Risk assessment of highway construction projects using fuzzy logic and multiple regression analysis

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Abstract - *Highway construction projects are associated with different levels of risks. The main aim of this study is to identify the most significant risk factors affecting highway construction project in Kerala to decrease the likelihood and impact of those risks. A set of 12 risk groups consisting of 53 risk factors was selected and a questionnaire survey was conducted to determine the likelihood and impact of the identified risks. Later software applications were developed using SPSS and MATLAB to facilitate risk evaluation of highway projects. From regression analysis results indicated that the most significant risk factor is the safety regulation and from fuzzy results it is land acquisition. However, the overall project risk of highway construction projects in Kerala is considered as at a medium level.*

Key Words: **Membership function, Risk assessment, Risk factors, Regression analysis, Variables etc…**

1. INTRODUCTION

Construction industry is an important industry that plays a major role in economic growth of a nation and occupies a pivotal position in the nation's development plans. It improves the quality of life by providing necessary structures such as roads, hospital, schools etc. Hence it is necessary to complete within specified duration, budget and required quality expected without any risk. The majority of industry work is related to highway, road and street construction. New highway and street construction typically involves seven stages of development: planning, design and project administration; clearing and earthworks; alterations to public utilities; drainage, structures; paving and surfacing and project finishing. Different types of risks are associated with each and every stages of construction.

A risk is a potential event, either internal or external to a project, that is, if it occurs, may cause the project to fail to meet one or more of its objectives. Risk is defined as the expected likelihood or probability of an event occurring.

Highway construction projects are associated with different risk categories such as force majeure, economical, project finance, standards and regulations, sponsor, design, subcontractor, equipment, site location, project staff, environmental and geotechnical and construction. Risk assessment should be necessary for the successful completion of the project.

1.1 Need For The Study

In Kerala highway construction projects carry out higher risk than traditional because they entail high capital outlays and intricate site conditions. Risk and uncertainty of highway construction projects did not receive sufficient attention from researchers. Therefore, current study is trying to open up this area by identifying the major impacts and the role of major risks in Kerala highway construction projects.

1.2 Scope

This study adopts quantitative approach in identifying and assessing the significant risk factors affecting highway construction projects in Kerala by conducting a questionnaire survey among various consultant, clients and contractors. Further to develop multiple regression and fuzzy models for the estimation of probability of risk in highway construction.

1.3 Objectives

The objectives of the project are:

- To identify various risk factors affecting highway construction
- To conduct a questionnaire survey among clients, contractors and consultants to estimate major risk factors
- To develop models using multiple regression analysis and fuzzy logic
- To compare the results obtained from the models
- To validate the results obtained from the multiple regression models.

2. LITERATURE REVIEW

Gajendran and Ganesh [1] focused to identify project uncertainty factors and examine the influence of Risk factors on type of funding projects. Influence of risk factors on project progress of each activity is analyzed using multiple regression.

Lowe *et.al* [2] utilized a multiple linear regression technique to predict the building construction cost using data from 286 building constructed in United Kingdom. A predictive tool was desired that could be used during early stage of construction cost estimation before the detailed design has been completed. The identified 41 input models are used in the regression model. The input models were categorized as strategic, site related or design. They concluded that linear drivers of cost were predominately design specific. The coefficient of determination and mean absolute percentage error was used to judge model performance.

Sharaf and Abdelwahab [3] utilized the fuzzy logic to perform risk assessment in European highway construction. Significant risk events are identified and incorporated in this assessment and a questionnaire survey was conducted to determine the likelihood and consequences of the identified risks. Later fuzzy logic was developed using MATLAB to facilitate risk evaluation of highways projects. Results of this research indicated that the most significant risk factors are delay in making decision and land acquisition. Based on the model, the overall risk in the highway construction projects in Egypt is considered at a medium level and hence needs to deploy the use of proper risk management.

3. METHODOLOGY

A risk is defined as the potential for complications and problems with respect to the completion of a project and the achievement of a project goal. The aim of the risk assessment is to identify hazards, after which it may be possible to treat risk, thereby preventing them. Regression analysis using SPSS and fuzzy analysis using MATLAB were used in this study for developing the models.

3.1 Identification of Various Risk Factors

From different literature the 12 risk categories of 53 major factors were identified which is listed in Annexure A which include force majeure, economical, project finance, standards and regulation, sponsor, design, subcontractor, equipment, site location, project staff, construction, environmental and geotechnical.

