Risk Evaluation on Construction Projects Using Fuzzy Logic and Binomial Probit Regression

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Abstract

In construction projects, risk is an event or occurrence in uncertain conditions and in case of happening risk, it has positive or negative effects on projects' goals. It should be mentioned that all uncertainties in projects don't lead to risk; therefore, it is evident that just a limited subgroup of all uncertainties in a project is considered as the risk of project. In the present research, a risk evaluation process is proposed to determine the likelihood of risky construction projects. At the first step, four kinds of risks were identified which are very important in the project of installing a weight in motion system. Using multi-criteria decision-making technique and fuzzy number (triangular fuzzy number) as well as pair-wise comparison of the risk components, the overall rate of risk has been evaluated utilizing the proposed method. Next, in order to quantify fuzzy numbers the likelihood of risky project was calculated by the possible method of binomial Probit. Questionnaires containing risk instances and their importance have also been used for gathering necessary information according to experts' opinions about an operating system in Isfahan-Naeen road which has been selected as case study. Results revealed that the proposed method is capable to evaluate the level of risk in construction projects.

Keywords

Risk, Project Management, Fuzzy Logic, Triangular Fuzzy Numbers, Binomial Probit Regression

1. Introduction

Risk management is a new branch of management science and in spite of being new, it is developing and growing quickly and it has been welcomed by experts and managers in various branches. Today, risk and its related orientations found its position in a vast range of matters such as investment, business, insurance, security, healthcare, industrial and construction projects and even political, social and military issues. In this regard, risk management has a special position in project management discussion and it has common roots with these discussions. (PMI, 2008)

Some believe that it is not necessary to manage the risk and it is possible to eliminate the whole uncertainty of project by accurate planning, it means that by collecting a plan in details we can cover all probabilities and events and predict the future. There are two problems related to this attitude. Firstly, by experience it was shown that in order to increase the accuracy of a plan more attempt is needed. For example, in order to double the accuracy of a plan an attempt about four times of initial attempt is needed. The problem is that more planning gives us less valuable results and information than our attempt and spent energy. Therefore, we have to stop planning at the end and manage the projects' risk. The second problem is that there is no way to eliminate the risk in project; it means that future is not predictable accurately. Thus, risk management is an absolute and necessary matter in project management. (PMI, 2008)

Hwang et al (2013) investigated the risk management in small projects in Singapore from the view point of status, obstructions and the effect of risk management on project's performance. A questionnaire was presented and the

information of 668 projects by 34 companies was used. The results of analysis shows that a relatively low level of risk management implementation in small projects are related to the lack of time, lack of budget, low profit margin and not being economical obstruction. Also, results show the positive correlation between risk management implementation and improving the quality, cost and the performance of small projects' plan (Hwang et al, 2013).
Tamosaitiene et al (2013) evaluated the risk in constructing business center project. They selected the risk evaluation standards with regard to macro, middle and micro levels of a construction project. In order to evaluate the standards the TOPSIS- F method with fuzzy information was used. After analyzing the obtained results of proposed model, key findings were presented (Tamosaitiene et al, 2013).
Jacobson et al (2003) used two- variable Probit method in their research to estimate the credit risk probability. In this paper the effective factors on credit risk containing financial and personal information of Swedish credit customers were used for both rejected and approved applicants. Risk calculations show that the true and effective selection of loan applicants can reduce the credit risk to 80 percent. (Jacobson et al, 2003)
Among other performed studies, Zhang et al (2013) proposed a new method in their paper in order to solve the problem of selecting a strategy to response the risk in project risk management. This method is a developed optimization model which consider the integration of three vital elements of project costs, project scheduling and project quality. By solving the model, obtaining an optimized solution is possible and with its aid we can determine the most desirable response strategy to risk probability when encounter events and risks. They presented a simple example in order to show the practicality and efficacy of proposed method. (Zhang et al, 2013)
Zeng et al (2007) utilized fuzzy reasoning techniques to improve an effective tool to handle the uncertainties and subjectivities arising in the construction process and showed that the application of fuzzy reasoning technique provides an effective tool to handle the uncertainties and subjectivities arising in the construction process. (Zeng et al, 2007). In another study, the integration of fuzzy AHP and fuzzy TOPSIS methodologies which are hybrid application of soft computing techniques, studied for construction projects risk assessment under vague and uncertain environments. (Taylan et al, 2014). Amaral et al (2014) has also used a spatial Probit model to study the effect of contagion between banking systems of different countries and showed that the study of banking crises through a traditional Probit model is not satisfactory (Amaral et al, 2014).
In this paper a model has been introduced to estimate the likelihood of low- risk and high- risk project and as a case study the presented model for constructing the project of weight in motion in Isfahan- Naeen road was utilized by means of fuzzy logic and binomial Probit method.

