International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 17
November 2016

# Analysis of Cost Overrun For Flyover Bridges Construction Project Using Fuzzy Logic

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***Abstract:*** *Bridges Construction industry is measured as one of the most dynamic and risky industrial sector. Project failure takes place in terms of project delay, cost over runs and poor quality. In this project, I aim to identify and analyze the major cost overrun factors in bridge construction projects in Indore. The cost is measured as one of the most important success parameter of any project. The cost overrun factors are identified based on questionnaire survey and expert opinion which is ranked using Relative Important Index (RII) scale. Graphs showing the variation of cost overrun for different combination of cost overrun factors are obtained. This project work presents an application of fuzzy logic for developing cost overrun evaluation model using Fuzzy toolbox of MATLAB Program Software. This project work aims to identify the main factors affecting the construction cost overrun in the construction industries. A list containing 74 factors of cost overrun which are accountable for the cost overrun in the construction industries was prepared based on data collection, questionnaire survey and by conducting interviews. Finally, the model has been calibrated on real case study.*

***Keywords:*** *Cost overrun Causes and factors, Questionnaire Survey, Relative Importance Index (RII), Fuzzy logic, Construction Project.*

## Introduction

The Indian construction industry contributes more than five percent (5%) to the country's Gross Domestic Product (GDP). Construction industry includes highways, railways, ports, bridges, power plants, tunnels, municipal facilities etc (Maheshwari 2015). Timely completion of construction projects is a display of efficient planning, management and construction. A project is considered to be successful if it is completed on time and within budget. Normally, when the projects are overdue, they are either extended or accelerated and therefore, incur additional cost. To the dislike of owners, contractors and consultants many projects experience extensive time delay and thereby go over initial time and cost estimates. Bridges Construction industry is considered as one of the most dynamic and risky industrial sector. Budget is considered as an important key parameter for the success of any project. Many authors have suggested that risk cost should be adopted as an evaluation scale (Elhag et al. 1999). In unkindness of the importance of this factor, construction industry is full of projects that functionally operate with extensive cost flooded. Cost overflow in projects generates a considerable financial loss to both contractor and owners. Cost overrun is widespread in most bridge construction projects around the world (Kasimu, 2012). Some overrun may occur in the preconstruction phase which is defined as the beginning from the origin of the project to the signing of the contract between the owner and the contractor however; some of them may occur in the construction phase that is the period when actual construction is in progress. Cost overrun must be analyzed in order to apportion responsibility for the duration of the delay among the project participants (owner, contractor, and/or third party). There are various methods that exist for schedule delay analysis like Delphi method survey method, additive approach of delay analysis method fuzzy theory etc.

## OBJECTIVE OF THE STUDY

The main objective of this research work is to analyze cost overruns in flyover construction projects using Fuzzy Logic. Factors affecting cost over run for the flyover construction projects were analyzed using questionnaire survey and literature review. Survey data were then used to develop the fuzzy model for the assessment of cost overrun. The assessment model was calibrated at Rajendra Nagar railway over bridge and Kesharbagh railway over bridge in Indore. The model is applied at Teen Imli Flyover Bridge constructing in Indore. The objectives of the study are:

1. To perform questionnaire survey to obtain factors affecting of cost overruns for bridge construction project.
2. Ranking of cost overrun factors for the bridge construction project.
3. To develop cost overrun analysis model using fuzzy set theory.

## LITERATURE SURVEY

Shreenaath et al. (2015) identified the factors affecting the construction cost in the construction industries of Tamil Nadu. A list containing 54 factors were responsible for the cost overrun in the construction industries was prepared based on literature review and they were ranked using Relative Important Index (RII) scale based on the opinion of the engineers by distributing the list in the form of Questionnaire to 60 respondents (30 Government engineers and 30 private engineers). They applied fuzzy logic for developing cost overrun assessment model using Fuzzy toolbox of MATLAB Program Software. The top five factors were used for this purpose. Finally, the model has been validated using four case studies.

Sharma and Goyal (2014) applied fuzzy logic for developing cost overrun assessment model. Project failure takes place in terms of project time delay, cost over runs and poor quality. The cost overrun factors are identified based on literature review and expert opinion which is ranked using Relative Important Index (RII) scale. Results showed that, slow decision making, poor schedule management, increase in material/machine prices, poor contract management, poor design/ delay in providing design, rework due to wrong work, problems in land acquisition, wrong estimation/ estimation method, and long period.