3.2 Preparation of Questionnaire Survey

Various literatures were studied and based on the preliminary investigation conducted at the outset of this study. A questionnaire was then drawn up and was divided into two sections. Section A sought to know the general particulars of the respondents while section B includes various risk factors. A five point scale is adopted to facilitate ranking exercise and to facilitate the analysis of the responses, the following numerical values were assigned to the respondents' ratings. They were very low-1, low-2, medium-3, high-4, very high-5. The questionnaire survey was carried out among three groups of construction practitioners which are clients, consultants and contractors related to road construction.

3.3 Analysis of Risk Factors

A five point scale of 1-5 was adopted to assess the rating of each risk where 1 represents very low, 2-low, 3-moderate, 4-high, 5-very high. This five point scale is converted into Relative Important Index (RII).

$RII=\sum W/ (H*N)$

Where W is the weight given to each factor by the respondents ranges from1-5, H is the highest weight and N is the total number of respondents.

3.4 Development of Regression Model

The present study has made an attempt to examine the influence of risk factors on Kerala highway construction project, multiple regressions was administered. The regression model is,

$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + \ldots$

Where, Y = Mean score on risk of the Project
a=Constant,
$X_1, X_2, X_3 \ldots$ = Variables

3.5 Development of Fuzzy Model

For developing fuzzy model firstly define input and output variables, here the input variables are critical factors and the output is considered as risk. Then define linguistic variables like very low, low, medium, high and very high and the shape of the membership function is considered as triangular because of its simplicity. The operator used in the study is AND operator. Set up different mamdani style fuzzy inference rules and assigning weights to the rules.

In this study, the defuzzification method was selected as Center of Gravity (COG) Method and aggregation method was selected as "max" (maximum).

Fuzzy Logic Toolbox software is a collection of certain functions built on the MATLAB. It provides tools to create and edit fuzzy inference systems within MATLAB software.

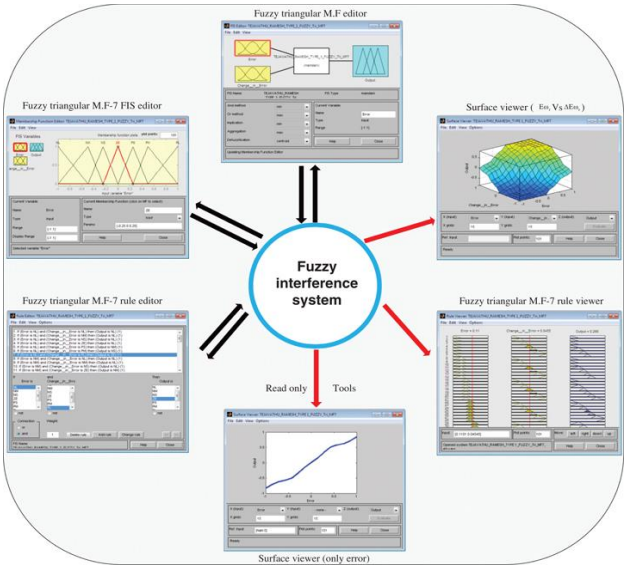

Fig -1: Graphical User Interface tool (GUI) for fuzzy model

4. RESULTS AND DISCUSSIONS

4.1 Critical Factors

The Relative Important Index of different risk that affects highway construction projects is calculated. From that the critical factors obtained are shown in table 1.

Table -1: Critical Factors

Category	Risk	RII	Rank
Site location	Land acquisition	0.73	1
Project finance	Advance payment	0.71	2
Design	Traffic flow	0.69	3
Environmental &geotechnical	Environmental factor	0.69	3
Standards and regulation	Safety regulation	0.67	4

4.2 Impact Probability

The average impact and probability of each risk factor are shown in table 2.

Table-2: impact and probability of risk factors

Impact probability					Risk factor	Risk
LA	AP	TF	SR	EF		
0.95	0.85	0.76	0.89	0.98	0.886	high
0.41	0.6	0.31	0.25	0.3	0.374	moderate
0.73	0.71	0.69	0.69	0.67	0.698	high
0.21	0.36	0.10	0.31	0.21	0.238	low
0.05	0.06	0.01	0.03	0.03	0.036	Very low

Where LA, AP, TF, SR and EF are the critical factors such as land acquisition, Advance payment, Traffic flow, Safety regulation and Environmental factors.

