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Risk analysis and Fuzzy Based Model for the Estimation of Contingency Cost of Construction Projects

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Abstract: Construction projects play a significant role in the economic and overall development of any country. They also involve significant financial investments, and costs related to risks are known as contingency costs. In order to determine the contingency cost, contractors must take project risks into account while estimating and projecting the cost of completion. Typically, contractors use their subjective judgment to estimate cost contingencies, ranging from 5 to 10% of the expected cost based on previous projects that are comparable to theirs. Nevertheless, this approach lacks a solid foundation and is difficult to support or defend. As a result, more impartial techniques for calculating project cost contingency have been offered. But the majority of approaches still depend on formal modeling techniques, which are difficult to implement in the construction sector. Based on risk analysis and the fuzzy expert system idea, this study suggests a flexible and logical way for estimating cost contingency that might take into account contractors' subjective assessment. The creation of a cost contingency model for Indian construction and infrastructure projects was the suggested technique in this study. A case study project is examined to show how the proposed model may be used. The validation result showed that, in comparison to real cost contingencies, the system's forecasts were within 20% of accuracy.

Keywords: Construction projects, building and infrastructure projects, contingency cost, fuzzy expert system.

I. INTRODUCTION

A project is made up of many connected activities that, when completed in the right sequence, will result in the project's completion. Temporary in nature, projects often provide a measurable output or result. This contrasts with a program, which is a collection of connected initiatives that are often or always carried out to support a continuous process. A construction project is the planned process of creating, repairing, remodeling, etc. a building, structure, or infrastructure. It is frequently simply referred to as a "project." An overarching need is usually the first step in the project process, and it is evolved via the preparation of a brief, feasibility and option studies, design, finance, and construction. A building project usually consists of several smaller projects that demand for the cooperation of numerous specialties. A normal construction project involves a large number of people, and during the course of the project, the team's makeup and structure often change. Project managers, also known as lead consultants, oversee projects under the guidance of many experts like architects, engineers, cost consultants, and so on.

A. Project Cost (PC)

The sum of individual activity cost (AC) of project constitutes the project completion cost (PC). While, AC comprises of direct cost and indirect cost of an activity. Direct cost (D.C) include mainly the cost of labour, material and equipment while indirect cost (I.C) include overhead expenses and outage losses.

$$PC = \sum_A D.C + \text{I.C per day} \times \text{PCT in days} \tag{1}$$

Where, $\sum_A D.C$ is the sum of direct cost of individual activity of project while indirect cost of project can be estimated by multiplying the indirect cost per day and completion time of project (PCT: project completion time).

B. Contingency Cost (CC)

The construction industry is always surrounded by many uncertainties which cause risk. One of the attempts to handle risks is by allocating ‘‘project cost contingency”. Project Management Institute (PM Institute., 2004) defines contingency as the amount of funds, budget, or time needed above the estimate to reduce the risk of overruns of project objectives to a level acceptable to the organization. Therefore, total cost of project (TCP) should be;

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$$TCP = PC + CC \tag{2}$$

Based on above discussion, the construction projects play a significant role in the economic and overall development of any country. They also comprise of large amount of money investment, and cost associated to risks can be termed as contingency cost. During the estimation and prediction of project completion cost, contractors are required to considers risks associated to project, in order to estimate the contingency cost. Contractors traditionally estimate cost contingency based on subjective judgment, such as 5–10% from the cost estimated by considering past similar project. However, such method does not have a sound basis and is difficult to justify or defend. Therefore, more objective methods for estimating project cost contingency have been presented. However, most of the methods still rely on formal modeling techniques, which is not easy to be applied in construction industry. This research proposes a method to estimate cost contingency using a flexible and rational approach that could accommodate contractors' subjective judgment based on risk analysis and fuzzy expert system concept. In this research, the proposed method involved the development of cost contingency model for building and infrastructure projects in India. One case study project is analysed to demonstrate the applicability of developed model. According to the validation result, it was found that the predictions given by the system were within 20% accuracy compared to actual cost contingencies.

II. OBJECTIVES OF RESEARCH

The presented study aims to achieve following objectives;

1) Identification of risk factors for construction projects.
2) Analysis of risk factors for construction projects.
3) Development of fuzzy model for contingency cost estimation for construction projects.
4) Demonstration of a case study project to reveal the applicability of model.
5) To provide important suggestions to reduce the contingency cost of project.

