Uncertainty Management in Time Estimation of Construction Projects:  
A Systematic Literature Review and New Model Development

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Abstract

Nowadays, the very low reliability of the project planning in certainty-based approaches, caused to use more intelligent methods for uncertainty management in construction projects. This systematic study aims to survey the methods which have been used to manage the uncertainties in time estimation of construction projects. A series of steps were undertaken during the review. The study was started with determining the purpose of the study, selecting appropriate keywords, and reducing the selected papers using some criteria. A deeper analysis was carried out on the final paper that meets the criteria for this review. The study is limited solely to papers referred in six top online databases. It aims to review how the papers have been distributed by a period of publishing and by country and the domains that these methods have been applied for. The result confirms that uncertainties which affect any project are based probability and possibility theories controlled by Risk Management and Fuzzy Logic. Finally, a hybrid method for uncertainty management in project scheduling is proposed. The result of the implementation of this method in the construction project of Iranian Gas Company shows that proposed method increases the accuracy of time estimation about 8 to 24 percent.

Keywords: Time Estimation, Uncertainty, Fuzzy Logic, Risk Management, Construction Projects.
1. Introduction

Nowadays the importance of time management in the field of construction projects is well known. Time management can be effective in a project when the project schedule is based on reasonable and comprehensive time estimation. Uncertainties that affect the project are based on the two theories: probability and possibility. This paper aims to survey the methods which have been used to manage the uncertainties in time estimation of construction projects and proposed a comprehensive method for uncertainty management in construction projects schedule. A series of steps is undertaken during the review according to research methodology.

2. Research Methodology

In this paper, the literature related to uncertainty management in a construction project scheduling is reviewed, comprehensively, by documents referred to six main scientific online databases, these being Science Direct (Elsevier); ASCE Online Library; Taylor and Francis; Springer journal collection; Hindawi and John Wiley online databases.

Following to the diagram presented in Figure 1, the first publications in the area up to 31 March 2017 are reviewed. Three groups of combinations of the methods devoted for calculating the relative significance of criteria and ranking of alternatives can be identified:

1. Uncertainty + Project Scheduling + Construction Management
2. Project Stochastic Scheduling + Uncertainty + Comprehensive Time Management
3. Project Scheduling Methods + Artificial Intelligence + Meta Heuristic and Hybrid Methods

There are 9236 publications on the topic of uncertainty referred to the six mentioned databases. Figure 1 shows the research methodology diagram.
3. Detailed Review Results

The result of this research indicates that the methods of uncertainty managing in construction project scheduling are divided into three approaches: Fuzzy, risk and other mathematical and heuristic approaches. Figure 2 shows the distribution of the mentioned approaches.

Statistical view of published papers with the title of uncertainty management in construction project scheduling in last decade (from 2007 up to 31 March 2017) is shown in Figure 3.

Also, the comparison of published papers with the title of uncertainty management by Fuzzy and Risk in last decade is shown in Figure 4.

According to results of this research, about 250 Authors from 35 countries have contributed to improving the application of uncertainty management in construction projects. Figure 5 indicates the top ten countries that have the most related papers about this research subject. As it can be seen in this Figure, USA, China and Canada have the most researches. Also, a statistical view of the journals with the most papers about uncertainty management in construction project scheduling is shown in Figure 6. According to this figure, the Journal of Construction Engineering Management (ASCE) with 40 related papers is the top journal in the subject of this research.

It is worth to mention that 230 out of 242 selected papers have described just the theory of subject and only 12 papers are applications that are explained in Table 1. Also, 6 papers have a hybrid approach and the combination of their approaches is described in Table 2.

In the following, Table 3, Table 4 and Table 5 show this research selected papers according to 3 mentioned approaches of uncertainty management in construction project scheduling. According to the result of this review, the most papers that used Fuzzy approach have concentrated on possible uncertainty management in project scheduling, and the papers with risk management
approach have concentrated on managing the probable uncertainties. Also other mathematical, heuristic and hybrid methods have concentrated on managing the probable uncertainties. As a result, it is worth to mention that the best approach to managing possible uncertainties is Fuzzy method, because in fuzzy method uncertainty of project activities remains in whole calculation stages but in other mathematical algorithms and artificial intelligence methods, certainty based tools such as learning rules in neural networks method reduce the mentioned uncertainty in calculation stages and this leads to reduction of time estimation accuracy. Also the best way to managing probable uncertainties is the implementation of Risk Management in construction projects. So, comprehensive way for managing uncertainties in construction project scheduling is a method of dual approach. In the following part, a hybrid model is proposed to solve this problem. It is worth to mention that the proposed model has been implemented in construction projects of Iranian gas refineries and the related result is described after the model description.

4. A New Proposed Model for Managing Uncertainties in Construction Project Scheduling

According to the result of this paper systematic review, a new model based on the comprehensive integration of possible and probable uncertainty management is proposed for construction projects optimum scheduling. Figure 7 indicates the diagram of the proposed model. In fact, this model is an integration of risk management and fuzzy expert systems to manage uncertainties in construction projects schedule.