4.3 Regression Method In SPSS

The multiple regression analysis done based on the most significant factors which are previously identified. The regression analysis can be done in different ways such as forward, backward, step ways etc. Among this backward regression method (BRM) gives more accurate result.

Table -3: Regression model summary

Model	R	R Square	Adjusted R Square	Std. Error of the estimate
1	0.844	0.712	0.392	7.68982

Table 3 provides both R and R^2 values. The R value is 0.844 which indicates simple correlation, here it indicates a high degree of correlation. The R^2 value indicates how much of the total variation in the dependent variable, risk, can be explained by the independent variable, risk factors. In this case, 71.2% can be explained, which is very large.

Table -4: Analysis of variance

Model	Sum of squares	Df	Mean square	Sig.
1	Regression	1314.295	131.430	0.012
	Residual	532.206	59.134	
	Total	1846.501		

The Analysis of variance table, which reports how well the regression equation fits the data . Table 4 indicated that the regression model predicts the dependent variable significantly well. The "Sig." column indicates the statistical significance of the regression model. Here, p = 0.012, which is less than 0.05, and indicates that, overall, the regression model significantly predicts the outcome variable.

The regression model obtained is,

Risk = 52.930+(-1.701LA)+(2.183AP)+(2.105TF) + (-0.482EF)+(6.40SR)+(-0.446CD)+(1.688EC)+(0.566C) +(-5.42A)+(-3.199PTE)

Where,

LA = Land acquisition

AP = Advance payment

TF = Traffic flow

EF = Environmental factor

SR = Safety regulation

CD = Change in design

EC = Economic crisis

C = Equipment condition

A = Equipment availability

PTE = Project time extension

4.4 Fuzzy Logic In MATLAB

The results of fuzzy logic in MATLAB are rule viewer and surface viewer.

The Fig 1 shows the rules view of the system. The rule viewer window shows the relevant input and output membership functions for each rule. Rule 1 involves land acquisition and risk, so they are shown and rule 2 advance payment and risk. For the given input the modified output membership function is shown in solid blue. These are then aggregated and shown in bottom right membership function. This is the fuzzified result. For the input of 50 both rules are firing and aggregate membership function is same as previously determined. The default defuzzification process is the centroid method and the red line indicates where the centroid is and also what the output is.

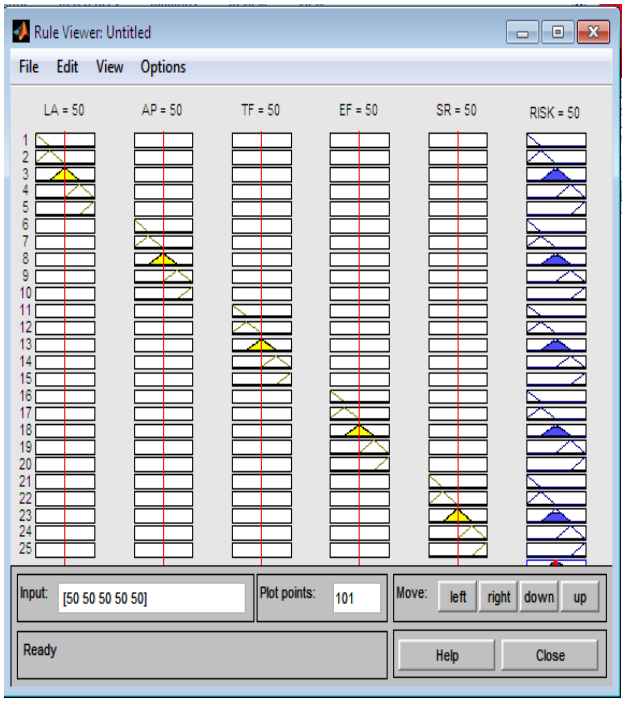

Fig -1: Rule viewer

Figure 2 shows the variation of land acquisition (LA) and advance payment (AP) with respect to risk. To display the dependency of one of the outputs on any one or two of the inputs that is, it generates and plots an output surface map for the system. In figure 2 land acquisition and advance payment are the input factors and the term risk is considered as output.

