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A Review on Risk Analysis of Construction Management By Fuzzy logic

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ABSTRACT
The uncertainty of construction environments has made them one of the most highlighted fields in risk management. Although recently the construction industry has started to benefit from risk management and risk analysis, it has been discovered since the 1980s that construction is one of the industries most in need of applying risk management. Risk management is a procedure to control the level of risk in projects and to mitigate its consequences; therefore construction projects which deal with high level of uncertainty due to geographical factors, weather conditions, type of project, economical impact, subcontractor availability, political factors, construction delivery methods, etc. should follow an effective risk management and analysis plan. Risk analysis and assessment, one of the important steps in risk management, involves analyzing identified risk factors using a qualitative or quantitative method to determine the severity of the risk factors. This research reviews some models and methods in construction engineering literature and makes an original contribution to developing a quantitative risk analysis method based on fuzzy logic. This research seeks to develop a model based on fuzzy logic and fuzzy set theory to fill in some of the gaps between real construction environments and scientific approaches. Fuzzy logic plays a key role as the converter of natural verbal human thoughts to computational comprehensive intervals. Fuzzy logic and fuzzy set theory have been used as the foundation of this new methodology. Fuzzy intervals were used for input data in order to create more realistic assumptions than those derived from a set of crisp numbers; this leads to better results, fewer failures, and a lower tolerance for risk in construction project planning.

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Background:

In recent years, intensive research and development have been carried out in the area of project risk management, widely recognized as one of the most critical procedures and potential areas in the field of project management. Voetsch (2004) found a statistically significant relationship between management support for risk management processes and reported project success. Cheng (2001) remarks that shortcomings and opportunities in this field have been identified. He also mentions that some of the deficiencies are related to the ever increasing complexity of construction projects. Subcontracting is expanding since many companies are focusing solely on their core business, which results in more complex project networks and greater numbers of project participants; therefore conflict of interests will result in higher risk level. Construction projects are characterized as very complex projects, where uncertainty comes from various sources (Miller 2001). Many research and practical techniques have been applied to manage all these uncertainties and their consequences; however, there is a gap between risk management techniques and their practical application by construction contractors and involved parties.

This study tries to find a quantification method for risk analysis and assessment based on fuzzy logic and fuzzy arithmetic. This method has been developed to meet the practical concerns of construction and to enhance the benefits of the procedure.

Problem Statement and Objectives:

Construction environments are one of the most highlighted fields in risk management as the nature of the industry carries uncertainty. Every new project, even identical ones such as residential developments, office buildings, or chain stores, has new constrains. In a risk analysis and management procedure, one of the important steps is to calculate and quantify risks in a comprehensive and meaningful way. Different methods

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have been developed in this area, and all various approaches have their own advantages and disadvantages. Despite different terminologies and definitions in the risk management literature the main goal and concept is almost the same, but different approaches are involved in gaining the best practice. In this research, many valuable methods are reviewed and a contribution in using the Fuzzy Logic methods and arithmetic for Construction Projects Risk Management has been made. The goals of this research are as follow:

1. To conduct an extensive review in literatures and current practices in Construction Risk Management systems
2. To develop a systematic quantification method using Fuzzy Logic in risk analysis and assessment for Project Risk Management
3. To verify the method by applying the data from an existing project's risk analysis and to demonstrate the results of their comparison

Literature Review:

Introduction:

This Section will review the literature, introducing the concepts, terminologies and definitions in risk management with a focus on construction projects. Although recently the construction industry has started to benefit from risk management and risk analysis, it has been discovered since the 1980s that construction is one of the industries in need of applying risk management.

Much research has been conducted on this topic which tried to find a systematic process to overcome the issues taking place in construction projects. Risks associated with construction projects are due to the inherent nature of construction jobs. A variety of issues has been considered such as budget overruns, time schedule extensions, technical problems, safety issues and so on.

The first three Subsections of this Section demonstrate what the literature says about uncertainty as the origin of risks and opportunities, risk as a result of uncertainty and some practiced methods to measure it. Afterwards, in part 2.5, the literature about fuzzy logic and fuzzy set theory are mentioned. The methodology for the quantitative part is based on fuzzy logic, fuzzy sets and related terms; therefore, fuzzy logic and fuzzy set theory and its application and terms in risk assessment are reviewed as well. Part 2.6 reviews more literature on risk management. Additionally, a few risk management standards are introduced in the last section.