5. Implementation of the Proposed Model in SGPC Construction Projects

For implementing the proposed model, at first, two professional questionnaires were distributed between 200 experts of a professional team which was selected by the staff of 70 contractors, consultant, and client 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 Painting activity is presented in Table 6. As it can be seen in the mentioned Table, the value of the linguistic variables is classified into five types.

As in Table 6, seven factors are considered to estimate the time of painting activity. To examine the reliability of the questionnaire, data analysis was done by SPSS. The results show that factors 2, 3 and 7 do not have considerable influence on the timing of painting activity (Table 7). So these factors were eliminated, and calculations were repeated. In the new analysis, the index rose up to 0.938 which is desirable. Table 8 shows the result of the second analysis. Consequently, the main factors of painting activity are climatic Condition, quality of Paint, availability of skilled workers and rate of Surface Opening.

Also, the result of correlation survey by Pearson coefficient indicates that the mentioned factors are correlated (Table 9). Consequently, the volume of statistical society is enough, and there is no need to an extension.

In the next step, the second questionnaire which relates to estimation of activity durations would be distributed among the mentioned team members. The second questionnaire is about estimating the time of each activity based on the experience of the professional team. After summing up the results of the first and second questionnaires, obtained results would be examined by a team composed of 9 expert project managers to determine its content validity. In the next stages of the proposed model, membership functions of activities time factors would be drawn according to the second questionnaire. In this research, Fuzzy diagrams were of triangular and trapezoidal types. In the present example, Figures 8 to 11 indicate the Fuzzy membership functions of painting activity factors. These diagrams are considered as the input of MATLAB analysis.
Also, Figure 12 shows the output function of painting activity time. In the next stage, the results of the previous step as input would be analyzed in Fuzzy Toolbox of MATLAB. This toolbox follows a Rule Base System. Diagram of Analysis is presented in Figure 13. As it could be seen in this Figure, inputs are processed by intelligence and rule base system.

“IF … Then …” rules were set by the expert team in Rule Base system. For example, for 4 mentioned factors, 625 operating modes may occur. After analysis, the duration of activities under uncertainty and fuzzy approach can be achieved. Figure 14 shows the calculated painting time.

After calculating the time of all activities according to this model, 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 2017 (Table 10). 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 project as probable activities.

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
destruction operations activity, the risk of "Wasps nests found" with a probability of 5% is allocated to risk management in project scheduling (Figure 15). Also, Risks can be allocated to activities as probable branches. For example, in "Excavation" activity, three probable branches are considered. These branches are: (1) "Normal condition" with the probability of 70%; (2) “Finding ground water in the site area” with the probability of 20%; (3) "Finding Antique objects underground" with the probability of 5% (Figure 16).

In the final stage of the proposed model, project schedule will be designed based on managing both types of uncertainties. Then, the provided schedule is analyzed on the basis of Monte Carlo model. This analysis was done by the Risk Analysis software. Primavera Risk Analysis is a full lifecycle risk analytics solution that provides a comprehensive means for 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.

6. 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. Table 12 presents the title of the project that used in research studies with correspondent to the project estimation accuracy with ascending order.

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 client 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. Figure 17, indicates the improvement of the mentioned project time estimation.

7. Conclusions

In this paper, the literature related to uncertainty management in construction projects is reviewed comprehensively. At first 9236 papers from 6 main online databases were preliminary reviewed and 242 papers were selected for precise review. According to the analysis of these mentioned papers, the following conclusions were derived:

1. About 29 percent of last studies have considered the possible theory to manage uncertainties in construction project scheduling. They used application of Fuzzy technique in this field. So, the Fuzzy technique is the most applicable method to manage possible uncertainties in construction project scheduling.

2. About 71 percent of last studies have considered the probable theory to manage uncertainties in construction project scheduling and about 80 percent of probable approach (equal to 57 percent of last studies) belongs to the application of Risk Management in this field. Other contingency approaches belong to Genetic Algorithm, Neural Network, Linear Programming, Markov Chain, Monte Carlo Simulation and other mathematical methods and heuristic algorithms. So, Risk Management is the most applicable method to manage probable uncertainties in construction project scheduling.
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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List of Tables
Table 1. List of the application papers by the title of uncertainty management in project schedule
Table 2. List of the hybrid papers by the title of uncertainty management in project schedule
Table 3. Specification of the most important fuzzy approach papers
Table 4. Specification of the most important authors of papers by risk management approach
Table 5. Specification of the selected papers by other Contingency-Mathematical approaches
Table 6. Questionnaire of Fuzzy Expert System for Painting activity
Table 7. First reliability analysis of questionnaire (Cronbach's Alpha = 0.538)
Table 8. Second reliability analysis of questionnaire (Cronbach's Alpha = 0.939)
Table 9. Correlation reliability analysis of questionnaire
Table 10. The main historical researchers of risk management in Iranian gas refineries from 2010 to 2017
Table 11. Sample database of construction project risk index (RPN) in gas refineries
Table 12. The title of project which is used in the research studies

