RISK ASSESSMENT OF A RESIDENTIAL COMPLEX USING FUZZY LOGIC APPROACH

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Abstract : Modern construction projects being complex and unique are prone to risks. Risks are uncertain events that occur throughout the life cycle of the project. It has either a positive or a negative impact on the objectives of the project, where positive risks are known as opportunities and negative risks as threats. In order to mobilize these opportunities and threats, Risk Management is necessary. A new set of theory, called as Fuzzy theory, fuels the process of risk management. It not only helps to deal with in-accurate data but also explains the methodology to arrive at conclusions. By implementing the use of Fuzzy theory, the risk assessment of an on-going residential building project is illustrated. By providing a systematic fuzzy model approach, the expert judgement values are converted into accurate values. This paper aims at the use of fuzzy logic model in the construction industry and also shows the advantages of using this method over the conventional risk assessment method.

IndexTerms **– Risk Assessment, Fuzzy Logic, Construction, Decision making, Uncertainty, Management**

I. INTRODUCTION

The Construction Industry in India is the second largest after agriculture. It accounts for about 11 % of India's GDP and contributes to the national economy also by providing employment to large number of people (maier and vidorno, 2013). India is on the path of becoming world's third largest construction industry by 2025. Because of the policies laid down by the government for world class infrastructure facilities there is a rise in construction activities especially related to large infrastructure projects. The cost of infrastructure projects such as dams, roads, airports etc. can easily run into billions of Indian Rupees, amount of risks involved is also very high in such projects. The construction industry experiences a wide variety of risks which may occur in financing, designing, constructing and managing facilities of a project. There are different definitions of risk in construction industry. In order to understand the process of risk management, it is important to understand the basic concept of risk in all aspects (UK essays, 2018). According to Cornelius Keating, risk is not the present problem which should be immediately addressed, but it is considered as future issues that can be avoided or mitigated. PMBOK defines risk is an uncertain event or condition that, if it occurs, has an effect on at least one project objective (PMI, 2008). We can summarize from this definitions that risk is an uncertain event which can have a positive or negative outcome. Risk management has now become an important part of construction management all over the world as it helps to identify and manage the risk proactively which decreases the negative impact of risk and focuses on increasing the positive outcome, however risk management is seldom used in Indian construction industry which leads to huge amount financial losses and project delays. This paper focuses on risk assessment part of risk management process as no efficient risk mitigation strategy can be planned without optimum identification and assessment of risk.

There are many methods suggested and used by scholars for risk assessment but this research focuses on use of fuzzy logic for assessing risk as this methods use is still not widely used for risk assessment of construction project. Fuzzy Logic is a form of logic used in some expert systems and other artificial intelligence applications in which variables can have degrees of truthfulness or falsehood represented by a range of values between 1 (true) and 0 (false). With fuzzy logic, the outcome of an operation can be expressed as a probability rather than as a certainty. For example, in addition to being either true or false, an outcome might have such meanings as probably true, possibly true, possibly false, and probably false (POKORÁDI, 2002). The idea of fuzzy logic was first advanced by Dr. Lotfi Zadeh of the University of California at Berkeley in the 1960s. (Rouse, 2016). Kosko very well 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 analysed: 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 (Kosko, 1994).

II. LITERATURE REVIEW

LÁSZLÓ POKORÁDI, mentions the importance of safety and reliability in modern sciences. The author also states that risks are of different types and they can vary from project to project depending upon the nature the project. The author mentions about the use of fuzzy theory in risk assessment, and the results can be represented by the values between 1(true) and 0(false). It is a systematic process, which begins with the evaluation of risk by comparing it with another risk. In the second step, identification of hazards, assessment of risks, analysis of risk control measure, supervise and reviewing takes place. Risk assessment itself being a major step, is further broken down into several small steps. This is followed by the Fuzzy assessment of the project where in the inconsistencies found in the project are resolved by the fuzzy logic. This is process is a combination of four processes: fuzzification, inference , composition, and defuzzification. A helicopter mission is taken into the consideration, in which factors like degree of severity, probability of occurrence are obtained. Rules are made, and with respect to those rules , the magnitude of

risk is determined. Lastly, Weighted mean of maximum (WMoM) is used for defuzzination. The results thus obtained helps in assessing the risk and decide if there is need to use the risk mitigation tool (POKORÁDI, 2002).