The Nature of Uncertainty in Construction Industry:

The Construction Industry Institute defines Uncertainty as "the gap between the information required to estimate an outcome and the information already possessed by the decision maker" (CII 1989). El-Cheikh (2007) suggests that "the nature of uncertainty in any problem is a vital point; scientists in general and engineers in particular should be able to determine this nature before choosing the suitable methods or models to express and address that uncertainty." In practice, the uncertainty in construction may arise from many possible sources such as geographical factors, weather conditions, type of project, economical impact, subcontractor availability, political factors, and construction delivery methods.

To have a deeper understanding of uncertainty, the nature of uncertainty should be reviewed. As a common example, Teres (2005) compared two origins of uncertainty by explaining throwing dice versus playing dominos. He discussed that if we throw a dice an infinite number of times and record the frequency with which each number appears, we will find that the probability of any of the numbers (1 to 6) appearing is 1/6. Knowing this for a fact, the next time we roll the dice we are uncertain as to which of the six numbers will appear, but this time we have a measure of the uncertainty. This type of uncertainty is due to the random nature of the events, also known as Aleatory Uncertainty. Krinitzsky (2002) also remarks that "aleatory knowledge is predicted knowledge. It is satisfactory or unsatisfactory, depending on the nature of the prediction and the use that is made of it."

Terese (2005) clarifies the other form of uncertainty by explaining the game of dominos. The game starts with shuffling the pieces and distributing them between players. The fact is the pieces' arrangement is fixed while the values are unknown. By examining the pieces, we can discover the exact pieces each player has, but this is what the game is all about. The key to winning the game is to find the values of the pieces through observation during the game. In this scenario, uncertainty is due to a lack of knowledge. The more pieces we are allowed to see, the lower the uncertainty in guessing the value of the remaining pieces. This sort of uncertainty is known as Epistemic Uncertainty. Krinitzsky (2002) also defines epistemic knowledge as interpreted knowledge; he mentions that 'it may or may not be uncertain. Interpreted knowledge has been certain enough in the past to constitute a highly rational basis for the development and growth of engineering, or there would be no engineering or much of anything else on a creative level."

These definitions denote that when more information becomes available, epistemic uncertainty tends to reduce, while aleatory uncertainty will not. It can be inferred that most engineering practices relate to epistemic uncertainty more than to aleatory uncertainty, as the risks involved in projects lessen through the end of them. This concept is shown in Figure 2.1. As the project proceeds the level of uncertainty decreases relatively. At

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the time of starting a project during feasibility studies through the end as the information and knowledge about tasks is clarified, the level of uncertainty and fuzziness of the project decreases.

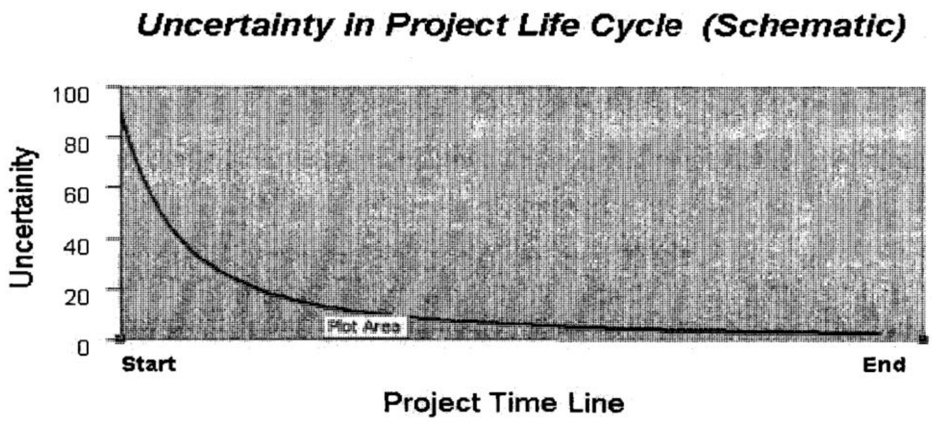

Fig. 2(1): The uncertainty schematic chart during project life cycle.

