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Applying fuzzy related timing in project scheduling and instant comparison with Monte-Carlo timing method In third project design for urea and ammonia of Shiraz petrochemical Co.

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ABSTRACT
A project is a set of activities which should begin and finish at a specific time and managers should achieve this by using the least resources to accomplish at the minimum time required. A manager must plan before and through project processing. Planning is determining the activities and superiority and the resource required. Until the present time the planning and controlling techniques have undergone a lot's of modifications. At recent decades, in order to reduce the ambiguity in estimating the actual time of activities, mathematical theories have been devised. In this thesis, in addition to the typical CPM method as a ordinary and prevalent method, two new methods have been used for project scheduling. Comparing these three methods for a particular case study, we present the more precise and accurate method. These two methods are fuzzy critical path method and Monte Carlo simulation. In first method, even the effective factors can be calculated, but still some uncontrollable factors may lead the plans to out of track. So, we consider them in a fuzzy number instead of determining the exact time of operations.The second method against the CPM method is not restricted for continues time distribution of activities. In typical CPM method it is assumed that there is only one critical path. This is not true for a compound network, where each path can be critical. Results show that above used methods are more efficient than ordinary scheduling methods as CPM.

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INTRODUCTION

Project scheduling is one of basic pillars of project management and is deemed as one of main inputs of other pillars of the project (cost and budget of resources and quality provisions) (Nurang, 2006). Applying proper timing methods is one of factors to make the project successful. Modern timing techniques of project scheduling includes creative methods, methods based on artificial intelligence and neural networks and especially fuzzy approach with which we can beside conventional methods for timing (such as deterministic including Critical Path Method and non-deterministic network including Program Evaluation and Review Technique, Graphical Evaluation and Review Technique) present proper tool for project scheduling users (Sohrabi, 2010).

In this research, first we use scheduling on part of the project design for urea and ammonia of Shiraz petrochemical Co.'s site, in which we used of collected information by CPM method which is manager's first option for scheduling in most of companies and organizations, next project scheduling is introduced using fuzzy numbers and times based on information and times gained by CPM method. in the next stage of scheduling, we used of Monte-Carlo method and related software; and at the end results of two above methods were compared with each other according to goals and related questions of the research, then advantages and disadvantages of each methods were examined to find the better one.

Subject Literature:

Project fuzzy scheduling methods:

Considering many studies conducted regarding fuzzy concept and applying it in operational projects and decision-making sciences, which we can use them in scheduling and timing methods; however in first studies conducted regarding fuzzy theory and applying it in project scheduling, they presented a method named fuzzy PERT which was similar to classic PERT method, the only difference in this method was that classic relations were replaced with fuzzy relations and indicators. With this method, they reached completion time of project

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which was a fuzzy number. In this research, we categorize those into three applied classes as follows(Sadeghi, 2010):

1- Fuzzy time:
Scheduling project networks in which the only fuzzy indicator in them is time indicator.

2- Fuzzy networks:
Means networks in which all scheduling project indicators are fuzzy indicators

3- Fuzzy GERT:
Non-deterministic GERT in which non-deterministic indicators are replaced with fuzzy indicators.

Those abovementioned methods are basically summarized in following stages:

1- way of fuzzy showing of scheduling indicators (defining activities, activities succession and time):

2- Selecting basic solution and substituting fuzzy relations: fuzzy scheduling solutions are based on classic methods including CPM, PERT, GERT in which methods fuzzy relations such as max fuzzy, min fuzzy, fuzzy adding, multiplication and subtraction are used instead of deterministic and non-deterministic relations.

3- Conclusion interpretation: considering fuzzy inputs and outputs of system such as project completion, we conclude that critical path method and other fuzzy indicators would be related to fuzzy; meaning that they are not unique and would be interpreted in different ways.

Fuzzy time:
Methods of project scheduling could be categorized in this section that they have only considered time indicator of project activity as fuzzy indicator.

Pioneers of scheduling using fuzzy time indicator were Chanas, Kambrofsky and Henry in the late 1970s who we explained about them in previous chapter. Later, many articles were published regarding this subject that make fuzzy application in scheduling more complete. One of important examples regarding these studies is "Luterapang & Moslehi".

