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Assessment of Risk in Construction Projects by Modified Fuzzy Analytic Hierarchy Process

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Abstract - *Construction industry has significantly changed over the past years and it is vulnerably subjected to risks because the construction projects are complex and dynamic in nature. So, a comprehensive procedure for risk assessment of construction projects is needed. This paper offers a risk assessment methodology that acts as a decision support tool, directed for the Commercial Construction projects. By the study of the risk registers of commercial construction projects, key risk factors category and their attributes which affects the project are identified based on the project objectives. The main objective of this study is to provide a risk assessment tool using the Modified Fuzzy Analytic Hierarchy Process(MFAHP) in order to overcome the risks. Risk factors are identified by the study of risk registers of various projects collected from projects managers of a globalized organization. The importance of risk assessment and tool is elaborated with the key risk factors identified.*

Key Words: **Construction Projects, Risk assessment, Fuzzy Analytic Hierarchy Process, Risk Factors, Risk Index**

1.INTRODUCTION

In construction industry, intensive research has been done in the area of project risk management because construction projects are very complex, where uncertainty comes from various sources. The complex and strategic nature of construction projects makes construction industry a risky business. The construction industry is often considered as a risky business due to its dynamic and strategic nature. In its path of advancement, the industry has to overcome a number of challenges and risks. Unfortunately, the construction industry has a poor reputation in risk analysis when compared to other industries. Risk is a multi-facet concept and Project risk management is the processes concerned with identifying, analysing, and responding to project risk [19]. Risk in construction can be handled by managing, minimizing, sharing, transferring or accepting them. Moreover, in the construction projects, it witnesses the involvement of various parties throughout lifecycle of project; each of which carryout different perspective.

On the other hand, the severe competition endured by the construction organizations and the margin of profit set by organization has always acted as factors to seek better opportunities not only for organization growth but also its bare survival within the industry, where risks creeps into the projects. Hence, risks play a significant role in decision making and may affect the performance of a project. Several studies and researches were conducted to assess risk particularly related to construction projects. Construction risk analysis, especially at the early stages of the project, is difficult and cumbersome because the nature of risk is usually affected by numerous factors including human error and the information available.

Due to the great uncertainty involved, in many circumstances of construction projects, it makes it extremely difficult to assess the risks associated with a project. In record of construction, industries are very poor in terms of handling risks, which results in the failure of projects by not adhering to the planned time schedules, targets of budget and sometimes even the scope of work. Many risk assessment techniques currently used in the construction industry such as Event Tree Analysis, Monte Carlo Analysis, Fault Tree Analysis, Sensitivity Analysis, Programme Evaluation and Review Technique are mature [2]. High quality data required for these techniques are difficult to obtain, so a new method development is essential to handle risks. Therefore, analytical methods that rely on historical information and the experiences of experts and organization will be easier and comfortable to assess the risk and so, these methods reduce the difficulty of data collection by using the already available data.

In literature, several classifications were proposed for different construction risk factors and various risk breakdown structures are available, some factors are found in more than one group of classification and overlaps are identified between the risk breakdown structures. Usually, following the identification of the risk factors a multicriteria decision making method (MCDM) is used to assess the level of risk according to the predetermined objectives [5]. The analytic hierarchy process, and simple multi attribute rating techniques are examples of mathematical tools that are related to risk assessment in international construction. With regard to MCDM techniques; even with all numerous researches that provide models for risk assessment there is

some frequent limitations in the models generated for utilizing the specified tools [5]. Therefore, it is essential to develop new risk analysis methods to identify and assess construction risks in an acceptable way so that the information is reliably applied to decision making.

2.CONSTRUCTION PROJECT RISK MANAGEMENT

2.1 Definition of Risk

A risk is simply the potential for complications and problems which is expected to occur with respect to the completion of a project activities and the achievement of a project goal. Risk is inherent in all the level of projects, as such it can never be completely eliminated, but then it can be effectively managed by providing mitigation measures for the impacts which is barrier to the achievement of project's goals. Other definitions of risk are available in the literature such as "the exposure to possibility of economic loss or gain, physical damage or delay" [7], "the probability of losses in a project which hinders objectives" [13], "uncertain event if occurs, will have an effect on objectives achievement", "the likelihood of a detrimental event occurring to the project" or "a barrier to success".

2.2 Project Risk Management

Project risk management is associated with identifying, analysing, and managing the project risks effectively and efficiently. On the aspect of risk management process, recently there have been an extensive research which have proposed various methods. All of these approaches have similar models generated with differences in the established steps in order to get the risks under control. Risks, wherever exist needs to be adequately managed, and the actions taken will try to mitigate the impact of risk systematically in a predefined way. In order to provide effective mitigation, the risks need to assessed with a perspective of their uncertainty basis with the thought of the future event which may happen.

