ENGINEERING JOURNAL

Article

Proposing an Optimum Model for Time Estimation of Construction Projects in Iranian Gas Refineries

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Abstract. Time management can be effective in a project when the project schedule is based on comprehensive time scheduling. In the industries with complicated processes, many uncertainties and risks affect the timing of projects. Considering the very low reliability of the project planning in certainty-based approach, using more secure models for control and interact with uncertainty should be placed on the agenda. Iranian Gas Company has been using risk management to manage probable uncertainties in construction projects but in the field of possible uncertainties, actions are very scarce. This article aims to propose an optimum model based on the integrated risk management and fuzzy expert systems in order to provide comprehensive project time estimation and in this regard, reviews the results of the implementation of this model in construction projects of Iranian gas refineries. The results show that the proposed model increases the accuracy of time estimation about 8 to 24 percent.

Keywords: Time management, uncertainty, risk management, fuzzy expert systems.

ENGINEERING JOURNAL Volume 21 Issue 5
Received 13 January 2017
Accepted 28 March 2017
Published 29 September 2017
Online at http://www.engj.org/
DOI:10.4186/ej.2017.21.5.285

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1. Introduction

National Iranian Gas Company (NIGC) is one of the top ten gas companies in the gas industry in the Middle East and at present, it is comprised of 7 gas refineries. As the ongoing projects are directly or indirectly linked with continuous production in the gas refineries, the factors such as operational musts and site classification based on the HSE risks impose an unusual condition to project performance. There are two types of uncertainty that influence the project scheduling. The first type includes probable uncertainties and the second one covers possible uncertainties. Iranian gas refineries have been using risk techniques to manage probable uncertainties for many years but regard to non-probable uncertainties, actions are very scarce. This article aims to present a new model for managing uncertainties of construction project scheduling in gas refineries. So, as a preliminary step, there is a need to review some basic definitions and then the proposed model will be described.

2. Uncertainty Management in Construction Projects

Uncertainties that affect the project are based on the two theories: probability and possibility. These theories are analogous but they are different [1]. For example, consider protesting of rural residents against refinery road construction in a location close to them. For several reasons, the rural residents might (or might not) protest to stop the engineering work which reveals the likelihood of protest and its consequences. The impact of this uncertainty can be high if the protesters cut off the way to the site, and it could be very low if they accept the road construction. Thus, such types of uncertainties are probable because their impact and likelihood are due to probable uncertainty. In possibility theory, we do consider several possible outcomes at the same time and when a decision is made, it is built on the highest possibility event [2]. For example, assume that there is a need to establish an access to a new refinery that has no opponent. Therefore, the solution could be either enlarge the existing truck road, establish a new link with the highway, or transform the pathway into an access road or may be some other possible solutions; however, each possible solution has its own possibility which might be 100% each or 80%, etc, and this possibility is not affected anyway by the possibility of the other options.

3. Risk Management in Construction Projects

Risk management is the process of identification, analysis and acceptance or mitigation of probable uncertainties in project decisions [3]. A project manager has to identify as many uncertainties as possible in risk management process (Fig. 1).

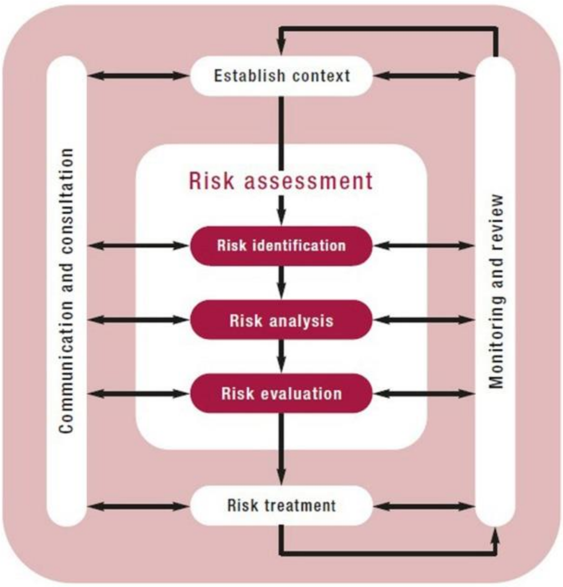


Fig. 1. Risk management process.

A risk may or may not happen. This inherently probable uncertainty cannot be eliminated, but it can be made little clearer by clarifying the probability of occurrence of the risk, to get a better understanding of the consequences and alternatives if the risk occurs and determine the factors that influence the magnitude and likelihood of occurrence of the particular risk. This means that an uncertainty can never be completely eliminated, but it can be reduced to a level the project find tolerable. The authors of this paper have reviewed the literature on construction risk management that has been published in ten selected top quality journals from 1983 to 2015, It has been found that risk research, as applied in construction management discipline in the past three decades, can be divided into six broad fields, encompassing: (1) Risk Identifications; (2) Risk Approaches; (3) Risk Methods; (4) Risk Measurements; (5) Risk Integrations and (6) Risk Improvements (Fig. 2).

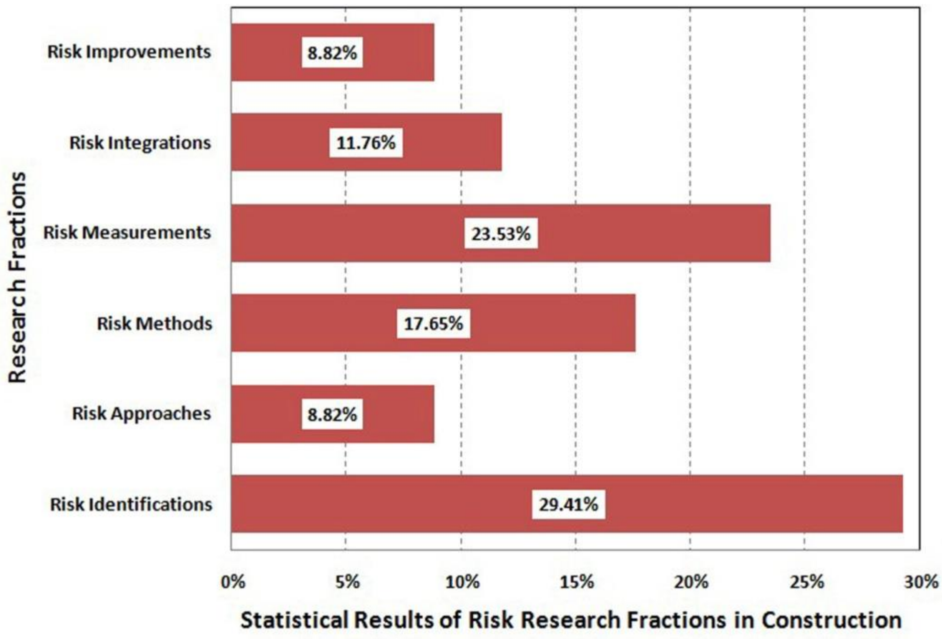


Fig. 2. Statistical results of risk research fractions in construction management.

4. Possible Uncertainty Management in Construction Projects

The old methods of project scheduling such as Critical Path Method (CPM) are still used commonly in many countries such as IRAN. But these methods are not successful in complicated projects [5]. The reason for this inefficiency is related to the inefficiency of old scheduling methods to manage project possible uncertainties. Sources of these uncertainties are wide ranging and have a fundamental effect on projects and project management. These sources are not confined to potential events and include lack of information, ambiguity, characteristics of project parties, tradeoffs between trust and control mechanisms, and varying agendas in different stages of the project lifecycle. It is Because of the high complexity in modeling and analysis of possible uncertainties in construction projects, artificial intelligence based methods and expert systems are utilized [6]. In this case, generally, two methods are recommended including Artificial Neural Network (ANN) and Fuzzy Logic. In neural networks, possible uncertainties could be eliminated by learning the ability of system [7]. While in the model needed to manage possible uncertainty, these uncertainties will always exist in the project and will remain up to the last stages. Thus, because of the high level of complexity and possible uncertainty associated with construction projects, the fuzzy expert systems are efficient. For example, consider the fuzzy project network indicated in Fig. 3. This project network illustrating an installation and commissioning of the Nitrogen package in one of the famous refineries located in South of Iran. The project time was estimated at 56 days in certainty-based approach.