Stern & Fineberg (1996) discuss in their paper the fact that uncertainty is more a subject of judgment and agreement than a matter of measurement. Still, the next step after finding the origin of uncertainty would be to determine how we should deal with that in a global comprehensive method. The answer would be provided by searching for a proper measuring system.

Measurement of Uncertainty:

Uncertainty measurement has kept the human mind busy since the 17^{th} century. The history of the calculation of uncertainty leads us to the curiosity of gamblers in the 17l century who tried hard to find a mathematical solution to evaluate the risk and probabilities in throwing dice. Finding a way to convert the concepts of luck and chance to a comprehensive Figure has been a serious concern by for centuries, but the first attempt to formulate it as a mathematical method did not take place until 1965 after a gambler's dispute.

Based on the literature, one of the best ways to express uncertainty is to use probability as the measure of uncertainty. Lindley (1987) mentions in his paper that "the only satisfactory description of uncertainty is probability." He strongly believes that every statement should be in the form of probability and that every uncertainty statement must be in the form of a probability, and he also believes that by using the rules of probability, several uncertainties can be combined together. He concludes that "calculus of probabilities is adequate to handle all situations involving uncertainty; in particular, alternative descriptions of uncertainty are unnecessary."

Uncertainty can be quantified with the use of probability but its mathematical interpretation is not always straightforward (Whitman, 1996). Based on Vick (2002) there are two schools in the interpretation of probability: frequentist and degree-of-beliefs. Teres (2005) summarizes Vick's two schools of thought in his review of uncertainty measurement and describes "the Frequentist point of view assumes that the probability at which an event happens is the result of an intrinsic frequency underlying the system being observed." This state of nature could be explained by conducting experiments and observations. He continues with the other school of thought and remarks that The Degree ofbelief 'school of probability estimates uncertainty in circumstances where not enough evidence is available and its estimation needs to be elicited from people's minds. Judgment plays a paramount role in this evaluation as many things that appear evident for an expert, might be difficult to evaluate for another. (3)

The mathematical analysis of uncertainty has its origins in probability theory. In classical probability theory, precision and likelihood are in conflict as the higher the precision the less likely it is to happen. Using the classical probability theory, a theory has been developed at the University of Bristol called the Interval Probability Theory. This theory represents the probability as an interval number. The probability of some tasks to take place or their possible consequences might be defined fairly well while others are impossible or difficult to define.

Still there are many arguments on the approaches used in measuring uncertainty. Some scholars discuss the measurement of uncertainty in the possibility theory and there are more who prefer other methods and a third group who link all these theories to achieve their goal. Jamison (1998) explains in his paper that "it is shown that possibility distributions can be formulated within the context of probability theory and that membership values of fuzzy set theory can be interpreted as cumulative probabilities."

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Sometimes uncertainty is recognized but cannot be measured, quantified or expressed in statistical terms. In such cases, all that can be done is to examine various possible hazard scenarios and subjectively rank them in terms of probability and consequence (Sun 2002). That is the link between uncertainty and fuzzy logic. The relationship between these two concepts is explained more in section 2.5.

Risk:

Result of Uncertainty:

Kirchsteiger (2005) defines Risk as the" possibilities that technological activities or natural events lead to consequences that affect what human values." While the risk definition in RAMP (1998) explains "risk is the likelihood of variation in the occurrence of an event, which may have either positive or negative consequences." The latter definition matches more the concept of the author of this research. Hillson (2002) mentions in his paper that "the traditional view of risk is negative, representing loss, hazard, harm and adverse consequences. But some current risk guidelines and standards include the possibility of 'upside risk' or opportunity." Opportunities are circumstances in which an uncertainty leads to a benefit or positive effect on the project. Despite recent considerations for upside risks, most risk analysis and management process still focus on managing hazards and threats, and the area of opportunities needs more work. While the concept of risk might bring only negative issues to most people's mind, it includes all kinds of risk like opportunities; the risk management process is considered as a Risk/Opportunity Management analysis, called ROM in current research.