Mahamid and Bruland (2011) recognized the cost overrun reasons in road construction projects in the West Bank in Palestine from consultants view. A questionnaire survey of 40 consultants from was performed. Survey was included 51 suggested factors through literature review. The factors were ranked according to the degree of importance as assessed by the respondents. The findings disclose that the top five affecting factors were: materials price fluctuation, insufficient time for estimate, experience in contracts, size of contract, and incomplete drawings.

## METHODOLOGY

Identification of factors affecting cost overrun. A thorough literature review was done and the expert opinions from industry experts were taken, through which a number of cost overrun factors were identified for the fly over bridge construction projects. In total 72 factors of cost overrun were finalized to make part of the survey questionnaire. A questionnaire form which consists of two parts A and B was been developed. In Part A contains personal Information of the respondents (for e.g. work experience, organization, annual volume of construction work). Part B was aimed to obtain information about causes of cost overrun and time delay Indore bridge construction industry. It was asked to rate those initially identified 72 factors of cost overrun according to their severity level on the given scale, Indore bridge construction site have been approached for this study. A total of 60 respondents were selected for the survey. (20 Site engineer, 10 contractors, 10 Govt.Engineer, 8 consultants and 12 Academician). Ranking of factors were done using RII (Relative importance index) using the assessment of feedback from questionnaire survey.

### Ranking of cost overrun and time delay factors

A five point like scale ranging from 1-5 was adopted to assess the degree of agreement of each factor Where 1 means strongly agree, 2 means Agree 3 means Neither; 4 means Disagree and 5 means Strongly disagree.. This five-point scale was converted to a Relative Importance Index (RII) for each individual factor, using the following formula, as adopted by Kumaraswamy and Chan (1997, 1998) and Assaf et al (1995).

$$(RII) = \Sigma W / (H \times N)$$

Where ΣW is the total weight given to each factor by the respondents, which ranges from 1 to 5 and is calculated by an addition of the various weightings given to a factor by the entire respondent, H is the highest ranking available (i.e. 5 in this case) and N is the total number of respondents that have answered the question. The RII value range from 0 to 1 (0 as not inclusive); and the higher the RII, the more important is the cause of Cost overrun.

## Fuzzy logic model to analyze of cost overrun factors

The fuzzy set theory is a convenient mathematical tool that can process linguistic terms, and it can be utilized to propose an efficient and systematic uncertainty modeling method (Beriha et al. 2012).

To construct the proposed fuzzy assessment model to be used in estimating the cost overrun and time delay, the following steps were followed:

- The delay factors and groups which were identified in the previous sections were the main input variable of this assessment model.
- The linguistic variables and fuzzy membership functions were determined.
- The fuzzy rules (if-then rules) were constructed; the relative importance indices of the factors and groups of factors given in previous section were selected as the weights of the fuzzy rules; and the aggregation and defuzzification methods were determined to construct the fuzzy assessment model to estimate cost overrun and time delay.
- The constructed fuzzy assessment model was calibrated on Kesarbagh railway over bridge. The model was validated and tested on Rajendra Nagar Railway over bridge and Teen Imli flyover bridge projects in Indore.

## Linguistic variables and fuzzy membership functions

The linguistic variables categorized as "very low, low, medium, high, and very high" out of a scale ranging from zero to 100. The only condition a membership function must really satisfy is that it must vary between 0 and 1.we has selected triangular membership function for this project. The function itself can be an arbitrary curve whose shape we can define as a function that suits us from the point of view of simplicity, convenience, speed, and efficiency. The Fuzzy Logic Toolbox includes 11 built-in membership function types. These 11 functions are, in turn, built from several basic functions: piecewise linear functions, the Gaussian distribution function, the sigmoid curve, and quadratic and cubic polynomial curves. The simplest membership functions are formed using straight lines. Of these, the simplest is the triangular membership function, and it has the function name trimf. It's nothing more than a collection of three points forming a triangle. Equation of triangular membership function

y = trimf (x, [a b c])

## Construction of the fuzzy rules (if-then rules), assigning weights to the rules, and aggregation and defuzzification operations

