Triangular fuzzy numbers, the smallest of the calculated values of representative value optimistic, pessimistic value is considered to be the biggest in the program, and WinQSB these values were obtained using the optimistic and pessimistic solutions (Chanas, Kamburowski, 1981)

Table 2 For each activity, pessimistic and optimistic Triangular Fuzzy Numbers and Representative Values

Activity Code	Previous Activity	A*(Triangular Fuzzy Numbers) Pessimistic	Represe ntive Value	A*(Triangular Fuzzy Numbers) Pessimistic	Represe ntive Value
A	-	(5,8,9,)	7.5	(5,7,9)	7
B	A	(90,95,100)	93.75	(75,90,95)	87.5
C	B	(15,15,17)	15.5	(15,15,15)	15
D	C	(7,8,9)	8	(6,7,8)	7
E	D	(5,7,9)	7	(5,7,9)	7
F	C	(15,17,18)	16.75	(13,15,18)	15.25
G	C	(6,7,8)	7	(6,7,8)	7
H	C	(3,3,3)	3	(3,3,3)	3
I	G,H	(1,3,5)	3	(1,1,1)	1
J	I	(7,7,7)	7	(7,7,7)	7
K	F	(7,8,9)	8	(6,7,8)	7

In the first phase of activities pessimistic representative values have been entered into WinQSB display and analysis was initiated.

As a result of this pessimistic analysis of the optimal solution of the model is calculated as 141.5 days. Pessimistic duration of the project with triangular fuzzy numbers (132, 143, 153) was found and was identified as the critical path A-B-C-F. In the second phase of activities optimistic representative values have been entered into WinQSB display and analysis was initiated.

WinQSB optimistic optimal solution of this model with the program is calculated as 131.75 days. Optimistic duration of the project with triangular fuzzy numbers (114, 134, 145) was found and was identified as the critical path A-B-C-F.

In the light of these results. Fuzzy modeling with applications in the solution of the CPM (FCPM) is more flexible and provide the appropriate framework (Dubois and Prade, 1980) (Buckley, 1995) has been observed that a mathematical *definition.*

3.4. Classic PERT Calculation Of The Project Duration

Classic PERT method, we used the largest, optimally and smallest values from the firm. When we take a look the PERT formula, a = the minimum value, m is considered as the optimal value and b = is the maximum value. Utilizing all three times the estimated weighted-average expected time for each activity is calculated.

Expected time (ET) is calculated by the formula:

$ET = (a + 4m + b) / 6$

The first stage of completion of activities in time for the 3-time estimates and the logical relationships between the activities and analyzes have been entered into WINQSB program was started.

Activity Name	Immediate Predecessor (list number/name, separated by ',')	Optimistic time (a)	Most likely time (m)	Pessimistic time (b)
A		5	7	9
B	A	75	90	105
C	B	13	15	18
D	C	6	7	9
E	D	5	7	9
F	C	13	15	18
G	C	6	7	8
H	C	3	3	3
I	G,H	1	3	5
J	I	7	7	7
K	F	6	7	10

Figure 5 Time Estimates for each activity WINQSB Screen Display

The first column in Figure 7 (activity name) related activity, the second column (immediate predecessor) related activities indicate activities that should happen before. Third, fourth and fifth columns of the related activities performed according to PERT technique has been entered 3-time estimates. Using time estimates for activities WinQSB program analyzed and activity results were obtained.

05-10-2014 23:23:25	Activity Name	On Critical Path	Activity Mean Time	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack (LS-ES)	Activity Time Distribution	Standard Deviation
1	A	Yes	7	0	7	0	7	0	3-Time estimate	0,6667
2	B	Yes	90	7	97	7	97	0	3-Time estimate	5
3	C	Yes	15,1667	97	112,1667	97	112,1667	0	3-Time estimate	0,8333
4	D	no	7,1667	112,1667	119,3333	120,5	127,6667	8,3333	3-Time estimate	0,5
5	E	no	7	119,3333	126,3333	127,6667	134,6667	8,3333	3-Time estimate	0,6667
6	F	Yes	15,1667	112,1667	127,3333	112,1667	127,3333	0	3-Time estimate	0,8333
7	G	no	7	112,1667	119,1667	117,6667	124,6667	5,5	3-Time estimate	0,3333
8	H	no	3	112,1667	115,1667	121,6667	124,6667	9,5	3-Time estimate	0
9	I	no	3	119,1667	122,1667	124,6667	127,6667	5,5	3-Time estimate	0,6667
10	J	no	7	122,1667	129,1667	127,6667	134,6667	5,5	3-Time estimate	0
11	K	Yes	7,3333	127,3333	134,6667	127,3333	134,6667	0	3-Time estimate	0,6667
	Project	Completion	Time	=	134,67	weeks				
	Number of	Critical	Path(s)	=	1					