List of Figures
Figure 1. Research methodology diagram
Figure 2. Statistical view of uncertainty management approaches in project scheduling
Figure 3. Last decade researches of uncertainty management in project scheduling
Figure 4. Comparison of uncertainty management approaches in the last decade
Figure 5. Countries with the most papers about Uncertainty Management in Project Scheduling
Figure 6. Journal with the most papers about Uncertainty Management in Project Scheduling
Figure 7. Diagram of the proposed model
Figure 8. Fuzzy membership function of painting activity model in Variable Climatic Conditions
Figure 9. Fuzzy membership function of painting activity model in Variable Paint Quality
Figure 10. Fuzzy membership function of availability of skilled workers Factor
Figure 11. Fuzzy membership function of rate of Surface Opening Factor
Figure 12. Time of painting activity – Output Functions
Figure 13. Diagram of proposed model analysis for painting activity
Figure 14. Painting time calculated by fuzzy approach MATLAB software output
Figure 15. Sample of probable activity in project scheduling – Wasps nests found
Figure 16. Sample of probable activity in project scheduling - Excavation
Figure 17. The rate of improvement in project time estimation by the proposed model

`+-------------------------------- 1. List of the application papers by the title of uncertainty management in project schedule

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<tr>
<th>Considered issues and problems</th>
<th>Applied Methods</th>
<th>Author (s), Publishing Year</th>
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<tr>
<td>Presenting a scheduling algorithm for the real-world steelmaking-continuous casting production</td>
<td>Mathematical Heuristic Method</td>
<td>Jiang et al., 2016 [1]</td>
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<td>GA approach for the quay crane scheduling under uncertainty</td>
<td>Genetic Algorithm method</td>
<td>Al-Daheri et al., 2016 [2]</td>
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<tr>
<td>GA approach for remanufacturing process planning and scheduling</td>
<td>Genetic Algorithm method</td>
<td>Zhang et al., 2015 [3]</td>
</tr>
<tr>
<td>Simulation Multiagent Approach for Scheduling Modular Construction</td>
<td>Scheduling Modular Construction</td>
<td>Taghaddos et al., 2012 [9]</td>
</tr>
<tr>
<td>Uncertainty Modeling in Development Projects (Case Study)</td>
<td>Manufacturing Companies in Turkey</td>
<td>Özdamar &amp; Alanya, 2001 [10]</td>
</tr>
<tr>
<td>Integrating the mean–variance and scheduling approaches to allow for schedule delay and trip time variability under uncertainty</td>
<td>Schedule Delay and Trip Time Variability</td>
<td>Li et al., 2016 [11]</td>
</tr>
<tr>
<td>Robust multi-objective maintenance planning of deteriorating bridges against uncertainty in performance</td>
<td>maintenance planning of deteriorating bridges against uncertainty in performance model</td>
<td>Ok et al., 2013 [12]</td>
</tr>
</tbody>
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Table 2. List of the hybrid papers by the title of uncertainty management in project schedule