Basis of scheduling methods using fuzzy time could be summarized in these following stages(Shahsavany, 2004):

Time showing: we assume that definition of activities succession is deterministic and in project network, only time indicator is inaccurate and ambiguous.

Operators and experts naturally estimate time activities as time variables (such as near 20 days, more than 20 days and less than 40 days and…), these are fuzzy expressions which can be expressed in different forms using fuzzy numbers. Time activities are generally showed in the form of fuzzy sets of discrete time, fuzzy sets with continuous time in the form of triangular fuzzy numbers, trapezoidal fuzzy numbers and LR fuzzy numbers (Shankar et al,2010).

1. Determining basic solution and substituting fuzzy relations: after determining the network and estimating activities fuzzy time, next step is to choose fuzzy scheduling method which generally base on the same classic resolving methods such as CPM for fuzzy indicators, therefore, classical algebraic relations should be replaced with proper fuzzy relations.

2. Conclusion interpretation: considering that inputs are fuzzy then outputs such as the latest and earliest time of project activities' initiation and completion, time of project completion, critical path indicators are fuzzy as well(Yu-chuan, 2010).

A) Cut method for L-R fuzzy numbers

α-cut interval for fuzzy number, $\tilde{T}_{ij} = (t_1, n, m)_{L-R}$ is a closed interval which is calculated as follows:

$$\tilde{T}_{ij}^{\lambda} = \left[t_{ij}^{al}, t_{ij}^{ak}\right] = \left[t_1 - L^{-1}(\alpha)n,\ t_2 + R^{-1}(\alpha)m\right]$$

In this equation, L^{-1} and R^{-1} are reverse functions of L and R functions in its positive domain.

B) α in p-path:

Considering the hypothesis in which $[t_{ij}^{al}, t_{ij}^{ah}]$ was an α-cut interval for fuzzy time, $\tilde{T}_{ij}$; with this in mind, when we say that α is determined in p-path that by putting lower limit of the above interval, t_{ij}^{ah} which is deterministic time, instead of activities time located in p-path and also by putting t_{ij}^{al} deterministic time, instead of other activities time, p-path become critical. By assigning these values in activities time parameters, fuzzy networks turn into deterministic network, computation and determining critical path would be much easier:

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$$t_{ij} = \begin{cases} t_{ij}^{ah} & ij \in p \\ t_{ij}^{aI} & ij \notin p \end{cases}$$

Algorithm to calculate critical degree of a path:

Now considering previous definitions, critical degree of p-path is calculated by following algorithm. Performance of this method is based on determining maximum α determination value in p-path and maximum critical value of p-path. In this method, in each k-stage, value of determination $a_k \in [0,1]$ is examined in p-path, in order to find maximum value of a. Maximum value of a, is in fact critical degree of p-path meaning $\mu_{\tilde{p}}(p)$. This algorithm works as follows:

First step: assign k to 0 value (k=0)

Second step: see whether $a = \varepsilon$, is determined or not? If it is not determined then assign $a_{\max} = 0$ and jump to 6th step, otherwise proceed to 3rd step.

Third step: assign $a_k = 1$ and then examine whether a_k in p-path is determined or not? If it is, then assign: $a_{\max} = 1$ and go to 6th step, otherwise proceed to 4th step.

Forth step: assign k=k+1 and determine value of a_k as follows:

$$a_k = \begin{cases} a_{k-1} + \left(\dfrac{1}{2^k}\right) & \text{If } a_{k-1} \text{ was determined} \\ a_{k-1} - \left(\dfrac{1}{2^k}\right) & \text{If } a_{k-1} \text{ was not determined} \end{cases}$$

If a_k in p-path is determined then assign $a_{\max} = a_k$ and proceed to 5th step.

Fifth step: if $k < K$ then return to 4th step, otherwise proceed to 6th step.

Sixth step: assign $\mu_{\tilde{p}}(p) = a_{\max}$ and then stop.

