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Review

An Invistigation About The Fuzzy Logic Aplications In Construction Management

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ABSTRACT

In this study some fuzzy logic aplications in Construction Management (CM) discipline has been investigated. By this way tried to have an idea about the usifulness and practicability of fuzzy logic in the area of CM. For the aim of investigation of the fuzzy logic aplications' provides in CM discipline; there have been made a literature invistigation on different sub-branches of CM. Because of CM is a very large area, this invistigations' scope is determined on the some top quality journals' papers in the Science Situation Index (SCI). Chosen researchs' results from this investigations given in the text. It's confirmed that the applications in this area before, scattered in four main categories, including: decision making, performance, evaluation/assessment; and modeling. Olso optimisation is another aim for using fuzzy logic.

Keywords: *Fuzzy Sets, Construction Management*

İnşaat Yönetimi Alanındaki Bulanık Mantık Uygulamalarına Yönelik Bir Araştırma

ÖZET

Bu çalışmada İnşaat Yönetimi (İY) disiplini içinde yapılan bazı bulanık mantık uygulamaları incelenmiştir. Bu şekilde bulanık mantık uygulamalarının İY alanındaki kullanışlılığı ve pratikliği hakkında bir fikir sahibi olunmaya çalışılmıştır. Bulanık mantık uygulamalarının İY disiplini içindeki getirilerinin incelenmesi amacı için; İY ana konusunun farklı alt dallarında bir literatür taraması yapılmıştır. İY çok geniş bir alan olduğu için bu araştırmanın kapsamı, Science Situation Index (SCI) dahilinde yüksek kalitedeki dergilerde yayınlanmış olan sınırlı sayıdaki araştırma makaleleri ile sınırlandırılmıştır. Seçilen makale araştırmalarının bulguları çalışma içinde verilmiştir. Bu konuda daha önce yapılan araştırmaların; karar verme, performans, değerlendirme/değerlendirme ve modellemeyi içeren dört ana kategoriye ayrıldığı teyit edilmiştir. Optimizasyon da başka bir bulanık mantık kullanım amacıdır.

Anahtar Kelimeler: *Bulanık Kümeler, İnşaat Yönetimi*

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I. INTRODUCTION

Construction Management (CM) or Construction Project Management (CPM) is the overall planning, coordination, and control of a project from beginning to completion. CM is aimed at meeting a client's requirement in order to produce a functionally and financially viable project [1].
The functions of CM typically include the following:
1. Specifying project objectives and plans including delineation of scope, budgeting, scheduling, setting performance requirements, and selecting project participants.
2. Maximizing the resource efficiency through procurement of labor, materials and equipment.
3. Implementing various operations through proper coordination and control of planning, design, estimating, contracting and construction in the entire process.
4. Developing effective communications and mechanisms for resolving conflicts [2].

Construction managers, also called general contractors or project managers, typically do the following:
•Prepare and negotiate cost estimates, budgets, and work timetables
•Select appropriate construction methods and strategies
•Interpret and explain contracts and technical information to workers and other professionals
•Report on work progress and budget matters to clients
•Collaborate with architects, engineers, and other construction and building specialists
•Instruct and supervise construction personnel and activities onsite
•Respond to work delays and other problems and emergencies
•Select, hire, and instruct labourers and subcontractors
•Comply with legal requirements, building and safety codes, and other regulations[3].

A general fuzzy inference system (FIS) has basically four components: these fuzzification, fuzzy rule base, fuzzy output engine and defuzzification [4, 5]. Moreover, input and output data can be added. Fuzzification converts each piece of input data to degrees of membership by a lookup in one or more several membership functions [5]. Fuzzy rule base contains rules that include all possible fuzzy relation between inputs and outputs. These rules are expressed in the IF–THEN format. There are basically two kinds of fuzzy rules. In this study, the Sugeno-type fuzzy rules were constituted. Fuzzy inference engine takes into consideration all the fuzzy rules in the fuzzy rule base and learns how to transform a set of inputs to corresponding outputs. There are basically two kinds of inference operators: minimization (min) and product (prod) [4, 5]. Fuzzy logic allows the use of systematic mathematical formulations for investigating and characterizing different types of uncertain problems. It is best suited when a fully descriptive mathematical model of the process does not exist, or it is formulated in such a way that is too complex to be evaluated fast enough for real time operations, or it is too difficult to encode [6].

In this study some fuzzy logic aplications in CM discipline has been investigated. By this way tried to have an idea about the usifulness and practicability of fuzzy logic on the area of CM.

II. METHOD

For the aim of fuzzy logic aplications' provides in CM discipline; there have been made a literature invistigation on different sub-branches of CM. Because of CM is a very large area, this invistigations' scope is determined on the some papers in the Science Situation Index. The research method used for this paper was to launch a comprehensive review of the related literature from 2001 to 2015. The

selection of literature was mainly based on the top quality journals in construction management and other related fields, which include: European Journal of Operational Research, Applied Mathematical Modelling, Fuzzy Setsand Systems, Automation in Construction, Advances in Engineering Software, Knowledge-Based Systems, Expert Systems with Applications, Applied Soft Computing, Safety Science, Structural Safety, International Journal of Industrial Ergonomics, Building and Environment, Procedia - Social and Behavioral Sciences, Procedia Engineering and with major content: International Journal of Project Management. Keywords for searching were "building", "construction", "construction management", "fuzzy set," "fuzzy logic," "fuzzy control," and other hybrid fuzzy techniques. These terms were well known of having been used in writing papers on fuzzy techniques. Each studies' aims, methods and findigs are expressed in the result part. An evaluation about the study has made in the conclusion part.

III. RESULTS

Shih-Pin Chen, Ming-Jiun Tsai's studys' name is Time–cost trade-off analysis of project networks in fuzzy environments. This paper proposes a novel approach for time–cost trade-off analysis of a project network in fuzzy environments. Different from the results of previous studies, in this paper the membership function of the fuzzy minimum total crash cost is constructed based on Zadeh's extension principle and fuzzy solutions are provided. A pair of two-level mathematical programs parameterized by possibility level a is formulated to calculate the lower and upper bounds of the fuzzy minimum total crash cost at a. By enumerating different values of a, the membership function of the fuzzy minimum total crash cost is constructed, and the corresponding optimal activity time for each activity is also obtained at the same time. An example of time–cost trade-off problem with several fuzzy parameters is solved successfully to demonstrate the validity of the proposed approach. Since the minimum total crash cost is expressed by a membership function rather than by a crisp value, the fuzziness of parameters is conserved completely, and more information is provided for time–cost trade-off analysis in project management. The proposed approach also can be applied to time–cost trade-off problems with other characteristics [7].