AROKIA PRAKASH, shows that the risks are caused by bad decisions due to Lack of information, knowledge of risk management and unrealistic expectations. Projects subjected to time and cost escalation lead to conflict. Risk management should be an integral part of Construction industry because project uncertainties and risk assessment are crucial. The results of the previous situations must be effectively used for future decisions, which cannot be achieved without the effective use of risk management and data storage. Therefore, the advantage of fuzzy system to deal with inaccurate and vague information helps to assess risk more accurately. Therefore, it is expected that this study will provide the results to project managers, which will further help to formulate the risk assessment strategies to cover the costs and burden of implementation against the benefits achieved (Prakash & Prabhu, 2017).

SHANMUGA PRIYA, mentions the importance of understanding the various risk factors that may be faced by building projects. This paper aimed at identifying risk that are more likely to occur in case of construction practitioners. It emphasizes the relationship between time, schedule and planned budget for the successful completion of the project. The critical risk factors and its assessment techniques were determined through a review of various construction projects (S.Sugumar & R.Shanmuga, 2017).

III. RISK AND RISK MANAGEMENT

Risks are nothing more than the variables or circumstances associated with the implementation of a specific project that has the potential to adversely affect the development of a project or the interests of a participant, as the case may be. Revenue risks, design risks, construction risks, operating risks, political risks, legal risks, are the various categories of risks just to name a few.

"Risk Management" is a branch of applied economics with the primary objective to minimise the costs of pure risks and consists of a combination of loss control (such as loss prevention) and loss financing (such as insurance) activities. After the adequate identification of risks application of risk management techniques aims to provide risk treatment techniques that would bring about the best possibility of occurrence of only the minimal possible losses from various risks.

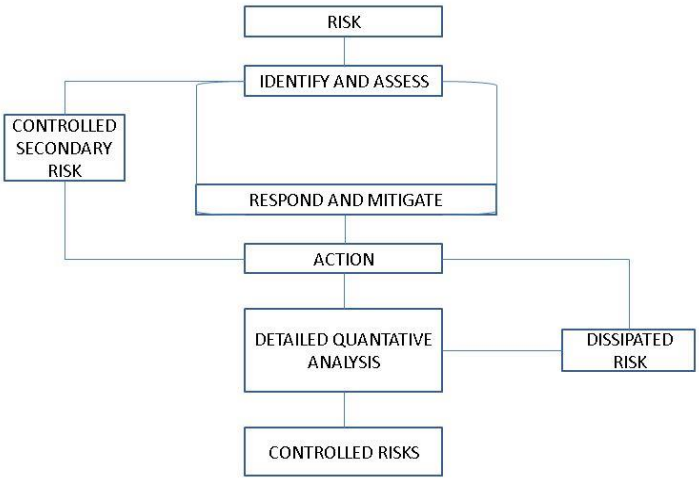

FIG 1 – RISK MANAGEMENT PROCESS

1) Risk Identification

Risks generally arise as a result of uncertainties. Where uncertainty surrounds a project there is likely to be a distinct lack of a confidence in the potential outcome. However, if we can identify where this uncertainty exists we can go along way to managing that uncertainty and therefore the resultant risks that are likely to manifest themselves. Methods of identifying risks could include brainstorming, interviews, questionnaires, use of specialists, previous experience etc to name a few. In identifying risk, it should be seen that such an exercise can never be undertaken too late. It is at this stage that the changes can be made with least disruption.

2) Assessment

The purpose of risk assessment is to understand and quantify the likely effect of any potential risks. Essentially this assessment phase is split into two:

A) Qualitative Assessment : Qualitative assessment is where the source, cause and effect of the potential risk is reviewed and described in detail. By doing this a risk register can be compiled where the status of each risk can be considered and updated on a regular basis. This is at the core of on-going risk management.

B) Quantitative Assessment : In quantitative assessment, the likely effect of the risk is analysed in detail along with the resultant knock on effect on the overall outcome of the project. By undertaking such detailed analysis the most likely and worst case project outcome can be calculated.

3) Response And Mitigate

Initially, it is often not possible or indeed appropriate to separate the activities of risk identification and qualitative assessment and considering a necessary response action. Responses to risk may include : Risk Avoidance, Risk Reduction, Risk transfer, Risk Sharing, Risk Retention. In considering response to risk, thought should be given to the Cost of the course of action proposed. In some instance, it may be more appropriate to retain a risk and suffer the consequences should it materialise etc.

4) Controlled And Uncontrolled Risks

Controllable risks is a risk, which within the control of the project or can be controlled by the project participants. The outcome of the occurrence of the situation is within team control.