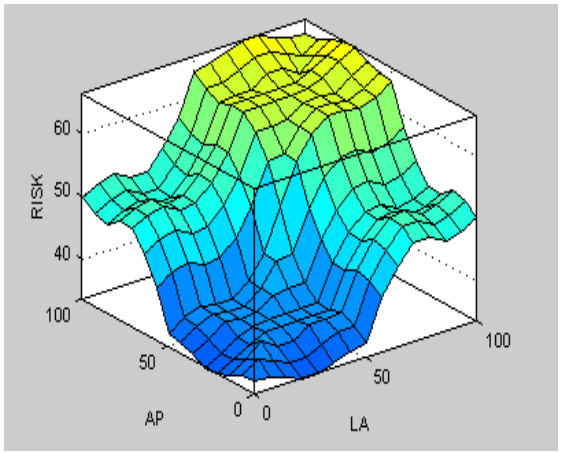

Fig -2: Surface viewer

4.5 Validation Of Regression Results

For the validation of regression model the actual Relative Important Index of different risk that affects ten different highway construction projects are calculated and also the predicted Relative Important Index of these ten projects are calculated are shown in table 5. The graph showing the value of R square as shown in figure 3.

Percentage error =

((Actual RII – Predicted RII cost)/Actual RII)*100

Table -5: Percentage error in regression model

RII (Actual)	RII (Predicted)	Error (%)
35.867	65.3	45
56.545	63.3	10
39.494	62.6	36
72.7	73.3	8
69.717	69.3	6
47.63	65.3	2.7
43.443	64.6	3.2
58.375	67.3	13.2
68.704	71.3	3.6
59.246	68	12.8

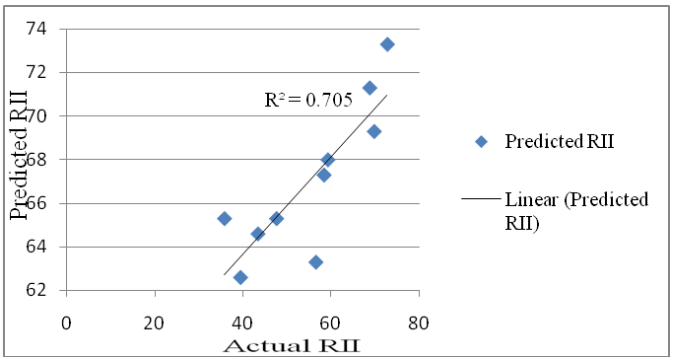

Chart -1: Actual Vs predicted RII

Table -6: Regression parameters obtained from validation

Parameters	Value
R	0.812
R^2	0.705
Adjusted R^2	0.315
Total sum of squares	1365
Residual error	545

5. CONCLUSION

The first step in assessing risk is the identification and evaluation of risk factors. The main objective of this study was to identify the main causes of risk in highway construction project and analyzed using multiple regression and statistical fuzzy method. Regression analysis was performed in SPSS software, statistical fuzzy was performed in MATLAB program software.

Regression model has a strong correlation coefficient R equal 0.844 and coefficient of determination R square equal 0.712 which is a best fit which means that 71.2% of the total variation in risk can be explained by the model. Average percentage error for each project is lesser than 50%. Therefore the predicted model in this study will be only an average model to determine the probability of risk that occurs in the highway construction projects. From the regression analysis the most significant factors affecting highway construction are safety regulation and advance payment.

Fuzzy logic models were developed in order to evaluate project risk. Results of the fuzzy model indicated that the most significant risk factors are land acquisition and advance payment. These factors have risk values more than 50%. Based on the models, the overall risk in the highway construction projects in Kerala is considered at a medium level.

On comparing the results of analysis using multiple regression and fuzzy logic methods, fuzzy theory was proposed as an effective probability analysis technique in highway construction projects. Fuzzy theory provides mathematical tools to deal with uncertain and vague data. Therefore statistical fuzzy method is more reliable in analyzing the impact of risk in highway construction projects.

5.1 SCOPE FOR FUTURE WOK

Future studies could be performed for different specific types of construction projects, such as railway construction projects, building housing projects, utility projects and dam construction projects, etc. Future studies can be designed by utilizing different model parameters such as: different number and group of risk factors, linguistic variables and membership functions, fuzzy rules, weights of rules, aggregation and defuzzification methods. This thesis opens up a realm of possibilities where future researchers can produce more powerful, user friendly software's that can analyze all the possible risk factors, producing fast and reliable results. Various risk assessment models can be developed using fuzzy AHP, fuzzy TOPSIS methodology, and artificial neural network etc.

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