Masoud Yaghini, Mohsen Momeni, Mohammadreza Sarmadi, Masoud Seyedabadi, Mohammad M. Khoshraftar's studys' name is A fuzzy railroad blocking model with genetic algorithm solution approach for Iranian railways. In the railway, the fright car classification takes place in the terminals. This classification always imposes a remarkable delay to the movement of the cars from origin to destination. To reduce car handling, it is necessary to group various shipments together with respect to their destination in the railroad blocking plan. In this paper, for the first time, a railroad blocking model with fuzzy travel costs is proposed. In the model, the preferred fuzzy paths are determined by a fuzzy shortest path method. Then, the fuzzy model is transformed into a classic railroad blocking model. The real-life blocking problems are very large with many variables and constraints, and modeling and solving them using commercially available software is very time consuming. Therefore, a solution method based on genetic algorithm is developed. To evaluate the performance of the solution method, several simulated problems are tested and the solutions of genetic algorithm are compared with those of the CPLEX software. The results reveal the algorithm has promising accuracy and computing speed for solving the railroad blocking problem. As a case study, the proposed model for creating the Iranian railway blocking plan is utilized. Iran railways can significantly diminish the some costs and save the time in delivering the loads [8].

RaúlPérez-Fernándeza, PedroAlonsob, IreneDíazc, SusanaMontesas' investigation has the name of Multi-factorial risk assessment: An approach based on fuzzy preference relations. The main purpose of this paper is to develop a new method to aggregate the information given by several experts or criteria about different alternatives in order to obtain the preferred alternative or alternatives. This method has to take into account the interaction of the different alternatives and a parameter modelling the flexibility of this method has to be introduced. More precisely, this method uses fuzzy preference relations, aggregated by means of weighted ordered weighted averaging aggregation operators (WOWA). For the exploitation phase the extended weighted voting algorithm is introduced and studied in detail. Finally, the goodness of this approach is analyzedusing it to combine different points of view (people, environment, assets and reputation impact for the company) in the assessment of risk associated with human reliability [9].

Jiahao Zeng, Min An, Nigel John Smiths' work is Application of a fuzzy based decision making methodology to construction project risk assessment. The increasing complexity and dynamics of construction projects have plagued the construction industry with substantial hazards and losses. Project risk management, therefore, has been recognised critical for the construction industry to improve their performance and secure the success of projects. Risk magnitude may be assessed by considering two parameters: risk likelihood and risk severity. However, there are many possible risk factors in construction, which lead to a project failure and these risk factors should be incorporated into the evaluation process. Factor index is therefore introduced to structure and evaluate these factors and integrate them into the decision making process of risk assessment. This article presents a risk assessment methodology to cope with risks in complicated construction situations. The application of fuzzy reasoning techniques provides an effective tool to handle the uncertainties and subjectivities arising in the construction process. A modified analytical hierarchy process is used to structure and prioritize diverse risk factors. Finally, an illustrative example on risk analysis of steel erection of the superstructure in a shopping centre is used to demonstrate the proposed methodology. The results indicate that by using the proposed methodology the risks associated with steel erection can be assessed effectively and efficiently [10].

An T. Nguyen, Long D. Nguyen, Long Le-Hoai, Chau N. Dang made a parer; Quantifying the complexity of transportation projects using the fuzzy analytic hierarchy process. Transportation projects are increasingly complex. A systematic approach for measuring and evaluating complexity in transportation projects is imperative. Thirty six project complexity factors were identified specifically for transportation construction. Using factor analysis, this study deduced the six components of project complexity, namely sociopolitical, environmental, organizational, infrastructural, technological, and scope complexity. The Fuzzy Analytic Hierarchy Process (Fuzzy AHP) method was employed to determine the weights of the components and parameters of project complexity. Sociopolitical complexity was the most defining component of complexity in transportation construction. A complexity level (CL) was proposed to measure the overall project complexity. The application of the proposed approach was demonstrated in a case study of three transportation projects performed by a heavy construction company. As a quantitative measure CL enables managers to betteranticipate potential difficulties in complex transportation projects. As a result, scarce resources will be allocated efficiently among transportation projects in a company's portfolio [11].

Abel Pinto's study have the name QRAM a Qualitative Occupational Safety Risk Assessment Model for the construction industry that incorporate uncertainties by the use of fuzzy sets. Occupational safety risk assessment is the core of safety practices. Is a complex process that requires the consideration of sundry parameters, which are often difficult to quantify. This paper presents the new

developed fuzzy QRAM model, which intends to support construction companies in carrying out their responsibilities to reduce occupational safety risks. The innovative aspects of QRAM model is to embody assess of the safety climate and the safety barriers effectiveness as assessment dimensions and the use of fuzzy sets theory to enhance the use of imprecise and incomplete information, elicited by linguistic variables. The QRAM model was designed based on the best academic and empirical knowledge about safety risks on construction industry, biomechanical data and laws of physics, chemistry and engineering. The lack of credible and accurate data, resulting from the in-depth investigation of work accidents in construction industry was the greatest difficulty in carry-out this work. QRAM was, firstly evaluated by ‘‘peer’’ review, with 12 safety experts from Brazil (2), Bulgaria (1), Greece (3), Turkey (3) and Portugal (3) and, then, appraised by comparing QRAM with 2 other occupational safety risk assessment techniques. The safety experts evaluators concluded that: (a) QRAM is a versatile tool to assess occupational safety risk assessment on construction sites; (b) the specific checklists for knowledge elicitation are a good aid and enhance the process objectivity, and (c) the use of linguistic variables is a better way to rate the risk factors thus to render the risk assessment process more objective and reliable [12].

Ehsan Eshtehardian, Abbas Afshar b, Reza Abbasnias’ study is Fuzzy-based MOGA approach to stochastic time–cost trade-off problem. In construction projects, time and cost are manageable objectives with significant interdependencies for which sets of trade-offsmay exist. This study presents a newapproach for the solution of time–cost trade off problemsin an uncertain environment. Fuzzy numbers are used to address the uncertainties in the activities execution times and costs. Fuzzy sets theory is then explicitly embedded into the optimization procedure. A multi-objective genetic algorithmis specially tailored to solve the discontinuous andmulti-objective fuzzy time- cost modelwith relatively large search space. The proposed approach identifies the best set of implementation options defined by the sets of non-dominated solutions Accepted risk level and optimismof the decision maker are addressed using α-cut approach and optimismindex (β) respectively. To illustrate the application and performance of themodel, two case examples are presented, for which separate Pareto fronts are developed. The fuzzy presentation of the non-dominated solution helps the project manager to apply his own level of risk acceptance and degree of optimism in decision making process. Different risk acceptance level and/or optimism leads to different scheduling and sets of Pareto solutions from which the project manager may select his preferred options [13].

Fuzzy model for predicting project performance based on procurement experiences, is Li-Chung Chao, Chih-Sheng Hsiaos’ invistigation. This paper presents a data-clustering-based fuzzy model for predicting the performance of construction projects delivered through different procurement methods. To illustrate themodel, a sample of 96 substation projects of an electric power company, delivered through the design–bid–build (DBB), design–build (DB), and turnkey (TK) methods, were used as training and testing data for model development and verification. Through a factor analysis, an initial set of 48 variables was reduced to nine inputs to themodel for predicting eight performancemetrics as outputs of the model. To establish the input–output relationships for each metric, Sugeno-type fuzzy inference systemswere built, wherein the fuzzy rules were derived fromselected projects as the estimated cluster centers in the training data. For the limited sample, zeroth-order systems built with hybrid training were found to outperformboth first-order systems and stepwise regressionmodels in prediction accuracy, while sensitivity analyses confirmed their robustness. As the data represents the company's procurement experiences of substation projects, the model may be regarded as a way of implementing organizational learning to improve procurement decision [14].