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<thead>
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<td>Real-time task scheduling by Fuzzy method</td>
<td>Muhuri &amp; Shukla, 2017 [19]</td>
<td></td>
</tr>
<tr>
<td>flexible scheduling model by Fuzzy method</td>
<td>Dubios et al., 2003 [20]</td>
<td></td>
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<tr>
<td>linguistic approach to non-identical parallel processor scheduling with fuzzy processing times</td>
<td>Geyik &amp; Elibal, 2016 [21]</td>
<td></td>
</tr>
<tr>
<td>Using trapezoidal intuitionist Fuzzy number to find optimized Path in a schedule network</td>
<td>Jayagowri &amp; Ramani, 2014 [22]</td>
<td></td>
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<tr>
<td>Fuzzy networked systems design by Scheduling restrictions</td>
<td>Benítez-Pérez et al., 2012 [23]</td>
<td></td>
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<tr>
<td>An integration of the fuzzy reasoning technique and optimization method in construction project management decision-making</td>
<td>Lam et al., 2001 [26]</td>
<td></td>
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<tr>
<td>Some design issues in cellular manufacturing using the fuzzy programming approach</td>
<td>Shanker &amp; vart, 1999 [27]</td>
<td></td>
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<tr>
<td>Project Scheduling Using Fuzzy Set Concepts</td>
<td>Ayyub &amp; Haldar, 1984 [28]</td>
<td></td>
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<tr>
<td>Fuzzy Optimal Model for Resource-Constrained Construction Scheduling</td>
<td>Leu et al., 1999 [29]</td>
<td></td>
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<tr>
<td>Fuzzy Project Scheduling</td>
<td>Bonnal et al., 2004 [30]</td>
<td></td>
</tr>
<tr>
<td>Fuzzy approach for activity delay analysis and schedule Updating</td>
<td>Oliveros &amp; Fayek, 2005 [31]</td>
<td></td>
</tr>
<tr>
<td>A Process for the Estimation of the Duration of Activities in Fuzzy Project Scheduling</td>
<td>Maravas &amp; Pantouvakis, 2011 [33]</td>
<td></td>
</tr>
<tr>
<td>Emergency Scheduling Model of Multi-Objective-to-Resource under Uncertain Requirements</td>
<td>Xiong et al., 2014 [34]</td>
<td></td>
</tr>
<tr>
<td>Inexact Fuzzy Chance-Constrained Nonlinear Programming Approach for Crop Water Allocation under Precipitation Variation and Sustainable Development</td>
<td>Guo et al., 2014 [35]</td>
<td></td>
</tr>
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<td>Authors</td>
<td>Year</td>
</tr>
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<td>----------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Network Resource Allocation with Support of a Fuzzy System</td>
<td>Chang et al., 1990 [37]</td>
<td></td>
</tr>
<tr>
<td>Scheduling demand-responsive transportation vehicles using fuzzy-set theory</td>
<td>Kikuchi &amp; Donnelly, 1989 [38]</td>
<td></td>
</tr>
<tr>
<td>Fuzzy-Set Approach for Optimizing Sludge Application Land Selection</td>
<td>Crump et al., 1993 [39]</td>
<td></td>
</tr>
<tr>
<td>Application of Fuzzy Linear Programming in Civil Engineering</td>
<td>Kumar et al., 2000 [40]</td>
<td></td>
</tr>
<tr>
<td>Forecasting Project Status by Using Fuzzy Logic</td>
<td>Li et al., 2006 [41]</td>
<td></td>
</tr>
<tr>
<td>Construction project scheduling using Fuzzy mathematical models and Critical Path Method</td>
<td>Castro-Lacouture et al., 2009 [42]</td>
<td></td>
</tr>
<tr>
<td>Multi objective Evolutionary Finance-Based Scheduling: Entire Projects' Portfolio</td>
<td>Abido &amp; Elazouni, 2010 [43]</td>
<td></td>
</tr>
<tr>
<td>Possibility Moments for the Task Duration in Fuzzy PERT</td>
<td>Chrysafis &amp; Papadopoulos, 2014 [45]</td>
<td></td>
</tr>
<tr>
<td>A Fuzzy Discrete Event Simulation for Construction Applications</td>
<td>Sadeghi et al., 2016 [46]</td>
<td></td>
</tr>
<tr>
<td>Fuzzy Optimal Model for Resource-Constrained Scheduling</td>
<td>Leu et al., 1999 [50]</td>
<td></td>
</tr>
<tr>
<td>Robustness measure for fuzzy maintenance activities schedule</td>
<td>Marmier et al., 2007 [51]</td>
<td></td>
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<tr>
<td>Location of cross-docking centers and vehicle routing scheduling under uncertainty: A fuzzy possibilistic programming model</td>
<td>Mousavi et al., 2014 [52]</td>
<td></td>
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<tr>
<td>Modeling project time–cost trade-off in fuzzy random environment</td>
<td>Ke &amp; Ma, 2014 [53]</td>
<td></td>
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<tr>
<td>Procurement scheduling for complex projects with fuzzy activity durations and lead times</td>
<td>Dixit et al., 2014 [54]</td>
<td></td>
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<tr>
<td>Project scheduling under uncertainty using fuzzy modeling and solving techniques</td>
<td>Masmoudi et al., 2013 [55]</td>
<td></td>
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<tr>
<td>Intelligent timetable evaluation using fuzzy AHP, Expert Systems with Applications</td>
<td>Isaai et al., 2011 [56]</td>
<td></td>
</tr>
<tr>
<td>Real-time scheduling of periodic tasks with processing times and deadlines as parametric fuzzy numbers</td>
<td>Muhuri &amp; Shukla, 2009 [57]</td>
<td></td>
</tr>
<tr>
<td>Fuzzy hierarchical production planning</td>
<td>Torabi et al., 2010 [58]</td>
<td></td>
</tr>
<tr>
<td>MRP with flexible constraints: A fuzzy mathematical programming approach</td>
<td>Mula et al., 2006 [59]</td>
<td></td>
</tr>
<tr>
<td>Material Requirement Planning with fuzzy constraints and fuzzy coefficients</td>
<td>Mula et al., 2007 [60]</td>
<td></td>
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<tr>
<td>Fuzzy critical chain method for project scheduling under resource constraints and uncertainty</td>
<td>Long &amp; Ohsato, 2008 [61]</td>
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<tr>
<td>Fuzzy project scheduling system for software development</td>
<td>Hapke et al., 1994 [62]</td>
<td></td>
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<tr>
<td>A fuzzy project scheduling approach to minimize schedule risk for product development</td>
<td>Wang, 2002 [63]</td>
<td></td>
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<td>Fuzzy Logic-Based Secure and Fault Tolerant Job Scheduling</td>
<td>Wang et al., 2007 [64]</td>
<td></td>
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<td>Fuzzy resource-constrained project scheduling using taboo search algorithm</td>
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<td>The Fuzzy Project Scheduling Problem with Minimal Generalized Precedence Relations</td>
<td>Ponz-Tienda et al., 2015 [67]</td>
<td></td>
</tr>
<tr>
<td>4 Estimating Risk Adjusted Cost or Schedule Using Fuzzy Logic</td>
<td>Bellagamba, 1999 [68]</td>
<td></td>
</tr>
<tr>
<td>Fuzzy Monte Carlo Simulation and Risk Assessment in Construction</td>
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<td></td>
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<td>Computer-Aided Project Duration Forecasting Subjected to the Impact of Rain</td>
<td>Guo, 2000 [70]</td>
<td></td>
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<tr>
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</tr>
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<td>Resource preprocessing and optimal task scheduling in cloud computing environments</td>
<td>Liu et al., 2015 [72]</td>
<td></td>
</tr>
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<td>Fuzzy due-date scheduling problem with fuzzy processing time</td>
<td>Itoh &amp; Ishii, 1999 [73]</td>
<td></td>
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<tr>
<td>Survey on fuzzy shop scheduling</td>
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<td></td>
</tr>
<tr>
<td>Demand uncertainty in construction supply chains: a discrete event simulation study</td>
<td>Vidalakis et al., 2013 [75]</td>
<td></td>
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<tr>
<td>A new approach to solving time–cost trade-off problem with fuzzy decision variables</td>
<td>Ghazanfari et al., 2009 [76]</td>
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</tr>
<tr>
<td>A theoretic and practical framework for scheduling in a stochastic environment</td>
<td>Bidot et al., 2009 [77]</td>
<td></td>
</tr>
<tr>
<td>A fuzzy set approach to activity scheduling for product development</td>
<td>Wang, 1999 [78]</td>
<td></td>
</tr>
<tr>
<td>Project Scheduling Problem for Software Development with Random Fuzzy Activity Duration Times</td>
<td>Huang et al., 2009 [79]</td>
<td></td>
</tr>
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<td>Two uncertain empirical models for project scheduling problem</td>
<td>Ding &amp; Zhu, 2015 [80]</td>
<td></td>
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<td>Critical analysis of activity networks under interval uncertainty</td>
<td>Fortin et al., 2010 [81]</td>
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Table 4. Specification of the most important authors of papers by risk management approach