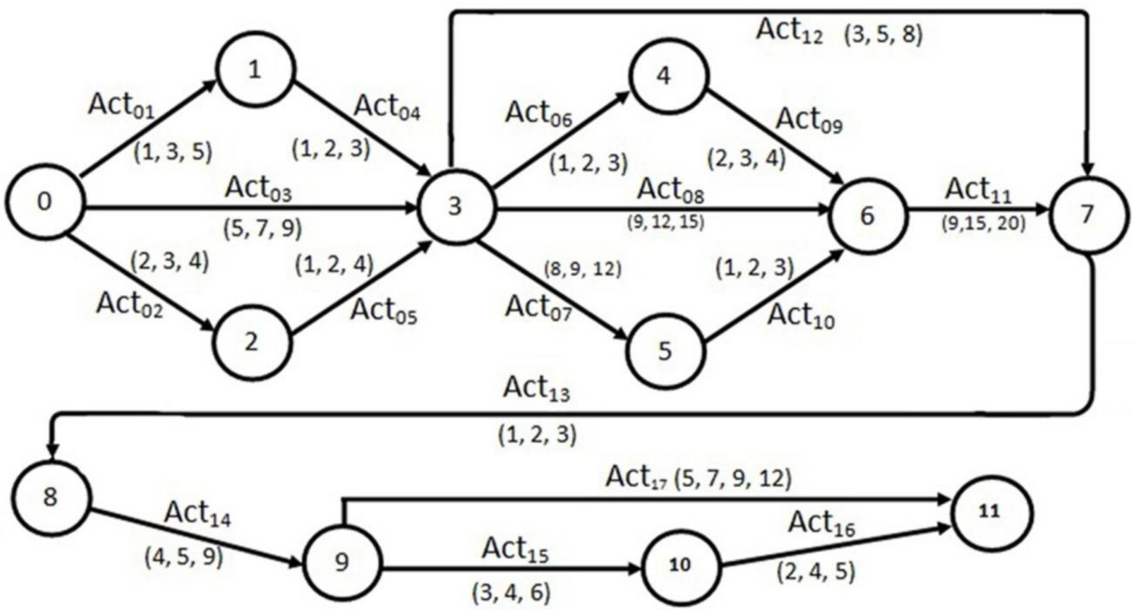


Fig. 3. CPM of the nitrogen package project by fuzzy approach.

The description of all activities regarding the mentioned project by Fuzzy approach is presented in Table 1 and a pictorial view of the project is shown in Fig. 4. In order to determine the project time by the fuzzy approach, it is necessary to rank the fuzzy numbers in scheduling network calculation and select the maximum. Since fuzzy numbers do not form a natural linear order (similar to real numbers) a key issue in applications of fuzzy set theory is how to compare fuzzy numbers. Various approaches have been developed for ranking fuzzy numbers up to now which are used according to the nature of the project. For calculation of this project time network, five ranking methods were considered [8-12].

Table 1. Nitrogen Package Project activities information.

Activity ID	Activity Description	Activity Time (days)
0 - 1	Sending Samples to Laboratory	(1, 3, 5)
0 - 2	Valves Procurement	(2, 3, 4)
0 - 3	Site preparation	(5, 7, 9)
1 - 3	Material Confirmation	(1, 2, 3)
2 - 3	Valve Confirmation	(1, 2, 4)
3 - 7	Valve Installation	(3, 5, 8)
3 - 4	Evaporator Procurement	(1, 2, 3)
3 - 5	Built-in Pipe Supports	(8, 9, 12)
3 - 6	Built and Installation of Structures	(9, 12, 15)
4 - 6	Evaporator Installation	(2, 3, 4)
5 - 6	Installation of Pipe Supports	(1, 2, 3)
6 - 7	Piping Installation	(9, 15, 20)
7 - 8	Pre-commissioning Test	(1, 2, 3)
8 - 9	Insulating	(4, 5, 9)
9 - 10	Painting	(3, 4, 6)
10 - 11	Cleaning of the Site	(2, 4, 5)
9 - 11	Commissioning	(5, 7, 9,12)

Fig. 4. Pictorial view of the Nitrogen Package Project.

As it could be seen from Table 1, 16 out of whole 17 activity times have triangular fuzzy type format and only the remaining one is in trapezoidal form. Equations 1 to 12 represent the stages of FCPM calculations of the project network. The calculations indicate that the project total time is the maximum of three fuzzy numbers (Eq. 12). Consequently, in order to determine the project time, it is necessary to rank the fuzzy numbers and select the maximum.

$$FES0 = (0,0,0) \quad (1)$$

$$FES1 = (0,0,0) + (1,3,5) = (1,3,5) \quad (2)$$

$$FES2 = (0,0,0) + (2,3,4) = (2,3,4) \quad (3)$$

$$FES3 = Max\ ((1,3,5)+(1,2,3), (2,3,4)+(1,2,4), (5,7,9)) = (5,7,9) \quad (4)$$

$$FES4 = (5,7,9) + (1,2,3) = (6,9,12) \quad (5)$$

$$FES5 = (5,7,9) + (8,9,12) = (13,16,21) \quad (6)$$

$$FES6 = Max\ ((6,9,12)+(2,3,4), (5,7,9)+(9,12,15), (13,16,21)+(1,2,3)) = (14,19,24) \quad (7)$$

$$FES7 = Max\ ((14,19,24)+(9,15,20), (5,7,9)+(3,5,8)) = (23,34,44) \quad (8)$$

$$FES8 = (23,34,44) + (1,2,3) = (24,36,47) \quad (9)$$

$$FES9 = (24,36,47) + (4,5,9) = (28,41,56) \quad (10)$$

$$FES10 = (28,41,56) + (3,4,6) = (31,45,62) \quad (11)$$

$$FES11 = Max\ ((31,45,62)+(2,4,5), (28,41,56)+(5, 7, 9,12)) \quad (12)$$

Selected methods for ranking fuzzy numbers in CPM calculation have proposed by: (1) Choobineh & Li [8]; (2) Yager [9]; (3) Cheng [10]; (4) Chen & Sanguansat [11]; and (5) Abbasbandy & Hajjari [12]. Table 4, shows the results of this ranking and Fig. 2 compares the results in bar charts. Also, the project total time and critical path for each method are indicated in Table 2 and Fig. 5.

Table 2. Results of fuzzy ranking by 5 different methods.

Fuzzy Ranking Method	Project Critical Path	Total Time (days)
Choobineh & Li	0-3-5-7-8-9-10-11	49.9
Yager	0-3-5-7-8-9-10-11	43.66
Cheng	0-3-5-7-8-9-11	53.86
Chen & Sanguansat	0-3-5-7-8-9-10-11	46.91
Abbasbandy & Hajjari	0-3-5-7-8-9-10-11	47.96