The term "risk" has become relative to an aspect of daily life of human being. Somehow, the risks generated can be related to circumstances, society and business as well. Though an intense amount of risks is being generated, the mankind seeks to deal and try to manage it effectively. Effective risk management proposed by Nieto-Morote involves four process such as Risk identification, Risk assessment, Risk response and Risk Monitoring and reviewing. Risk identification is the process of determining risks that could potentially prevent the organization or project from achieving its objectives. Whereas, risk assessment is the evaluation, and estimation of the levels of risks involved in a situation, their comparison against generalized reference values, and calculation of an acceptable level of risk, for the project. Therefore, risk assessment holds an important process in the management of risk.

Project Risk management will prove to be beneficial, when it is implemented in a manner systematically from planning stage to the completion stage of the project. Risk assessment plays a major role in achieving the project objectives irrespective of the characteristics of construction project. The risks are the uncertainty of future event that should be controlled systematically through risk management and analysis methods [25].

The objective of this study is to perform risk assessment considering the project objectives and propose a risk index for the attributes which are identified and rank them. To achieve this objective, a multi criteria decision making tool called Fuzzy Analytic Hierarchy Process is used. The potential sources of risk on commercial construction project will be identified by studying the risk registers of various commercial construction projects of a globalized organization existing in the local region.

3.MODIFIED FUZZY ANALYTIC HIERARCHY PROCESS

3.1 Classical AHP

Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty in the year 1980. Generally, Analytic Hierarchy Process organizes the basic items of decision making by breaking it down into problem of smaller constituent elements. This AHP is carried out by two phases (1) the hierarchy design and (2) components evaluation within the hierarchy. Basic simple linguistic variables have the limitations in quantifying the various risks therefore, some quantification with giving specific value or scale are used to get over the limitations [10]. If a variable can take words in natural languages as its value, it is called a linguistic variable [14]. The AHP consists of three main operations which includes construction of hierarchy, priority analysis, and verification of consistency. First of all, the decision makers need to break down and make a hierarchy for the multiple criteria decision problems into its component parts of which every possible attribute are arranged into multiple hierarchical levels. Once the hierarchy is built, the decision makers methodically assess its various hierarchical elements by comparing them to each other two at a time, with respect to their impact on an element above them in the hierarchy. After that, the decision makers have to compare each cluster in the same level in a pair-wise fashion based on their own experience and knowledge.

During the course of comparisons, the decision makers can solid data about the elements of hierarchy, but they typically use their judgments about the elements and their relative importance. The pair wise comparisons for each level with respect to the goal of the best alternative selection are conducted using a nine-point scale. But, since the AHP method creates and deals with an unbalanced scale of judgment and human biasedness, it doesn't take into account the fuzziness associated with the marking of one's judgment

to a scale. Therefore, conventional AHP seems inadequate to capture decision maker's requirements explicitly. So, Fuzzy Sets 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 [16].

3.2 Why FAHP Instead of AHP?

In the conventional AHP, the pair wise comparisons for each level is done with respect to the objective of the best alternative selection and are conducted using a nine-point scale proposed by Saaty. The application of AHP has some limitations for the reasons (1) AHP method itself paves way for the creation of an unbalanced scale of judgment and has to deal with it, (2) The AHP method not takes into account the fuzziness associated with the marking of judgment of a decision maker to a number, (3) Ranking of the AHP method is imprecise and mainly used for crisp decision applications, (4) The subjective judgment, selection and preference of decision makers has great influence on the AHP results where human biased nature always exists [8].

The AHP is commonly preferred to solve decision making problems based on pairwise comparison of alternatives. Experts have to compare each element of hierarchy with any remaining elements in the hierarchy. Therefore, when the comparison elements are large, there will be huge amount of pairwise comparisons involved, and thus the AHP becomes a long process that sometimes it irritates a respondent and the inconsistencies may creep into the responses. In order to, to deal with the inconsistency and large number of comparisons for applying the AHP, Fuzzy sets are introduced. Therefore, the conventional Process is not adequate to capture the needs of decision makers explicitly.

3.3 Fuzzy Analytic Hierarchy Process

The Fuzzy Analytic Hierarchy Process can be viewed as an advanced method developed from the traditionally existing AHP. Generally, it is impossible to reflect the decision maker's preferences which are uncertain through very crisp values. There are the several procedures to attain the priorities in FAHP. Fuzzy theory is introduced to solve problems involving the absence of sharply defined criteria. The application of fuzzy theory provides a systematic tool to deal with data and information which are both qualitative and quantitative in nature, arising in the construction process. If fuzziness within decision making of humans are not taken into account, the results can be misleading.