III. LITERATURE REVIEW

Rami A. Bahamid et al. (2022): Construction is a critical sector of any economy in terms of value production, labor, and contributing to the gross national product. Managing risk is a relatively young area in Yemen's construction sector, but it is gaining traction as building activity and competition rise. Construction firms mitigate risk by using a variety of risk management methods. Therefore, there is a need to assess these procedures in order to detect shortcomings. The purpose of this study is to identify the current risk management techniques used in construction projects in Yemen. To gather data, survey questionnaires were used. Respondents came from building companies in Yemen. The majority of organizations' risk management practices are reactive, semipermanent, informal, and unstructured, with little to no committed resources to handle hazards. Risk management is not carried out methodically, consciously, or constantly. This approach deviates from widely acknowledged risk management guidelines. However, the results point to a broad knowledge of risk management and a readiness to grow from past mistakes. According to the examination of the data, risk identification techniques including judgment and historical data are used for risk analysis, and in Yemeni construction projects, the industry usually tries to transfer or minimize risks. The outcomes highlighted the flaws in Yemen's project management procedures. Project managers of large construction companies in Yemen must possess a thorough awareness of and training in internationally recognized systematic risk management techniques in order to ensure that construction projects provide the best possible return on investment. Lastly, this research may assist future participants in figuring out how to collaborate to limit risk.

Saurabh Pawade et al. (2022) One of the most exciting, dangerous, and difficult sectors of the economy is the building industry. The intricacy and singularity of building projects mean that there are usually more risks involved than in other businesses. The purpose of this study is to examine the risk management procedure in building projects and to provide the groundwork for further research aimed at creating a risk management framework that would be embraced by potential developers, contractors, and investors. A survey was created and distributed to get feedback about the many hazards that arise on building sites. Because of this, the individuals working on the projects are exposed to a variety of hazards, including operational needs, cost overruns, and other kinds of accidents. With the use of assessment forms, the risks were examined using the risk matrix approach, and further recommendations for reducing the risks in a building project were made.

Hai Xie[1] and Zhihui Yang (2021) The foundation of China's national economy is the building sector. The National Bureau of Statistics reports that the value of China's construction production in 2016 was 193.567 billion yuan, or 6.5 percent of the country's GDP, of which the country's GDP was 744.127 billion yuan. The growth of society has been greatly aided by the building sector. Construction projects have always been classified as typical high-risk industries.

As such, they are subject to a wide range of influences, most of which come from the social and natural environments. As a result, it can be challenging to achieve the project's desired level of quality, safety, and other aspects at the anticipated cost and duration. The goals include several specializations, a broad scope, a protracted construction duration, and a substantial financial outlay, particularly for large- and medium-sized construction projects. The repercussions are unfathomable if the dangers materialize. Furthermore, during the implementation phase, unintentional influences will impact building projects. It will negatively impact the regular functioning of construction projects if it is not addressed in a timely manner. Given the aforementioned issues, the purpose of this paper is to examine risk management research related to building project management in the context of the Internet of Things' multimedia environment. Numerous issues are examined throughout the construction phase of construction projects by combining the features of mobile construction projects. The goals and guiding concepts of construction project quality management, a multimedia-based construction project management system, and schedule risk prediction are all presented in this study. The experimental findings presented in this article demonstrate that, using a building project in a multimedia environment as an example, the study of the project's communication and quality control management is done. Construction projects operating in the multimedia environment of the Internet of Things are certain to be finished on schedule and with excellent quality via the integration of theory and practice.

Vishwa N. Vaghela (2020) - Globally, the building sector has seen fast expansion, and throughout the last 20 years, new and inventive approaches have been introduced. Yet, the changing nature of the project environment puts the construction sector at significant risk. Thus, risk management assumes a crucial role in the accomplishment of projects. With a short proposal for a literature analysis on risk management in the construction sector, my article aims to illustrate and comprehend the principles of risk management. By breaking down risk management into four components—risk identification, risk assessment, risk response planning, and risk control—the research shows how successful risk management.

Ali Akbari Ahmadabali and Gholamreza Heravi (2019) collected data via a questionnaire survey about the prevalence and effects of 34 identified risks, and then suggested a model to examine the function of risk interaction in the framework for risk assessment of PPP-magaprojects. They listed eight potential ways for the initiative to fail.