Uncontrollable risk is an factor which is outside the control of the project team and cannot be influenced in any way. Such risks very often originate from external sources, environmental, political, economic, or climatic.

IV. PROJECT DETAILS

SR. NO.	PARTICULARS	DETAILS
	Name of the project	Poonam Imperia
	Contractor	Shree Buildwell
	Client	Poonam Developers
	Estimated Cost	60.00 CRORES (Approx.)
	Estimated Duration	4 YEARS
	Plot Area	15000 SQ. Meters.
	Built Up Area	21856 SQ. Feet.
	Type	Residential
	No of Wings	7
	No of Flats	781
	Cost of Construction Per M2	1350
	Any Other Useful Data	NA

V. METHODOLOGY

5.1 IDENTIFICATION OF RISK

The identification of risk is the most important phase of the risk management process as no action can be taken on a risk if it has not been recognised. By interviewing the project manager, we were able to identify over 30 types of risks which might affect the project. Later on, with the help of brainstorming session with all the project stakeholders, we narrowed the number of risks to 10 by prioritising the most important ones. Given below are the list of risks which has a high chance of affecting the project activities.

Table 1 – Types Of Risks

Risks	Severity	Likelihood
Project scope, schedule, objectives, cost, and deliverables are not clearly defined or understood.	2	0.15
Consultant or contractor delays.	4	0.45
Unanticipated escalation in right of way values or construction cost.	4	0.30
Local agency support not attained.	3	0.25
Unforeseen agreements required.	3	0.1
Changes during construction require additional coordination with resource agencies.	3	0.40
Labor shortage or strike.	3	0.45
Political factors or support for project changes.	3	0.30
Electrical power lines not seen and in conflict with construction.	3	0.6
Design changes require additional Environmental analysis.	5	0.1

Table no 2 – Severity Index

Category	Severity
Negligible	1
Low	2
Moderate	3
High	4
Catastrophic	5

2 *RISK ASSESSMENT BY FUZZY LOGIC*

Fuzzy sets deals with degrees of membership to a certain class and degrees of truth. Fuzzy logic uses fuzzy rules that should receive desired results from input linguistic data or variables. The linguistic variable – a variable whose values are sentences in a natural language. For example, a linguistic variable "temperature", this can contain values: cold, hot etc. Fuzzy set theory provides a way to use imprecise and uncertain information generated by the system and human judgments in a precise way. When the environmental data available do not provide a proper statistical treatment, fuzzy approaches can solve this problem, since they work well for addressing poorly characterized parameters and linguistic variables (Radionovs & Uzhga-Rebrov, 2014)

Table no 3 – Likelihood Index

Category	Likelihood
Very Low	0-0.20
Low	0.21-0.40
Moderate	0.41-0.60
High	0.61-0.80
Very High	0.81-1.0

The above mentioned risk in construction of residential building were assessed by means of fuzzy logic . The severity and probability of all the possible risk were determined through experts report. Given below is the example of a risk named, Labour shortage or strike (The difficulty in availability of labours during festivals such as Diwali and the major shortage of labours due to strikes caused because to low wage scale)which had the following results:

Degree of severity is 3 on a scale of 0 to 5

Probability of occurrence is 45% i.e. 0.45

5.3 FUZZIFICATION

In fuzzification sub process the first step is to know the degree of truth μ(x) of each input variable by use of severity graph which is plotted by having severity value on x-axis and degree of truth on y-axis, with the help of degree of truth obtained from severity graph and probability graph which helps in formation of fuzzy logic rules. Give below is the severity and probability graph of risk due to labour shortage.