In this research, the Mamdani-style fuzzy rules (Mamdani and Assilian 1975) was implemented due to the advantages of the Mamdani's approach, being the most popular in the literature, also being intuitive, having widespread acceptance, and well-suited to human input (Kaur and Kaur 2012). To perform the fuzzy inference, the rules that connect the input variables to the output variables in If: Then: forms were used to describe the desired model in terms of linguistic variables (words) rather than mathematical formulas. Aggregation is an operation by which several fuzzy sets are combined in a desirable way to produce a single fuzzy set. Max method is commonly used as an aggregation method in the literature therefore it was selected. Defuzzification is a mathematical process used to extract crisp output

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p-ISSN: 2348-6848
e-ISSN: 2348-795X
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from fuzzy output set(s). This process is necessary because all fuzzy sets inferred by fuzzy inference in the fuzzy rules must be aggregated to produce one single number as the output of the fuzzy model. Graphical user interface tools to construct the fuzzy assessment model in the fuzzy logic tool as a shown in Fig.-1

## Fuzzy logic model calibration, validation and testing

We have selected three Flyover bridge construction project situated in Indore that is Kesarbagh railway over bridge, Rajendra Nagar railway over bridge and Teen Imli Flyover Bridge for the calibration, validation and testing. The fuzzy logic model was calibrated on Kesarbagh railway over bridge. The fuzzy logic model was validated and tested on Rajendra Nagar railway over bridge and Teen Imli Flyover Bridge.

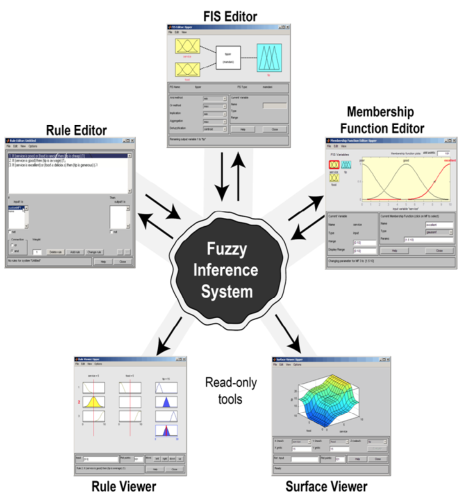



Fig.-1: Graphical user interface tools to construct the fuzzy assessment model in the fuzzy logic tool

## DATA ANALYSIS AND DISCUSSION

- **Analysis of factors affecting cost overrun**

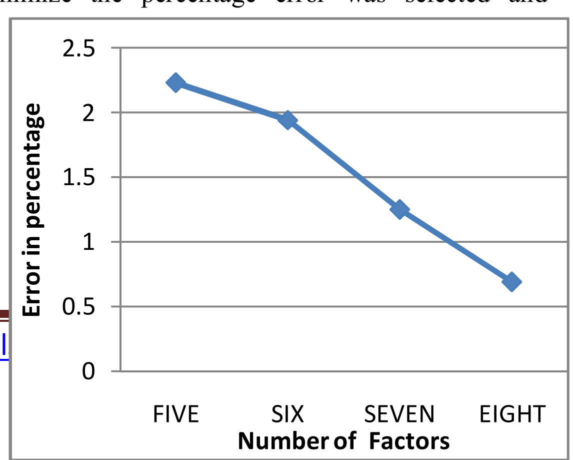
Data collection was carried out by conducting a questionnaire survey for identifying significant factors affecting construction cost performance. A total of 60 respondents participated in the survey process. Data was checked for reliability prior to ranking the factors. The scoring was done on a five-point scale and was later converted to a Relative Importance Index (RII) for each individual factor. The factors affecting cost overrun are shown in Table: 1.

- **Fuzzy logic model for predicting cost overrun**

A fuzzy logic model was developed to predict cost overrun. For the model, a Mamdani inference engine with a triangular membership functions was used. Five fuzzy subsets namely, very low (VL), low (L), medium (M), high (H) and very high (VH) were used. Sensitivity analysis was used to select the topmost factors affecting cost overrun. The fuzzy model was calibrated for Kesarbagh Bridge; the model was validated for Rajendra Nagar railway over bridge and the model was tested for Teen Imli Flyover Bridge.