AbouRizk (2008) explains the Risk Factors as "every possible event or issue that may cause harm to the project, "and the Risk Analysis would be the approach to identify these factors and the methodology used to quantify them. Risk Analysis is defined as the process of identifying risk factors and using a qualitative or quantitative method to calculate the severity of those factors in order to manage them. The need for early conduction of Risk Analysis in the engineering curricula has been suggested by Whitman (1996), Morgenstern (1995), Faber and Stewart (2003), and others. The risk in projects is a direct result of uncertainty from different aspects, either because of the nature of project as Frequentist point of view or judgmental uncertainty. Therefore it is important to state the approach adopted in the characterization of risk, and what is assumed of the associated uncertainty, when the risk factors are communicated to the concerned parties or the decision makers.

Risk Severity is an index for demonstrating the level of risk to be dealt with in the project. In this research it has been assumed to be the product of the likelihood of a risk or opportunity taking place and the magnitude of the risk-consequence impact. Obviously the first step to find the risk severity would be calculating or estimating the likelihood and impact of the risk factors.

Severity = (likelihood of occurrence a risk) x {magnitude of impact):

Likelihood, in other words, can be the probability of a risk factor happening. The Impact can also be defined as the magnitude of the risk's result, which can be described in terms of monetary value, time or other values. In this research, all the terms are considered to be dimensionless in order to unifying them.

Fuzzy Logic and Fuzzy Set Theory:

Fuzzy Logic has emerged out of Lotfi Zadeh's (1965) developments in theory of fuzzy sets by Lotfi Zadeh (1965). Fuzzy Sets are sets with partial membership function. Fuzzy sets have been introduced by Zadeh as an extension of the classical set theory. In other words, a classical or standard set can be considered as a subset of a fuzzy set. In classical set theory, the membership of elements in a set is bivalent: an element pertains or does not pertain to a set. It is not allowed to be included and in a set and its complementary set simultaneously. Based on the classical theory, many real situations cannot be handled. On the contrary, fuzzy set theory allows the gradual membership of elements in a set; this is described with the term called membership function, which has a value in real interval of [0, 1].

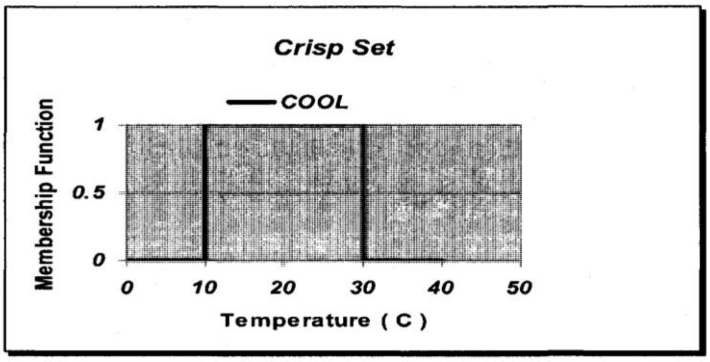

Fig. 2(2): Crisp set of members demonstrating "cool temperature"

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A good example is in the situation of using imprecise and vague and propositions like "this person is smart" (handsome, rich, etc). In Figures 2.2 and 2.3 below a non-fuzzy set (crisp set) and a fuzzy set are illustrated. In Figure 2.2 an interval of 10 to 30 degrees centigrade is considered as absolutely cool whilst other temperatures are not cool at all. It is obvious there are sharp edges on end points, which is not realistic at all. In the real world we cannot even distinguish between 30 C and 31 C, but in a crisp set demonstration there is a sharp edge dividing these areas. Comparing Figure 2.2 and Figure 2.3 shows clearly the difference of using fuzzy concepts instead of crisp methods. The partial membership function for members of a set showing the temperature for instance makes more sense.