Value of K in forth step, depends on level of accuracy in computation. If we intend to have value of computation error not bigger than 10^{-N}, then K would be yielded as follows:

$$K \geq \frac{N}{\log_{10}^{2}}$$

Value of ε used in second step, should be a little positive value and not bigger than determined error value of 10^{-N}.

$a_{\max}$ Which is gained from 6th step, is critical degree of p-path. These steps would repeat for each of paths, in order to calculate the value of critical degree for all paths (Chanas, 2009).

Examining the possibility of completing project in deterministic time by use of fuzzy method:

It is of great importance for project managers to know whether project would be completed in specific and pre-determined time or not. In order to calculate possibility of completing project on pre-determined time, assume that project completion time which is gained by fuzzy scheduling computations, equal to fuzzy number, $\tilde{T}_{end} = (e_1, \alpha, \beta)_{L-R}$ and pre-determined time for project completion, equal to $\tilde{R} = (r_1, \gamma, \delta)_{L-R}$. Therefore, we have:

$$\tilde{R} - \tilde{T}_{end} = (r_1 - e_1, \gamma + \beta, \alpha + \delta)_{L-R}$$

Possibility of completing project (PM) in fuzzy time of $\tilde{R}$, is as follows:

$$PM = \begin{cases} 1 & r_1 - e_1 - (\gamma + \beta) \geq 0 \\ \dfrac{s_1}{s_1 + s_2} & r_1 - e_1 - (\gamma + \beta) < 0 \leq r_1 - e_1 + (\alpha + \delta) \\ 0 & r_1 - e_1 + (\alpha + \delta) < 0 \end{cases}$$

In which:

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S_1 And S_1 are areas of right side and left side of the diagram.

In the above method, a value in [0, 1] range is assigned to PM. By increasing this value, project completion possibility would be increases in pre-determined time (Hsian and Chun, 2010).

Research method:

Since the goal of this research is to schedule the project with the use of non-deterministic times (fuzzy-probable) and modern methods and comparing it with conventional scheduling methods, first the scheduling of third design project for urea and ammonia of Shiraz petrochemical would be done by CPM method which is a conventional method in project scheduling that consider activities time deterministic. For this purpose, first information related to the project, would be estimated by interview with project control engineers of similar projects and other control project engineers and high-level managers in third design project for urea and ammonia of Shiraz petrochemical Co. as elite's viewpoints of this research, and also related existing information regarding third design project for urea and ammonia of Shiraz petrochemical Co., scheduling and critical path of this project is also determined by use of CPM method.

After fulfilling this step, activities time are expressed considering estimations in PERT method in the form of triangular L-R fuzzy numbers and project scheduling and critical path would be determined by presented fuzzy method.

In this method, relations to use changed fuzzy numbers and previous relations were replaced with relations of triangular L-R fuzzy numbers. After fulfilling scheduling by using fuzzy method, scheduling would be fulfilled this time by using Monte-Carlo simulation, by using Possibility distributions which are used to estimate activities time in PERT method, and PertMaster simulation software, activities of critical path would be determined and finally results of these three methods would be examined and compared with each other.

Information analysis:

-project scheduling with the use of presented methods:

In this chapter, time computations, determination of activities and paths, gaining other indicators including possibility and probability of project completion in determined time by two different methods, would be considered. For this purpose, first the above parameters would be calculated by CPM method which is a frequently used method in network scheduling. In continue, this work would be fulfilled by Monte-Carlo simulation and finally by presented method which is called fuzzy critical path.

-illustrating activities and estimating project times:

Project times in CPM method, doesn't have sufficient confidence degree, this is because times are deterministic. Therefore, in methods utilized in this research, times used for Monte-Carlo method, should be used in the form of non-deterministic and fuzzy times would be used for fuzzy methods, hence with the use of optimistic times, probable and pessimistic and in the case activities of a project were repeated in the past, we can estimate possibility distribution upon this, on the other hand, we can use of mean and variance of this specific distribution (Normal, homogeneous distribution and …) for our computation fulfillment.

In this project, information and statistical data in similar projects and the experiences of cooperators were utilized, in order to evaluate activities time; one possibility distribution was also estimated for each activities. In order to determine critical path and related computations, mean (of expected time) and standard deviation of these distributions were utilized.

