# 4

A FRAMEWORK FOR DEVELOPMENT OF RISK SEVERITY THROUGH THE APPLICATION OF FUZZY EXPECTED VALUE METHOD (FEVM) FOR INFRASTRUCTURE TRANSPORTATION PROJECT

Manvinder Singh, Debasis Sarkar

**ABSTRACT:** Mega infrastructure transportation projects are exposed to very high uncertainties and critical risks due to complexity starting from pre-conception to operation phase of a project life cycle. Hence, fully organized method of risk assessment is required for the formulation of risk detection and mitigation measures. This research work is an effort to determine risk severity and risk ranking of the various risky activities of elevated corridor metro rail projects using Fuzzy Expected Value Method (FEVM). Fuzzy logic is incorporated within conventional Expected Value Method (EVM) to map the interrelationship between probability of occurrence and impact generated for a particular activity. Based upon fuzzy risk severity values, it has been concluded that erection of pre-cast segments, detailed project report and feasibility, land handing over, traffic diversion and piling activities are having very high fuzzy risk severity values and came under first five ranks with respect to risk involved and associated with them. The developed fuzzy risk severity values would enable the project authorities to identify the activities with high risk severity and to take the mitigation measures accordingly.

#### Introduction

Rapid economic development has augmented the demand for the construction of public and private infrastructure and facilities in metropolitan areas worldwide and has resulted in the undertaking of numerous public construction projects which are very uncertain and risky due to complexity and problems in utility diversion, land acquisitions, approval of funds from government authorities and financial institutions, safety and environmental issues. Mostly government authorities and construction firms fail to take a proactive approach regarding risks involved, which results into huge cost overruns and delays. Hence for the successful completion of the project with respect to cost, time, scope, quality and safety, potential risk should be identified, prioritised and accordingly risk mitigation measures have to be implemented.

This research work is an effort to determine risk severity and Fuzzy Expected Value Method (FEVM) ranking of the various major risky activities of metro projects using Fuzzy EVM (FEVM). This FEVM ranking helps the project management team to develop and implement risk mitigation measures to avoid undue time and cost overrun in projects.

#### **KEYWORDS**

Risk severity, Fuzzy expected value method (FEVM), Elevated corridor, Metro rail project, Infrastructure transportation

#### **Literature Review**

Askari, Reza, and Ghane (2014) stated that, effective risk management techniques are required to cope up with various construction activities. Hence identification and assessment of the important risks involved in infrastructure projects is essential. Klose, Damm, and Terhorst (2015) stated that, most common method for transportation related studies is expert interviews, questionnaire surveys and cost surveys. Liang and Wey (2013). expressed that, proper planning of transportation infrastructure projects can have significant impacts on urban development. Kangiri (1995) stated that, significant risks associated in all execution projects are mainly affected by wrong safety practices, improper quality, lack of competence and technical know - how.

Johnsen and Veen (2013) had carried out risk assessment of Norwegian railway using emergency communications and was based upon preliminary hazard analysis. Their work seems to have improved the total system resilience. Park and Papadopoulou (2012) analysed guestionnaire data to rank causes of cost overruns according to their frequency, severity and significance. Ameyaw and Chan (2015) had prepared risk factor list, ranking of factors and describes the "top-ranked" risk factors. Their study on Public Private Partnership (PPP) water supply projects would help Governments and investors to develop feasible risk mitigation strategies. Liang and Wey (2013) carried out their work on allocation of resources and the risks and uncertainties associated with the highway development projects. They developed a risk a robust risk management model based on Monte Carlo simulation and Analytic Network Process (ANP). Klose et al. (2015) studied the risks and vulnerabilities due to occurrence of landslides and further made an attempt to develop a cost model which would quantify the approximate damage created by the landslides and also its impact on society.