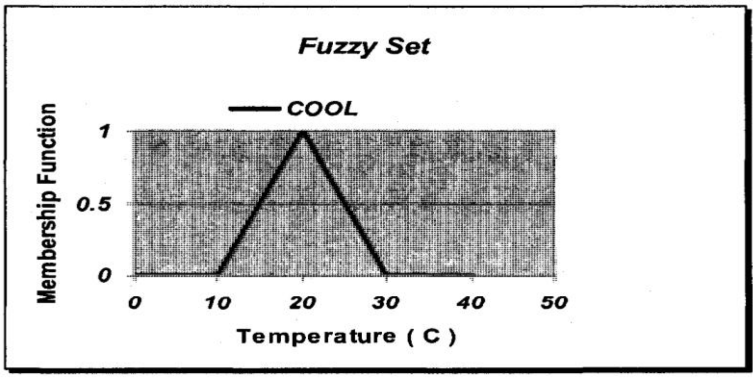

Fig. 2(3): Fuzzy set of members demonstrating "cool temperature"

Kosko (1997) mentioned that the difference between fuzzy sets and classical sets is called the law of the excluded middle. Denoting the definition of a classical set in which an object either belongs or does not belong to the set, he brings an example that a number fully belongs to the set of even numbers and not at all to the set of odd numbers and vice versa. Kosko (1993) summarizes the origin and history of developing fuzzy logic in a paragraph: The modern study of fuzzy logic and partial contradictions had its origins early in this century, when Bertrand Russell found the ancient Greek paradox at the core of modern set theory and logic. According to the old riddle, a Cretan asserts that all Cretans lie. So, is he lying? If he lies, then he tells the truth and does not lie. If he does not lie, then he tells the truth and so lies. Both cases lead to a contradiction because the statement is both true and false. Faced with such a conundrum, classical logic surrenders.

In fuzzy logic, this statement can be analyzed: the answer is actually partially true and partially false. He mentions that 50 percent of the time the Cretans lie and the other half they do not lie. In the 1920s a Polish logician, Jan Lukasiewicz, evolved the principles of multi-valued logic, in which statements can take partial true values between the interval zero and one of black or white logic. In 1937 quantum philosopher Max Black brought up the term "Vagueness" and applied multi-valued logic to sets of objects; therefore the first fuzzy set curves emerged. It was 30 years later that Lotfi A. Zadeh, the chair of the electrical engineering department at UC Berkeley at that time, published the paper "Fuzzy Sets," a remarkable literature which gave the field its name. Zadeh applied Lukasiewicz's logic and developed a complete algebra for fuzzy sets. Despite all, fuzzy sets have not been used until the mid 1970s, when Ebrahim H. Mamdani of Queen Mary College in London designed a fuzzy controller for a steam engine. He used the term
'fuzzy logic' in his developed system and since then it has stand for any mathematical or computer system that reasons with fuzzy sets.

Zadeh (1994) divides fuzzy logic into two main directions:

1. Fuzzy logic in the broad sense
2. Fuzzy logic in the narrow sense

The latter one is a relatively new discipline of generalized classical multivalued logic. On the other hand, fuzzy logic in a broad sense is used to convert the vagueness of linguistic terms, in analysis of natural language statements. Vagueness is a form of epistemic uncertainty that is not due to lack of knowledge but because of imprecise meanings of linguistic terms (Hajek 2006). In this research the fuzzy logic in the broad sense has been used, to analyze of vagueness in natural language and convert the opinions of managers and participants in a construction project to a mathematical index that can be dealt with in computational systems like programs or simulators.

Computers do not reason as brains do. Computers understand determined facts; they can analyze the information which has been reduced to strings of zeros and ones and statements that are either true or false. The human brain can reason with vague assertions or claims that involve uncertainties or value judgments: "He is handsome," or "That car is fast," or "She is slim." Unlike computers, humans have intuition that enables them to reason in a world where things are only partially true. Kosko (1993) explains: "fuzzy logic is a branch of machine intelligence that helps computers paint gray, commonsense pictures of an uncertain world." Logicians in the 1920s first broached its key concept: everything is a matter of degree.

Fuzzy Logic filled many gaps in scientific and practical problems .The concept of fuzziness is something that we deal with in our daily life. Simple examples about a fuzzy description can be our idea about the weather such as "Cold" "Hot," or "Nice": without necessarily mentioning the degree or humidity we can recognize these explanations as a human being. Obviously, different interpretations could be made by these explanations depending on the context or environment and group of people, but it still makes sense when people talk about these terms in every day tasks and events. As a good example portfolio theory mentioned by Eldukair (1990) in his paper, is one of the areas which cannot be dealt with classical logic. This theory seeks for a correlation between projects due to their several factors which have different importance and level of contribution to projects. He states that:

The importance and the level of contribution of each factor can be estimated based on experience and judgment. Experience and judgment may easily be expressed in subjective measures rather than mathematical terms. Classical portfolio theory fails to incorporate subjective information. The subjective measures can be translated into mathematical values using the fuzzy set theory.