-network depiction:

The next step in scheduling is depicting network related to under examination network. Network depiction related to third design project for urea and ammonia of Shiraz petrochemical Co. is depicted below:

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Fig. 1: vector network

-time related computations:

After determining activities, estimating times and depicting network, it is time to time computation and determining activities and critical path. As mentioned above, calculations regarding return and run, are the same in PERT and CPM and the only difference between them, is time estimation activities fulfillment. Results of scheduling calculations by use of CPM method and based on deterministic time for each activities fulfillment which is calculated by using related software, all are presented in the appendix. Assigning deterministic time for each activities, completion time of the project is yielded as 410 days.

-project scheduling by use of fuzzy critical path method(Sohrabi, 2010):

In this chapter, calculations done in CPM method, would repeat by fuzzy critical path method which is illustrated previously. Times which are considered for activities in these calculations, are triangular L-R fuzzy numbers.

We have to use of different functions for R(x) and L(x), but selecting type of function depends on the subject, therefore, main problem is to find proper function for this purpose.

Consider number $\tilde{M} = (m, \alpha, \beta)_{LR}$; if L=R, then $\tilde{M}$ would be L fuzzy number, with equation of $\tilde{M} = (m, \alpha, \beta)_L$.

In LR fuzzy numbers, triangular fuzzy numbers would defined as follows: assume that $\tilde{M} = (m, \alpha, \beta)_L$, then $\tilde{M}$ would be a triangular fuzzy number (T.F.N), if:

$$\mu_{\tilde{M}}(x) = \begin{cases} L\left(\frac{m-x}{\alpha}\right), & x \le m \\ R\left(\frac{x-m}{\beta}\right), & x > m \end{cases}$$

Triangular fuzzy number, would be shown as follows:

$$\mu_{\tilde{M}}(x) = \begin{cases} L\left(\frac{m-x}{\alpha}\right), & 0 \le \frac{m-x}{\alpha} \le 1 \\ R\left(\frac{x-m}{\beta}\right), & 0 \le \frac{x-m}{\beta} \le 1 \\ 0, & Otherpoints \end{cases}$$

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$$\Rightarrow \mu_{\tilde{N}}(x) = \begin{cases} 1 - \left(\frac{m - x}{\alpha}\right), & \& m - \alpha \le x \le m \\ 1 - \left(\frac{x - m}{\beta}\right), & m \le x \le m + \beta \\ 0 \quad , & Otherpoints \end{cases}$$

In order to reach project times by using fuzzy methods, we can use of optimistic and probable and also pessimistic times to define wanted parameters of fuzzy triangular function.

-calculating critical degree of paths and project activities with fuzzy time:

As mentioned above, one of misleading concept in conventional methods of scheduling including CPM method, is the way of illustrating this subject which leads to only one critical path, while in this method, activities time, is an accidental variable and each of paths, could be critical due to activities time being probable which in conventional method would be overleaped in practice. In fuzzy scheduling methods, considering that times are fuzzy, we can't certainly say that there is only one critical path in each network, but each of paths could be critical to a specific level. Therefore, it is necessary to examine criticality criterion when times are fuzzy.

Degree of paths criticality possibility or $\mu_{\tilde{p}}(p)$, by means of the algorithm mentioned above, can be calculated. Considering the value of 10^{-2} for calculation error, value of $K \ge 7$ is yielded for K. Considering these values, results gained by utilizing the algorithm is shown in below table:

Table 1: degree of paths criticality with the use of fuzzy data

		Criticality Index
1	A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-AC-AD-AE-AF-AG-AH-AI-AJ-AK-AL-AM	90.01%
2	A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-Y-Z-AA-AB	10.00%
3	A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-X-AC-AD-AE-AF-AG-AH-AI-AJ-AN	6.28%
4	Other paths	0

According to this algorithm, degree of criticality probability of one path, is always a value in the range of [0,1], in which number 1 indicates the most probable for criticality and number 0 indicates lack of probability for criticality. As you can see below, following path:

A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-AC-AD-AE-AF-AG-AH-AI-AJ-AK-AL-AM

Have probability degree of 0.90 and following path:

A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-Y-Z-AA-AB

Have probability degree of 0.10 and following path:

A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-X-AC-AD-AE-AF-AG-AH-AI-AJ-AN

Have criticality degree of 0.6, other paths of this network doesn't have probability of criticality.