Figure 6 Activity for classical PERT Analysis and Results Obtained

Figure 8 As seen in all its activities, the average completion time (Activity Mean Time), the early start (Earliest Start), latest start (Latest Start), the early finish (Earliest Finish) and the late finish (Lastest Finish) time , margin values (Slack), standard deviation (Standard deviation) and the expected duration of the project (Project completion time) has been shown in the respective column. At the same time, which was determined to be on the critical path activities. Statements in the second column (Ten Critical Path) and the intersecting lines in some of the reference to "yes", the phrase about the activity on the critical path that expresses and 8 th columns in (Slack, LS - ES) As can be seen, the critical activities gap value is zero (Makropoulos ve Butler, 2005). The total space of non-critical activities in the same column values are also shown in the same row. Accordingly activities and administration sequences forming the critical path of the project, and the standard deviation of the expected duration of Figure 9 are indicated.

05-10-2014	Critical Path 1
1	A
2	B
3	C
4	F
5	K
Completion Time	134,67
Std. Dev.	5,22

Figure 7 Critical Path of the project and the expected completion time of the Representation of Variance

Analysis II. stage, in the light of the values of the models WINQSB program results through the solution, project network programmed, 134.67 days of expected project completion time, critical path and variance A-B-C-F 5.22 days.

3.5. *Fuzzy PERT Calculation of the Project Duration*

In the Table 4, X Y and Z are taken from companies operating time has been considered as triangular fuzzy number. This activity period on the basis of the average values were calculated for fuzzy PERT. In calculating the average value of the weight of each company by 1/3 and by summing the values are assumed to be average values were obtained.

Average value = (a (x, y, z), m (x, y, z), B (x, y, z))

a (x, y, z) = X, Y, and Z companies optimistic activity time's average values

a(x, y, z)= ax+ay+az is calculated by formula.

Here, ax = X1 / 3, ay = Y1 / 3, az = Z1 / 3,

X1 = X, Y1 = Y = Z and Z1 are the company's optimistic activity time period refers to the activities of the firm optimistic (Russel ve Norvig, 2003).

m (x, y, z) = X, Y, and Z companies considered the optimal operation time and the average value was calculated in the same method.

b (x, y, z) = X, Y, and Z companies pessimistic activity time has been considered as the average value was calculated in the same method.

Table 3 X, Y and Z Company received from Operations Fuzzy And Average Value of Time

Activity	**Previous Activity**	**Duration of activity**	**Average Value (a(x,y,z), m(x,y,z), b(x,y,z))**
A	-	(5,7,9) (5,8,9) (5,7,9)	(5,7.3,9)
B	A	(75,90,95) (90,95,100) (75,95,105)	(80,93.3,100)
C	B	(13,15,18) (15,15,15) (15,15,15)	(14.3,15,16)
D	C	(6,7,8) (7,8,9) (6,8,9)	(6.3,7.6,8.6)
E	D	(5,7,9)	(5,7,9)
F	C	(13,15,18) (15,16,17) (15,17,18)	(14.3,16,17.6)
G	C	(6,7,8)	(6,7,8)
H	C	(3,3,3)	(3,3,3)
I	G,H	(1,3,5) (1,1,3) (1,1,1)	(1,1.6,3)
J	I	(7,7,7)	(7,7,7)
		(6,7,8)	

Fuzzy activity time on the basis of the average value of the ES (Early Start), EF (Early Finish time) in Table 5, LS (Late Start) and LF (Late Finish) is calculated and shown in Table 6.