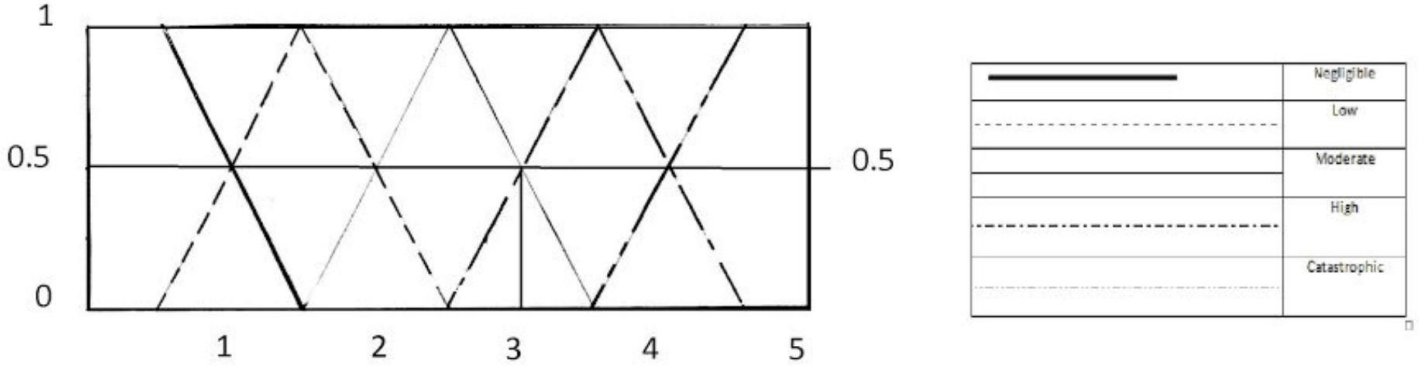

FIG - 2 Degree of truth of severity

From the severity graph we have obtained the degree of truth value for moderate severity for labour shortage having severity 3

μ (severity_moderate) = 0.5

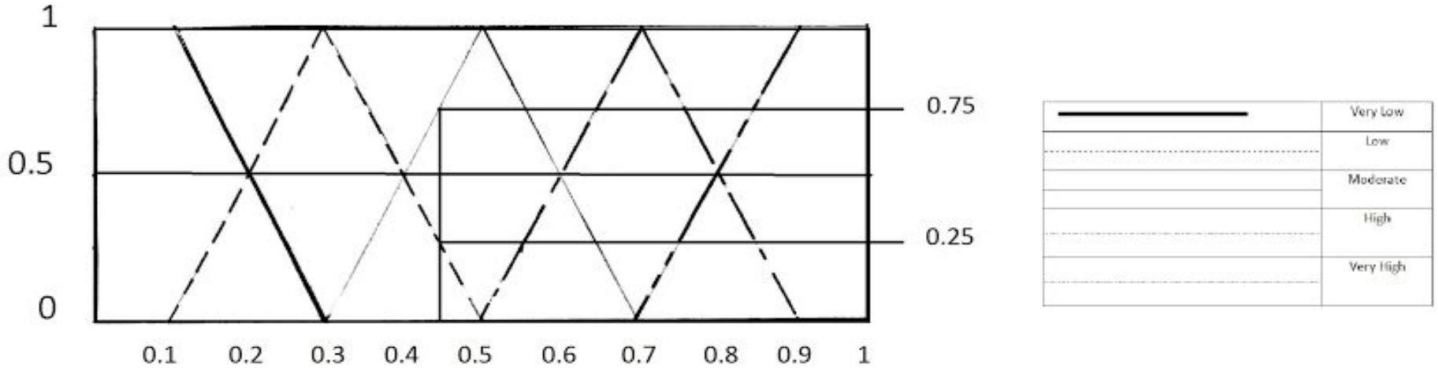

FIG - 3 Degree of truth of probability

From the probability graph we have obtained the degree of truth value for low and moderate probability for labour shortage having likelihood 0.45.

μ (probability_low) = 0.25

μ (probability_moderate) = 075

5.4 INFERENCE

In the inference sub process the rules required for fuzzy sets are determined from the degree of truth values obtained from the graphs this helps in determination fuzzy value.

Rule (1): If severity is critical and probability is moderate then risk is high;
Rule (2): If severity is moderate and probability is moderate then risk is medium;
Rule (3): If severity is critical and probability is low then risk is medium;
Rule (4): If severity is moderate and probability is low then risk is low.

It can be seen that by using these rule we can obtain values of risk in term of – high, medium and low. By use of fuzzy logic we can obtain a numerical value.

By using the above results we can have obtained the following values-

μ (risk_high) = 0.75

μ (risk_moderate) = 0.5

μ (risk_low) = 0.2

5.5 DEFUZZIFICATION

From the fuzzy sets obtained above a crisp fuzzy logic set is created. There are several methods to obtain the crisp set but we have made use of centroid method to obtain the centre of gravity of the figure obtained from fuzzy sets.