Criticality degree for activities and nodes, is the same value as criticality degree of paths, with this difference that as for activities and nodes belong to more than one path, criticality degree is equal to the most criticality degree of paths which pass through those activities or nodes.

-probability of project completion on determined fuzzy time:

Like CPM method, in this section we calculate the probability of project completion on determined fuzzy time. In order to calculate probability of project completion on pre-determined time such as $\tilde{R} = (402,40,50)_{L-R}$ (meaning almost 402 days) and by considering time of project completion which is yielded as $\tilde{T}_{end} = (410,56,90)_{L-R}$ by means of calculations regarding fuzzy scheduling, we would have:

$$\tilde{R}\Theta\tilde{T}_{end} = (-8,130,106)_{L-R}$$

Considering number yielded and according to the below relations, we would have:

Probability of project completion in fuzzy time, $\tilde{R}$ which is expressed as PM, and is equal to:

$$PM = \begin{cases} 1 & r_1 - e_1 - (r + \beta) \ge 0 \\ \frac{s_1}{s_1 + s_2} & r_1 - e_1 - (r + \beta) < 0 \le r_1 - e_1 + (\alpha + \delta) \\ 0 & r_1 - e_1 + (\alpha + \delta) < 0 \end{cases}$$

In which:

$S_1 = \int_{x \ge 0} \mu_{\tilde{R}\Theta\tilde{T}_{end}}(x)dx$ And $S_2 = \int_{x \le 0} \mu_{\tilde{R}\Theta\tilde{T}_{end}}(x)dx$

$$PM = 0.37 \quad \rightarrow \quad S_2 = 42 \quad , \quad S_1 = 25$$

According to calculations, it is yielded that probability of project completion in mentioned fuzzy time is equal to 0.37 or 37.3%.

project scheduling by use of Monte-Carlo simulation method:

It is obvious that by applying Monte-Carlo simulation method, in order to do time calculations in networks having non-deterministic time, the more numbers of times calculations are, the more reliable final results would be. What makes this method acceptable and justifiable, is its accessibility to computer and related simulation softwares. With this method, we can do calculations within many computation cycles and gain more reliable results.

In this internship, in order to simulate for numerous repetitions, we have used of PertMaster software. This software is a project risk management software which analyze risk with the use Monte-Carlo simulation and since being non-deterministic activities time is deemed risky in project, we can utilize this software for analyzing network by considering possibility distribution of activities time. In this software, we use of all distribution functions introduced in Monte-Carlo simulation section, for determining activities time. PertMaster shows the results of simulation in the form of diagrams to analyze resulting data.

-scheduling results of simulation:

This section is related to do Monte-Carlo simulation. Therefore, we can use of results gained from these two methods to compare these methods with each other. After completing 70000 simulation repetition cycles, results are shown in the form of diagrams.

Following diagram is one of this software's outputs which indicates results gained within 70000 calculation cycles for determining time of project completion by use of accidental times. In this histogram, horizontal axis shows times for project completion and vertical axis show frequencies of these times. This figure for project completion time has distribution similar to normal distribution and results in right side of the diagram implies the mean of 402 days for project completion time. Standard deviation for project completion is equal to 8.986.