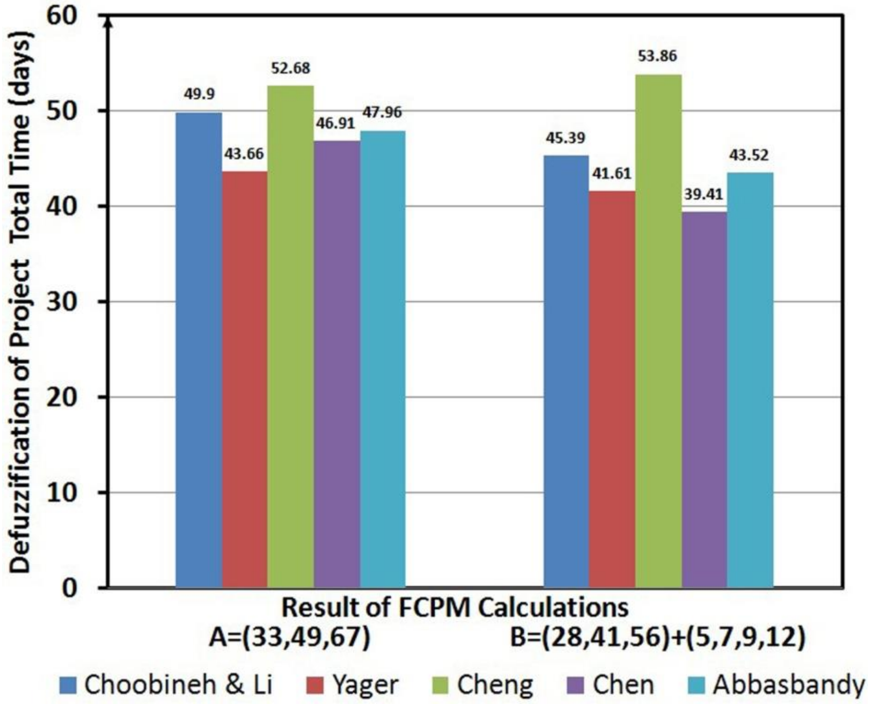


Fig. 5. Results of project time calculation by various fuzzy ranking methods.

5. Literature Review on Fuzzy Critical Path Method

Several methods have been proposed for finding the fuzzy critical path over the past years. The main common topic in all of these methods is converting the classic time of project activities to fuzzy numbers for schedule calculation. For the reason that CPM calculation needs to compare the time of activities to determining critical path, a ranking of fuzzy numbers is necessary. So fuzzy numbers ranking is the most important factor in these methods.

For the first time, Chanas and Kamburowski [13] introduced the preliminary concept of FCPM in 1981. They presented the time of project activities by fuzzy set in the time space. Their method provides more direct processing verbally expressed opinions of experts. The significant problem not quite solved in their method was the question of deriving membership functions for activity duration times.

Gazdik [14] used algebraic operators to estimate the time of project activities and project critical path in 1983. Kaufman and Gupta [15] proposed the critical path method in which activity times was represented by fuzzy numbers in 1988. kaufman was one of the great fuzzy logic researchers. He and Aluja had reviewed many types of research about fuzzy logic before. After passing away of Kaufmann, Aluja published the result of their researches [16].

Mc Cahon and Lee [17] presented a new methodology to calculate the fuzzy completion time in 1988. Nasution [18] proposed how to compute total floats and find critical paths in a project network by the fuzzy approach in 1994. Also, Chang et al. [19] presented a methodology to calculate the fuzzy completion project time in 1995 and Lorterapong and Moselhi [20] proposed an extension of fuzzy schedule networks in 1996. Yao and Lin [21] proposed a method for ranking fuzzy numbers without the need for any assumptions and have used both positive and negative values to define ordering which then is applied to CPM in 2000.

Chanas and Zielinski [22] presented an approach to the critical concept in a network with fuzzy activity times in 2001. Their approach was devoid of faults which were characteristic for the definitions of fuzzy criticality proposed till 2001 and also Kuchta presented another method to determine fuzzy critical paths and critical activities in this year.

Blue et al. [23] presented a taxonomy of fuzzy graphs that treated fuzziness in vertex existence, edge connectivity and edge weight in 2002. Within that framework, they formulated some standard graph-theoretic problems (shortest paths and minimum cut) for fuzzy graphs using a unified approach distinguished by its uniform application of guiding principles such as the construction of membership grades via the ranking of fuzzy numbers, the preservation of membership grade normalization, and the collapsing of fuzzy sets of graphs into fuzzy graphs and Finally as a result of their research they provided an algorithm solution for fuzzy critical path method.

Yao [24] presented a new approach to implementing a fuzzy CPM for activity networks based on statistical confidence interval estimates and a ranking method for level $(1-\alpha)$ fuzzy numbers in 2003. The focus of his study was to introduce an approach that combined fuzzy mathematics with statistics that includes the signed-distance ranking of level $(1-\alpha)$ fuzzy numbers, derived from $(1-\alpha)\times 100\%$ confidence-interval estimates. Dubios et al [25] extended the fuzzy arithmetic operational model to compute the latest starting time of each activity in project's network in 2003. Liang and Han [26] presented an algorithm to perform fuzzy critical path analysis for project network problem in 2004.

Oliveros and Robinson [27] presented another method to calculate fuzzy critical paths and critical activities and activity delays in 2005 and also Zielinski [28] extended some results for interval numbers to the fuzzy case for determining the possibility distributions to describe latest starting time of activities in 2006. Also, Han et al [29] used fuzzy critical path method to optimize the airport's cargo ground operation systems in this year. They used this method to tackle the problem in fuzzy airport's ground operation decision makers.

Chen [30] proposed an approach based on the extension principle and linear programming (LP) formulation to critical path analysis in networks with fuzzy activity durations in 2007. Also, Chen and Hsueh [31] presented another simple approach to solving the CPM problems in 2008. They used fuzzy activity times according to linear programming formulation and fuzzy number ordering (ranking) method that was more realistic than crisp one which solved by using the conventional streamlined LP solution approaches. Their obtained fuzzy critical path was assured to be the most critical one from the viewpoint of Yager.

Yakhchali and Ghodsypour [32] introduced the problems of determining possible values of earliest and latest starting times of an activity in networks with minimal time lags and imprecise durations that are represented by means of the interval of fuzzy numbers in 2010. Also, Kumar and Kaur [33] proposed a new method for fuzzy critical analysis in project networks with a new representation of triangular fuzzy numbers in this year. Sathish and Ganesan [34] proposed a new approach based on fuzzy critical path calculation in 2012. They used fuzzy arithmetic and the fuzzy ranking method to determine the fuzzy critical path of the project network without converting the fuzzy activity times to classical numbers and compared their method with other methods.

Rao and Ravi Shankar [35] proposed a new method of fuzzy critical path analysis based on the centroid of centroids of fuzzy numbers in 2013. In their method, durations of activities were considered to be positive trapezoidal fuzzy numbers and a new subtraction operation was proposed to find the fuzzy latest times in the project network. In Continues, Morovatdar et al [36] proposed a new algorithm in this year. Their algorithm instead of asserting a path as critical or non-critical, calculated critically degrees of all project paths along with all project activities. Unlike the existing algorithms up to that year, their proposed algorithm first distinguishes all possibly critical paths of the project and then assigns critically degrees to them determine total project time.

Elizabeth and Sujatha [37] proposed few indices and developed the new algorithms based on them to identify the critical path in a fuzzy environment of project network in 2015. Finally, Kazemi et al. [38] proposed a new method for solving CPM problems by using the expected duration optimization model and the mean-variance model with Liu's definition for random fuzzy variables in 2016. Table 6 summarizes the main historical developments of FCPM ranking from 1981 to 2016.

DOI:10.4186/ej.2017.21.5.285

Table 3. The Main historical developments and applications of Fuzzy CPM from 1981 to 2016.