Mahdi Safa, Arash Shahi, Carl T. Haas, Dawn Fiander-McCann, Majeed Safa, Keith Hipel, Sandra MacGillivrays' work is Competitive intelligence (CI) for evaluation of construction contractors. This paper investigates the application of competitive intelligence (CI) techniques for construction contractor selection process, as part of the overall construction contract management. While comprehensive and ongoing CI applications are employed in a variety of industries to provide valuable input for broad strategic decisions, the construction industry lags behind in adopting this methodology. The use of CI for contract management is an important development in light of the realization on the part of major construction contractors that the diffuse nature of the information and lack of robust analysis create numerous uncertainties during the decision-making processes. The findings of this paper show that CI has the potential to improve the process for assessing and selecting contractors, through supporting an unbiased and auditable decision making process. A case-study on using CI for contractor selection on a megaproject in the industrial sector is presented along with the guidelines for the use and implementation of CI in the construction industry as a whole [15].

Optimal deployment of construction equipment using linear programming with fuzzy coefficients, is the name of K. Eshwar, Vellanki S.S. Kumas' exploratory. Decisions made by the experts in the construction industry are usually approximate and contain some sort of imprecision. Classical linear programming (LP) model optimize the decision making situation in a crisp environment. It is difficult to get an optimum decision with imprecise information of the project environment using LP. In the construction industry, identifying optimum number of construction pieces of equipment require experts' knowledge. When certain degree of flexibility needs to be incorporated in the given model to get more realistic results, fuzzy LP is used. But when the parameters on constraints and objective function are in a state of ambiguity then the extension principle is best suited, which is based on personal opinions and subjective judgments. The objective of this paper is to identify the optimum number of pieces of equipment required to complete the project in the targeted period with fuzzy data. A realistic case study has been considered for optimization and LINGO6 has been used to solve the various non-linear equations [16].

Uwe Reuter, Ulrike Schirwitz wrote a paper which called Cost-effectiveness fuzzy analysis for an efficient reduction of uncertainty. Many planning and production processes are characterized by uncertain data and uncertain information. For realistic modeling of such processes these uncertainties have to be considered. The new approach presented in this paper takes epistemic uncertainty into account, for which fuzzy set theory is applicable. In some cases it is possible and useful to reduce epistemic uncertainty by additional monetary investments. It is postulated that uncertain forecast values, e.g. expected safety, quality, or the completion date of a structure, can be improved or scheduled more precisely by a higher investment. Aim of the presented cost-effectiveness fuzzy analysis is the evaluation of the effectiveness of monetary investments on the reduction of uncertainty of the analyzed forecast values [17].

G. Emre Gürcanlı, Ugur Mungens' work is An occupational safety risk analysis method at construction sites using fuzzy sets. The nature of construction work ensures that uncertainties are inherent in every condition; and on-site inspections generally use linguistic expressions rather than metrics to assess the risks of workers at a construction site. Additionally legal records, statistical data and documentation produced by companies are generally insufficient for determining risk. This fact increases the uncertainty of the job site atmosphere. This paper proposes a method for assessment of the risks that workers expose to at construction sites using a fuzzy rule-based safety analysis to deal with uncertain and insufficient data. Using this approach, historical accident data, subjective judgements of experts and the current safety level of a construction site can be combined. In the scope

of this study, first 5239 occupational accidents in the construction industry are identified from 40,000 unclassified occupational accidents in all industries. Next, these 5239 construction accidents are investigated and classified in detail. Combining these data and the subjective judgement of safety experts, we derive three parameters namely the accident likelihood, current safety level and accident severity and they are utilized as input parameters for the fuzzy rule-based system. The method is then implemented on a tunnelling construction site and risk level for all type of accidents is derived. Relevance to the industry: The relevance of this study to industry is linked to the possibility of providing, through the use of proposed methodology, safety level scores for the construction sites that could result in work improvement and productivity. The application of the proposed method can reveal which safety items and factors are most important in improving workers safety, and therefore decide where to concentrate resources in order to improve the safety of the work environment [18].

Risk analysis in construction sites using fuzzy reasoning and fuzzy analytic hierarchy process, is the name of Debasish Majumdera, Joy Debnathb, Animesh Biswas' probe. In this paper a risk assessment process is discussed by considering all kinds of body part wise injuries which are commonly occurred in construction sites. The risk corresponding to each body part wise injuries are measured using a combination of fuzzy reasoning and fuzzy-analytic hierarchy process. In the proposed methodology, risk scores corresponding to each body part wise injuries are measured first using fuzzy reasoning. Then associated weights of each body part wise injuries are calculated on the basis of current safety situation using fuzzy-analytic hierarchy process. The overall risk score of the concerned construction sites are evaluated using sum of product method. This risk assessment system is advantageous in dealing with both qualitative and quantitative risk data due to its capability of capturing vague and possibilistic data in an effective and efficient manner and which may help safety professionals and engineers to improve their safety management system of the construction sites. A case study on risk analysis of an Indian construction company is used to illustrate the application potentiality of the proposed approach [19].

Daniel Baloia, Andrew D.F. Prices' studys' name is Modelling global risk factors affecting construction cost performance. This paper discusses the core issues of global risk factors modelling, assessment and management. The research reported upon forms part of a larger study that aims to develop a fuzzy decision framework for contractors to handle global risk factors affecting construction cost performance at a project level. Major global risk factors affecting cost performance were identified through an extensive literature review and preliminary discussions with construction contractors. The main decision perspectives namely normative and behavioural were explored. Different decision-making technologies, both classical and emergent, such as classical management science techniques and DSSs, KBSs were explored and evaluated. Preliminary indications show that Fuzzy Set Theory is a viable technology for modelling, assessing and managing global risk factors affecting construction cost performance and thus a fuzzy decision framework for risk management can be successfully developed [20].

Using fuzzy risk assessment to rate cost overrun risk in international construction projects, is the name of Irem Dikmen, M. Talat Birgonul, Sedat Han's work. Determination of an appropriate mark-up while bidding for international construction projects is a critical decision. Level of mark-up is a function of risks associated with a project. Construction companies may benefit from a tool that helps them to assess the level of risk so that they can determine an appropriate mark-up. The aim of this paper is to propose a fuzzy risk assessment methodology for international construction projects and develop a tool to implement the proposed methodology. The proposed methodology uses the influence diagramming method for construction of a risk model and a fuzzy risk assessment approach for

estimating a cost overrun risk rating. A computerized system has been developed for an international construction company and applicability of this system during risk assessment at the bidding stage has been tested by using real company and project information. Although the developed tool is company-specific, similar tools may be developed for other companies using the same methodology and expert judgments that reflect different company objectives and risk policies [21].