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<th>No.</th>
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<td>Keller &amp; Bayraksan, 2009 [82]</td>
<td>51</td>
<td>Mawlana &amp; Hammad, 2015 [131]</td>
</tr>
<tr>
<td>3</td>
<td>Reed &amp; Knight, 2013 [84]</td>
<td>53</td>
<td>Likhachev &amp; Stentz, 2009 [133]</td>
</tr>
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<td>Oztas &amp; Okmen, 2005 [134]</td>
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<td>Kang et al.,2011 [86]</td>
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<td>Poshdar et al., 2016 [87]</td>
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<tr>
<td>8</td>
<td>De Marco et al., 2015 [89]</td>
<td>58</td>
<td>Ryu et al., 2015 [138]</td>
</tr>
<tr>
<td>9</td>
<td>Li et al., 2014 [90]</td>
<td>59</td>
<td>Dehghan &amp; Ruwanpura, 2011 [139]</td>
</tr>
<tr>
<td>10</td>
<td>El-Kholy, 2013 [91]</td>
<td>60</td>
<td>Yang &amp; Chang, 2005 [140]</td>
</tr>
<tr>
<td>11</td>
<td>Yang et al.,2013 [92]</td>
<td>61</td>
<td>Tabrizi &amp; Ghaderi, 2016 [141]</td>
</tr>
<tr>
<td>14</td>
<td>Khamooshi &amp; Cioffi, 2012 [95]</td>
<td>64</td>
<td>Herroelen &amp; Leus, 2004 [143]</td>
</tr>
<tr>
<td>16</td>
<td>Dikmen et al., 2012 [96]</td>
<td>66</td>
<td>Gálvez &amp; Capuz-Rizo, 2016 [145]</td>
</tr>
<tr>
<td>18</td>
<td>Mohamed et al., 2009 [98]</td>
<td>68</td>
<td>Kadipasaoglu &amp; Sridharan, 1995 [147]</td>
</tr>
<tr>
<td>19</td>
<td>Schatteman et al., 2008 [99]</td>
<td>69</td>
<td>Gong &amp; Rowings, 1995 [148]</td>
</tr>
<tr>
<td>20</td>
<td>Ökmen &amp; Óztas, 2008 [100]</td>
<td>70</td>
<td>Rahmani et al., 2013 [149]</td>
</tr>
</tbody>
</table>
Presenting an uncertain model for scheduling the logistics projects

A genetic algorithm

Responding to schedule changes in build

Applicability of optimal control theory to adaptive supply chain

Knowledge based

An event

A two-stage-priority-rule-based algorithm for robust resource-constrained project scheduling

A hybrid heuristic algorithm for flowshop inverse scheduling problem under a dynamic environment. Cluster Computing