Bambang Purwanggono and Anastasia Margarette (2019) evaluated the dangers associated with underpass infrastructure projects. They used root cause analysis to identify the risks in these projects and collected data on the likelihood, significance, and detectability of risk occurrences. then multiplied the likelihood, impact, and detectability of risk events to get the RPN values, and then multiplied the likelihood and impact of risk events to get the RS values. They analyzed the risk occurrences in accordance with ISO criteria. By creating a scatter plot between the RPN and RS values of the risk events, they are able to distinguish between the distinct risk events. Additionally, they used professional judgment to determine the necessary course of action against risk occurrences.

Prathamesh Brid and Raju Narwade (2017) discovered that the fuzzy logic technique makes the difficult task of project managers analyzing ambiguous and confusing data and information easier. Additionally, they discovered that fuzzy logic is an effective and satisfying method for making decisions in the construction sector.

Mohammad Hayati and Mohammad Reza Abroshan (2017) Fuzzy-FMEA was used to analyze the risk elements of the Tehran Subway Tunnel's operating process. The assessment revealed that one of the most effective methods for identifying, assessing, and effectively managing risk factors is FMEA. To get the RPN values for each risk factor, they used the triangle membership function for incidence, severity, and detectability. They perform a questionnaire on the Tehran Subway Tunnel in order to get information on danger indicators. Compared to other conventional tools and methodologies, they discovered that Fuzzy-FMEA was a more adaptable and practical instrument and methodology for risk analysis.

Subya. R and Manjusha Manoj (2017) evaluated the risk elements while building roadway projects. For risk evaluation, they used multiple regression analysis and fuzzy logic. They classified the 53 risk variables they found into 12 categories. Using a questionnaire survey, they get data on risk parameters. The two biggest risk factors in the development of highway projects, according to their findings, are safety regulations and land acquisition. They discovered that fuzzy set theory provides a solid mathematical instrument for managing and addressing imprecise, ambiguous, and uncertain data.

Hesham Abd El Khalek, Remon Fayek Aziz, Hamada Mohamed Kamel (2016) applied the fuzzy logic method to risk and effect assessment, taking into account the ambiguity in risk and impact assessment. Construction projects' risk is assessed by computing each risk's R-index, which is a function of the risk's effect and likelihood.

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IV. RESEARCH METHODOLOGY

The link between the dependent and independent variables in the cost contingency is shown using a conceptual model. In this study, the amount of risk variables known as risk magnitude (RM) is used to calculate project cost contingency (CC). The RM of all risk variables deemed important for a project is compiled here (Al-Bahar, 1988; Mak & Picken, 2000; Tah et al., 1993). The relationship between CC and RM for any risk factor may be mathematically represented as in Eq. (3)

$$CC = RM_1 + RM_2 + RM_3 + RM_n \qquad (3)$$

where CC is the cost contingency value, RM is the risk magnitude for each risk factor, 1, 2, 3, ..., n is the number of risk factor.
RM is measured based on two risk variables, namely, risk likelihood (RL) and risk severity (RS). The relationship between RM, RL and RS can be stated as in Eq. (4)

$$RM_i = f(RL_i, RS_i) \qquad (4)$$

where i is the number of risk factors, RL is the probability of the risk, RS is the severity of the risk, and RM is the magnitude of the risk. Within its categorization, the RM of risk variables may be categorized using major risk (MR). As shown in Eq. (5), MR may be expressed as the summation of RM of all risk variables inside its categorization.

$$MR = RM_1 + RM_2 + RM_n \qquad (5)$$

where MR is the major risk category, RM is the risk magnitude, 1, 2, ... , n is the number of risk factor and major risk category. Therefore, CC can also be stated as Eq. (6)

$$CC = MR_A + MR_B + MR_C + \dots\dots\dots\dots + MR_N \qquad (6)$$

The proposed conceptual model of cost contingency can be illustrated in Fig. 1.

