Application of Fuzzy MAHP for Computing Risk Severity Index for Elevated Corridor Metro Rail Project

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Abstract—**Complex giant infrastructure projects are endangered to greater risks due to its unique features in various phases like feasibility, design, development, implementation and execution. So, a systematic process of risk analysis is required to classify, identify, and analyse these risks, and to formulate risk response strategies. This paper is an attempt to compute risk severity index of the elevated corridor metro rail project using Fuzzy MAHP (Modified Analytical Hierarchy Process). AHP is a structured technique that can help in identifying the risk severity for the major activities of a project. Fuzzy logic is incorporated within AHP to map the interrelationship between input parameters of AHP like priority vectors of likelihood of occurrence and impact created due to that risk for a particular activity. Case study of Bangalore elevated corridor metro rail project construction at various phases are presented to validate the concept of this technique.**

Keywords— **Risk severity index, MAHP, elevated corridor, metro rail, fuzzy MAHP, risk analysis.**

I. INTRODUCTION

According to Choi et.al (2004), Risk identification is a process to acknowledge risk events and to identify characteristics of risk events for the selected project based on the risk-related information. It is of considerable importance because the processes of risk analysis and response strategies may only be performed on the identified potential risks.

To improve the chance of success and reduce potential risks, in the initial phase, project risks and uncertain factors should be carefully identified, assessed and monitored (Kuo and Lu, 2013).Project risks have a direct impact on the project schedule, cost and performance (Sarkar and Dutta, 2011).

Sarkar et.al (2016), had developed risk indices for Quality, Safety and Environment by using MAHP for Delhi metro elevated rail corridor project.

AHP was familiarized by Saaty (1980) as a management tool for decision making in multi attribute environments. The fundamental approach of AHP is to break down a “big” problem into several “small” problems; while the solution of these small problems is relatively simple, it is conducted with a view to the overall solution of the big problem. The main uniqueness of AHP is its inherent capability of weighting a great number of different-nature factors-qualitative and quantitative-in order to make a decision, thereby producing a formal and numeric basis for solution(Saaty1987).

Shapira and Simcha (2009) had explained AHP in a simplified manner. Firstly identified the problem and then Hierarchy construction, in this step, a list of attributes are generated. The attributes are organized in a hierarchy -type structure that reflects their mutual relationships. The highest level of the structure consists of the primary goal of the problem. A second -level attribute set includes all of the secondary goals that together contribute to achieving the primary goal. The second level attributes are directly affected by all of the attributes in the set located one level lower. Attributes with no other attributes under them in the hierarchy structure are termed as leaf attributes.

The third step is Pair-wise Comparison, after mapping interrelationship between attributes by the hierarchy, relative weights of the attributes are determined by comparing them in pairs, separately for each set in the hierarchy. The results for each set are in the hierarchy. The results for each set are recorded in a separate comparison matrix. When comparing attribute pairs, the following must be determined:

Importance of two attributes is compared by giving them numbers on a scale. Shapira and Simcha (2009) used 1-9 scale as developed by Satty (1980) to convert qualitative equations into quantitative ones. Integers in comparison matrices that are greater than 1 represent a higher degree of importance attributed to the attribute in the row relative to the attribute in the column. The number 1 means that the two attributes compared have equal importance.

The fourth step is Synthesized Matrix, this matrix is obtained from the pair wise comparison matrix. Each element of the synthesized matrix is obtained by dividing the value of the element of the pair wise comparison matrix by their respective column total.

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After Synthesized Matrix, Priority Vectors (PV's) are calculated. The outcomes of synthesized matrix are priority vectors. These are obtained by summing up the elements in each row of the synthesized matrix and then dividing by the number of the elements in that row. The highest value of the vector is given the maximum priority.

Relative Weight Computation: Several approximation methods can be used to compute the eigenvector, of the comparison matrix, of which the Average of Normalized Columns (ANC) method is the most accurate. ANC computation of vector wi, the relative weight of the attribute in row i which is an element of the eigenvector w, for a reciprocal n x n matrix, is as follows:

$$Wi = \frac{1}{n}\sum_{j=1}^{n}(aij/\sum_{k=1}^{n}akj) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where;

n= Number of rows or columns in a square matrix
wi= The relative weight of the attribute in row i
aij= Element located in row i and column j of the comparison matrix
akj=Element located in row k of any normalized column i , j , k =1,2,....n

Weighted Sum Matrix: The weighted factor elements of the weighted sum matrix are obtained by multiplying each element of the pair wise comparison matrix by their respective priority vector. The weighted sum is the summation of the elements row wise. The Eigen Values (λ) are obtained from the following relationship:

Eigen Value (λ) = Weighted Sum / Priority Vector .... (2)

Consistency index (CI) = (λmax- n) / (n-1)..................... (3)

Where;
n= number of attributes

The consistency ratio CR is a measure for controlling the consistency of pair wise comparisons. Consistency Ratio (CR) is to measure how consistent the judgements have been relative to large samples of purely random judgements. Value of consistency ratio should be less than 0.2 for more consistent judgements.

CR = CI / RC .... (4)

Where;

RC is the Random Consistency Index

The AHP is used for scaling the weights of the elements (risks) in each level of hierarchy with respect to elements (risks) of the next higher level. The fuzzy AHP model is often used to tackle complex decision making that calls for subjective judgment on the basis of logical reasoning rather than simple feeling or intuition (Zhang and Zou, 2007).