A. Nieto-Morote, F. Ruz-Vilas' inquiry is A fuzzy approach to construction project risk assessment. The increasing complexity and dynamism of construction projects have imposed substantial uncertainties and subjectivities in the risk analysis process. Most of the real-world risk analysis problems contain a mixture of quantitative and qualitative data; therefore quantitative risk assessment techniques are inadequate for prioritizing risks. This article presents a risk assessment methodology based on the Fuzzy Sets Theory, which is an effective tool to deal with subjective judgement, and on the Analytic Hierarchy Process (AHP), which is used to structure a large number of risks. The proposed methodology incorporates knowledge and experience acquired from many experts, since they carry out the risks identification and their structuring, and also the subjective judgements of the parameters which are considered to assess the overall risk factor: risk impact, risk probability and risk discrimination. All of these factors are expressed by qualitative scales which are defined by trapezoidal fuzzy numbers to capture the vagueness in the linguistic variables. The most notable differences with other fuzzy risk assessment methods are the use of an algorithm to handle the inconsistencies in the fuzzy preference relation when pair-wise comparison judgements are necessary, and the use of trapezoidal fuzzy numbers until the defuzzification step. An illustrative example on risk assessment of a rehabilitation project of a building is used to demonstrate the proposed methodology [22].

Discrete time–cost–environment trade-off problem for large-scale construction systems with multiple modes under fuzzy uncertainty and its application to Jinping-II Hydroelectric Project, is the name of Jiuping Xu, Huan Zheng, Ziqiang Zeng, Shiyong Wu, Manbin Shen's invistigation. This paper presents a discrete time–cost–environment trade-off problem for large-scale construction systems with multiple modes under fuzzy uncertainty. A multi-objective decision making model is established in which the total project duration is regarded as a fuzzy variable. To deal with the uncertainty, the fuzzy numbers in the model are defuzzified by using an expected value operator with an optimistic–pessimistic index. The objective functions are to minimize the total project cost, project duration, crashing cost, and environmental impact. Furthermore, a fuzzy-based adaptive-hybrid genetic algorithm is developed to find feasible solutions. The one-point crossover and repairing strategy for mutations are designed to avoid infeasible solutions. Finally, the Jinping-II Hydroelectric Project is used as a practical example to demonstrate the practicality and efficiency of the model. Results and a sensitivity analysis are presented to highlight the performance of the optimization method, which proves to be very effective and efficient compared to other algorithms [23].

Yao-Chen Kuo a, Shih-Tong Lu made a study which called Using fuzzy multiple criteria decision making approach to enhance risk assessment for metropolitan construction projects. The undertaking of construction projects in metropolitan areas is a risky, competitive, and dynamic proposition requiring a reliable risk assessment model for adequate planning. This study employs a fuzzy multiple criteria decision making (FMCDM) approach to systematically assess risk for a metropolitan construction project. Consistent fuzzy preference relations (CFPR) are used to measure and investigate the relative impact on project performance of twenty identified risk factors included in four risk dimensions. The fuzzy multiple attributes direct rating (FMADR) approach is employed to analyze the occurrence probability of multiple risk factors. Furthermore, the level of risk for the overall Project

caused by individual risk factor is evaluated with the synthesized analysis of the relative impacts and probability of occurrence. The implementation of FMCDM makes the proposed risk assessment approach more reliable and practical than the traditional statistical approach. The proposed approach can be employed to effectively evaluate the overall project risk, and can be benefited to efficiently identify significant risks of a metropolitan construction Project [24].

Measuring the complexity of mega construction projects in China—A fuzzy analytic network process analysis, is the name of Qinghua He, Lan Luo, Yi Hu, Albert P.C. Chan. Mega construction projects in China are usually very complicated in nature, thus evaluating and understanding these complexities are critical to the success of these megaprojects. However, empirical studies related to the measurement of the complexity of megaprojects remain lacking. This paper aims to fill this gap by developing a complexity measurement model based on the Shanghai Expo construction project in China using fuzzy analytic network process (FANP). Firstly, a complexity measurement model consisting of 28 factors, which are grouped under six categories, namely, technological, organizational, goal, environmental, cultural and information complexities, is formulated through literature review using the content analysis technique. The model is then refined by a two-round Delphi survey conducted in the case megaproject. Finally, the refined model and suggestions for its application are provided based on the survey results. The model is believed to be beneficial for scholars and serve as reference for professionals in managing megaprojects [25].

Stefan Verweij'es quests' name is Producing satisfactory outcomes in the implementation phase of PPP infrastructure projects: A fuzzy set qualitative comparative analysis of 27 road constructions in the Netherlands. An understudied aspect for the successful completion of PPP infrastructure projects is the extent to which they are satisfactorily implemented. Studying PPP implementation is important though, because well-planned projects can fail if project implementation is inadequately managed. This article aims to find out which management and public–private cooperation approaches produce satisfaction for public procurers in the implementation phase of different kinds of infrastructure projects. To this purpose, twenty-seven Dutch road construction projects are systematically analyzed with fuzzy set qualitative comparative analysis (fsQCA). The results show four configurations that produce satisfaction. It is concluded that externally-oriented management, which is characterized by a stakeholder-oriented project implementation approach, and close public–private cooperation, where public and private partners work together closely and interactively, are important for achieving satisfaction. In less complex projects with narrower scopes, however, the partners may rely on less interactive forms of cooperation, more characterized by monitoring contract compliance [26].

Prediction of outcome of construction dispute claims using multilayer perceptron neural network model, is N.B. Chaphalkar, K.C. Iyer, Smita K. Patil's work. The occurrence of disputes in Indian construction contracts results in damaging the relationship between the parties apart from the time and cost overruns. However, if the parties to a dispute can predict the outcome of the dispute with some certainty, they are more likely to settle the matter out of court resulting in the avoidance of expenses and aggravation associated with adjudication. Dispute resolution process is mainly based upon the facts about the case like conditions of the contracts; actual situations on site; documents presented during arbitrational proceedings, etc., which are termed as 'intrinsic factors' in this research. These facts and evidences being intrinsic to the cases have been explored by researchers to develop dispute resolution mechanisms. This study focuses on determining the intrinsic factors for construction disputes related to claims raised due to variation from 72 arbitration awards through Case Study approach and furthermore statistically proving their importance in arbitral decision making by seeking professional cognizance through a questionnaire survey. It also further asserts the feasibility of the

multilayer perceptron neural network approach based on the intrinsic factors existing in the construction dispute case for predicting the outcome of a dispute. Data from 204 variation claims from the awards is employed for developing the model. A three-layer multilayer perceptron neural network was appropriate in building this model, which has been trained, validated, and tested. The tool so developed would result in dispute avoidance, to some extent, and would reduce the pressure on the Indian judiciary [27].