## Sensitivity Analysis for Cost Overrun

Initially total 72 factors affecting cost overrun were established form the literature review. Prior to selecting the number of cost overrun factors for the fuzzy logic model, a sensitivity analysis was conducted. The factors affecting the cost overrun were varied from 5-8 and the error in the simulated cost overrun was computed. The number of factors which gave minimum error was selected. The analysis of cost overrun was calculated using fuzzy logic model. According to Table-2, actual estimated cost was 21.5 crore but actual construction cost was 36 crore. If we consider five factors fuzzy model predicts a cost overrun of Rs. 351955000 with an error of 2.23%. If we consider six factors, fuzzy model predicts cost overrun of Rs. 353000000 and error is 1.94%. If we consider seven factors fuzzy model predicts cost overrun is Rs. 355500000 with an error of 1.25%. If we consider eight factors, model predicts cost overrun is Rs. 2500000 and error of 0.69%. From Fig.-2 we can say that as the number of factors increases, the cost overrun error decreases. Based on Fuzzy analysis for cost overrun, out of the 72 cost overrun factors, eight topmost factors which minimize the percentage error was selected and



shown in Table-3.

Fig-2: Sensitivity Analysis for cost overrun factors v/s error in percentage

**Table-1: Relative Importance Indexes and Ranking of the Factors of Cost Overrun**

| Sr. No | Cost Overrun Analysis of Bridge | Number of respondents scoring | | | | | RII | Rank |
|---|---|---|---|---|---|---|---|---|
| | | Strongly Agree-5 | Agree-4 | Neither-3 | Disagree-2 | Strongly Disagree-1 | | |
| 1 | Escalation of material & labor prices | 56 | 4 | 0 | 0 | 0 | 0.987 | **1** |
| 2 | Unreliable suppliers | 54 | 6 | 0 | 0 | 0 | 0.980 | **2** |
| 3 | Slow mobilization of equipment | 44 | 16 | 0 | 0 | 0 | 0.947 | **3** |
| 4 | Poor site management and supervision | 42 | 18 | 0 | 0 | 0 | 0.940 | **4** |
| 5 | Shortage of equipment | 39 | 21 | 0 | 0 | 0 | 0.930 | **5** |
| 6 | Poor quality of construction materials | 39 | 21 | 0 | 0 | 0 | 0.930 | **5** |
| 7 | Unqualified / inexperienced labor | 38 | 22 | 0 | 0 | 0 | 0.927 | **6** |
| 8 | Poor financial control on site | 29 | 28 | 3 | 0 | 0 | 0.887 | **7** |
| 9 | Complexity of project design | 27 | 30 | 3 | 0 | 0 | 0.880 | **8** |
| 10 | Inadequate modern equipment | 37 | 11 | 9 | 3 | 0 | 0.873 | **9** |
| 11 | Incompetent Project team (designers and contractors) | 27 | 28 | 3 | 2 | 0 | 0.867 | **10** |
| 12 | Incorrect planning and scheduling by contractors | 34 | 13 | 8 | 5 | 0 | 0.853 | **11** |
| 13 | Natural disasters (flood, hurricane, earthquake) | 21 | 34 | 5 | 0 | 0 | 0.853 | **11** |
| 14 | Absenteeism of labor | 30 | 15 | 15 | 0 | 0 | 0.850 | **12** |
| 15 | Changes in material types and specifications during construction | 20 | 32 | 8 | 0 | 0 | 0.840 | **13** |
| 16 | High cost of labor | 26 | 20 | 14 | 0 | 0 | 0.840 | **13** |
| 17 | Financing by contractor during construction | 22 | 26 | 12 | 0 | 0 | 0.833 | **14** |
| 18 | Inaccurate site investigation | 21 | 25 | 9 | 5 | 0 | 0.807 | **15** |
| 19 | Inappropriate construction methods | 24 | 22 | 8 | 1 | 5 | 0.797 | **16** |
| 20 | Ineffective project planning and scheduling | 23 | 17 | 16 | 4 | 0 | 0.797 | **17** |
| 21 | Delay in obtaining permits from municipality | 17 | 23 | 20 | 0 | 0 | 0.790 | **18** |
| 22 | Low efficiency of equipment | 18 | 23 | 14 | 5 | 0 | 0.780 | **19** |
| 23 | Lack of coordination at design phase | 18 | 25 | 8 | 9 | 0 | 0.773 | **20** |
| 24 | Inadequate contractor experience | 20 | 20 | 12 | 8 | 0 | 0.773 | **20** |
| 25 | Late in reviewing and approving design documents | 15 | 25 | 16 | 4 | 0 | 0.770 | **21** |
| 26 | Incomplete design at the time of tender | 22 | 20 | 8 | 5 | 5 | 0.763 | **22** |
| 27 | High cost of transportation | 25 | 8 | 18 | 9 | 0 | 0.763 | **22** |
| 28 | Delay in progress payments | 13 | 28 | 14 | 0 | 5 | 0.747 | **23** |
| 29 | Improvements to standard drawings during construction stage | 20 | 15 | 13 | 12 | 0 | 0.743 | **24** |
| 30 | High interest rates charged by banks | 15 | 23 | 16 | 2 | 4 | 0.743 | **24** |
| 31 | Lack of experience of project type | 18 | 15 | 16 | 11 | 0 | 0.733 | **25** |
| 32 | Delay in providing services from utilities (such as water, electricity) | 7 | 32 | 15 | 6 | 0 | 0.733 | **25** |