Researchers/Year	Approach of Proposed Method/Events
Chanas & Kamburowski, 1981)[13]	Presenting the time of project activities in the form of fuzzy set in the time space.
(Gazdik, 1983)[14]	Using algebraic operators to estimate the time of project activities.
Kaufman & Gupta (1988)[15]	Proposing the CPM in which activity times was represented by fuzzy numbers.
(McCahon & Lee, 1988)[16]	Presenting a new methodology to calculate the fuzzy completion time.
(Nasution, 1994) [17]	Proposed how to compute total floats and find critical paths in a project network.
(Chang et al.,1995)[18]	Presenting a methodology to calculate the fuzzy completion project time.
(Loterapong & Moslehi, 1996) [19]	An extension of fuzzy schedule networks proposed.
(Yao & Lin, 2000) [20]	Proposing a new method for ranking fuzzy numbers in CPM calculation.
(Chanas & Zielinski, 2001) [21]	Presenting the critical concept in a network with fuzzy activity times.
(Kuchta, 2001) [22]	Presenting another method to obtain fuzzy critical paths and critical activities.
(Blue et al., 2002) [23]	Providing an algorithm solution for fuzzy critical path method.
(Yao & Lin, 2003) [24]	Presenting a new approach based on statistical confidence interval estimates and a ranking method for level (1-α) fuzzy numbers. The focus of his study was to introduce an approach that combined fuzzy mathematics with statistics that includes the signed-distance ranking of level $(1-\alpha)$ fuzzy numbers, derived from $(1-\alpha) \times 100\%$ confidence interval estimates.
(Dubios et al., 2003)[25]	Extending the fuzzy arithmetic operational model to compute the latest starting time of each activity in a project network.
(Liang & Han, 2004)[26]	presenting an algorithm to perform fuzzy critical path analysis for project network
(Oliveros & Robinson, 2005)[27]	Calculation of fuzzy critical paths and critical activities and activity delays.
Zielinski (2005)[28]	Extending some results for interval numbers to the fuzzy case for determining the possibility distributions describing latest starting time for activities.
(Han et al., 2006)[29]	Using Fuzzy critical path method to optimize the airport's cargo ground operation systems.
(Chen et al., 2007)[30]	Proposing a new approach based on the extension of linear programming (LP).
(chen, 2009)[31]	Analyzing fuzzy risk based on ranking generalized fuzzy numbers.
(Yakhchali & Ghodsypour, 2010) [32]	Introducing the problems of determining possible values of earliest and latest starting times of a project activity by means of the interval of fuzzy numbers.
(Kumar & Kaur, 2010) [33]	Proposing a new method with a new representation of triangular fuzzy numbers.
(sathish & Ganessan, 2012)[34]	Proposing a new approach based on fuzzy critical path calculation.
(Rao & Ravi Shankar, 2013) [35]	Proposing another method based on the centroid of centroids of fuzzy numbers.
(Morovatdar et al., 2013)[36]	Proposing an algorithm that first distinguished all possibly critical paths and then assigned critically degrees to them to determine total project time.
(Elizabet & Sujatha, 2015)[37]	Proposing few indices to identify the critical path in fuzzy environment.
(Kazemi et al. , 2016)[38]	Proposing a new method for solving CPM problems by using the expected duration optimization model and the mean-variance model with Liu's definition for random fuzzy variables.

6. Proposed Model for Managing Project Uncertainties

As described in the previous sections, both types of project uncertainties should be considered in a comprehensive project scheduling. Consequently, the present study proposes a new model based on possible and probable uncertainty management for achieving this purpose. Figure 6 indicates the diagram of the proposed model.

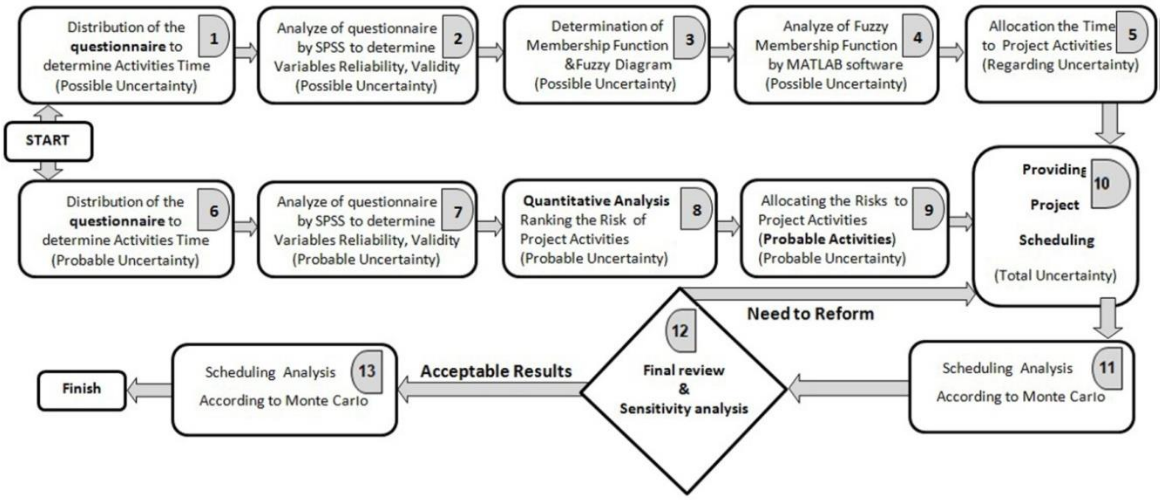


Fig. 6. Diagram of the proposed model.

For implementing the models, at first, two professional questionnaires were distributed between more than 200 experts of a professional team which was selected by the staff of 70 contractors, consultant, and employee companies. The first questionnaire was designed to identify effective factors such as site organization, weather, labor skills and quality of equipment on doing project activities. Then obtained Linguistic variables were translated into mathematical measures. For instance, the questionnaire designed for concreting activity is presented in Table 4. As it can be seen in Table 4, the value of the Linguistic variables is classified into 5 types (Fig. 7).

Table 4. Questionnaire of Fuzzy Expert System Model for concreting activity.

Please determine the effect of each factor in the time of Activity concreting.
S01- Concrete Providing Method (Beaching Plant, Concrete Machine, …) Very Poor ☐ Poor ☐ Medium ☐ High ☐ Very High ☐
S02- Co-Ownership of Project Supervisions for issuance of Work Permit Very Poor ☐ Poor ☐ Medium ☐ High ☐ Very High ☐
S03- Co-Ownership of Concrete Laboratory for Sampling Very Poor ☐ Poor ☐ Medium ☐ High ☐ Very High ☐
S04- Climatic Condition (Very Cold, Cold, Moderate. Warm, Very Warm) Very Poor ☐ Poor ☐ Medium ☐ High ☐ Very High ☐
S05- HSE (Health-Safety-Environments) Criteria Very Poor ☐ Poor ☐ Medium ☐ High ☐ Very High ☐
S06- The Geometry of the Structure (Simple, Complicated, …) Very Poor ☐ Poor ☐ Medium ☐ High ☐ Very High ☐
S07- Type of Cement Used in Concrete (Cement Type 3, Cement Type 5, …) Very Poor ☐ Poor ☐ Medium ☐ High ☐ Very High ☐

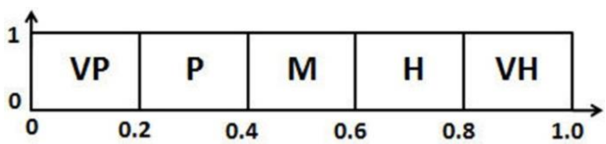


Fig. 7. Categorization of membership functions.

As in Table 5, a large number of factors are considered to estimate the time of concreting activity. To examine the reliability of the questionnaire, data analysis was done by SPSS. According to SPPS analysis, the Cronbach's alpha (Reliability Index) was 0.388, while it should be greater than 0.7.

Table 5. Results of reliability index calculated by SPSS.

Factor Code	Factor Description	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Total Correlation
S01	Concrete Providing Method	13.00	7.926	0.613
S02	Co-Ownership of Project Supervisions	14.14	12.423	- 0.200
S03	Co-Ownership of Concrete Laboratory	14.61	11.507	0.114
S04	Climatic Condition	12.29	7.545	0.798
S05	HSE Criteria	12.68	10.078	0.242
S06	The Geometry of the Structure	14.29	12.063	- 0.105
S07	Type of Cement Used in Concrete	14.14	8.868	0.186

The results show that factors 2, 3, 6 and 7 do not have an effective influence on the timing of concreting activity. So these factors were eliminated and calculations were repeated. In the new analysis, the index rose up to 0.854 which is desirable. So the main factors of concreting activity are concrete providing method, climatic conditions, and HSE criteria. In the next step, the second questionnaire which relates to estimating activity durations was distributed among team members. After summing up the results of the first and second questionnaires, obtained results were examined by an expert team that composed of 8 expert project managers (With more than 25 years of experience) to determine its content validity. Then, according to satisfactory results, the structural validity of survey questionnaires was evaluated by Factor Analysis method. According to the KMO index, the acceptable construct validity of research was approved. The results of the analysis are summarized in Table 6.