Sarkar and Dutta (2011) have studied and identified the risks associated with the construction of underground corridor for metro rail operations. They developed a risk management model which classified the risks according to severity and recommended suitable risk mitigation measures. Jannadi and Almishari (2003) worked on a basic risk management model which can assess the different risk and hazard categories of a construction industry. A comprehensive model by using Analytic Hierarchy Process (AHP) and Failure Mode Effect Analysis (FMEA) was developed and validated by Abdelgawad and Fayek (2010). Choi, Cho, and Seo (2004) applied fuzzy concepts for developing user friendly risk analysis software's particularly for underground construction projects. Chan et al. (2009) had thoroughly reviewed the fuzzy literature for last two decades. Li and Zou (2011) had proposed Fuzzy AHP Method for PPP Projects. Bhagat (2017) shared his experience in developing a community based disaster mitigation strategies for natural and man-made disasters. According to him community participation and awareness is the most essential component for achieving sustainability in dealing with disasters. Shah, Mehta, & Mukhopadhyay (2017) studied the financial risks and challenges faced by the investors and consumers of solar PV. The impact on the financial challenges were studied by comparing cash flows, Net Present Value (NPV), Internal Rate of Return (IRR) and pay back periods. Further, Singh et al. (2017) made a comparative study of the risk analysis methods like EVM and Fuzzy EVM for complex infrastructure projects like construction of elevated corridor metro rail constructions. Singh et al. (2017) also applied Modified AHP (MAHP) for computing the risk severity index for elevated corridor metro rail projects.

## Methodology and Conceptual Framework

Modified EVM is used for the risk analysis. We have extended the work of Sarkar & Dutta (2011) by incorporating fuzzy in EVM. The variables are defined as below:

- P<sub>st</sub>: Probability of s<sup>th</sup> risk source for t<sup>th</sup> activity
- W<sub>st</sub>: Weightage of s<sup>th</sup> risk source for t<sup>th</sup> activity
- I<sub>st</sub>: Impact of s<sup>th</sup> risk source for t<sup>th</sup> activity

Every activity is having various risk sources, probability and risk impacts. The value of probability and impact of risks should range between 0 to 1. The detailed questionnaire was prepared after brain storming session with experts. The questionnaire consisted of 24 major risk categories and 255 questions and these were distributed to 77 experts out of which 62 experts (80%) answered the questionnaire.

$$\sum_{s=1}^{M} W_{st} = 1 \text{ for all } t \ (t = 1...N)$$
(1)

The Probability( $P_{st}$ ) for every activity, 't' can be clubbed and represented as a composite Probability factor (CPF<sub>t</sub>).  $W_{st}$  of the sub-risk activities are multiplied with their respective probabilities to achieve the CPF of the major risk categories. Composite Probability Factor (CPF),=

$$\sum_{s=1}^{M} P_{st}. W_{st} \text{ for all } t$$
 (2)

Composite Impact Factor (CIF)<sub>t</sub>=

$$\sum_{s=1}^{M} I_{st} \cdot W_{st} \text{ for all } t$$
 (3)

$$0 \le I_{st} \le 1 \sum_{s=1}^{M} W_{st}$$
 for all t

CPF and CIF are to be computed for each risk category from the feedback of every expert.

For the incorporation of fuzzy into EVM, there is a need to define membership function for probability, impact and severity. Triangular fuzzy numbers due to its simplicity were used for defining the membership functions. 25 fuzzy rules were framed on the basis of five risk classifications of probability and impact Sarkar and Dutta (2011). Sarkar and Dutta(2011). The values of the linguistic scale for each membership function are taken from 0 to 1 at an increment of 0.25.