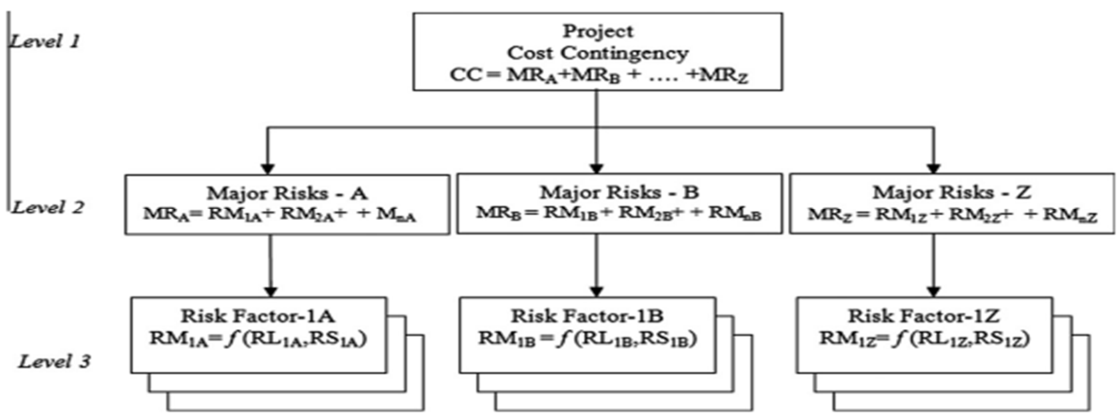

Fig. 1. Cost contingency model

It is possible to suppose that each risk factor's RM is an independent variable and that CC is the dependent variable. The quantity of RM is determined by how many risk variables are deemed important for a project. Risk factors are categorized using MR according to their attributes. The magnitude of the first risk factor in the main risk A (MRA), for instance, is denoted by RM1A. To make the use of fuzzy expert systems easier, the link between each risk factor and main risk category is assumed to be independent, as shown in Fig. 1. The link between each risk factor is modeled using an event tree diagram (Tah et al., 1993). In this study, a fuzzy expert system is intended to be used to estimate the RM value for each individual risk element at the third level of the project risk hierarchy in Figure 1. It is suggested that the relationship between RM, RL, and RS be investigated using the IF-THEN rule base in order to take into account the contractor's subjective evaluation throughout the risk assessment process, which is predicated on the usage of language phrases like low, medium, and high.
After identification, the number of risk variables was whittled down to facilitate the interview process and model application. Subjectively, the number of risk variables was lowered according to the degree of severity. Certain unusual risk events, such owner bankruptcy, financial crises, and natural disasters like earthquakes and tsunamis, are often not included into the cost contingency during the bidding process, hence they were not included in the model. Finally, the model made use of 14 risk variables. To provide a clear image of the link between risk factor and project cost contingency, the 14 risk variables that were chosen in the previous stage were categorized and built into a construction project risk hierarchy. As shown in Fig. 2, there are two main hazards in a project: internal and external risks.

Figure 2 Project Risk Hierarchy

A. Development Preliminary fuzzy expert System and Scenario Composition

A basic notion for a fuzzy expert system was created using a few cases. The composition of scenarios is contingent upon potential substitutes for the attributes of each fuzzy expert system, including the membership function, rule base, and inference mechanism. To determine which fuzzy expert system model was the best, all of the scenarios in the preliminary model were evaluated utilizing case project data that was gathered from the interview survey. With standard fuzzy expert system features including the membership function, fuzzy rule base, and fuzzy inference mechanism, a preliminary fuzzy expert system was created for 14 risk variables. Three phases may be used to develop a fuzzy expert system: creating a fuzzy membership function, defining a fuzzy rule foundation, and figuring out the fuzzy inference mechanism.

B. Construction of the Fuzzy Membership Function

In a fuzzy set, each fuzzy subset's degree of belief is represented by a membership function (MF), which is a progressive transition from "belongs to set" to "not belongs to set." The membership function uses a value between 0 and 1 to reflect each subset's level of trust in the discourse universe. For more information, see Jang, Sun, and Mizutani (1997) and Cox (1998) on the fuzzy set notion.

Three fuzzy membership functions (RL, RS, and RM) were created for the three risk variables. One membership function serves as the output variable (RM), and two membership functions—RL and RS—serve as the input variables for the fuzzy expert system.

The universe of discourse, the quantity of linguistic words, the form of the membership function, the numerical range of each linguistic term, and the overlap between each membership function are the attributes of a membership function.

A number scale ranging from 0 to 100 represents the universe of discourse for the RL variable. As a number between 0 and 1 or 0% and 100%, RL, also known as likelihood, is often stated (Loosemore, Raftery, Reilly, & Higgon, 2005). In this approach, the RL value was represented by five language terms: very low (VL), low (L), medium (M), high (H), and very high (VH). The quantity of linguistic phrases employed can't be strictly regulated by guidelines. But the quantity of language terms used must accurately reflect the real field situation (Kasabov, 1996).

Fuzzy expert systems may be developed using a variety of membership function shapes, including the Z function, bell function, trapezoidal, triangular, sigmoid, and single value or singleton forms. Since triangle membership function shapes are often employed in fuzzy expert system modeling, they were utilized in this instance for all RL values (Negnevitsky, 2004).