Table 6. The results of factor analysis method (KMO and Bartlett's Test).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		**0.635**
Bartlett's Test of Sphericity	Approx. Chi-Square	49.534
	df	3
	Sig.	0.000

Also, the results of the total variance of analysis explained that these three factors are not reducible to the number of agent-less (Table 7). According to the results obtained from computing of the Pearson Correlation coefficient, the correlation between these factors is also desirable. Table 8 indicates related results.

Table 7. The results of total variance of analysis.

Component	Total Variance Explained		
	Total	% of Variance	Cumulative %
1	1.335	38.14	38.14
2	1.058	30.23	68.37
3	1.107	31.63	100

Table 8. The results of correlation between concreting activity's efficient factors.

Correlation Results		S01	S04	S05
S01	Pearson Correlation	1	0.89	0.57
	Sig. (2-tailed)		0.000	0.001
S04	Pearson Correlation	0.89	1	0.52
	Sig. (2-tailed)	0.000		0.005
S05	Pearson Correlation	0.57	0.52	1
	Sig. (2-tailed)	0.001	0.005	

In Later stages of the proposed model, membership functions of these factors were drawn according to the second questionnaire. The second questionnaire is in regard to a time estimation of the experiences of the professional team. In this research, Fuzzy diagrams were of triangular and trapezoidal types. In the present example, Figures 8 to 10 indicate the fuzzy membership functions of concreting activity factors.

These diagrams are considered as the input of analysis.

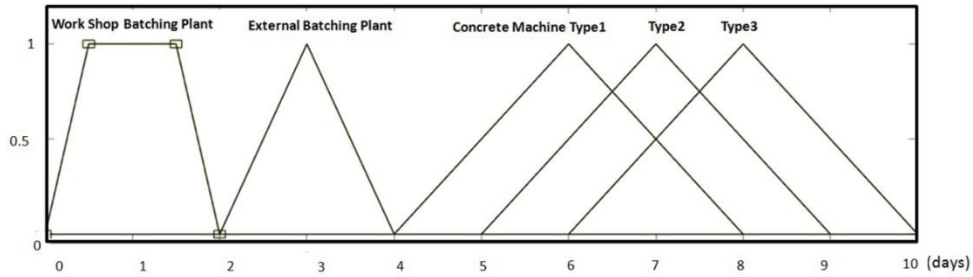


Fig. 8. Fuzzy Membership Function of Concrete Providing Method Factor.

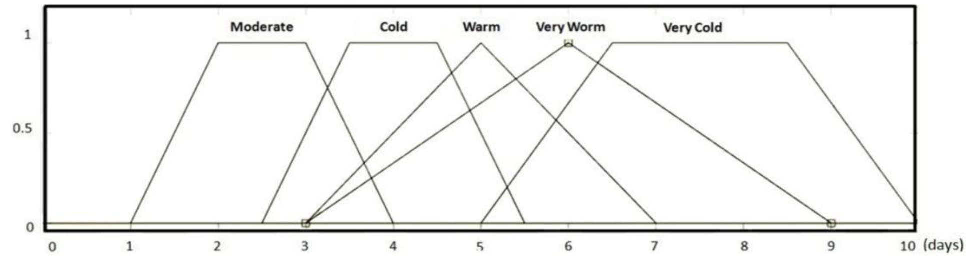


Fig. 9. Fuzzy Membership Function of Climatic Conditions Factor.

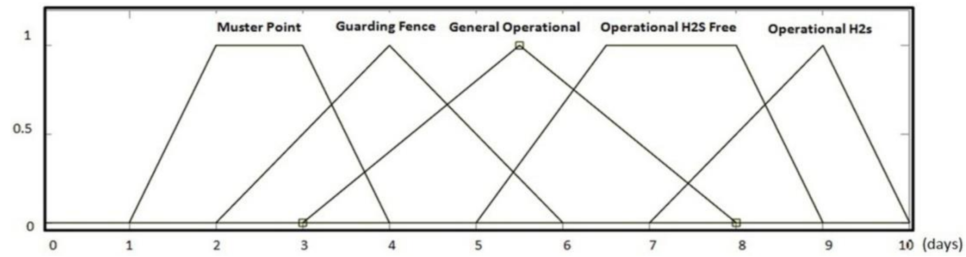


Fig. 10. Fuzzy Membership Function of HSE Criteria Factor.

Then, the results of the previous step were analyzed in Fuzzy Toolbox of MATLAB. This toolbox follows a Rule Base System. Analysis of model is presented in Fig. 11. As it could be seen in this figure, inputs are processed by a smart and rule base system.

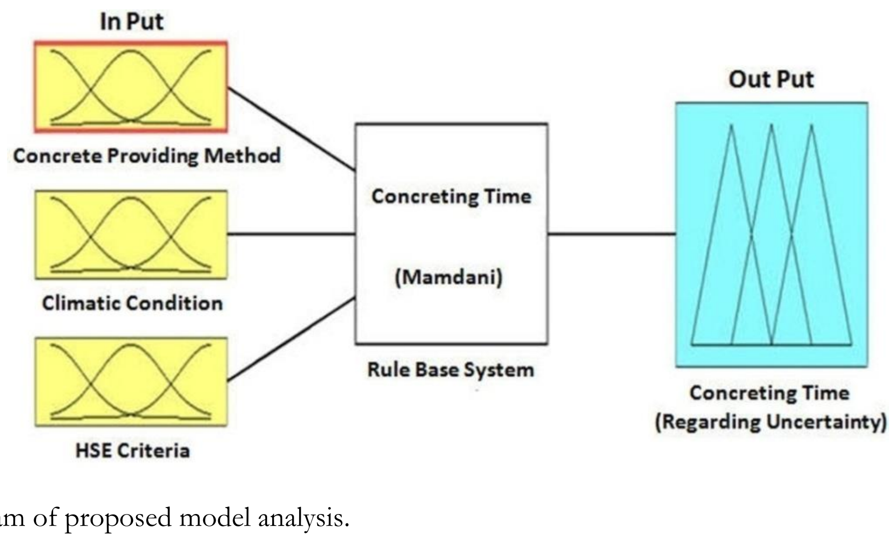


Fig. 11. Diagram of proposed model analysis.

DOI:10.4186/ej.2017.21.5.285

"IF … Then …" rules were set by the expert team in Rule Base system. For example, for these 3 factors, 125 operating modes may occur. Three states of these rules are observed in Table 9.

Table 9. An example of Rules that are used in the Rule Base system.

Rule No	The Rule
Rule 1	If concrete providing method is Batching plant and climatic conditions moderate and HSE zone is muster point then the time of concreting is very short.
Rule 2	If concrete providing method is concrete machine type 1 and the climatic condition is cold and HSE zone is with H2S penetration then the time of concreting is very long.
Rule 3	If concrete providing method is out of site Batching and the climatic condition is warm and HSE zone is muster point then the time of concreting is very short.

After analysis, the duration of activities under uncertainty and fuzzy approach can be achieved. For example, this time for the above-mentioned activity (concreting) will be 8.5 days for each 200 cubic meters of concrete (Fig. 12).