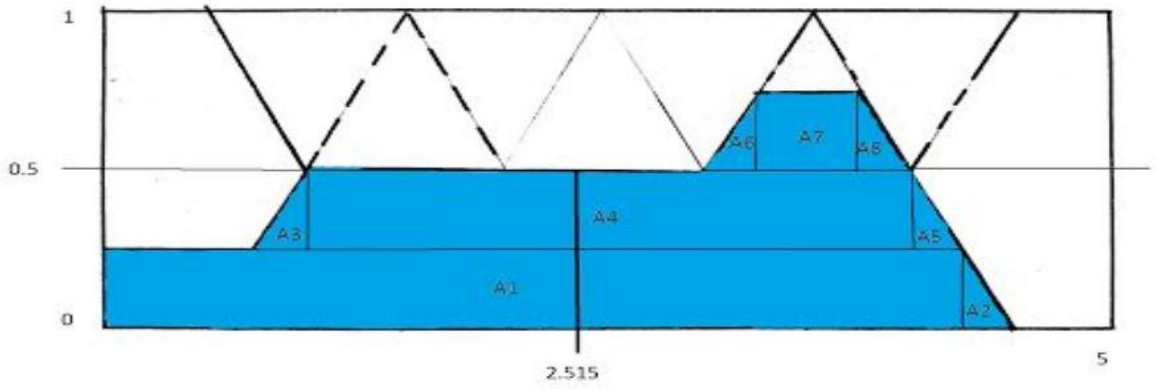

FIG - 4 Result of Composition

Table - 2 Calculation of Crisp Value

Sr. No.	Area	Distance	Area x Distance
1	A1 = 4.25 X 0.25 = 1.0625	C1 = 2.125	2.257
2	A2 = 0.25 X 0.25 X 0.5 = 0.03125	C2 = 4.33	0.135
3	A3 = 0.25 X 0.25 X 0.5 = 0.03125	C3 = 0.916	0.028
4	A4 = 3 X 0.25 = 0.75	C4 = 2.5	1.875
5	A5 = 0.25 X 0.25 X 0.5 = 0.03125	C5 = 4.083	0.127
6	A6 = 0.25 X 0.25 X 0.5 = 0.03125	C6 = 3.167	0.0989
7	A7 = 0.25 X 0.25 X 0.5 = 0.03125	C7 = 3.83	0.118
8	A8 = 1 X 0.25 = 0.25	C8 = 3.75	0.937
Total	2.218		5.575

$$\text{Crisp set value} = \frac{\text{Area x Distance}}{\text{Area}} = \frac{5.575}{2.218} = \mathbf{2.515}$$

On the basis of above calculation we have obtained the fuzzy logic value of risk named labour shortage similarly by using the above given method the project manager can calculate the fuzzy value of remaining risk and accordingly plan the risk mitigation strategy.

VI. OBSERVATION

While carrying out the research work, it was observed that there are several fuzzy logic models available such as Artificial Intelligence, Braking Systems, Computing etc. However, an appropriate model of fuzzy logic for construction projects was not available, so we have developed a basic fuzzy logic model which helped in accurate risk assessment which is not possible by using traditional risk assessment matrix .The infrastructure projects are prone to number of risks which may run in to hundreds and by using conventional risk matrix the risk cannot be mitigated with utmost accuracy. Given below are the various risk associated with the above mentioned construction project along with its risk assessed value by fuzzy logic

Table 3 – Fuzzy Value Assessed Table

Risk	Severity	Probability	Fuzzy Value
Project scope, schedule, objectives, cost, and deliverables are not clearly defined or understood.	2	0.15	0.558
Consultant or contractor delays.	4	0.45	3.351
Unanticipated escalation in right of way values or construction cost.	4	0.30	2.234
Local agency support not attained.	3	0.25	1.397
Unforeseen agreements required.	3	0.10	0.558
Changes during construction require additional coordination with resource agencies.	3	0.40	2.235
Labor shortage or strike.	3	0.45	2.515
Political factors or support for project changes.	3	0.30	1.676
Electrical power lines not seen and in conflict with construction.	3	0.60	3.353
Design changes require additional Environmental analysis.	5	0.10	0.930

VII.CONCLUSION

Fuzzy model system helps in providing an additional logic to the existing model assessed. It helps to overcome the imprecision and vagueness. This research paper provides results of the various risks identified in construction of a residential building by means of both the conventional risk assessment by expert judgement as well as by the fuzzy logic system. This eventually helps to categorize and prioritize all the risks based on its severity and its probability of occurrence which will help in better decision making and thus leads to successful completion of project by meeting the project scope and objectives. This research paper shows the procedure for carrying out the risk assessment by fuzzy logic system. Although there are numerous ways of computing the fuzzy logic system, the basic composition of it remains the same. The process carried out in this research paper is done completely by manual method, and can be carried out more efficiently by software such as MATLAB. The output obtained by this model helps the engineers on-site and the project manager to prioritize the work accordingly. The research paper is aimed at fostering the use of fuzzy logic system in the construction industry.

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