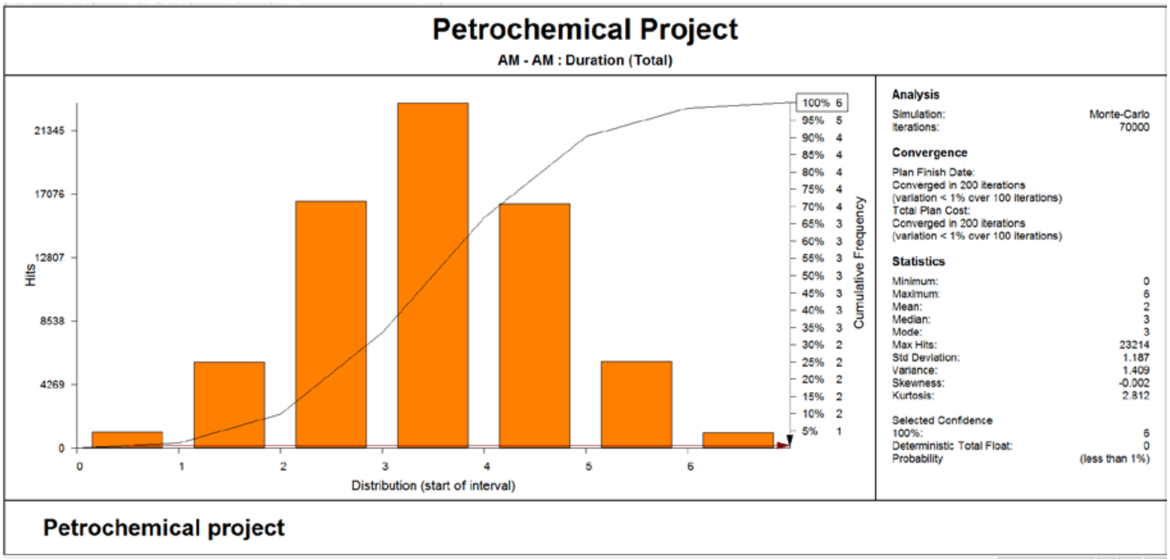

Fig. 2: time of final activity completion

Time of initiation and completion of each activity (node) and also floating time can be computed with the use of Monte-Carlo simulation. For example, results of initiation time and F activity floating, is shown in following figures.

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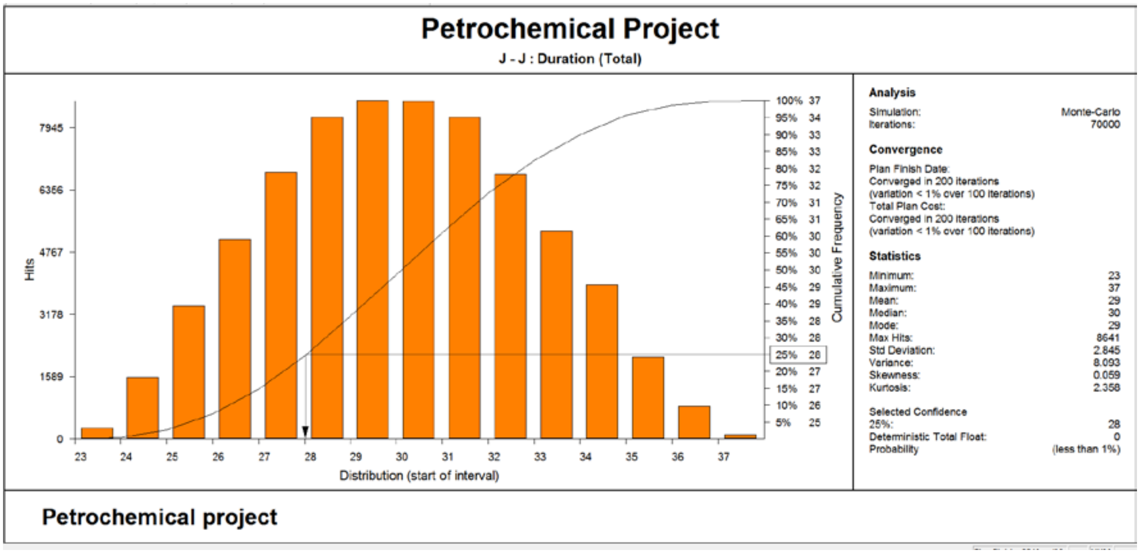