A genetic algorithm-based optimizing approach for project time-

| Table 5. Specification of the selected papers by other Contingency-Mathematical approaches |
|------------------------------------------|------------------------------------------|
| Presenting an uncertain model for scheduling the logistics projects | KE et al., 2015 [180] |
| GA approach for remanufacturing process scheduling | Zhang et al., 2015 [3] |
| Heuristic procedures for reactive project scheduling | Van de Vonder et al., 2007 [181] |
| Applicability of optimal control theory to adaptive supply chain planning and scheduling | Ivanov, 2012 [183] |
| Genetic optimization of order scheduling with uncertainties | Guo et al., 2008 [184] |
| A two-stage-priority-rule-based algorithm for robust resource-constrained project scheduling | Chtourov & Haouari, 2008 [185] |
| An event-driven approach with makespan/cost tradeoff analysis for project portfolio scheduling. | Kao et al., 2006 [186] |
| Responding to schedule changes in build-to-order supply chains | Krajewski et al., 2005 [187] |
| Knowledge based-system for alternative design, cost estimating and scheduling | Mohamed & Celik, 2002 [188] |
| A hybrid heuristic algorithm for flowshop inverse scheduling problem under a dynamic environment. Cluster Computing | Mou et al., 2017 [189] |
| A genetic algorithm-based optimizing approach for project time- | Ke, 2014 [190] |
cost trade-off with uncertain measure.

A self-adjusting algorithm for driver scheduling

Model for evaluating networks under correlated uncertainty

Monte carlo simulation analysis at Lester B Pearson international airport development project.

Reliability buffering for construction projects. Journal of Construction Engineering and Management

Construction planning method using case-based reasoning (CONPLA-CBR). Journal of computing in civil engineering

System of multiple ANNs for online project planning

Real-time simulation for look-ahead scheduling of projects

time-cost optimization of nonserial repetitive construction projects

time-scale network simulation by chronographic relations.

Simulating construction duration for multistory buildings

A Mathematical Structure for Modeling Uncertainty in Cost, Schedule, and Escalation Factor in a Portfolio of Projects

Scenario-based optimization for critical-chain project scheduling.

Real-time construction schedule analysis of long-distance diversion tunnels based predictions using a Markov process

Application of Weibull Analysis to Evaluate and Forecast Schedule Performance in Repetitive Projects

Simulating Uncertainties in Construction Projects with Chronographical Scheduling Logic

A genetic scheduling methodology for virtual cellular manufacturing systems: an industrial application

The application of the ant colony optimization algorithm to the construction site layout planning problem

A framework for developing intelligent real time scheduling

Recommender system for software project planning one application of revised CBR algorithm

Development of a gray critical path for construction planning

---

Table 6. Questionnaire of Fuzzy Expert System for Painting activity

Please determine the effect of each factor in the time of Painting Activity.

1- Climatic Condition (Very Cold, Cold, Moderate, Warm, Hot)
   - Very Cold
   - Cold
   - Moderate
   - Warm
   - Very Warm

2- HSE Criteria (Classification of site in Operational Zones)
   - Out site
   - Guard Fence
   - Muster point
   - Operational
   - H2S Penetrate

3- Height of the surface (need or not need to scaffold)
   - Very Short
   - Short
   - Moderate
   - Tall
   - Very Tall

4- Quality of Paint (Grade1, Grade2, Grade3, Grade1, Special, FireProof Safe)
   - Grade3
   - Grade2
   - Grade1
   - Special
   - FP Safe

5- Availability of skilled workers
   - Very Scare
   - Scare
   - Moderate
   - Available
   - Accessible

6- Rate of Surface Opening (30%, 20% - 30%, 10% - 20%, 5% - 10%, < 5%)
   - > 30%
   - 20% - 30%
   - 10% - 20%
   - 5% - 10%
   - < 5%

7- Type of Paint Material (Plastic colorT1, …, Oil Color-T2)
   - Plastic color1
   - Plastic color2
   - Plastic color3
   - Oil Color-T1
   - Oil Color-T2

---

26
Table 7. First reliability analysis of questionnaire (Cronbach's Alpha = 0.538)

<table>
<thead>
<tr>
<th></th>
<th>Scale Mean if Item Deleted</th>
<th>Scale Variance if Item Deleted</th>
<th>Corrected Item-Total Correlation</th>
<th>Cronbach's Alpha if Item Deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1601</td>
<td>11.73</td>
<td>3.857</td>
<td>.709</td>
<td>.287</td>
</tr>
<tr>
<td>S1602</td>
<td>11.70</td>
<td>6.562</td>
<td>.161</td>
<td>.647</td>
</tr>
<tr>
<td>S1603</td>
<td>11.33</td>
<td>5.816</td>
<td>.006</td>
<td>.620</td>
</tr>
<tr>
<td>S1604</td>
<td>11.73</td>
<td>3.857</td>
<td>.709</td>
<td>.287</td>
</tr>
<tr>
<td>S1605</td>
<td>11.73</td>
<td>3.857</td>
<td>.709</td>
<td>.287</td>
</tr>
<tr>
<td>S1606</td>
<td>10.87</td>
<td>5.292</td>
<td>.403</td>
<td>.467</td>
</tr>
<tr>
<td>S1607</td>
<td>11.70</td>
<td>6.562</td>
<td>-.161</td>
<td>.647</td>
</tr>
</tbody>
</table>

Table 8. Second reliability analysis of questionnaire (Cronbach's Alpha = 0.939)