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|---|---|---|---|---|---|---|---|---|
| 33 | Lack of experience of local regulation | 18 | 18 | 10 | 12 | 2 | 0.727 | **26** |
| 34 | Lack of cost planning/monitoring during pre and post contract stages | 14 | 25 | 10 | 6 | 5 | 0.723 | **27** |
| 35 | Expenence of the consultant's project manager | 6 | 29 | 20 | 5 | 0 | 0.720 | **28** |

**Table-2: Sensitivity Analysis for cost overrun factors using fuzzy model**

| Sr. No. | Factor's | Project Name | Estimated Cost | Actual Cost-(A) | Cost Over run | Fuzzy Prediction For cost overrun-(B) | Error (A-B) | Error in Percentage (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | FIVE | Kesharbagh Railway over bridge | 21.5 crore | 36 crore | 14.5 crore | 351955000 | 8045000 | 2.23% |
| 2 | SIX | | | | | 353000000 | 7000000 | 1.94% |
| 3 | SEVEN | | | | | 355500000 | 4500000 | 1.25% |
| 4 | EIGHT | | | | | 357500000 | 2500000 | 0.69% |

**Table-3: Top 8 most important factors affecting cost overrun of bridge construction**

| Sr. No. | Factors of Cost Overrun | RII | Rank |
|---|---|---|---|
| 1 | Escalation of material & Labor Prices | **0.987** | **1** |
| 2 | Unreliable Suppliers | **0.980** | **2** |
| 3 | Slow Mobilization of equipment | **0.947** | **3** |
| 4 | Poor site management and supervision | **0.940** | **4** |
| 5 | Shortage of equipment and Poor quality of construction materials | **0.930** | **5** |
| 6 | Unqualified / inexperienced labor | **0.927** | **6** |
| 7 | Poor financial control on site | **0.887** | **7** |
| 8 | Complexity of project design | **0.880** | **8** |

- ## Cost overruns using fuzzy controller

The main causes of cost overruns were studied in this work; the fuzzy controller was used to predict the cost overrun based on the top eight factors. The eight input and one output fuzzy based cost overrun is discussed here. Table-4 shows sample fuzzy rules for the cost assessment model.

The eight top most factors are used as inputs and cost overrun was computed through the fuzzy controller. In fuzzy logic controller, all membership functions are considered as triangular membership functions with five segments. The five fuzzy subsets namely very low (VL), low (L), medium (M), high (H) and very high (VH) were used.

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The Mamdani inference engine is used in the fuzzy controller. Fig.3 shows input and output members for the fuzzy cost overrun assessment model. Fig.4-5 shows membership function for the input and output variable respectively.

## Model calibration for Kesharbagh railway over bridge

The fuzzy model was calibrated for the Kesarbagh railway over bridge. The estimated cost of completion of project was obtained through interviews, discussions with construction managers and detailed study of project documents and contracts. Table-5 shows the performance of the fuzzy logic model .For the project, the estimated cost was 21.5 crore whereas; the actual completion cost was 36 crore thus having a cost overrun of 14.5 crore. The completion cost predicted by the developed fuzzy logic model was 357500000 Rs. predicting a percentage error of 0.69 %.