Fuzzy theory is used to clear the uncertainty of decision making errors of human, and it has been applied in a variety of fields. Recently, many risk assessment approaches have been based on using linguistic assessments instead of numerical values and the fuzzy linguistic terms employed for facilitating the comparisons between the subject criteria, has provided better judgements for the inventory classification [8]. Using Fuzzy Sets data may be defined on vague, linguistic terms such as low probability, high risk or strongly important. These terms cannot be defined meaningfully with a precise single value, but Fuzzy Sets provides the means to formally defined it in mathematical logic.

A triangular fuzzy number, a special case of a trapezoidal fuzzy number, is very effective in fuzzy applications and were used due to their computational simplicity. The fuzzy evaluation matrix of the alternatives is constructed by the pairwise comparison of different factors in their group.

4.IDENTIFICATION OF KEY RISK FACTORS

In order to classify key risk factors in construction, several risk register documents are analysed and the appropriate risk based classification of factors category. Risk register documents relating to commercial construction projects from globalized organization are collected. A risk register is a risk log which contains the occurrences of risks entered with respect to the daily activities. About 10 such commercial projects risk registers are considered for data collection. In those risk registers, predominantly identified type of risks are listed in Table-1. Those listed Risk factors are then grouped accordingly under separate category, with the help of experts. The risk factors category which are identified are Design and Statutory Approvals, Communication and Vendor Prequalification, Base Building, Material Handling and Logistics, Resource Management, Occupational Health and Safety, Construction Execution and External factors category.

Statutory approvals of a building project come during the planning stage of construction. It includes the clearances to be provided as permit to proceed with the planned drawings and designs to be approved. Design changes are inevitable during the course of construction projects and their changes mainly have the influence in the time and budget of projects. Within the Design and Statutory Approvals, the subfactors identified includes, Delay in statutory approvals, Delay in finalization of layout plans, Delay in finalization of shop drawings, Improper drawing review between consultants and Improper implementation of design and drawing changes.

Prequalification of vendor is an important task in order to prioritize the vendors based on their efficiency and experience. But then, improper prequalification can lead misleading judgement in the finalization of vendors. The task of project management comes into existence during the construction by executing with proper communication between all of the vendors of the project which when goes wrong will lead to problems. With those in mind the subfactors identified in Communication and Vendor Prequalification category includes Unclear organization chart, Delay in vendor finalization, Improper scope allocation between vendors and Delay in payment to vendors & consultants.

Base building of a structure play a very important role, since they are the primary factor of a construction projects. When something goes wrong in the account of their construction the packages proceeding with the construction of the base building will subjected to problems. Subfactors identified in Base Building Category includes Deviation from drawings, Delay in completion and handover, Structural defects and Need for strengthening of members.

Materials are the primary substance of constructional activities, so handling them with proper care and planning of their usage at proper locations and time intervals will save from unwanted troubles. Subfactors identified in Material Handling and Logistics category includes Unplanned procurement, Storage space constraints, Unclear material specification, Non-uniformity & Non-availability of material (at required time) and Damage to property/ material / Manpower (during movement & installation). Manpower who handle those materials should be with proper knowledge about the task to be handled and manage the work effectively. Subfactors identified in Resource Management includes Lack of training for workers, Deployment of low grade vendors, Low productivity of workers and Lack of labors for specific-work activities.

Occupational Health and safety is the very important category of all because this factors concerns the safety, health and welfare of the people at work and proper deployment of Health and Safety rules will decrease the work place accidents, injuries, illnesses and death. Subfactors identified in Occupational Health and Safety category includes Unsafe working environment, Improper working condition of tools and equipment and Selection of material bypassing Occupational Health and Safety.

During the phase of construction execution various sorts of problems leading to the failure will arise. So, proper planning to complete the work without any sort of complication to proceed further will control failures. Subfactors identified in Construction Execution category includes Execution not in accordance with GFC / Shop drawings, Schedule Constraints, Failure during testing, Identification & rectification of defects during execution and Improper Change Management. Some of the external driven factors are generally considered to be those imposed by government and their new regulations which are enacted and that hinders the project completion. Such factors identified are Monsoon changes, Work time constraints imposed by government and Movement restriction of heavy vehicles.