Table 4 ES (Early Start), EF (Early Finish time)

Activity	ES	EF
A	(0,0,0)	(5,7.3,9)
B	(5,7.3,9)	(85,100.6,109)
C	(85,100.6,109)	(99.3,115.6,125)
D	(99.3,115.6,125)	(105.6,123.6,133.6)
E	(105.6,123.6,133.6)	(110.6,130.6,142.6)
F	(99.3,115.6,125)	(113.6,131.6,142.6)
G	(99.3,115.6,125)	(105.3,122.6,133)
H	(99.3,115.6,125)	(102.3,118.6,128)
I	Max [EFG,EFH]= EFG= (105.3.122.6,133)	(106.3,124.2,136)
J	(106.3,124.2,136)	(113.3,131.2,143)
K	(113.6,131.6,142.6)	(119.9,138.9,151.6)

Table 5 LS (Late Start) and LF (Late Finish)

Activity	LS	LF
A	(0,0,0)	(5,7.3,9)
B	(5,7.3,9)	(85,100.6,109)
C	(85,100.6,109)	Min [LSD,LSF,LSG, LSH]= LSF =(99.3,115.6,125)
D	(106.6,124.3,134)	(112.9,131.9,142.6)
E	(112.9,131.9,142.6)	(119.9,138.9,151.6)
F	(99.3,115.6,125)	(113.6,131.6,142.6)
G	(105.9,123.3,133.6)	(111.9,130.3,141.6)
H	108.9,127.3,138.6)	(111.9,130.3,141.6)
I	111.9,130.3,141.6	(112.9,131.9,144.6)
J	112.9,131.9,144.6	(119.9,138.9,151.6)
K	113.6,131.6,142.6	(119.9,138.9,151.6)

In this case, fuzzy project completion time shown as T, EF is the time of K activity and is expressed as follows:

$$\mu T(x)= \begin{cases} (x-119.9)/(138.9-119.9), & 119.9 \le x \le 138.9 \\ (151.6-x)/(151.6-138.9) & 138.9 < x \le 151.6 \\ 0, & 151.6<x \end{cases}$$

Activity time is difficult to determine the critical path is fuzzy. Therefore, each of routes network located on the degree of criticality should be calculated and should be decided accordingly. A good degree of criticality of the road can be calculated as follows: Cpi (Gencer vd., 2001).

$Cpi=\sup [Tpi \wedge T]$

There are 4 alternative ways ;these routes, (A-B-C-D-E), (A-B-C-F), (A-B-C-G-I-J) and (A-B-C-H-I-J) .

All activity durations is expressed as fuzzy numbers, fuzzy path length is calculated in the following way.

Route 1 (A-B-C-D-E): (5,7.3,9) + (80,93.3,100) + (14.3,15,16) + (6.3,7.6,8.6) + (5,7,9) = (110.6, 130.2,142.6)

Route 2 (A-B-C-F): (5,7.3,9) + (80,93.3,100) + (14.3,15,16) + (14.3,16,17.6) + (6.3,7.3,9) = (119.9, 138.9,151.6)

Route 3 (A-B-C-G-I-J): (5,7.3,9) + (80,93.3,100) + (14.3,15,16) + (6,7,8) + (1,1.6,3) + (7, 7.7) = (113.3,131.2,143)

Route 4 (A-B-C-H-I-J): (5,7.3,9) + (80,93.3,100) + (14.3,15,16) + (3,3,3) + (1,1.6,3) + (7, 7.7) = (110.3,127.2,148)

After calculating alternative routes calculated degree of criticality of each path (Gencer vd., 2001).

In Figure 9, each of the road are calculated and the degree of criticality are shown in Table 7.

Table 6 Criticality Degrees Of Routes

Routes	*Cpi*
1	0.72
2	**1.00**
3	0.75
4	0.71

According to the results of 2. Routes, which is the critical path of the project (A-B-C-F-K) and the project completion time (119.9,138.9,151.6) .

3.6 Fuzzy PERT Calculation of the Project Duration

In this part in order to assure better CPM, PERT FCPM FPERT solutions and the results obtained are shown in Table 8.Fuzzy PERT (FPERT) method, the obtained solution is a triangular fuzzy number (119.9,138.9,151.6) ease of operation and because it is more meaningful to compare the exact number of these triangles are converted into precise integer numbers (Turan ve Khisty, 2003). There are several methods in the literature for this transformation in this study Lee and Li (1988) and recommended Bortolin then Degani (1989) method is used in proving by the average value. Average value management by taking the arithmetic mean of the triangular fuzzy number is an exact number in this example extraction (119.9 +138.9 +151.6) / 3 = 136.8 was converted into the exact number.