A GA-based fuzzy optimal model for construction time-cost trade-off is the name of Sou-Sen Leu, An-Ting Chen, Chung-Huei Yang's study. Owing to different resource utilization, activity duration might need to be adjusted and the project direct cost could also change accordingly. Moreover, activity duration is uncertain due to variations in the outside environment, such as weather, site congestion, productivity level, etc. A new optimal construction time-cost trade-of method is proposed in this paper, in which the effects of both uncertain activity duration and time-cost trade-of are taken into account. Fuzzy set theory is used to model the uncertainties of activity durations. A searching technique using genetic algorithms (GAs) is adopted to search for the optimal project time-cost trade-of profiles under different risk levels. The method provides an insight into the optimal balance of time and cost under dif- ferent risk levels defined by decision makers [28].

C.M. Tam, Thomas K.L. Tong, Gerald W.C. Chiues' study has the name Comparing non-structural fuzzy decision support system and analytical hierarchy process in decision-making for construction problems. Analytical Hierarchy Process (AHP) is a commonly used decision-aiding tool for resolving multi-criteria decision problems. However, users sometimes find it difficult to ensure a consistent pairwise comparison between voluminous decisions. The cause of which is that the Consistency Ratio (CR) is produced after the evaluation process and its global acceptance criteria is limited. When the derived ratio reports some inconsistency, it requires a long process to locate and rectify the problem. The major aim of this study is to look for an alternative decision-aiding tool to AHP, helping to avoid the above problem. The alternative approach proposed in this study is the Non-Structural Fuzzy Decision Support System (NSFDSS). The application of the system is illustrated with a worked example. The results generated by NSFDSS are compared against those generated by the conventional AHP that shows the effectiveness and some unique advantages of the proposed tool over AHP [29].

A fuzzy based multi-objective path planning of construction sites is A.R. Soltani, T. Fernando's study. Movement of materials, plant and site operative from one place to another on construction sites and construction workplaces are of paramount importance to site planners as savings in travel distance can reduce cost and increase productivity. In addition, risks on construction sites can be reduced if the use of vehicles and mobile plant is properly managed by setting out paths avoiding high risks areas. The work reported in this paper presents a framework for supporting path planning analysis of construction sites based on multi-objective evaluation of transport cost, safety, and visibility. This paper investigates the use of fuzzy-based multi-objective optimisation approach in making a more informed strategic decisions regarding the movement path of people and vehicles on construction sites, and detailed decisions regarding travel distance and operational paths on workplaces, enabling site planners to examine paths scenarios that are subjected to a high degree of uncertainty and subjectivity [30].

Fuzzy-multi-objective particle swarm optimization for time–cost–quality tradeoff in construction, is Hong Zhang, Feng Xing's invistigation. The time–cost–quality tradeoff (TCQT) problem is to decide an optimal combination of construction methods with the objective of minimizing cost and time while maximizing quality. Searching for such an optimal combination of construction methods needs to

evaluate the total cost, time and quality of the project. These performances, especially the quality, may be collected and recorded in terms of imprecise or vague data rather than precise numbers. This paper presents a fuzzy-multi-objective particle swarm optimization to solve the fuzzy TCQT problem. The time, cost and quality are described by fuzzy numbers and a fuzzy multiattribute utility methodology incorporated with constrained fuzzy arithmetic operations is adopted to evaluate the selected construction methods. The particle swarm optimization is applied to search for the TCQT solutions by incorporating the fuzzy multi-attribute utility methodology. The proposed methodology is implemented and justified through computational analyses. The study is expected to provide an alternative methodology for solving the time–cost–quality tradeoff problem [31].

Min-Yuan Cheng, Hsing-Chih Tsai, Erick Sudjono' work is Evolutionary fuzzy hybrid neural network for dynamic project success assessment in construction industry. This paper developed an evolutionary fuzzy hybrid neural network (EFHNN) to enhance project cash flow management. Neural networks (NN) and high order neural networks (HONN) are combined in the developed EFHNN to form a hybrid neural network (HNN), which acts as the major inference engine and operates with alternating linear and non-linear NN layer connections. Fuzzy logic (FL) is employed to sandwich the HNN between a fuzzification and defuzzification layer. The authors developed and applied this EFHNN to assess construction industry project success by fusing HNN, FL and GA. CAPP (Continuous Assessment of Project Performance) software was used to study in a dynamic manner the significant factors that influence Project performance. Results showed that the proposed EFHNN can be deployed effectively to achieve optimal mapping of input factors and project success output. Moreover, the performance of linear and non-linear (high order) neuron layer connectors in the EFHNN was significantly better than the performance achieved by previous models that used singular linear NN [32].

A fuzzy multi-criteria decision-making model for construction contractor prequalification, is Ana Nieto-Morote, Francisco Ruz-Vila's study. Selecting an appropriate contractor is essential for the success of any construction project. Contractor prequalification procedure makes it possible to admit for tendering only competent contractor. Prequalification is a multi-criteria decision problem that is, in essence, largely dependent on the uncertainty and vagueness in the nature of construction projects and subjective judgement of the decision maker. This paper presents a systematic prequalification procedure, based on Fuzzy Set Theory, whose main differences and advantages in comparison with other models are the use of an algorithm to handle the inconsistencies in the fuzzy preference relation when pair-wise comparison judgements are used and the use of linguistic assessment or exact assessment of performance of the contractors on qualitative or quantitative criterion, respectively. Finally, a case study for the rehabilitation project of a building at Universidad Politécnica de Cartagena is presented to illustrate the use of the proposed model and to demonstrate its effectiveness [33].

Terry H.Y. Li, S. Thomas Ng, Martin Skitmore's exploratory has the name Evaluating stakeholder satisfaction during public participation in majör infrastructure and construction projects: A fuzzy approach. Numerous different and sometimes discrepant interests can be affected, both positively and negatively, throughout the course of a major infrastructure and construction (MIC) project. Failing to address and meet the concerns and expectations of the stakeholders involved has resulted in many project failures. One way to address this issue is through a participatory approach to project decision making. Whether the participation mechanism is effective or not depends largely on the client/owner. This paper provides a means of systematically evaluating the effectiveness of the public participation exercise, or even the whole project, through the measurement of stakeholder satisfaction. Since the

process of satisfaction measurement is complicated and uncertain, requiring approximate reasoning involving human intuition, a fuzzy approach is adopted. From this, a multi-factor hierarchical fuzzy comprehensive evaluation model is established to facilitate the evaluation of satisfaction in both single stakeholder group and overall MIC project stakeholders [34].

Fuzzy clustering validity for contractor performance evaluation: Application to UAE contractors, is Khaled Nassar, Ossama Hosny's study. Several statistical algorithms are used to categorize contractors. The number of categories depends on the clustering algorithm used. This paper presents a framework for classifying contractors using five of the most common clustering algorithms and assesses their performance with appropriate validity measures. The framework was implemented on actual data for 14 contractors working in UAE using a database of 294 projects. Quantitative measures were suggested and calculated for the contractors in the database. Qualitative measures were determined using AHP. The quality of contractor's staff and equipment was deemed to be the most important measure. The results show that contractors are grouped into four categories based on the quantitative and qualitative measures identified. The Fuzzy-C means algorithm had the highest validity measures when applied to the studied data set. The results show that the proposed framework can be used to categorize contractors into different performance groups in a rational and unbiased way [35].