The amount of linguistic phrases employed in each of the five categories that comprised the discourse universe was used to subjectively establish the numerical range of the RL value. Each linguistic term's fuzzy membership function overlap was chosen within a range of 25–50% (Cox, 1998).

Figure 3 shows the design of the fuzzy membership function for the RL variable. Every kind of membership function has a triangle form. Three variables are utilized as membership parameters for the triangle fuzzy membership function shape: the peak value of the fuzzy membership function and the membership degree values for the left and right legs.

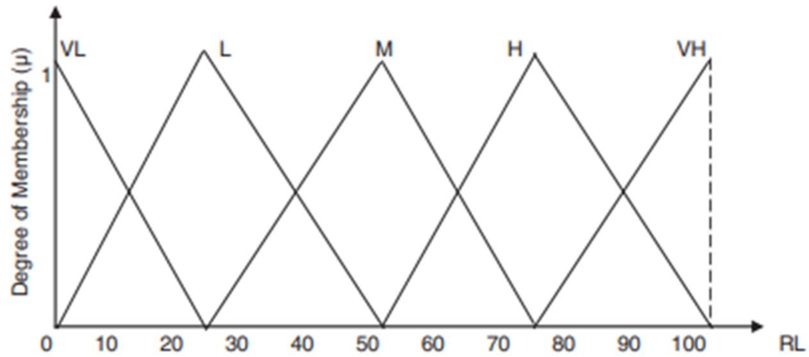

Fig. 3 Preliminary MF for RL

Since the RS and RM variables are often expressed in the same unit, comparable membership functions were created for them. Typically, it is expressed as a percentage of the project's overall cost (Smith & Bohn, 1999). It is assumed that all RS kinds for each risk factor have a monetary value.

Based on a few options, the universe of discourse scale for the RS and RM variables was established. For the RS and RM variables, five different membership function options were created.

Along with the RL variable, the discourse range universe was also split into five areas: VL, L, M, H, and VH. For every RS and RM value, fuzzy triangular membership functions were also applied. Figure 4 shows the example membership function design for the RM and RS variables for the first option scale, which is 0–2%.

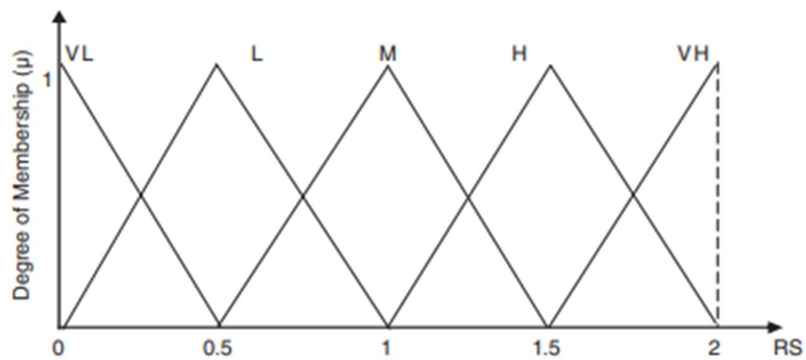

Fig. 4. Preliminary MF for RS and RM

C. *Specification of Fuzzy Rule Base*

The fuzzy rule base serves as the foundation for the fuzzy system model's construction or logic. Fuzzy rule bases are often expressed as IF (antecedent)-THEN (consequent). The RL and RS variables in this instance are the antecedent sections, while the RM variable is the consequence component. Since these two requirements must be met in order to determine the level of RM, the antecedent component of the RL and RS variables are connected using the fuzzy operator "AND." Table 1's rule basis, for instance, may be understood as follows: When RS is VL and RL is VL, RM must also be VL.

Table 1 Preliminary fuzzy rule base

Risk Magnitude (RM)		Risk Severity (RS)				
		VL	L	M	H	VH
Risk Likelihood	VL	VL	M	L	L	M
	L	VL	L	L	M	M
	M	VL	L	M	M	H
	H	VL	L	M	H	H
	VH	VL	L	M	H	VH

Since there are five risk terms value for RL and RS variables, 25 rules have to be developed.

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D. Determination of Fuzzy Inference Mechanism

The process of translating a given input to an output using the fuzzy set theory is known as a fuzzy inference mechanism. Since the Mamdani approach is well recognized in the creation of fuzzy expert systems, it was included into this model (Negnevitsky, 2004).