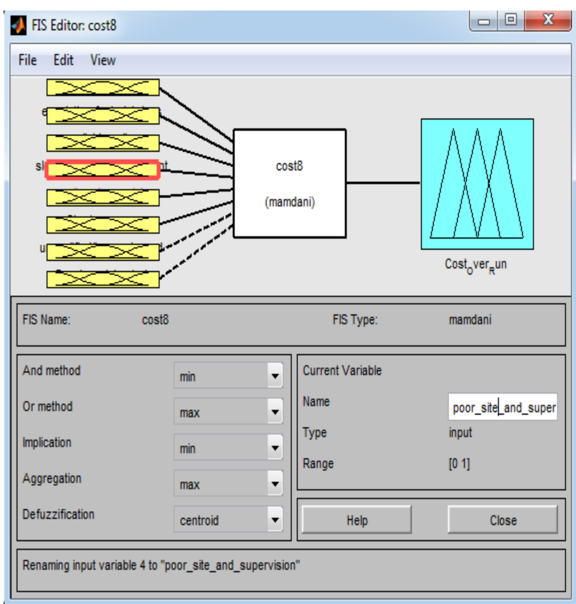


Fig.-3: Input and output members for cost overrun assessment model for Kesharbagh railway over bridge

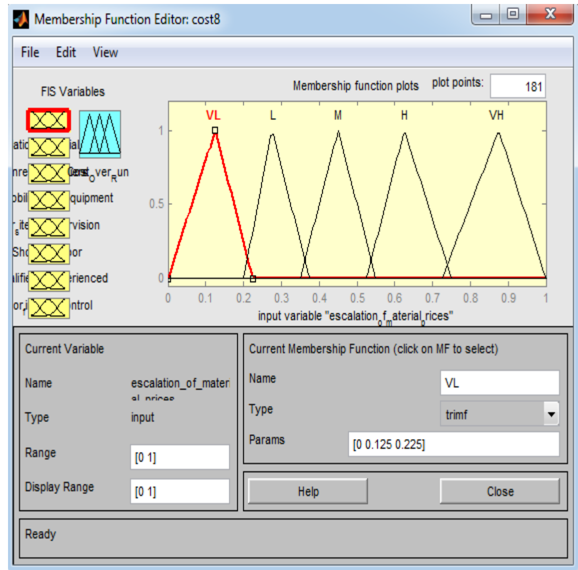


Fig.-4: Membership function for the cost overrun assessment model (Input) for Kesharbagh railway over bridge

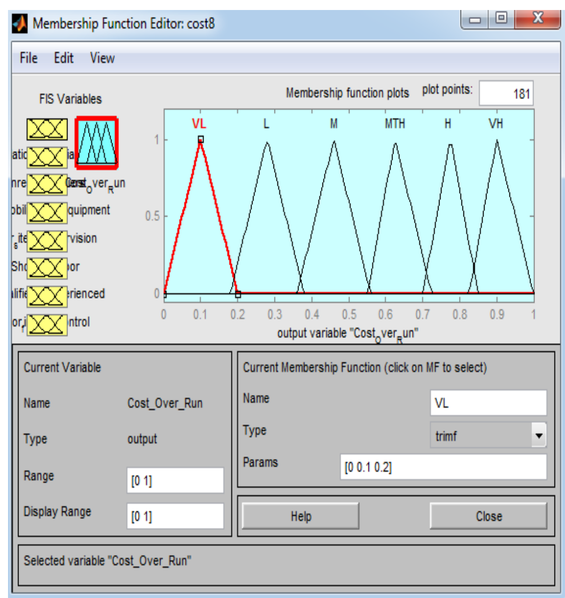


Fig.-5: Membership function for the cost assessment model (Output) for Kesharbagh railway over bridge

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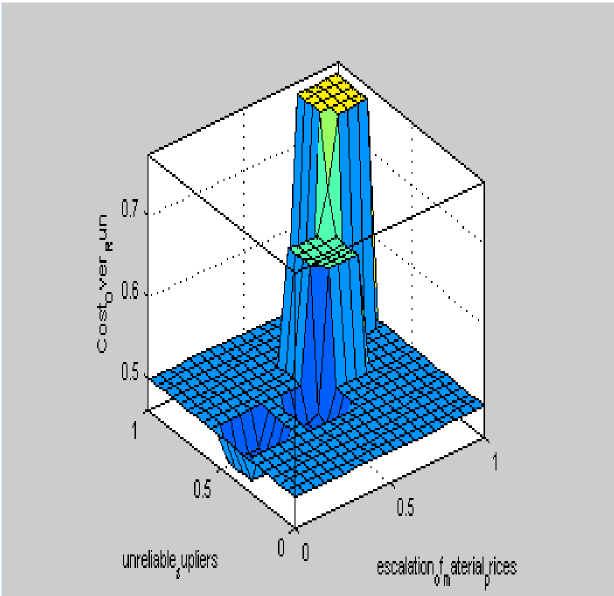