Min-Yuan Cheng, Duc-Hoc Tran, Yu-Wei Wu's paper's called Using a fuzzy clustering chaotic-based differential evolution with serial method to solve resource-constrained project scheduling problems. The resource-constrained problem seeks to find the optimal sequence that minimizes project duration under current precedence constraints and resource limitations. This study integrates the fuzzy c-means clustering technique and the chaotic technique into the Differential Evolution (DE) algorithm to develop the Fuzzy Clustering Chaotic-based Differential Evolution (FCDE) algorithm, an innovative approach to solving complex optimization problems. Within the FCDE, the chaotic technique prevents the optimization algorithm from premature convergence and the fuzzy c-means clustering technique acts as several multi-parent crossover operators in order to utilize population information efficiently and enhance convergence efficiency. Further, this study applies a serial method to reflect individual-user priorities into the active schedule and the Project duration calculations. The FCDE and serial method are then integrated into a novel optimization model called the Fuzzy Clustering Chaotic-based Differential Evolution for Solving Resource Constrained Project Scheduling Problem (FCDE-RCPSP). Experiments run indicate that the proposed FCDE-RCPSP obtains optimal results more reliably and efficiently than the benchmark algorithms considered. The FCDE-RCPSP is a promising alternative approach to handling resource-constrained project scheduling problems [36].

Supplier selection process in an integrated construction materials management model, is Mahdi Safa, Arash Shahi, Carl T. Haas, Keith W. Hipel's work. The procurement and management of construction materials involve challenges related to reducing inventory, speeding delivery, and increasing the control of materials, thus decreasing the overall project cost. The objective of this research was to define and develop an integrated construction materials management (ICMM) model to address these challenges by deploying principles of virtual inventory management, feasible materials management networks, and a supplier selection process. Contributions include the development of the ICMM model and the demonstrated potential of the selection supplier process for improving procurement for construction projects. The use of the supplier selection process has been demonstrated through implementation on an industrial project and using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method. This process optimizes and validates purchasing at each stage of

fabrication for each construction package. A variety of project-specific criteria are involved in the supplier selection process, including price, lead-time, cash rebate, and supplier performance [37].

A neuro-fuzzy computational approach to constructability knowledge acquisition for construction technology evaluation is Wen-der Yu, Miroslaw J. Skibniewski'es invistigation. This paper describes a methodology for constructability knowledge acquisition of construction technologies. The methodology combines a neuro-fuzzy network-based approach with genetic algorithms. The combination of fuzzy logic with learning abilities of neural networks and genetic algorithms may allow for automatic acquisition of constructability knowledge from training examples and for providing understandable explanations for the reasoning process. The proposed methodology can provide a mechanism to trace back factors causing unsatisfactory construction performance and the necessary feedback to construction engineers for technology innovation. An application example is provided to demonstrate the capabilities of the proposed methodology [38].

Jiuping Xu, Xiaoling Song's search's name is Multi-objective dynamic layout problem for temporary construction facilities with unequal-area departments under fuzzy random environment. An optimal layout problem for temporary construction facilities (TFLP) is very important in large-scale construction projects. This problem involves the planning of temporary construction facilities within the boundaries of the restricted sites so that materials transportation and rearrangement costs are minimized and distances between the various departments are optimized. As construction continues, however, the temporary facilities may need to be dynamically relocated several times to accommodate the various operational demands. Thus, this study proposes a new method for dynamic TFLP with unequal-area departments. To begin with, a multi-objective dynamic optimization layout model based on facilities coordinates is presented, in which the transportation costs between the facilities are described as fuzzy random variables and the temporary facilities, represented as rectangles or squares, are restricted to two-dimensional geometric constraints. Subsequently, the multi-objective positionbased adaptive particle swarm optimization (p-based MOPSO) is developed to obtain feasible optimization solutions for the proposed problem. In order to evaluate the performance of the proposed method, the Jinping-I Hydropower construction project is used as a practical example. The results and further analyses of the model, algorithm evaluation and effectiveness proved that satisfactory solutions were able to be obtained [39].

Min-Yuan Cheng, Hsing-Chih Tsai, Yi-Hsiang Chiu's study is Fuzzy case-based reasoning for coping with construction disputes. The nature of the construction business makes the industry one of the most litigious. Most recent studies of dispute settlement assistant system have applied case-based reasoning (CBR) models to identify similar dispute cases that may be used as references in dispute settlements. Typically, either Euclidean distance (EUD) or cosine angle distance (CAD) has been employed in CBR to measure similarity. However, both EUD and CAD present inherent problems. This situation offers the opportunity to further refine and improve the CBR approach. The CBR was combined with fuzzy-set theory to establish the ''fuzzy case-based reasoning model" (FCBR) for coping with construction disputes. FCBR incorporates a new similarity measurement (NSM) that fuses EUD and CAD, creating a more effective tool with which to calculate target case similarity with historical construction dispute cases. Information on cases similar to a target case assists mediators to deal effectively with construction disputes. The FCBR simulates the process of human reasoning, allowing users to not only easily review historical data, but also efficiently mine information on similar cases [40].

Conceptual cost estimates using evolutionary fuzzy hybrid neural network for projects in construction industry, is Min-Yuan Cheng, Hsing-Chih Tsai, Erick Sudjono's probe. Conceptual cost estimates are important to project feasibility studies and impact upon final project success. Such estimates provide significant information that can be used in project evaluations, engineering designs, cost budgeting and cost management. This study proposes an artificial intelligence approach, the evolutionary fuzzy hybrid neural network (EFHNN), to improve conceptual cost estimate precision. This approach first integrates neural networks (NN) and high order neural networks (HONN) into a hybrid neural network (HNN), which operates with alternating linear and non-linear neuron layer connectors. Fuzzy logic (FL) is then used in the HNN to handle uncertainties, an approach that evolves the HNN into a fuzzy hybrid neural network (FHNN). As a genetic algorithm is employed on the FL and HNN to optimize the FHNN, the final version used for this study may be most aptly termed an 'EFHNN'. For this study, estimates of overall and category costs for actual projects were calculated and compared. Results showed that the proposed EFHNN may be deployed effectively as an accurate cost estimator during the early stages of construction projects. Moreover, the performance of linear and non-linear neuron layer connectors in EFHNN surpasses models that deploy a singular linear NN [41].

Evolutionary fuzzy decision model for construction management using support vector machine, is Min-Yuan Cheng, Andreas F.V. Roy's study. Construction projects are, by their very nature, challenging; and project decision makers must work successfully within an environment that is frequently complex and fraught with uncertainty. As many decisions must be made intuitively based on limited information, successful decision making depends heavily on two factors, including the experience of the expert(s) involved and the quality of knowledge accumulated from previous experience. Knowledge, however, is subject to various factors that cause its value and accuracy to deteriorate. Research has demonstrated that artificial intelligence has the potential to overcome these factors. The Evolutionary Fuzzy Support Vector Machine Inference Model (EFSIM), an artificial intelligence hybrid system that fuses together fuzzy logic (FL), a support vector machine (SVM) and fast messy genetic algorithm (fmGA), represents an alternative approach to retaining and utilizing experiential knowledge. A fmGA is used as an optimization tool to search simultaneously for fittest membership functions, defuzzification parameter (dfp) and SVM hyperparameter (herein C and gamma, c). Two simulations on actual construction management problems demonstrated the EFSIM to be an effective tool for solving various problems in the construction industry [42].