The five phases of the fuzzy inference process are fuzzification, rule evaluation, implication, aggregation, and defuzzification. The process of mapping RL and RS variable inputs into the stated fuzzy membership function is known as "fuzzification." The strength of fire is the outcome of the fuzzification (a). The process of translating the outcome of the fuzzification (a) from the antecedent portion into the consequence (RM variable) is known as implication. The "AND" fuzzy operator is used to link the (a) from the RL and RS variables since there are two levels of firing intensity for RS and RS. The system performs the minimal action since the fuzzy rule was represented by the "AND" operator.

The relevant fuzzy rules are fired, and then the implication procedure is carried out. Multiple fuzzy rules may be fired simultaneously. Through the aggregation procedure, the implications findings are combined. Ultimately, the process of defuzzification is carried out in order to transform the aggregated result into a clear value for the RM output. Since the center of area (COA) defuzzification approach is widely utilized for the building of fuzzy expert systems, it is used in this instance (Negnevitsky, 2004).

Following that, each of these situations was coded into a computer software called the MATLAB fuzzy logic toolbox.

V. RESULTS AND DISCUSSION

This chapter provide an application of developed methodology by a case study project. The results are discussed to demonstrate the working of proposed fuzzy based contingency cost estimation model.

A. Case Study Project

For the demonstration purpose, in this study, the details of case study project are presented in Table 2. This project is a building construction project and located in Gwalior, India. The project consisted of thirteen activities. The time and cost for all activities are estimated based on the amount of resources associated with them. Indirect cost of project was 0.05 Lakhs per day. Actual contingency cost taken by contractor was 6.3 Lakhs.

Table 2 Details of the case study project (Gwalior, India)

Sr. No.	Activity Name	Successors	Time (days)	Estimated Cost (In Lakhs)
1	Ground-works	2, 3	8	1
2	Excavation	4	6	2.5
3	Footing	4	12	2.7
4	Formwork	5	5	1.5
5	Retaining wall	6	26	2.2
6	Basement	7	32	3.2
7	Slab	8	22	3.4
8	Exterior wall	9	18	1.5
9	Interior wall	13	37	1.9
10	Flooring	–	34	3.2
11	Exterior finish	–	9	1.5
12	Interior finish	–	41	2.2
13	Roof	10,11,12	23	3.8
Project Completion Time (PCT in Days)			187 Days	
Total Cost of Project i.e. Project Cost (PC) (In Lakhs)				Direct Cost (D.C) = 30.6 Lakhs I.C per day = 0.05 Lakhs $30.6 + 0.05 \times 187 = 39.95$ Lakhs

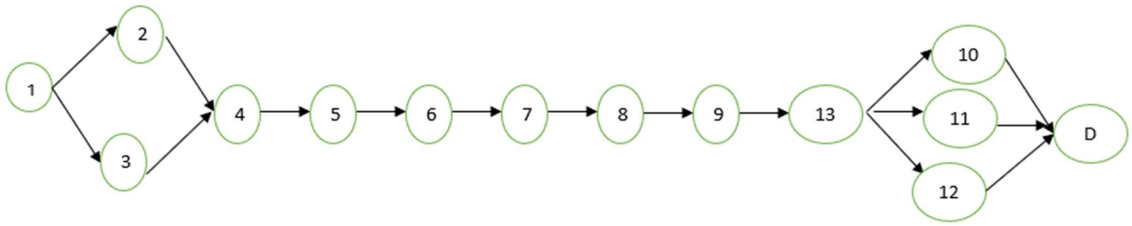

Fig. 5 Project Network Diagram for Case Study Project

Table 3 Contingency Cost Estimation for Project

Total Risks	Major Risks	Sr. No.	Risks	Risk Likelihood (in %)	Risk Severity (in %)	Risk Magnitude (in %)
Construction Project Risks	External Risks	1.	Different Site Condition	82	1.20	1.21
		2.	Weather Condition	87	1.70	1.55
		3.	Change in Government Policy	77	1.80	1.50
		4.	Social Impact	68	1.35	1.33
		5.	Changes in Economic Conditions	80	1.10	1.12
		6.	Delayed on Payments	95	0.80	0.79
		7.	Third Party Delays	60	0.90	0.865
	Internal Risks	1.	Safety	90	1.50	1.5
		2.	Unavailability of Resources	55	1.90	1.38
		3.	Labor Dispute	40	1.60	1.13
		4.	Defective Materials	30	1.70	1.13
		5.	Equipment Failure	25	1.75	1
		6.	Quality of Work	80	1.55	1.50
		7.	Mismanagement	70	1.15	1.17
						18.305 % (7.31 Lakhs)