Table 7 CPM, PERT, and FPERT obtained by FCPM Display of Project Duration

Method	*Project Duration*	*Critical Path*	*Standart Deviation*
CPM	*134*	*A-B-C-F-K*	-
PERT	*134.67*	*A-B-C-F-K*	*5.22*
FCPM (İyimser Çözüm)	*131.75*	*A-B-C-F-K*	-
FCPM (Kötümser Çözüm)	*141.5*	*A-B-C-F-K*	-
FPERT	*136.8*	*A-B-C-F-K*	-

4. Conclusion

CPM and PERT are the two of contemporary planning and scheduling techniques that are widely used in construction, IT, manufacturing and defense. They can be applied in the solutions of many problems and can be used in the programming of large-scale projects. Together with their easy application, these two techniques provide great benefit to the decision makers with being analytical. In this study, fuzzy and classical implementations of the two methods, which are used in project completion time, are compared. Then the project is assessed by cost-time point of view with the help of earned value techniques that are developed by project management institute. In the last part of the study, the most probable scenario is analyzed.

According to the results in general, there are no huge differences between methods. However, the method can be considered the challenges of the process. In the solution according to the methods of fuzzy logic trigonal each job has been expressed as fuzzy numbers As shown in working process is creating algorithm chaos. Should precede the use of fuzzy factor, especially for jobs all the time in cases where these factors can not be effective completion of the project, and this causes difficulties in defining time. In cases where these factors are valid, especially in systems with large-scale and more refined process than predecessors and causes a lot of confusion. When this method again increased the number of business transactions will increase confusion.

In this study, the PERT method is in the works when the average time to find and only one value is reduced to that process streamlined and simple at the same time PERT cpm according to the method of uncertainty is greater in environments more optimal solutions given is an indisputable fact. When viewed from this perspective, the classical PERT method projects online internet branch will be appropriate. CPM and PERT tecniques can also be blended with fuzzy logic and earned value tecnique. Thus these study focus on a project with different constraits. The most popular tecniques in the academic literature of project management are used in this study.

References

[1] Steyn, J. ve Stoker, P., (2013), ’’Does measurement theory impact Project performance? ’’, Procedia – Social and Behavioral Sciences, 119:635-644

[2] Aziz, R., (2013), ’’Optimizing strategy software for repetitive software projects within multi-mode resources ’’, Alexandria Engineering Journal, 52:373-385

[3] Junior, R. ve Carvalho, M., (2013), ’’Understanding the Impact of Project Risk Management on Project Performance: an Empirical Study’’, J.Technol.Manag.Innov., 8:64-79

[4] Meyer, A., Loch, C. ve Pich, M. , (2014), ’’A Framework for Project Management under Uncertainty’’, Management Science, 43:1104 – 1120

[5] Madhuri, U., Saradhi, P. ve Shankar, R.,(2014), ’’Fuzzy Linear Programming Model for Critical Path Analysis’’, İnternational Journal of Contemporary Mathematical Sciences, 8:93-116

[6] Kim, J., Kang , C. ve Hwang, I, (2013) ,’’ A practical approach to project scheduling: considering the potential quality loss cost in the time–cost tradeoff problem’’,International Journal of Project Management, 30:264-272

[7] Yakhchali, S.(2012), ’’A path enumeration approach for the analysis of critical activities in fuzzy networks’’,Information Sciences, 204:23-55

[8] Sadjadi, S.,J., Pourmoayed, R. ve Aryanezhad, M.B., (2012), ’’ A robust critical path in an environment with hybrid uncertainty’’, Applied Soft Computing Journal, 12:1087 - 1100

[9] Baykasoglu, A. ve Gokcen,T. , (2012) ,’’ A direct solution approach to fuzzy mathematical programs with fuzzy decision variables’’, Expert Sistems with Applications, 39:1972-1978

[10] Klein, C. M., (1991), Fuzzy shortest paths, Fuzzy Sets and Sistems, 39:27-41

[11] Chanas, S. ve Zielinski, P., (2001), “Critical Path Analysis in the Network with Fuzzy Activity Times”, Fuzzy Sets and Sistems , 122: 195-204.

[12] Dubois D. ve Prade H., 1980, Fuzzy Sets and Sistems: Theory and Applications,Academic Press Co., Toulouse

[13] J.J. Buckley, (1989), Fuzzy PERT, in Applications of Fuzzy Set Methodologies in Industrial Engineering, Elsevier, 115-125, Amsterdam

[14] Klir, G.J. ve Yuan, B., (1995),Fuzzy Sets and Fuzzy Logic: Theory and Application. Upper Saddle River, Prentice-Hall, New Jersey.