<table>
<thead>
<tr>
<th></th>
<th>Scale Mean if Item Deleted</th>
<th>Scale Variance if Item Deleted</th>
<th>Corrected Item-Total Correlation</th>
<th>Cronbach's Alpha if Item Deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1601</td>
<td>6.07</td>
<td>3.237</td>
<td>.973</td>
<td>.878</td>
</tr>
<tr>
<td>S1604</td>
<td>6.07</td>
<td>3.237</td>
<td>.973</td>
<td>.878</td>
</tr>
<tr>
<td>S1605</td>
<td>6.07</td>
<td>3.237</td>
<td>.973</td>
<td>.878</td>
</tr>
<tr>
<td>S1606</td>
<td>5.20</td>
<td>4.924</td>
<td>.543</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Table 9. Correlation Survey by Pearson coefficient

<table>
<thead>
<tr>
<th></th>
<th>S1601</th>
<th>S1604</th>
<th>S1605</th>
<th>S1606</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1601 Pearson Correlation</td>
<td>1</td>
<td>.843</td>
<td>.937</td>
<td>.742</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.000</td>
<td>.000</td>
<td>.002</td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>S1604 Pearson Correlation</td>
<td>.843</td>
<td>1</td>
<td>.711</td>
<td>.821</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td></td>
<td>.000</td>
<td>.002</td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>S1605 Pearson Correlation</td>
<td>.937</td>
<td>.711</td>
<td>1</td>
<td>.953</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.000</td>
<td></td>
<td>.002</td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>S1606 Pearson Correlation</td>
<td>.742</td>
<td>.821</td>
<td>.953</td>
<td>1</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.002</td>
<td>.002</td>
<td>.002</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).

Table 10. The main historical researchers of risk management in Iranian gas refineries from 2010 to 2017

<table>
<thead>
<tr>
<th>Researchers/Year</th>
<th>Approach of Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Rudloff, and Schultz, 2016) [211]</td>
<td>They reviewed project risk in the Oil and Gas industry.</td>
</tr>
<tr>
<td>(Ghasemi et al., 2015) [212]</td>
<td>They presented a new method for scrutiny the Insurable Risk in Iranian gas refineries by FMEA.</td>
</tr>
<tr>
<td>(Najafi et al., 2015) [213]</td>
<td>They reviewed risk quantification in complex and fast projects.</td>
</tr>
<tr>
<td>(Doosti et al., 2014) [214]</td>
<td>They reviewed the risk management in the construction of gas refineries.</td>
</tr>
<tr>
<td>(Ardeshir et al., 2014) [215]</td>
<td>They reviewed Safety Assessment in refinery and other construction projects based on Analytic Hierarchy Process.</td>
</tr>
</tbody>
</table>
They reviewed the identification and allocation of risks in construction projects of Sarkhoon & Gheshm gas refinery.

They reviewed risk management in Iranian oil and gas Companies.

They proposed a new hybrid method for project risk assessment in construction projects. Also, they reviewed the risks in refinery projects.

They reviewed the risk management of asalouye desalination projects.

They reviewed the risks of projects in Shiraz refinery by FMEA method.

They studied risk management in Iranian construction projects such as gas refineries as a survey study.

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

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

### Table 12. The title of project which is used in the research studies

<table>
<thead>
<tr>
<th>Project ID</th>
<th>Title of project</th>
<th>Project ID</th>
<th>Title of project</th>
</tr>
</thead>
<tbody>
<tr>
<td>P001</td>
<td>Construction of Sculpture Unit Road</td>
<td>P016</td>
<td>Construction of Housing center</td>
</tr>
<tr>
<td>P002</td>
<td>Construction of Pardis staff pension</td>
<td>P017</td>
<td>Movement of Gonbazli sole</td>
</tr>
<tr>
<td>P003</td>
<td>Construction of Ware House Building</td>
<td>P018</td>
<td>Construction of oil Loading Pavement</td>
</tr>
<tr>
<td>P004</td>
<td>Degassing of Granulation Unit</td>
<td>P019</td>
<td>Performing of Pardis Power &amp; Data line</td>
</tr>
<tr>
<td>P005</td>
<td>Performing of Senior Operator Room</td>
<td>P020</td>
<td>Construction of Loading HC-Condens area</td>
</tr>
<tr>
<td>P006</td>
<td>Performing of O.W.S Supports</td>
<td>P021</td>
<td>Performing of General Civil Maintenance</td>
</tr>
<tr>
<td>P007</td>
<td>Construction of Gas station</td>
<td>P022</td>
<td>Optimization of Shahid Mohajer Pool</td>
</tr>
<tr>
<td>P008</td>
<td>Construction of HSE Energy Chanel</td>
<td>P023</td>
<td>Construction of Transportation Sole</td>
</tr>
<tr>
<td>P009</td>
<td>Construction of Torshizi Sewage</td>
<td>P024</td>
<td>Construction of Contractor Building</td>
</tr>
<tr>
<td>P010</td>
<td>Performing of Refinery F &amp; G System</td>
<td>P025</td>
<td>Restaurant’s Cold and Mechanical Room</td>
</tr>
<tr>
<td>P011</td>
<td>Installation of the 7th boiler of refinery</td>
<td>P026</td>
<td>Construction of TPL Fencing</td>
</tr>
<tr>
<td>P012</td>
<td>Extending of Central Restaurant</td>
<td>P027</td>
<td>Performing of Pardis Waterline</td>
</tr>
<tr>
<td>P013</td>
<td>Construction of Sculpture Platform</td>
<td>P028</td>
<td>P.F Wall in Torshizi Residential</td>
</tr>
<tr>
<td>P014</td>
<td>Construction of Oily Water Separator</td>
<td>P029</td>
<td>Performing of Pardis Gas line</td>
</tr>
<tr>
<td>P015</td>
<td>Performing of Pardis Complex Sewage line</td>
<td>P030</td>
<td>Construction of CMF Pipe Line</td>
</tr>
</tbody>
</table>
Figure 1. Research methodology diagram
Figure 2. Statistical view of uncertainty management approaches in project scheduling