Therefore, contingency cost of project predicted by developed fuzzy model = 18.305 % of total project cost i.e. 7.31 Lakhs.
Then, total cost of project will be;

$$= 39.95 + 39.95 \times \frac{18.305}{100} = 47.26 \text{ Lakhs}$$

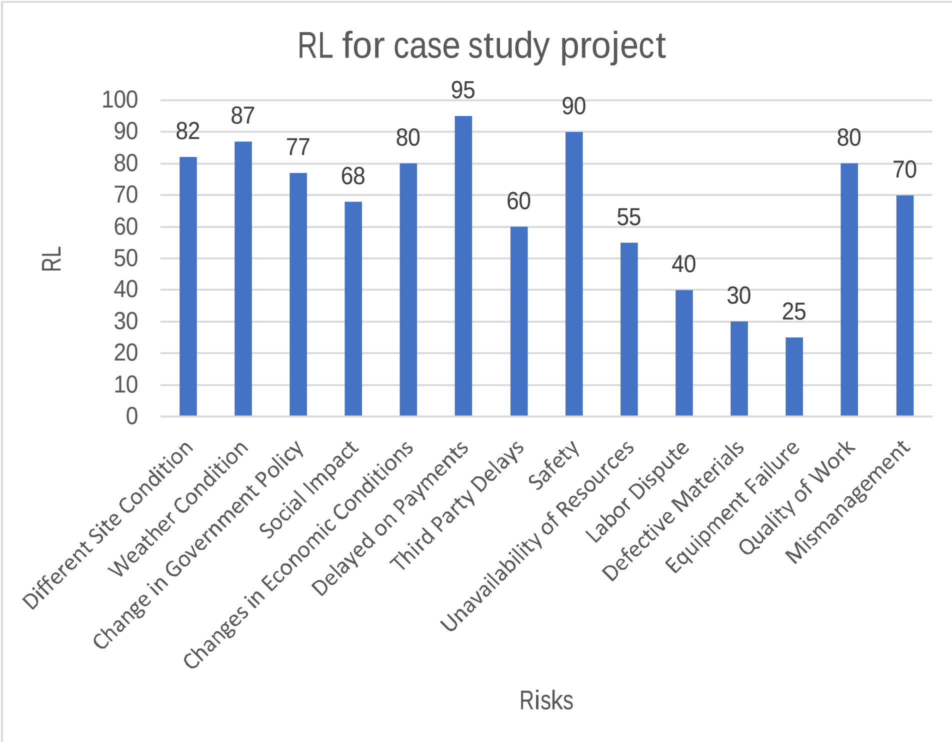

Fig. 6 RL for case study project

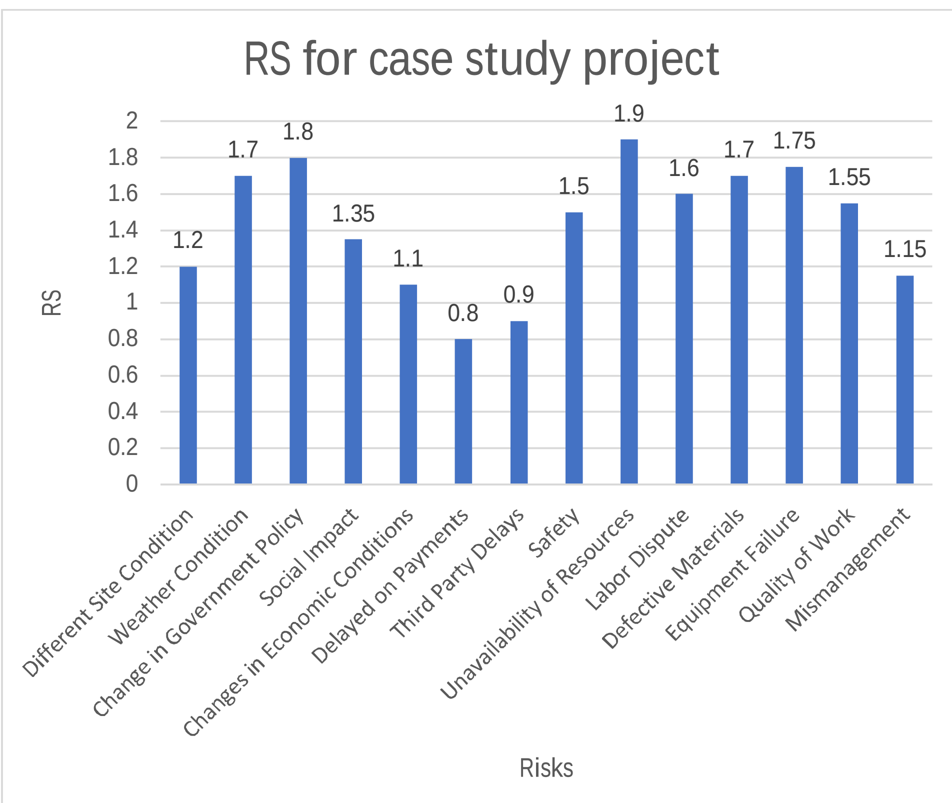

Fig. 7 RS for case study project

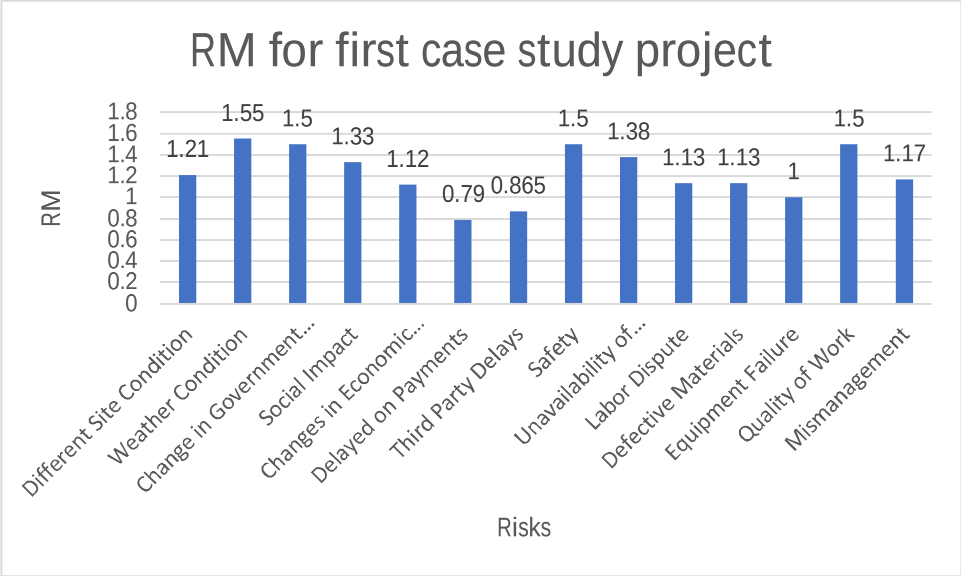

Fig. 8 RM for case study project

VI. CONCLUSION

Typically, contractors use their subjective judgment to estimate cost contingencies, ranging from 5 to 10% of the expected cost based on previous projects that are comparable to theirs. Nevertheless, this approach lacks a solid foundation and is difficult to support or defend. As a result, more impartial techniques for calculating project cost contingency have been offered. But the majority of approaches still depend on formal modeling techniques, which are difficult to implement in the construction sector. This paper offers a technique based on risk analysis and fuzzy expert system to predict cost contingency for a building project in order to get beyond these restrictions. The study's findings highlight the following important topics;

1) Contingency cost is an important component of total cost of project apart from direct and indirect cost components.
2) Contingency cost estimation can be done easily after analysing the risk factors of construction projects.
3) Major risks of project can be divided into two wide groups namely external risks and internal risks.
4) It is worthwhile to predict the risk likelihood and risk severity of construction project risks.
5) Since the construction projects are carried out under the open atmosphere with several risk and uncertainties, it is worthwhile to consider the uncertainties involved in the risk likelihood and risk severity of risk factors of construction projects.
6) In this study, the contingency cost of project is easily estimated by taking the contingency cost of project as a function of risk likelihood and risk severity.
7) One real case study project is solved in the presented study and contingency costs are estimated as 18.05 % of total project cost.

Ultimately, the fuzzy expert system and risk analysis idea serve as the foundation for the development of the suggested solution. Fuzzy expert systems are used as the way to evaluate the amount of risk in the risk assessment stage, while risk analysis is implemented as a concept to identify and estimate the risk of each risk component. An expert system known as a fuzzy expert system is one that is integrated into risk analysis techniques in order to forecast risk levels and calculate cost contingency value. There are seven steps involved in developing the suggested model: creating a conceptual model for cost contingency, identifying the model's risk variables, creating the fuzzy expert system, testing the model, and validating it.

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