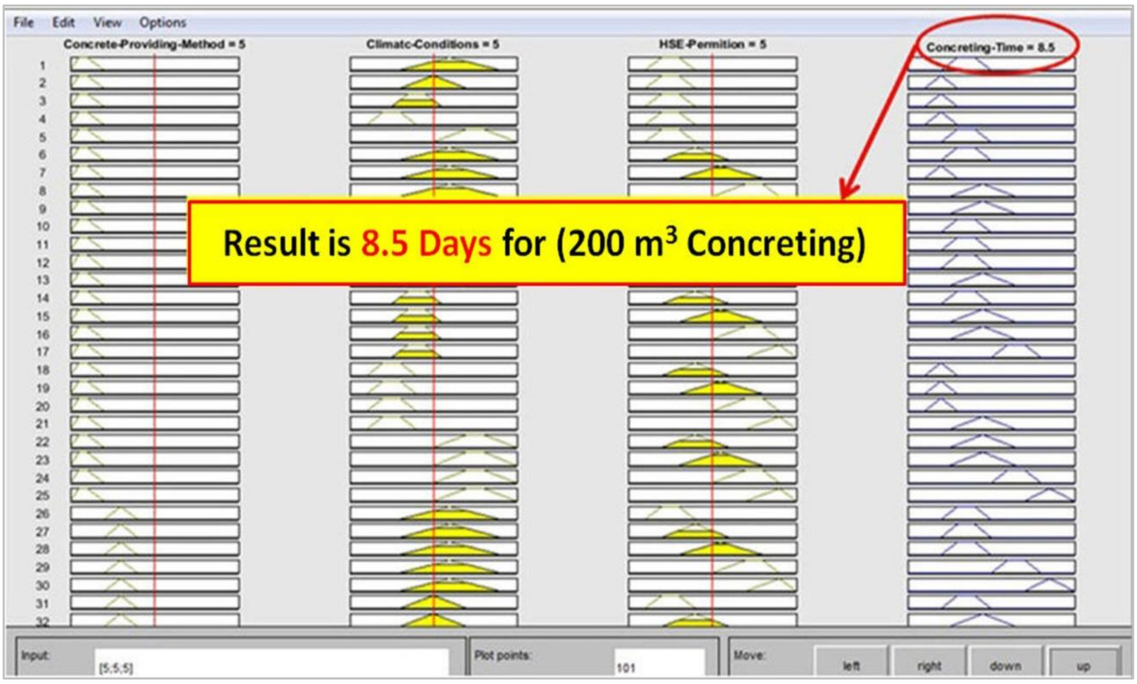


Fig. 12. Pictorial view of analysis output.

After calculating the time of all activities according to this method, project schedule was designed under possible uncertainty. So in the next stage, in order to regard probable uncertainty, we need to add project risks to designed project schedule. The probable uncertainty in the model could be considered by two methods. The first method recognizes the risks in terms of completed questionnaires and would handle other stages of project risk management based on the obtained results. In the second method, the results of previous studies through similar statistical data derived from similar projects would be utilized. Since the application of risk management in gas refineries goes back to many years ago, the second method is a high priority. Thus, this study attempts to review the literature of risk management in construction projects of Iranian gas refineries which have been completed from 2010 to 2016 (Table. 10) [39-48]. These studies were classified as a database of construction project risks in gas refineries (Table. 11). In the following stages, expert team allocates the selected risks to each activity of project as a probable activity.

Table 10. The main historical researchers of risk management in Iranian gas refineries from 2010 to 2016.

Researchers/Year	Approach of Research
(Jalaee & Mahdaviparsa, 2010) [39]	They studied risk management in Iranian construction projects such as gas refineries as a survey study.
(Soltani et al., 2011) [40]	They reviewed the risks of projects in Shiraz refinery by FMEA method.
(Hamzei & Alamtabriz, 2012) [41]	They proposed a new hybrid method for project risk assessment in construction projects. Also, they reviewed the risks in refinery projects.
(Moharramnejad & Amanatyazdi, 2013) [42]	They reviewed risk management in Iranian oil and gas Companies.
(Bordbar et al., 2013) [43]	They reviewed the Identification and allocation of risks in construction projects of Sarkhoon & Gheshm gas refinery.
(Ardeshir et al., 2014) [44]	They reviewed Safety Assessment in refinery and other construction projects based on Analytic Hierarchy Process.
(Doosti et al., 2014) [45]	They reviewed the risk management in the construction of gas refineries.
(Najafi et al., 2015) [47]	They reviewed risk quantification in complex and fast projects.
(Ghasemi et al., 2015) [48]	They presented a new method for scrutiny the Insurable Risk in Iranian gas refineries by FMEA.

Table 11. Sample database of construction project risk index (RPN) in gas refineries.

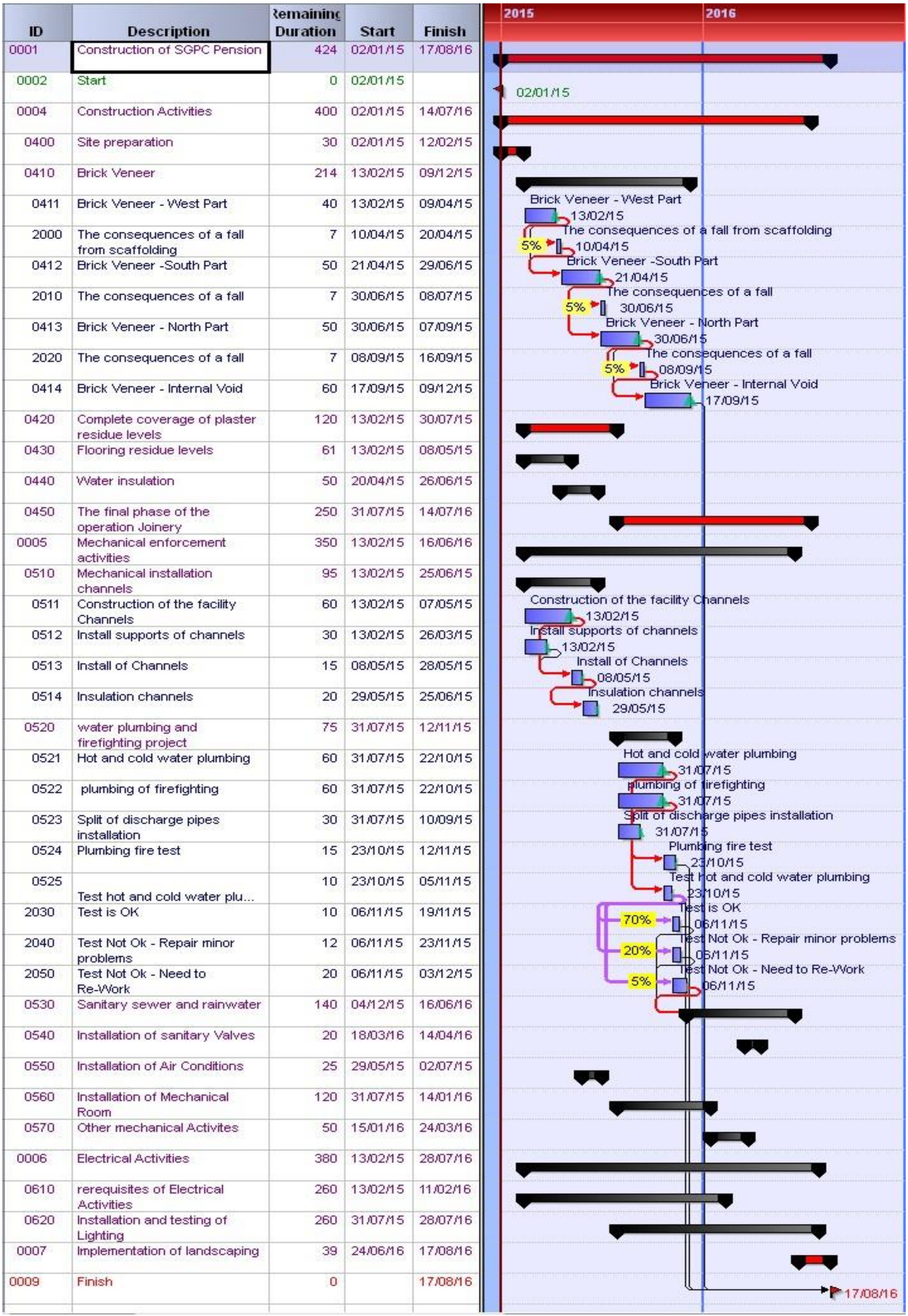
No	Risk Description	RPN	No	Risk Description	RPN
1	Falling from Crane	600	11	Political and economic sanctions	280
2	Falling from scaffolding	570	12	Fluctuations in steel prices & rebar	252
3	Falling from Structure	565	13	Price eccentric of contractors	216
4	Falling from Openings	524	14	Lack of necessary infrastructure	210
5	Work injury due to Falling objects	424	15	Fluctuations in the price of cement	150
6	Damage due to Excavation	392	16	Welding - damage to the eyes	120
7	Fire - Refinery Equipment Damage	390	17	Fire - damage to persons	120
8	burns from an electric shock	383	18	Clash with underground pipes	120
9	Explosion	373	19	Work injury due to Cutting	105
10	Toxicity of chemical spill	288	20	Damage caused by animals /insects	96