Construction is not apart from this concept as it is about people, communication, human skills, and qualitative technical issues. Ross (2002) divides the information world into some regions with different effects on the approach to calculate the risks caused by uncertainty.

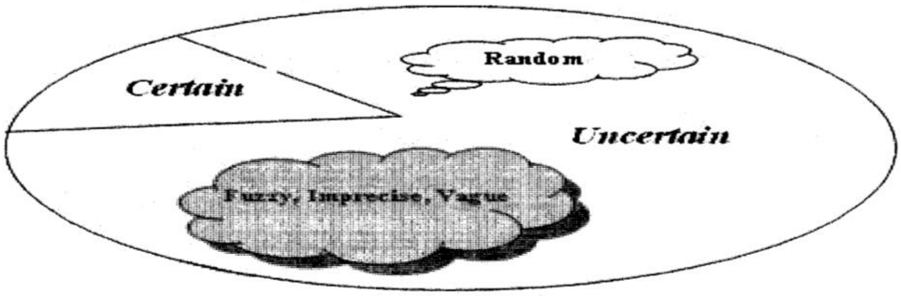

Fig. 2(4): Forms of uncertainty in the information world, (Ross 2002)

As it is shown in the Figure 2.4 the whole information world is divided into "Certain" and "Uncertain" zones. The uncertain part which causes the risk factors includes two major types of uncertainty: "Randomness" and "Impreciseness & Fuzziness." The randomness part of uncertainty is a concept related to probability and percentages while the fuzziness deals with degrees of membership- they are not the same Probabilities measure whether or not something will take place while fuzziness measures the degree to which something happens or exists. The statement, "There is 70 percent chances the weather will be cool" conveys the probability of cool weather happening, but saying that the morning feels "70 percent cool" means that the air feels cool to some extent.

Conversely, the statement can mean that the weather feels just right and warm to a different extent (Koskol993). It was discussed before that the origin of uncertainty affects the risk and risk factors, and consequently the approach to analyzing them. The random part of the uncertainty deals with the fact that in some events like tossing a dice the possible results are definite but the answer is based on randomness. This type of uncertainty can be calculated based on the probability theory. The other part of uncertainty that seems to have a larger portion in uncertain environment is a result of vagueness, impreciseness, and fuzziness. It can be a consequence of lack of knowledge, inadequate data, judgmental opinion, etc. This type of uncertainty is communicated easily between people. All these vague expressions such as "Low," "High," or "Medium" can be sufficient for understanding between human beings, but they are not effective for communicating with computers and programs like scheduling or simulation programs. Fuzzy logic is defined as a proper way to carry this translation from the subjective verbal form of judgments to the numeric, mathematical solutions.

Risk analysis is used to assess projects' risk data in a qualitative process or a quantitative process in which risks are measured by the use of probabilities. However, since being unique is one of the characteristics of every new project, it is clear that no previous data can be provided in advance. Decisions taken and the actions that may be carried out are highly subjective due to the nature of the risk. The risk management approach discussed in this literature identifies the risks, and assesses the likelihood of occurrence of each risk and the magnitude of their impact by using linguistic variables through fuzzy logic and fuzzy sets. The use of linguistic terms is a departure from conventional methods in risk analysis that mainly rely on statistical assessment to quantify the severity of risks in projects. The risk analysis process, using fuzzy logic, is found to be a better way to handle project risk management which is highly subjective, and varies substantially from project to project.

Risk Management:

A systematic concern with risk assessment methodology was raised in the Aerospace sector following the Apollo test in January 1967, in which three astronauts were killed. In April 1969, NASA formed a space shuttle task group. The task group developed "suggested criteria" for evaluating the safety policy which contained quantitative safety goal. (Bedford 2001). Later on, these studies and new probabilistic risk analysis were undertaken in the nuclear sector. The first full-scale application of these methods, including an extensive analysis of the accident consequences, was undertaken in the Reactor Safety Study in 1975. Flanagan (2004) explains the necessity of applying risk management in construction industry and mentions that "the construction industry, because of its nature, is subject to more risk and uncertainty than perhaps any other industry. Yet, managerial techniques used to identify, analyze and respond to risk were not applied in the industry until the 80s."