#### **Case Study**

The case study considered for this research work was Ahmedabad metro rail project. The total operation of the project is being executed by Special Purpose Vehicle (SPV) M/s. Metro Express-Link Gandhinagar-Ahmedabad (MEGA) a Government of Gujarat undertaking. The length of the corridor is 8.21 kms (Thaltej Gam to West Ramp stretch) part of East-West line (20.73 km). The construction work of this stretch was awarded to M/s. Tata Projects Ltd and China Civil Engineering Construction Corporation. It consists of seven numbers of elevated stations like Stadium Circle, Commerce Six Road, Gujarat University, Gurukul, Doordarshan Kendra, Thaltej and Thaltej Gam. Total number of piles and piers to be executed are 1152 and 278 numbers respectively. For this stretch, 1950 segments are to be casted and erected. The weight of each segment is 48 tons. The total cost of the project is approx. 721 cr.

# **Case Analysis and Results**

The CPF and CIF computed by EVM for all major risky activities which were about twenty four in number were used as inputs for fuzzy EVM method by using Mathworks. Matlab.R2014a version software. The outputs are risk severity values obtained for all twenty-four major risky activities. Table 1 is the representation of CPF and CIF values for four major risks of the Ahmedabad metro project (case study stretch). Figure 1 represents the final Fuzzy risk severity of erection of pre-cast segments.

Serial No.	Activity Name	Composite Probability Factor (CPF)	Composite Impact Factor (CIF)
1	Risks in traffic diversion	0.460	0.790
2	Risk in utility diversion	0.299	0.694
3	Risks in erection of pre- cast segments	0.460	0.790
4	Risks in piling activity	0.263	0.777

TABLE 1. CPF& CIF Values for Four Main Risky Activities of Ahmedabad Metro Project



FIGURE 1. Final Fuzzy Risk Severity of Erection of Pre-Cast Segments

The final fuzzy risk severities of five risk categories out of the 24 major risks in the construction of Ahmedabad metro rail project are presented in Table 2.

Serial No.	Activity Name	Quantitative Fuzzy Risk Severity	Qualitative Fuzzy Risk Severity	Fuzzy EVM Ranking
1	Risks in erection of pre-cast segments	0.705	Critical	1
2	Detailed Project Report and Feasibility	0.299	Critical	2
3	Risk in Land handing over	0.643	Very High Risk	3
4	Risks in traffic diversion	0.624	Very High Risk	4
5	Risks in piling activity	0.560	Very High Risk	5

TABLE 2. Fuzzy Risk Severity Values of five Risk Categories

# **Result Interpretation and Discussion**

The fuzzy risk severity values and risk rankings for major risk categories of Ahmedabad metro project as attained from fuzzy EVM were computed. By application of FEVM, risks in erection of pre-cast segments is having highest quantitative fuzzy risk severity value of 0.705 and are considered to be critical in terms of qualitative risk classification. This activity has obtained fuzzy ranking of one. Risks in Detailed Project Report and Feasibility activity are also critical with quantitative fuzzy risk severity value of 0.684 which obtained second rank. Risk in activity land handing over is having very high fuzzy risk severity value both quantitative (0.643) and qualitative and has obtained third rank. Risks in traffic diversion are very high both quantitative (0.624) and qualitative and has obtained fourth rank. Risk in piling activity works are also very high both quantitative (0.560) and qualitative and has obtained fifth rank. Risks in launching girder, obligatory span, risks in pile test, expansion joint, casting of segment, Risks in road widening, barricading, parapet erections, utility and traffic diversion works are categorised and mapped as risks which are critical. Risks in casting yard setup, cable tray, parapet casting and project office set up falls under medium risk severity category.

# Conclusion

The analysis carried out from the above research work helps us in identifying and ranking the major activities which has high degree of risks and uncertainties involved and associated with it. Analysis by FEVM method has highlighted that risks in activities like erecting of pre-cast segments, detailed project report and feasibility, land handing over, traffic diversion and piling activities are showing risk severity values of 0.705, 0.684, 0.643, 0.624 and 0.560 respectively which fall under the category of very high risks. The project authorities need to monitor these risks with high degree of carefulness, failing which these activities would lead to time overrun and cost overrun of the project which would finally lead to project failure. One of the limitation of this research is that the values of CPF and CIF are obtained from questionnaire survey which need to be consistent and validated with simulation studies.