Also, there are two procedures for allocating risks to project activities in the proposed model of the present study. The first procedure is allocating the risks to each activity as a probable activity and second is allocating probable branches to the intended activities. For example, in a brick veneer activity, the risk of "consequences of fall from the height" with a probability of 5% is allocated to risk management (Fig. 13).

Also, Risks can be allocated to activities as probable branches. For example, in "plumbing hot and cold water" activity, three probable branches are considered. These branches are: (1) "test is ok" with the probability of 70%; (2) "Minor problem that could be repaired by technicians" with the probability of 20%; (3) "A major problem that need to Re-Work" with the probability of 5% (Fig. 13).

In the final stage of the proposed model, project schedule will be designed based on managing both types of uncertainties. Figure 13 shows a sampling project schedule that designed according to the proposed model of this research that belongs to a sample project whit the title of SGPC Pardis staff pension construction project. Then the provided schedule is analyzed on the basis of Monte Carlo method. This analysis was done by the Risk Analysis software. Primavera Risk Analysis is a full lifecycle risk analytics solution that provides a comprehensive means of determining confidence levels for project success with quick and easy techniques for determining contingency and risk response plans. If the project schedule has a confidence level of 95 percent, it will be accepted; otherwise, it should be rechecked to experience possible modifications. Figure 14 presents the obtained results of proposed model in SGPC Pardis staff pension project. In this figure, high risks and low risks are shown by red and green colors respectively.

DOI:10.4186/ej.2017.21.5.285



ID	Description	Remaining Duration	Start	Finish
0001	Construction of SGPC Pension	424	02/01/15	17/08/16
0002	Start	0	02/01/15	
0004	Construction Activities	400	02/01/15	14/07/16
0400	Site preparation	30	02/01/15	12/02/15
0410	Brick Veneer	214	13/02/15	09/12/15
0411	Brick Veneer - West Part	40	13/02/15	09/04/15
2000	The consequences of a fall from scaffolding	7	10/04/15	20/04/15
0412	Brick Veneer -South Part	50	21/04/15	29/06/15
2010	The consequences of a fall	7	30/06/15	08/07/15
0413	Brick Veneer - North Part	50	30/06/15	07/09/15
2020	The consequences of a fall	7	08/09/15	16/09/15
0414	Brick Veneer - Internal Void	60	17/09/15	09/12/15
0420	Complete coverage of plaster residue levels	120	13/02/15	30/07/15
0430	Flooring residue levels	61	13/02/15	08/05/15
0440	Water insulation	50	20/04/15	26/06/15
0450	The final phase of the operation Joinery	250	31/07/15	14/07/16
0005	Mechanical enforcement activities	350	13/02/15	16/06/16
0510	Mechanical installation channels	95	13/02/15	25/06/15
0511	Construction of the facility Channels	60	13/02/15	07/05/15
0512	Install supports of channels	30	13/02/15	26/03/15
0513	Install of Channels	15	08/05/15	28/05/15
0514	Insulation channels	20	29/05/15	25/06/15
0520	water plumbing and firefighting project	75	31/07/15	12/11/15
0521	Hot and cold water plumbing	60	31/07/15	22/10/15
0522	plumbing of firefighting	60	31/07/15	22/10/15
0523	Split of discharge pipes installation	30	31/07/15	10/09/15
0524	Plumbing fire test	15	23/10/15	12/11/15
0525	Test hot and cold water plu...	10	23/10/15	05/11/15
2030	Test is OK	10	06/11/15	19/11/15
2040	Test Not Ok - Repair minor problems	12	06/11/15	23/11/15
2050	Test Not Ok - Need to Re-Work	20	06/11/15	03/12/15
0530	Sanitary sewer and rainwater	140	04/12/15	16/06/16
0540	Installation of sanitary Valves	20	18/03/16	14/04/16
0550	Installation of Air Conditions	25	29/05/15	02/07/15
0560	Installation of Mechanical Room	120	31/07/15	14/01/16
0570	Other mechanical Activites	50	15/01/16	24/03/16
0006	Electrical Activities	380	13/02/15	28/07/16
0610	rerequisites of Electrical Activities	260	13/02/15	11/02/16
0620	Installation and testing of Lighting	260	31/07/15	28/07/16
0007	Implementation of landscaping	39	24/06/16	17/08/16
0009	Finish	0		17/08/16

Fig. 13. Sampling project schedule that designed according to the proposed model of this research.