Risk/Opportunity Management is a constructive way to increase the likelihood of successful completion of the projects while avoiding cost and time overruns. Risk management is defined as a procedure to control the level of risk and to mitigate its effects (Toakley 1989). Risks for which there are ample data can be assessed statistically (PRAM 1997). However, no two projects are identical. Often things go wrong for reasons unique to a particular job condition, time constraints, or working environment. When data is available, a fair estimation of probabilities and consequences of risk factors can be provided. This analysis may bring us to reasons why conditions differed and to what extent, and also how things could have been changed if it was possible to minimize the risk factors and/or their magnitudes. The historical case analysis can help us identify the patterns of hazards and their likelihood in specific cases. This approach relies on data collected in the risk register. (Teres 2006)

The probabilities that can be obtained should be looked at with caution and within the context of the projects. A relevant frequency in one area might likely be meaningless in another. On the other hand, the calculation of small probabilities is almost impossible to elicit to experts without probability trees, for example (Fischoff, *et al*., 1977). Because of projects' engineering, innovations, strong technical or strategic content, a systematic procedure seems preferable to an intuitive approach. This process should not be considered only as a set of tools and techniques but as an integrated part of the project management. (PRAM 1997). Although projects are unique, and therefore their environments and surrounding hazards and risks are different, a generic pattern can be applied to lead the projects in a meaningful complimentary process of controlling risks.

Raftery (1994) well explains this underlying pattern in his book with simple words, as he believes that: "Many books and papers in the economy of constructions, estimating and forecasting contain ritual declarations of the 'uniqueness' of construction:

- Each project is different
- There are special problems in construction
- The future cannot be forecasted
- Construction is a high-risk business

These pleas are sometimes accompanied by suggestions that ...'different rules'... should apply." (Raftery 1994, 4) Then he continues by arguing this idea and mentions that it is obvious that each industry has their own special characteristics, but few of them are so special that they cannot be understood by an outsider.

Risk Management Best Practices in the Construction Industry:

Many companies and institutes have made efforts to develop numerical or non-numerical processes in order to conduct proper risk management. The most comprehensive project risk management processes today are as follows:

• *PRAM:*

Project Risk Analysis and Management Guide, Association for Project Management, U.K, 1997.

This booklet has been updated and republished by APM, The Association for Project Management, and it is introduced by them: "This Guide provides an introduction to the processes involved in Project Risk Analysis and Management, offering a simple but robust and practical framework to help new users get started" (PRAM 2000).

• *RAMP:*

Risk Analysis and Management for Projects is a comprehensive framework within which risks can be managed effectively and financial values placed upon them. It aims to achieve as much certainty as possible about a long term and uncertain future. In the case of a new project, the RAMP process covers the project's entire lifecycle, from initial conception to eventual termination. The process facilitates risk mitigation and provides a system for the control of the remaining risks. This guideline has been provided by Institution of Civil Engineers (ICE), Faculty of Actuaries, Institute of Actuaries, and London. (RAMP 1998).

• PMBoK (Risk management chapter):

Project Management Body of Knowledge, Project Management Institute (PMI).The PMBoK is the standard reference for terminology and processes in project management. It provides the core "body of knowledge" for studying for the Project Management Professional certification. Most changed in its last revision in 2000 (updated from the 1996 original version) is Chapter 11 on Project Risk Management. This has been rewritten and thereby much improved. Based on this guideline Project Risk Management has been expanded into six functional areas:

- Risk Management Planning
- Risk Identification
- Risk Assessment
- Risk Quantification
- Risk Response Planning
- Risk Monitoring and Control

Conclusions and Contributions:

The use of fuzzy logic in risk analysis makes the process more realistic for the construction context. This research enables project characteristics and risk events to be assessed subjectively, as is usually the case in practice. The output of the calculations can be presented both numerically and linguistically, providing the decision maker with a wide, useful, and realistic guide to the most severe risks in the projects.Using this method to consider monetary values or timelines can provide more information for decision makers to set appropriate contingency plans as well. One of the strong points of this method is that the decision maker can modify the basic impact and/or magnitude charts to better suit reality at any time in project and getting updated results to make better decisions at the time of mitigating and managing the risks and opportunities.