2. Triangular fuzzy number

A triangular fuzzy number is a fuzzy number which is shown with three real numbers as F= (l, m, u). The upper bound which is indicated by u is the maximum values that F fuzzy number can adopt. The lower bound which is indicated by l is the minimum values that F fuzzy number can adopt. The m value is the most probable value of a fuzzy number. The membership function of a triangular fuzzy number is shown as function (1). (Elzamly, et al 2014)

$$\mu_f(x) = \begin{cases} \dfrac{x-l}{m-l} & l < x < m \\ \dfrac{u-x}{u-m} & m < x < u \\ 0 & else \end{cases} \tag{1}$$

Triangular fuzzy number F= (l, m, u) is shown in geometric space as figure (1). (Kasko, 1993)

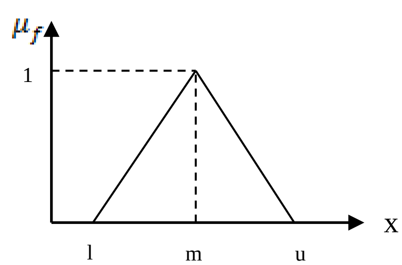

Figure 1. Fuzzy number diagram

According to the membership function of triangular numbers it is clear that if x is between l and m then the greater it is, its membership degree increases as well, as far as for x=m the membership degree equals 1. If x is between u and m, the greater it is, the less its membership degree will be and in x=u the membership degree is zero. (Chutia, et al, 2011)

3. Probit regression

Probit regression is practicable in two kinds of binomial and rank regression. Binomial Probit regression which is the most utilized kind of regression is used to clarify or predict a dependent variable with binary measurement scale based on a group of predictor variables or independent with quantitative and qualitative measurement scale. Rank Probit regression is also used like Rank Logistic when the dependent variable in research model is measured by rank scale (with natural order in variant level). (Ye, Lord, 2013)
The general form of dependent variable in Probit model is like function (2) and it can adopt the values of 0 and 1. Also in equation (3), X is the vector of independent variables and β is the vector of parameters in model which must be estimated. (Ye, Lord, 2013). According to figure (2) in this model it is supposed that dependent variable with binomial distribution have latent normal and continuous distribution in which a threshold or distinct boundary (π) changed it to a binomial distribution.

$$Y_i = \begin{cases} 1 & first\ case\ according\ to\ problem's assumption \\ 0 & second\ case\ to\ problem's assumption \end{cases} \quad (2)$$

$$\mathrm{Y_i = x_i\beta + \varepsilon_i} \quad (3)$$

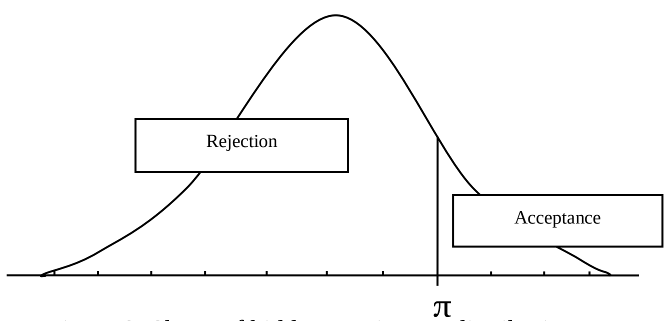

Figure 2. Shape of hidden continuous distribution one binomial variable

Accordingly, if it is assumed that dependent variable or response has infrastructural continuous and normal distribution, the Probit link function as it is presented in equation (4), uses the reverse cumulative normal distribution function for modeling and clarifying the success probability of (p(y=1)).

$$\mathrm{probit}\ [\mathrm{p(Y=1)}] = \emptyset^{-1}[\mathrm{p(Y=1)}] = \frac{1}{\sqrt{2\pi}} \mathrm{e}^{\left[-\frac{1}{2}(\mathrm{x\beta})^2\right]} \quad (4)$$

In equation (4), ϕ [.] indicates the cumulative normal distribution function and its reverse is used in Probit regression equation to convert predicted probability. (Nagler, 2016)

4 . Developing the risk project calculation model

After investigating and gathering information it was concluded that four risks are more important and used more. These four risks include national and regional risk, technical and technological risk, human resource risk and credit risk. In order to understand in under investigation project i.e. the project of constructing weight in motion system to what extent risks are existed a questionnaire composed of 22 questions was designed. Next, the questionnaires which have the answering spectrum of very low, low, medium, many and very much were completed by informed people who are present in the project of constructing weight in motion system. The answers are scored with regard to the triangular fuzzy scoring spectrum of table (1) and the answers of each questionnaire is converted to triangular fuzzy number as F= (l, m, u).
Pair-wise comparison table is prepared as table (2) and it is completed by people who are aware of project, for instance in order to complete this table the national and regional risks relative to itself has the value of 1 and other

risks relative to themselves have the value of 1. As it is observed in table (2) for example if the national and regional risks have the value of *a* relative to credit risk, then the value of credit risk relative to national and regional risk should be 1/a and other values of table are considered similarly.