### References

Abdelgawad, M. & Fayek, A. R. (2010). Risk management in the Construction Industry Using Combined Fuzzy FMEA and Fuzzy AHP. Journal of Construction and Management, 136(9), 1028 – 1036.

Ameyaw, E. E., & Chan, A. P. (2015). Risk ranking and analysis in PPP water supply infrastructure projects. An international survey of industry experts. Facilities, 33(7/8), 428-453.

Askari,M., Reza, H., & Ghane, S.(2014). A Fuzzy FMEA Model in Risk Ranking. European Journal of Business and Management, 6(14), 194-204.

Bhagat, S. (2017). Community- Based Disaster Management Strategy in India: An Experience Sharing. PDPU Journal of Energy and Management, 2 (1), 11–17.

Chan, A. P. C., Chan, D. W. M. & Yeung, J. F. Y. (2009). Overview of the Application of Fuzzy Techniques in Construction Management. Journal of Construction Engineering and Management, 135(11), 1241 – 1252.

Choi, H., Cho, H. & Seo, J. W. (2004). Risk Assessment Methodology for underground Construction Projects. Journal of Construction Engineering and Management, 130(2), 258 – 272.

Jannadi, O. A. & Almishari, S. (2003). Risk Assessment in Construction. Journal of Construction Engineering and Management, 129(5), 492 – 500.

Johnsen, S. O., & Veen, M. (2013). Risk assessment and resilience of critical communication infrastructure in railways. Cognition, technology & work, 15(1), 95-107.

Kangiri, R. (1995). Risk Management Perceptions and Trends of U.S. Construction. Journal of Construction Engineering and Management, 121(4), 422 - 429.

Klose, M., Damm, B., & Terhorst, B. (2015). Landslide cost modelling for transportation infrastructures: a methodological approach. Landslides, 12(2), 321-334.

Liang, S., & Wey, W. M. (2013). Resource allocation and uncertainty in transportation infrastructure planning: A study of highway improvement program in Taiwan. Habitat International, 39, 128-136.

Li, J. & Zou, P. X. W. (2011). Fuzzy AHP – Based Risk Assessment Methodology for PPP Projects. Journal of Construction Engineering and Management, 128(6), 1205 – 1209. Oliveros, A. V. O. & Fayek, A. R. (2005). Fuzzy Logic Approach for Activity Delay Analysis and Scheduling Updating. Journal of Construction Engineering and Management, 131(1), 42 – 51.

Park, Y. I., & Papadopoulou, T. C. (2012). Causes of cost overruns in transport infrastructure projects in Asia their significance and relationship with project size. Built Environment Project and Asset Management, 2(2), 195-216.

Sarkar, D & Dutta, G. (2011). A Framework of Project Risk Management for the Underground Corridor Construction of Metro Rail. International Journal of Construction project Management, .4 (1), 21–38.

Shah, N., Mehta, U. & Mukhopadhyay, I. (2017). Impact of Huge Variation in Cost of Debt and Reverse Auction Process on Feasibility of Solar PV Projects under Present Policy Framework in India. PDPU Journal of Energy and Management, 1 (2), 03–15.

Singh, M., Sarkar, D. & Raghavendra, H.B. (2017). Comparative Study of EVM and Fuzzy EVM Methods for Risk Analysis of Infrastructure Transportation Project. International Journal of Application or Innovation in Engineering & Management, 6(7), 164-171.

Singh, M., Sarkar, D., Raghavendra, H.B. & Vara, D. (2017). Application of Fuzzy MAHP for Computing Risk Severity for Elevated Corridor Metro Rail Project. Proceedings of 4th International Conference on Multidisciplinary Research & Practice, Ahmedabad, 11-13.

Manvinder Singh Senior GM, Arvind Smart Spaces Limited, Ph.D. Scholar.

**Debasis Sarkar** Associate Professor & HOD, Dept. of Civil Engineering, SOT, PDPU.