Min-Yuan Cheng, Hsing-Chih Tsai, Kai-Hsiang Chuang's study has the name of Supporting international entry decisions for construction firms using fuzzy preference relations and cumulative prospect theory. This paper emphasizes on supporting international entry decisions for construction firms in a threephase analysis process. Phase I identified significant factors as two categories, namely country and Project factor levels. Phase II stuck on identifying a risk of a country market for construction firms with fuzzy preference relations (FPR) and country factors. Of which, FPR helped elicit factor relative weights. Phase III devoted to figuring out which project or projects had the best prospects of success and profitability for assisting decisions of decision makers. Within phase III, project factors were used for project prospects, FPR for project success probability, and cumulative prospect theory (CPT) for decision maker prospects. This paper integrates FPR and CPT to select country markets and identify project prospects for decision makers of construction firms [43].

A novel multi criteria decision making model for optimizing time–cost–quality trade-off problems in construction projects, is Shahryar Monghasemi, Mohammad Reza Nikoo, Mohammad Ali Khaksar Fasaee, Jan Adamowski'es study. The planning phase of every construction project is entangled with multiple and occasionally conflicting criteria which need to be optimized simultaneously. Multi-

criterion decision-making (MCDM) approaches can aid decision-makers in selecting the most appropriate solution among numerous potential Pareto optimal solutions. An evidential reasoning (ER) approach was applied for the first time in the context of project scheduling to identify the best Pareto solution for discrete time–cost–quality trade-off problems (DTCQTPs). An exhaustive framework to synthesize the MCDM approaches with multi-objective optimization techniques was also proposed. To identify all global Pareto optimal solutions, a multi-objective genetic algorithm (MOGA) incorporating the NSGA-II procedure was developed and tested in a highway construction project case study. The Shannon's entropy technique served to determine the relative weights of the objectives according to their contributions to the uncertainty of the results obtained. A benchmark case study of DTCQTP was solved using the proposed methodology, and the Pareto optimal solutions obtained were subsequently ranked using the ER approach. By investigating the performance of each scheduling alternative based on multiple criteria (e.g., time, cost, and quality), the proposed approach proved effective in raising the efficiently of construction project scheduling [44].

Ibrahim A. Motawa, Chimay J. Anumba, Ashraf El-Hamalawi'es study is A fuzzy system for evaluating the risk of change in construction projects. A major source of risk in construction is the potential changes occurring during the project lifetime. Changes in construction projects often result from the uncertainty associated with the imprecise and vague knowledge of much project information at the early stages of projects. IT systems for change management largely focus on managing reactive changes, in which changes are recorded and then propagated to the concerned project members. However, proactive change management is hardly dealt with. Proactive change management requires estimating the likelihood of occurrence of a change event as well as estimating the degree of change impacts on project parameters. A fuzzy system is proposed in this paper to maintain these requirements. The system simulates the relationships between change causes and effects, and is intended to facilitate proactive change management on projects [45].

Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies is Osman Taylana, Abdallah O. Bafailb, Reda M.S. Abdulaala, Mohammed R. Kabliaa's invistigation. Construction projects are initiated in dynamic environment which result in circumstances of high uncer-tainty and risks due to accumulation of many interrelated parameters. The purpose of this study is to usenovel analytic tools to evaluate the construction projects and their overall risks under incomplete anduncertain situations. It was also aimed to place the risk in a proper category and predict the level of it inadvance to develop strategies and counteract the high-risk factors. The study covers identifying the keyrisk criteria of construction projects at King Abdulaziz University (KAU), and assessing the criteria by theintegrated hybrid methodologies.The proposed hybrid methodologies were initiated with a survey for data collection. The relative impor-tance index (RII) method was applied to prioritize the project risks based on the data obtained. Theconstruction projects were then categorized by fuzzy AHP and fuzzy TOPSIS methodologies. Fuzzy AHP(FAHP) was used to create favorable weights for fuzzy linguistic variable of construction projects overallrisk. The fuzzy TOPSIS method is very suitable for solving group decision making problems under thefuzzy environment. It attempted to incorporate vital qualitative attributes in performance analysis ofconstruction projects and transformed the qualitative data into equivalent quantitative measures. Thirtyconstruction projects were studied with respect to five main criteria that are the time, cost, quality, safetyand environment sustainability. The results showed that these novel methodologies are able to assess the overall risks of construction projects, select the project that has the lowest risk with the contributionof relative importance index. This approach will have potential applications in the future [46].

An integrated fuzzy multi criteria group decision making approachfor ERP system selection is Burak Efe's work. This paper aims to ease group decision-making by using an integration of fuzzy AHP (analytic hierar-chy process) and fuzzy TOPSIS (technique for order preference by similarity to ideal solution) and itsapplication to software selection of an electronic firm. Firstly, priority values of criteria in software selec-tion problem have been determined by using fuzzy extension of AHP method. Fuzzy extension of AHPis suggested in this paper because of little computation time and much simpler than other fuzzy AHPprocedures. Then, the result of the fuzzy TOPSIS model can be employed to define the most appropriatealternative with regard to this firm's goals in uncertain environment. Fuzzy numbers are presented in allphases in order to overcome any vagueness in decision making process. The final decision depends on thedegree of importance of each decision maker so that wrong degree of importance causes the mistakenresult. The researchers generally determine the degrees of importance of each decision maker accordingto special characteristics of each decision maker as subjectivity. In order to overcome this subjectivityin this paper, the judgments of decision makers are degraded to unique decision by using an attributebased aggregation technique. There is no study about software selection using integrated fuzzy AHP-fuzzy TOPSIS approach with group decision-making based on an attribute based aggregation technique.The results of the proposed approach and the other approaches are compared. Results indicate that ourmethodology allows decreasing the uncertainty and the information loss in group decision making andthus, ensures a robust solution to the firm [47].

Fuzzy-Entropy Theory Comprehensive Evaluation Method and Its Application in Building Construction Safety, is Liu Dunwena, Yu Leia, Li Boa's essay. In order to improve the safety management level of construction site, a new kind of safety evaluation method using the combination of fuzzy mathematics and the entropy theory was put forward. According to the hierarchical analysis, the evaluation index system of the safety management was firstly established. Then, the safety inspection table for the site was designed. At last, the weights and membership of the second class indexes were calculated and the membership matrix of the first class indexes was generated by fuzzy evaluation method. At the same time, the weights of the first class indexes were calculated using the entropy theory. Aimed at the evaluation results, some corresponding measures for improving the safety management level of the construction site was put forward. The results show that the hybrid method, which can overcome the shortcomings of each single method, is feasible, practical and operational in construction site safety assessment [48].