DOI:10.4186/ej.2017.21.5.285

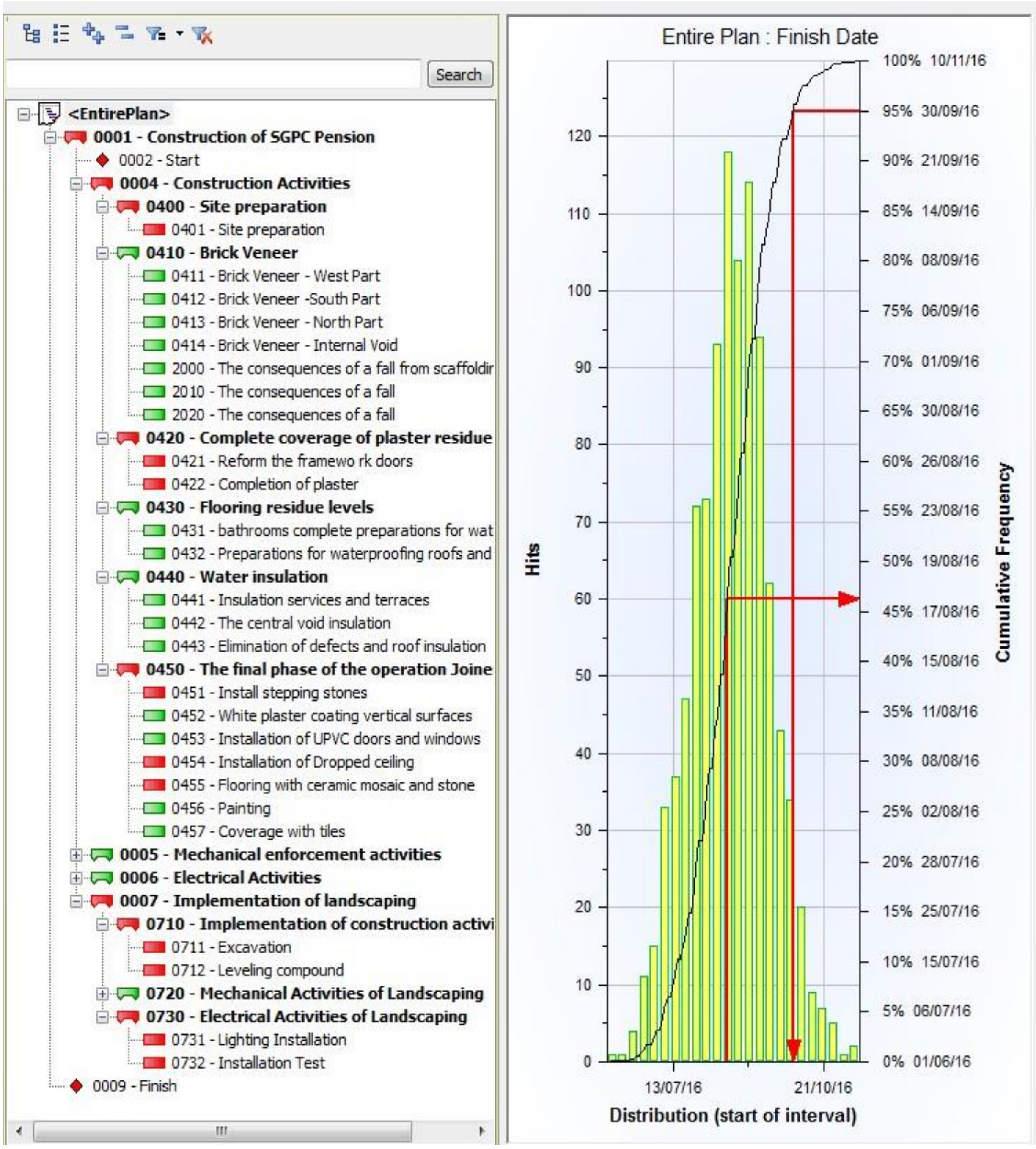


Fig. 14. A sample of results obtained from the proposed model analysis.

7. Results of Proposed Model Implementation

The proposed model of the research has been implemented in one gas refinery in the North East of Iran. This gas refinery provides cooking and industrial gas for 5 provinces in the north and east of Iran, including Khorassan, Semnan and, parts of Golestan. The study period was between 2014 and 2016 and the sampling of this study was composed of 30 projects based on Cochran formula [49]. Figure 15 shows the pictorial view of some of these sampling projects and Table 12 mentioned the title of the project that used in research studies.

DOI:10.4186/ej.2017.21.5.285

Construction of Oily Water Separator unit

Construction of refinery sewage

Installation of the seventh boiler of refinery

Construction of HSE building

Construction of Loading HC-Condensate Area

Construction of OWS transmission pipelines

Construction of new senior operator room

Construction of SGPC Pardis pension

Fig. 15. Pictorial view of some of the sampling projects.

DOI:10.4186/ej.2017.21.5.285

Table 12. The title of project that used in research studies.

Project ID	Title of project	Project ID	Title of project
P001	Construction of Pardis staff pension	P016	Construction of Sculpture Unit Road
P002	Construction of Oily Water Separator	P017	Construction of Senior Operator Room
P003	Degassing of Granulation Unit	P018	Construction of HSE Energy Chanel
P004	Construction of Housing center	P019	Performing P.F Wall in Torshizi Residential
P005	Construction of Ware House Building	P020	Performing of Pardis Gas line
P006	Movement of Gonbazli sole	P021	Performing of Pardis Power & Data line
P007	Extending of Central Restaurant	P022	Performing of Pardis Waterline
P008	Construction of Sculpture Platform	P023	Construction of Loading HC-Condens area
P009	Optimization of Shahid Mohajer Pool	P024	Performing of Pardis Complex Sewage line
P010	Construction of Gas station	P025	Construction of Contractor Building
P011	Construction of Torshizi Sewage	P026	Performing of O.W.S Supports
P012	Construction of TPL Fencing	P027	Installation of the 7th boiler of refinery
P013	Construction of oil Loading Pavement	P028	Construction of CMF Pipe Line
P014	Construction of Transportation Sole	P029	Performing of General Civil Maintenance
P015	Performing of Refinery F & G System	P030	Restaurant's Cold and Mechanical Room

For implementing the proposed model, at first, two professional questionnaires were distributed between a professional team which was selected by the staff of 70 contractors, consultant, and employee companies. The first questionnaire was designed to identify effective factors on doing project activities. Then obtained Linguistic variables were translated into mathematical measures. In the following, obtained information was processed by MATLAB and fuzzy times were dedicated to project activities. In the second phase, risks were added to project as probable activities. Finally, the integrated time of projects activities was analyzed by Monte Carlo method and outputs show that the accuracy of project time calculation was improved about 8 to 24 percent. Fig. 16 indicates the improvement of the mentioned project time estimation.

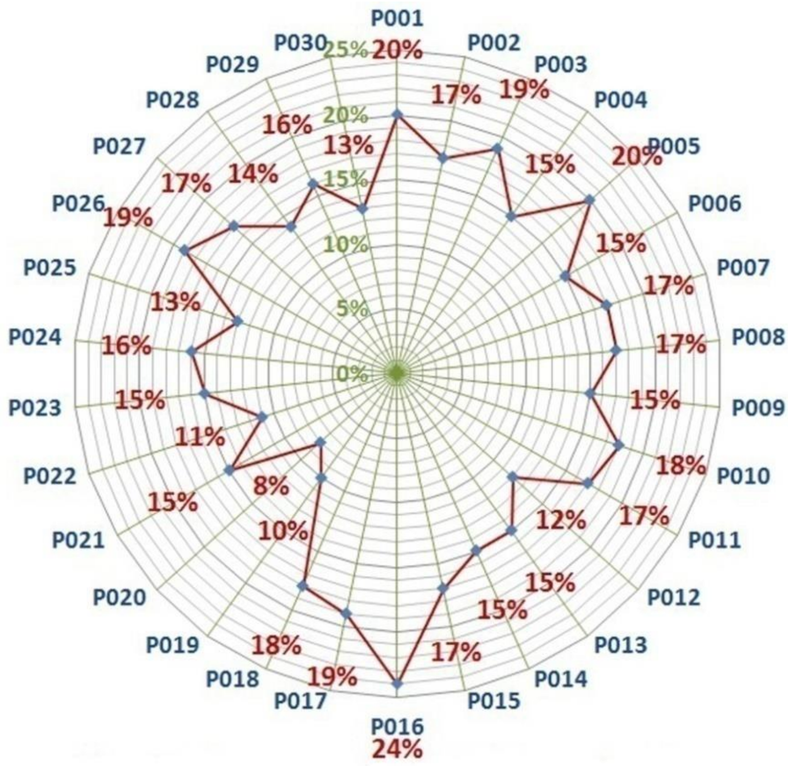


Fig. 16. The rate of improvement in project time estimation by proposed model.

8. Conclusion

This study investigated a new model for comprehensive time estimation in construction projects of the Iranian Gas Refineries. A gas refinery has a complicated process and ongoing projects are directly or indirectly linked with continuous production in this industry. Consequently managing the project time is a critical issue and considering the very low reliability of the project planning with certainty, using more secure models for control and interact with uncertainty is a necessity. It is obvious that successful project time management should be based on comprehensive time estimation. Therefore, considering the uncertainty in the estimation of project time is the main object. From the above discussion, the following conclusions were derived:

1. Uncertainties that affect the project time are based on probability and possibility theories. Many industries, such as gas refineries manage probable uncertainties in their projects by risk management but in the field of possible uncertainties, actions are very scarce. It implies on the fault that there is an urgent necessity to re-arrange the project time estimation model mix, with all modes integrated into a seamless time management system having smart interfacing among them.
2. This research considered the managing of possible uncertainties in gas refineries projects by Fuzzy Critical Path Method. Simultaneously, providing a database of project risks based on previous experience of construction projects in gas refineries was placed on the agenda.
3. Finally, a precise model was proposed to provide comprehensive project time estimation. The proposed model integrates the risk management and fuzzy expert systems in order to manage both modes of time uncertainty in the construction project of Iranian gas refineries.
4. The result of the implementation of proposed model shows that the accuracy of project time estimation increases about 8 to 24 percent. Finally, due to successful results of this research, it has been suggested that the proposed model could be generalized to other industries projects.

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