The conventional AHP method is incapable of handling the uncertainty and vagueness involved in the mapping of one's preference to an exact number or ratio. The major difficulty with classical AHP is its inability in mapping human judgments. In recent years it has been observed that due to confusion in decision makers mind probable deviations should be integrated to the decision making process. In Fuzzy-AHP, pair wise comparisons are done using fuzzy linguistic preference scale ranging from 0 to 10. For simplicity, the reciprocal fuzzy numbers are replaced by individual TFN's in the pair wise comparison matrix. (Chatterjee, 2010).

Li and Zou (2011) had developed Fuzzy AHP based risk assessment methodology for Public Private Partnership projects and also proposed fuzzy AHP and straight-AHP indicate that fuzzy AHP can improve the risk assessment accuracy and reduce the respondents' subjectivity. To extend the application of the fuzzy AHP, more studies should be conducted.

II. METHODOLOGY

The responses obtained from the questionnaire survey responded by about 51 experts were in a risk rating scale of 0 to 1, where "0" indicates low risky situation and "1" indicates very high risky situation causing huge time and cost over-run of the project. For computational simplicity, we have converted risk rating values obtained from questionnaire survey into "Satty Scale" (1,3,5,7,9) with the help of which pair-wise comparison matrix was constructed both for Likelihood and Impact reviews. Then synthesised matrix is constructed both for Likelihood and Impact reviews. The outcomes of synthesized matrix were priority vectors. These were obtained by summing up the elements in each row of the synthesized matrix and then dividing by the number of the elements in that row.

III. CASE STUDY

The case study considered for this work is Bangalore elevated metro rail corridor construction. The construction is being executed by IL & FS Company Limited starting from the Nayandahalli to RV college station. The length of the section under study is 4.2 km. There are 4 elevated stations. Total 133 piers and 540 piles would be constructed. The weight of each segment is 14 tons.For this section, IL & FS Company Limited will produce, erect and launch 1180 segments for the viaduct from Nayandahalli to RV college station. The methodology of research work was formulation of questionnaire. Firstly to identify the major activities / risks involved from beginning to handing over the project and survey where the replies of the 51 experts from the metro rail corridor projects were used as inputs for expressing the risk severity ranks. Hence two rounds of discussions with metro officials and staff including machine operators, foreman, supervisors, and engineers, site in charges, managers, and deputy general managers. Discussions with consultants and chief engineer were also carried out for the finalisation of questionnaire, rating scales and their responses. The risk

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assessment is carried out in terms of risk severity index and their ranks.

IV. RESULT OF THE RESEARCH

The priority vectors of likelihood and impact obtained from AHP method for all 22 major risk categories were used as inputs for Fuzzy method by using Matlab software. Five Membership functions and 25 rules were created in software. The outputs are obtained for all 22 major risk categories as risk severity value. All values are calculated and four major activities of Bangalore metro rail project is tabulated in Table I.

TABLE I
Priority Vectors for Major Activities

Sr. No.	Activity	Priority Vectors of Likelihood	Priority Vectors of Impact
1	Risks in casting yard setup	0.033	0.035
2	Risks in Traffic and utility diversion	0.044	0.038
3	Pile and Pier work	0.041	0.038
4	Risks in segment casting	0.046	0.042

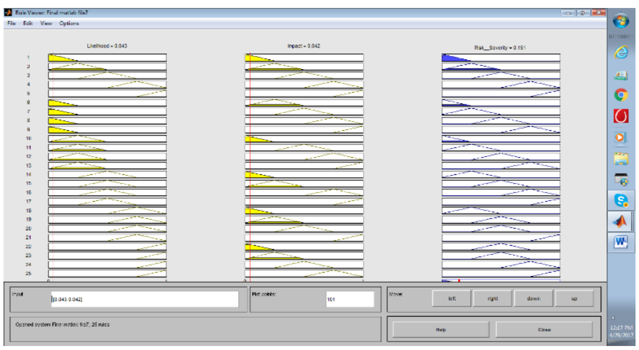

Fig. 1Matlab Representation for Risk Severity for Activity “Segment Casting”

TABLE III
Final Risk Severity values, Risk Index and Ranks by FAHP for the Elevated Corridor Project of Bangalore

Sr. no.	Activity	Final Risk Severity (FuzzyAHP Value)		Normal ized Weight	Final Risk Severity Index (Final Risk Severity x Normalized Weight)	Fuzzy MAHP Rankin g
		Quant itative	Qualit ative			
1	Risks in tender and award of contract	0.168	Very High Risk	0.055	0.00924	1
2	Feasibility and DPR risks	0.162	Very High Risk	0.05	0.00742	2
3	Risks in Land handover	0.159	Very High Risk	0.04	0.00715	3
4	Risks in Traffic and utility diversion	0.152	Very High Risk	0.04	0.00654	4

V. DISCUSSION AND INTERPRETATION

The final risk severity value, final risk index and Fuzzy MAHP rankings for all 22 major risk categories of an elevated metro corridor project obtained from Fuzzy MAHP are calculated and first four major activities are tabulated in Table II

In this table,4 major risk categories of an elevated metro corridor project are tabulated starting from ranking 1 to 4 w.r.t final risk severity index values obtained by Fuzzy MAHP method.

By Fuzzy MAHP method, Risks in tender and award of contract activity is very high both quantitative and qualitative and ranking is 1.

VI. CONCLUSION

There is distinct range of Risk severity quantitative values and Risk index values obtained by Fuzzy MAHP method for all 22 activities.Hence Fuzzy MAHP is a very good method for risk management tool for any Elevated corridor metro rail project.AHP is a well-structured technique and by incorporating Fuzzy as wellas normalised weights in AHP method helps in getting more reliable risk severities indices and ranks, hence proper risk mitigation measures can be formulated.

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