Fig. 3: diagram for F activity time in PertMaster software

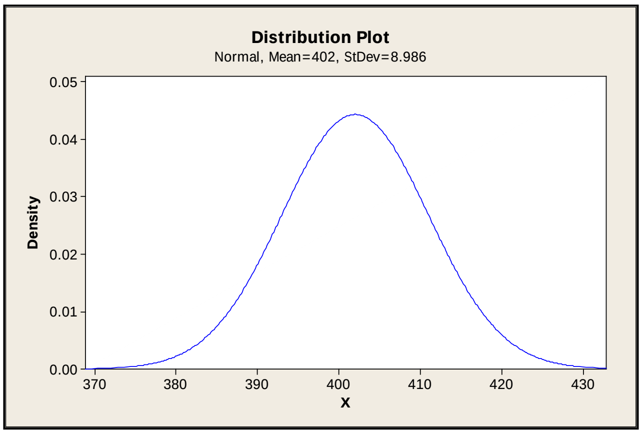
Examining criticality of paths and project activities in Monte-Carlo simulation method:

Table 2: criticality degree of non-deterministic paths

Critical Path		Criticality Index
1	A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-AC-AD-AE-AF-AG-AH-AI-AJ-AK-AL-AM	87.37%
2	A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-Y-Z-AA-AB	12.50%
3	A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-X-AC-AD-AE-AF-AG-AH-AI-AJ-AN	5.90%
4	Other paths	0

-probability of project completion within determined time:

Possibility of project completion within determined time which is calculated in previous methods, can be computed with this software. According to cumulative distribution diagram presented in figure (3), the possibility of project completion within 410 days, is 0.80.



Conclusions and suggestions:

The abovementioned methods are used for scheduling, determining project completion time and determining critical path that some of their results in order to comparison, are as follows:

CPM method:

-project completion time is 410 days

-the path A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-AC-AD-AE-AF-AG-AH-AI-AJ-AK-AL-AM is the only critical path.

Fuzzy critical path method:

-project completion time is equal to fuzzy number $(410\ ,56\ ,90)_{LR}$ days and real number 418.5.

-criticality probability of the path A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-AC-AD-AE-AF-AG-AH-AI-AJ-AK-AL-AM is equal to 90.01%.

And criticality probability of the path A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-Y-Z-AA-AB is equal to 10% and criticality probability of the path A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-X-AC-AD-AE-AF-AG-AH-AI-AJ-AN is equal to 6.28%. Criticality probabilities of the other paths are equal to zero.

- Probability of project completion in fuzzy time $\tilde{T}_{end} = (410{,}56{,}90)_{L-R}$ which is nearly 410 days, is equal to 37.2%.

Monte-Carlo simulation method:

-project completion time is equal to 402 days with standard deviation of 8.986.

-the path A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-AC-AD-AE-AF-AG-AH-AI-AJ-AK-AL-AM in 37.87% of events and the path A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-Y-Z-AA-AB in 12.50% of repetitions is critical and criticality probability of the path A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-X-AC-AD-AE-AF-AG-AH-AI-AJ-AN is equal to 8.28% and the path A-B-C-D-E-F-G-H-I-J-K-L-M-N-O-P-Q-S-T-U-W-X-X-AC-AD-AE-AF-AG-AH-AI-AJ-AN in 5.90% of repetitions is critical and other paths in none of repetitions are critical.

-in this method, probability of project completion in maximum 410 days is equal to 80%.

Considering what was said previously and considering the above cases, we can conclude as follows:

1-considering that the computed completion time is real and reasonable but by use of CPM method, this method cannot show critical path properly and always introduce one path as critical path.

2- Fuzzy method is more flexible in estimating times than PERT and CPM methods. Using this method would reach to its most efficient state when time and type of the selected time for activities are real and reasonable. This method has the ability to show critical paths and activities properly. Among disadvantages of this method we can mention its huge calculations which increase by enlarging network in which there is no software to do calculations for us.

3- Considering principles used in Monte-Carlo simulation method, typically completion time which is resulted by using this method is similar to the completion time gained by using PERT method. Main advantage of using this method comparing to PERT method or other conventional scheduling methods, is its ability to calculate criticality percent of each paths and activities and also presenting results for different decision-making parameters in the form of frequency diagrams which are easy to interpret.

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