Figure 3. Last decade researches of uncertainty management in project scheduling
Figure 4. Comparison of uncertainty management approaches in the last decade

Figure 5. Countries with the most papers about Uncertainty Management in Project Scheduling
Figure 6. Journal with the most papers about Uncertainty Management in Project Scheduling
Distribution of Questionnaire to Determine Activities Time (Regarding Possible Uncertainties)

Analyzing the Questionnaire by SPSS to determine Variables Reliability and Validity

Determining the Membership Functions and Fuzzy Diagrams

Analyzing the Fuzzy Membership Functions by MATLAB

Assigning the Possibility Times to Project Activities

Assigning the Probability Times to Project Activities

Providing Project Scheduling (Total Uncertainties)

Project Scheduling Analysis According to Monte Carlo

Analysis Result is Acceptable

Yes

Total Project Scheduling

Finish

Figure 7. Diagram of the proposed model

Figure 8. Fuzzy membership function of painting activity model in Variable Climatic Conditions
Figure 9. Fuzzy membership function of painting activity model in Variable Paint Quality

Figure 10. Fuzzy membership function of availability of skilled workers Factor

Figure 11. Fuzzy membership function of rate of Surface Opening Factor

Figure 12. Time of painting activity – Output Functions
Figure 13. Diagram of proposed model analysis for painting activity

Figure 14. Painting time calculated by fuzzy approach MATLAB software output

Figure 15. Sample of probable activity in project scheduling – Wasps nests found
Figure 16. Sample of probable activity in project scheduling - Excavation

Figure 17. The rate of improvement in project time estimation by the proposed model
Biographies

Abbas Naderpour is a Ph.D. student of Islamic Azad University Central Tehran Branch. He has M.Sc. degree in Construction Management from Islamic Azad University Tehran Science and Research Branch. He has a broad background in Civil Engineering. He is a member of the Project Management Institute (PMI) and also he has 15 years of practical experience in construction management in National Iranian Gas Company (NIGC). His Research Interests are: Earned Value Management, Project Resource Allocation, Project Risk Assessment, Soft Computing, Artificial Intelligence and Fuzzy Expert Systems.

Javad Majrouhi Sardroud holds a Ph.D. degree in Construction Management from Kingston University London and has M.Sc. degree in Structural Engineering from Tabriz University, Iran. He also has 20 years of practical experience in construction management, including contracting, consulting, and ownership. He has been an active member of the academic at the Azad University in Iran since 2002 and currently he is an assistant professor in the Faculty of Engineering at Central Tehran Branch, Islamic Azad University. His main research interests span the disciplines of automation and construction including sustainable construction. His research and teaching interests include Automation in Construction Management, Building Information Modeling, Operation Research and Green Building.

Massood Mofid is a Professor of Structural and Earthquake Engineering in Sharif University of Technology, Tehran, Iran. He received his BSc degree from the University of Tehran. Moreover, he received his MSc and PhD degrees from Rice University. His research interests are in the area of structural analysis and structural dynamics.

Yiannis Xenidis has taught at the department of Spatial Planning and Development in AUTH during 2005 – 2008, while, currently, he is a faculty member (Assistant Professor) at the department of Civil Engineering in AUTH and he is a tutor/advisor at the school of Science and Technology in the Hellenic Open University. He is the author of several peer reviewed papers in scientific journals and conferences and he has contributed, upon invitation, with book chapters to several publications. His research interests and teaching activities include: Resilient Systems, Risk Analysis and Decision-Making Theory, Infrastructure Investments and Development, Cost and Schedule Management in Civil Engineering Works, Project Management, Construction Management, and Human Resources Management.

Towhid Pourrostam holds a Ph.D. degree in Construction Management from University Kebangsaan Malaysia (UKM). He obtained his B.Sc. and M.Sc. in 1996 and 1999 respectively at the Islamic Azad University in Iran. He is currently a senior academic member and lecturer in the Faculty of Engineering at Islamic Azad University. His Research Interests are: Project Risk Management, Time and cost trade off and other construction management issues.
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