Wu Zhongguang, SHEN Ruijun's work's called Safety evaluation model of highway construction based on fuzzy grey theory. In the light of factors influencing highway construction safety that have characteristics of fuzziness and uncertainty, combined with the principle of close degree in fuzzy mathematics, a fuzzy grey connection degree is put forward. The evaluation model based on the fuzzy grey relational analysis theory is established and the construction safety evaluation index system is constructed, the weight of each index is determined by Analytic Hierarchy Process (AHP) and the connection degree is also calculated, and then the rank of evaluated highway construction sites is obtained. It is shown that under the condition of mastering the inspection data of actual construction sites, good results can be achieved through application of the model [49].

Contractor selection for construction project, with the use of fuzzy preference relation, is Nabi Ibadov's invistigation. During the phase of investment planning, choice of contractor is one of the most important decisions. One of the methods for assessing competences of contractors applying for the contract is their pre-selection. In the article, author describes algorithm for choice (selection) of contractor. The algorithm is based on fuzzy preference relation. In mathematical point of view, it is

based on ordering theory and fuzzy sets theory. The article provides an example of the algorithm used for selection of contractor for construction works. The choice was made basing on criteria such as: reputation, technical capabilities, financial situation and organizational skills [50].

Yanjun Zhaoa, Xiaojun Liuc, Yan Zhaoa's probe is Forecast for construction engineering risk based on fuzzy sets and systems theory. Risk management is a critical point of successful construction engineering in modern corporations, and furthermore, risk forecast provides a very important foundation for risk management. In order to forecast risk effectively and quantitatively, the fuzzy sets and systems theory is applied. According to the hierarchy of construction engineering risks, the risk system is established; depending on the expert meeting law and the Delphi, the forecast sets and weight sets of risk are completed; applying the fuzzy theory, the various levels of risks and holistic risk of construction engineering are forecasted; combining the maximum degree of membership, the weighted-average method and the fuzzy distribution method, the conclusion of forecast is put forward; in the light of the demand in construction engineering, the risks may be forecasted again after the control and transfer measures of risk have been made; thus, the risk forecast model is developed. To illustrate the rationality and practicability of this model, a case study will be demonstrated [51].

IV. Conclusion

This study has conducted a literature review on the application of fuzzy techniques in CM discipline. According to the studies which investigated in this perusal, it can be understand that fuzzy logic applications used in different areas of CM discipline with success, like; Time–cost trade-off analysis of project networks, Multi-factorial risk assessments, construction project risk assessments, Qualitative Occupational Safety Risk Assessment Models, Stochastic time–cost trade-off problems, Predicting project performances based on procurement experiences, Competitive intelligence (CI) for evaluations of construction contractors, Optimal deployment of construction equipments, Cost-effectiveness, Occupational safety risk analysis at construction sites, Risk analysis in construction sites, Modelling global risk factors affecting construction cost performances, Cost overrun risks in international construction projects, Construction projects' risk assessments, Contractors' perceptions of the use of costs of quality system in building construction projects, Discrete time–cost–environment trade-off problems for large-scale construction systems, Enhance risk assessments for metropolitan construction projects, Measuring the complexity of mega construction projects, The use of time and cost utility for construction contract awards, Decision-making for construction problems, multi-objective path planning of construction sites, Dynamic project success assessments in construction industry, Construction contractors prequalifications, Stakeholder satisfactions during public participation in major infrastructure and construction projects, Contractors' performance evaluations, Solving resource-constrained project scheduling problems, Supplier selection processes, Constructability knowledge acquisitions for construction technology evaluations, Dynamic layout problems for temporary construction facilities, Decision models for construction management, Supporting international entry decisions for construction firms, Optimizing time–cost–quality trade-off problems in construction projects, Evaluating the risk of changes in construction projects, Construction projects selections and risk assessments, ERP systems selections, Objective construction contract awards, Comprehensive evaluation methods and its applications in building construction safety, Safety evaluation models of highway constructions, Contractor selections for construction projects, Forecasting for construction engineering etc.

Albert P. C. Chan, Daniel W. M. Chan, John F. Y. Yeung tells in their paper which name is: Overview of the Application of Fuzzy Techniques in Construction Management Research; It has been found that fuzzy research, as applied in construction management discipline in the past decade, can be divided into two broad fields, encompassing: a) fuzzy set/fuzzy logic; and b) hybrid fuzzy techniques, with the applications in four main categories, including: a) decision making; b) performance; c) evaluation/assessment; and d) modeling. Based on a comprehensive literature review on the applications of fuzzy set/fuzzy logic, and hybrid fuzzy techniques in construction management research, an increasing trend of applying these techniques in construction management research is observed. Therefore, it is suggested that future research studies related to fuzzy techniques can be continuously applied to these four major categories. Fuzzy membership functions and linguistic variables in particular can be used to suit applications to solving problems encountered in the construction industry based on the nature of construction, which are widely regarded as complicated, full of uncertainties, and contingent on changing environments. Moreover, hybrid fuzzy techniques, such as neurofuzzy and fuzzy neural networks, can be more widely applied because they can better tackle some problems in construction that fuzzy set/fuzzy logic alone may not best suit. Finally, an increasing trend of applying fuzzy techniques in the building science and environmental disciplines is also observed; it is believed that the application of fuzzy techniques will go beyond the construction management area into these disciplines as well [52].

Fuzzy membership functions and linguistic variables can be particularly employed to suit applications to tackling construction problems facing the aforesaid nature of construction. In addition, hybrid fuzzy techniques, such as neurofuzzy and fuzzy neural network, can be more broadly adopted because they can better solve some construction problems that fuzzy set/fuzzy logic alone may not best suit [52].

This investigations' evidences are parallel with Albert P. C. Chan, Daniel W. M. Chan, John F. Y. Yeung's study. Olso optimisation is another aim for using fuzzy logic in CM. In addition, findings and recommendations which given below can be mentioned;

- FL applications, gives very positive results in CM applications.
- A construction project is achieving success with many unknowns at the end of a process. FL offers an appropriate risk management tool in such cases.
- For determining the magnitude of impact of the construction project risks, Analytic Hierarchy Processes' theory of FL's risk analysis and management model has been observed in recent years has become more available.
- Optimization and control of CM problems can be made with FL approach.
- It is often encountered that in construction projects, with the obligation to choose among alternatives. It's understood that it can be used as decision support systems for quantitative decision making methods in choosing from the available alternatives that require cases in acquisition and investment decisions. It has been shown in the examined studies that; in solving the problem of multi-purpose, Fuzzy AHP (Analytical Hierarchy) method with taking into account the uncertainties, to be useful as a tool to provide a solution.
- One of the methods commonly used in multi-criteria decision-making methods of fuzzy TOPSIS method, on multiple criteria-based assessment and decision-makers is a successful method. In addition to use of linguistic variables, it is able to offer a qualitative method.
- Optimization techniques with FL approach would develop decision-making skills in the construction industry.

- An important point for the success of fuzzy model results is; it is essential to have sufficient experience and foresight of the persons concerned (experts) who would realize the application.
- The number of membership functions of the inputs and the number of training epochs should be selected optimally and carefully.

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