Table -1: Risk Factors and its categorization

Category	Factors
DESIGN AND STATUTORY APPROVALS	Delay in statutory approvals
	Delay in finalization of layout plans
	Delay in finalization of shop drawings
	Improper drawing review between consultants
	Improper implementation of design and drawing changes
COMMUNATION AND VENDOR PREQUALIFICATION	Unclear organization chart
	Delay in vendor finalization
	Improper scope allocation between vendors
	Delay in payment to vendors & consultants
BASE BUILDING	Deviation from drawings
	Delay in completion and handover
	Structural defects
	Need for strengthening of members
MATERIAL HANDLING AND LOGISTICS	Unplanned procurement
	Storage space constraints
	Unclear material specification
	Non-uniformity & Non-availability of material (at required time)
	Damage to property/ material / Manpower (during movement & installation)
RESOURCE MANAGEMENT	Lack of training for workers
	Deployment of low grade vendors
	Low productivity of workers
	Lack of labors for specific-work activities
OCCUPATIONAL HEALTH & SAFETY	Unsafe working environment
	Improper working condition of tools and equipment
	Selection of material bypassing OHS
CONSTRUCTION EXECUTION	Execution not in accordance with GFC / Shop drawings
	Schedule Constraints
	Failure during testing
	Identification & rectification of defects during execution
	Improper Change Management
EXTERNAL CATEGORY	Monsoon changes
	Work time constraints imposed by government
	Movement restriction of heavy vehicles

5. RISK ASSESSMENT

A risk assessment method, based on fuzzy reasoning, is proposed. The phases in risk assessment includes:

Preliminary phase, Fuzzy inference phase and Risk index & Ranking of factors as shown in Fig-1. In the Preliminary Phase of Risk Assessment Classification of factors through study discussed in the previous section, and subjecting them to response from experts with a nine point Saaty scale as shown in Fig-2. Following the preliminary phase in the fuzzy inference phase the data from survey is fuzzified using the Triangular fuzzy numbers from the data collected for individual respondents. During the defuzzification using Centroid of Area method the TFN are defuzzified.

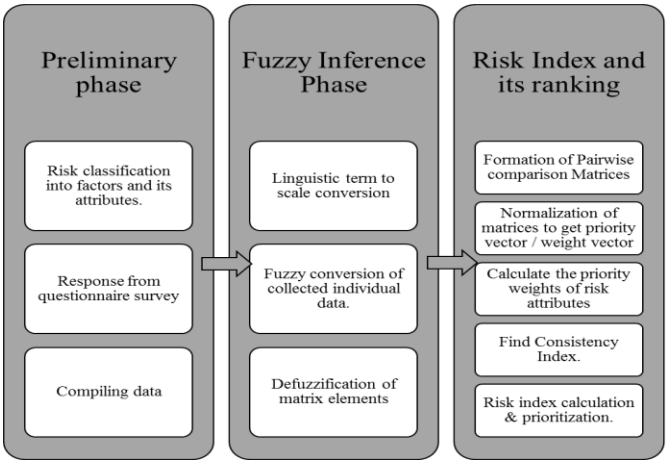

Fig -1: Risk assessment Method

Linguistic Term	Fuzzy Number	Triangular Fuzzy Scale
Equally important	1	(1, 1, 1)
Intermediate value	2	(1, 2, 4)
Moderately important	3	(1, 3, 5)
Intermediate value	4	(2, 4, 6)
Strongly important	5	(3, 5, 7)
Intermediate value	6	(4, 6, 8)
Very strongly important	7	(5, 7, 9)
Intermediate value	8	(6, 8, 9)
Extremely important	9	(7, 9, 9)

Fig -2: FAHP Scale for Comparison and its Triangular fuzzy scale

The risk index and ranking phase follows the normalization of column procedures to calculate the weightage. Initially the elements are organized in a matrix for each individual for each category and factors within each category. So, the pairwise comparison matrix formed are occupied in the upper triangular portion of matrix with 1 in the diagonal elements and lower triangular elements can be filled with their reversal, this matrix is called as Pairwise Comparison Matrix(PCM). Normalization is done by summing the columns of PCM and dividing the elements of PCM with their respective column sums.

The weightage of individual elements is calculated with the average of the rows forming a single column matrix. Using the eigen value method proposed by Saaty the consistency can be done with the random index values based on the size of the matrix of PCM. Using the weightage, the risk index of factors is calculated by their percentage contribution and ranked.

7. CONCLUSIONS

Various researches have proved that it is effective to use Analytic Hierarchy Process for Decision making problems, but then in order to overcome the lags of AHP, fuzzy incorporating can reduce the uncertainty in the results. This study concludes that Modified Fuzzy Analytic Hierarchy Process proves to be an effective tool for Multi Criteria Decision making Problems. Nowadays, the risk assessment in construction projects seems generalized without narrowing the perspectives for the project type. This study provided the risk factors for the commercial construction projects which are in growth currently. This method could be extended to other similar projects like residential, industrial and infrastructure projects etc. Also, when the factors identified for such projects are large in number, proper hierarchy categorization will make calculations easier. The methodology can be improved by covering more multiple attributes and for further development mitigation measures can be proposed and the risk index values after the mitigation implementation can be accessed.

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