REFERENCE

Al-Bahar, J.F., K.C. Crandall, 1990. "Risk management in construction projects: a systematic approach for contractors", Counseil International du Batiment W55/W65 Joint Symposium. Sydney, 14-21 March.

Artto, K., K. Kahkonen, P.J. Pitkanen, 2000. Unknown Soldier Revisited: A Story of risk Management, Project Management Association Finland, Helsinki.

Ayyub, M. Bilal and A. Haldar, 1984. "Project scheduling using fuzzy set concepts", Journal of Construction Engineering and Management, 110(2): 189-204.

Baccarini, D., R. Archer, 2001. "The risk ranking of projects: a methodology", International Journal of Project Management, 19: 139-145.

Baker, Scott, Ponniah, David, Smith, Simon, 1999. "Survey of Risk Management in Major U.K. Companies", Journal of Professional Issues in Engineering Education and

CAMS (Department of Contract and Management Systems), 1998. Managing risks in contracting. Perth: Government of Western Australia.

Chao,L. and M. Skibniewski, 1998. "Fuzzy Logic for Evaluating Alternative Construction Technology", Journal of Construction Engineering and Management.

El-Cheikh, M A.H.C. Chan and J. Lamb, 2007. "Fuzzy Applications in Cost Estimating and Construction Planning". Proceeding of the Eleventh International Conference on Civil, Structural and Environmental Engineering Computing. Civil-Comp Press.

El-Cheikh, M, A.H.C. Chan and J. Lamb, 2007. "Fuzzy Applications in Cost Estimating and Construction Planning". Proceeding of the Eleventh International Conference on Civil, Structural and Environmental Engineering Computing. Civil-Comp Press.

Eldukair, Z.A. and Ayyub, M. Bilal, 1990. "Uncertainty Assessment in Correlation of Construction Projects ", IEEE Xplore, December isssu, pp: 372-377.

Eschenbach, T.G., 1992. "Quick sensitivity analysis for small projects and feasibility studies", AACE Transactions. L, 6:1-8.

Faber, M.H. and M.G. Stewart, 2003. "Risk assessment for Civil Engineering Facilities: critical overview and discussion", Reliability Engineering and System Safety, 80: 173-184.

Guyonnet, D., B. Come, P. Perrochet and A. Parriaux, 1999. "Comparing two methods for addressing uncertainty in risk assessment", Journal of Environmental Engineering, 125(7): 660-666.

Hanna, A.S. and W.B. Lotfallah, 1999. "A fuzzy logic approach to the selection of cranes, Automation in Construction", 8: 597-608.

Hillson, David, 2002. "Extending the risk process to manage opportunities", International Journal of Project Management, 20: 235-240.

Klir, J. George and B. Yuon, 1995. "Fuzzy Sets and Fuzzy Logics: Theory and Applications", Prentice-Hall, New Jersey, USA.Practice

PRAM, 1997. Project Risk Analysis and Management Guide, Association for Project Management, High Wycombe, U.K.

Ross, J. Timothy, M. Bookers Jane and E. Parkinson, 2002. Fuzzy Logic and Probability Applications: Bridging the Gap, Wiley Press, Philadelphia, PA.

Stern, P.C., H.V. Fineberg, 1996. Understanding Risk - Informing Decisions in a Democratic Society. National Academy Press, Washington D.C., pp: 249.

Sun, H.W., N.C. Evans, 2002. "Comparative Risk Indicators & Possible Climate Change Trends In Hong Kong And Implications For The Slope Safety System " , Geo Report No. 128 , The Government of the Hong Kong Special Administrative Region publisher.

Wang, S.Q., M.F. Dulaimi, and M.Y. Agurai, 2004. "Risk management framework for construction projects in developing countries", Construction Management and Economics, 22: 237-252

Zimmermann, H..J., 1991. Fuzzy set theory and its applications, Dordrecht: Kluwer, second edition.