Fig.-6: Variation of escalation of material & labor prices (EM&LP) and unreliable suppliers with respect to cost overrun for Kesharbagh railway over bridge

## Model calibration for Kesharbagh railway over bridge

The fuzzy model was calibrated for the Kesarbagh railway over bridge. The estimated cost of completion of project was obtained through interviews, discussions with construction managers and detailed study of project documents and contracts. Table-5 shows the performance of the fuzzy logic model .For the project, the estimated cost was 21.5 crore whereas; the actual completion cost was 36 crore thus having a cost overrun of 14.5 crore. The completion cost predicted by the developed fuzzy logic model was 357500000 Rs. predicting a percentage error of 0.69 %.

The surface view of the Kesarbagh railway over bridge was used to understand the variation between two inputs to the output factor. The quantization factor and the scaling factor play a significant role in the performance of the fuzzy controller. Fig.6 shows variation of escalation of material & labor prices (EM&LP) and unreliable suppliers with respect to cost overrun.

**Table-4: Sample Fuzzy rules for the of cost assessment model and rule weight for very low**

| Sr. No. | Rules | Rule Weight |
|---|---|---|
| **1** | If the probability of Escalation of material & labor prices is very low the cost overrun is very low | **0.987** |
| **2** | If the probability of Unreliable Suppliers is very low the cost overrun is very low | **0.980** |
| **3** | If the probability of Slow Mobilization of equipment is very low the cost overrun is very low | **0.947** |
| **4** | If the probability of Poor site management and supervision is very low the cost overrun is very low | **0.940** |
| **5** | If the probability of Shortage of equipment and Poor quality of construction materials is very low the cost overrun is very low | **0.930** |
| **6** | If the probability of Unqualified / inexperienced labor is very low the cost overrun is very low | **0.927** |
| **7** | If the probability of Poor financial control on site is very low the cost overrun is very low | **0.887** |
| **8** | If the probability of Complexity of project design is very low the cost overrun is very low | **0.880** |

**Table-5: Performance of the project considered for calibration**

| Sr. No | Project Name | Estimated Cost | Actual Cost-(A) | Cost Overrun | Fuzzy Prediction For cost overrun-(B) | Error (A-B) | Error in Percentage (%) |
|---|---|---|---|---|---|---|---|
| 1 | Kesharbagh Railway over bridge | 21.5 crore | 36 crore | 14.5 crore | 357500000 Rs. | 2500000 Rs. | 0.69 % |

## CONCLUSION

In this project, the factors were identified and analyzed due to which major cost overrun occurs in bridge construction projects. In Indore through wide data collection, questionnaire survey, by conducting interviews and preparing model for further analysis using software's was done on one fly over bridges. This study presents an application of fuzzy logic for developing cost overrun evaluation model using Fuzzy toolbox of MATLAB Program Software. So it is essential to define the actual causes of cost overrun in order to minimize the impact of the increase in cost any construction project. Therefore it has been concluded that the each model holds good to predict the percentage of cost overrun in any construction project.

In cost overrun out of the 72 factors, eight topmost factors were selected according to the RII value and the RII values of the top eight factors were used to predict the percentage of cost overrun in construction industry. The first rank of causing of cost overrun according RII (0.987) is escalation of material & Labor Prices. Second rank of causing of cost overrun according RII (0.980) is unreliable suppliers in construction site. The third rank of causing of cost overrun according RII (0.947) is slow mobilization of equipment. The fourth rank of causing of cost overrun according RII (0.940) is poor site management and supervision and lack of modern equipment in contactor. The fifth rank of cost overrun according RII (0.930) is shortage of equipment and poor quality of construction materials. The sixth fifth rank of cost overrun according RII (0.927) is unqualified / inexperienced labor. The seventh rank of cost overrun according RII (0.887) is poor financial control on site. The eight rank of cost overrun according RII (0.880) is complexity of project design.

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