Table 1: Fuzzy scoring spectrum

Status	L	M	U
So low	1	3	5
Low	3	5	7
Average	5	7	9
High	7	9	11
So high	9	11	13

Table 2: Pair-wise comparison of risk components

Type of risk	Human resource risk	Technological risk	Credit risk	National and local risk
National and local risk	1/c	b	a	1
Credit risk	f	1/d	1	1/a
Technological risk	1/f	1	d	1/b
Human resource risk	1	f	1/e	c

In this step, the numbers of each row which are considered in equation (5) for the example of national and regional risk are added, and then its weight is calculated as equation (6):

$$National\ and\ local\ risk\ S_n = (1 + a + b + \frac{1}{c}) \quad (5)$$

$$\text{weight of national and local risk } \mathrm{W_n} = \frac{\mathrm{S_n}}{(\mathrm{S_n}+\mathrm{S_e}+\mathrm{S_f}+\mathrm{S_m})} \quad (6)$$

After converting the numbers of questionnaires to fuzzy numbers, firstly for questions related to each kind of risk, the average is calculated, and then these means (M_i) are multiplied by the obtained weight (W_i) of pairwise comparison table as equation (7) and (Z_i) is the weight mean of data then these weight mean are added as equation (8) and by adding these numbers the Likert Sc. number is obtained. This obtained Likert Sc. number that is a fuzzy number as F=(l,m,u), is used as a dependent variable for equation (10).

$$\mathrm{Z_i} = \mathrm{M_i} \times \mathrm{W_i} \quad (7)$$

$$\text{Likert Sc.} = \sum_{i=1}^{4} \mathrm{Z_i} \quad (8)$$

After converting the numbers of questionnaires to fuzzy numbers, firstly for questions related to each kind of risk, the average is calculated, and then these means (M_i) are multiplied by the obtained weight (W_i) of pair-wise comparison table as equation (7) and (Z_i) is the weight mean of data then these weight mean are added as equation (8) and by adding these numbers the Likert Sc. number is obtained. This obtained Likert Sc. number that is a fuzzy number as F=(l, m, u), is used as a dependent variable for equation (10).

$$\mathrm{Y_i} = \begin{cases} 1 & \text{first case according problem assumption} \\ 0 & \text{second case according problem assumption} \end{cases} \quad (9)$$

$$\mathrm{Y_i} = \mathrm{X_i}\beta + \varepsilon_i \quad (10)$$

$$\text{probit } [p(Y = 1)] = \varphi^{-1}[p(Y = 1)] = \varphi(x\beta) = \frac{1}{\sqrt{2\pi}} e^{\left[-\frac{1}{2}(x\beta)^2\right]} \quad (11)$$

By substituting the values of X and Y in equation (10) we can obtain ε andβ. β is the coefficient of X independent variable and ε is the error rate. Then by substitutingβ, ε, X in equation (11) and solving the Probit regression equation and finding the possible number in normal distribution table, the likelihood that the project is risky or not is specified.

5 . Conclusion

After calculating the Probit regression equations, results of table (3) are obtained. The first nine rows of table are related to calculated regression of questionnaires and the row 10 in table is related to calculated regression for the whole project.

Table 3: Probable obtained numbers

Questionnaire	The likelihood Probit regression			Questionnaire	The likelihood Probit regression		
1	0.63	0.65	0.64	6	0.69	0.68	0.68
2	0.65	0.65	0.65	7	0.52	0.52	0.51
3	0.37	0.39	0.39	8	0.70	0.69	0.69
4	0.62	0.63	0.64	9	0.76	0.75	0.76
5	0.69	0.69	0.69	10	0.66	0.65	0.65

Based on the indicated results in table (3) and especially with regard to the row 10 in table which is related to the whole project it can be concluded that the lower limit, possible limit and also the upper limit have low risk because the obtained numbers are lower than 68%. Then it is understood that the project of constructing weight in motion system in Isfahan- Naeen road has low risk. It is worth mentioning that the obtained probable values are calculated in terms of informed respondents' opinion; therefore, in each project values can be calculated differently and it cannot be concluded that the 68% probability is usable for all under investigation projects.

For the future researches about estimating the risk in construction projects recommendations can be proposed as the Use of the Logit method to evaluate the risk, other components of risk could be taken into account and Use the fuzzy numbers comparison to analyze the data.

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Biography

Abbas Mahmoudabadi, corresponding author (mahmoudabadi@mehrastan.ac.ir), is Ph.D. in Industrial Engineering and director of Master Program in Industrial Engineering at MehrAstan University, Guilan, Iran and deputy of Planning and Coordination in Transport and Fuel Management Centre, at Road Maintenance and Transport Organization, Tehran, Iran. He achieved his Ph.D. degree in January 2014 in the field of optimization in Hazmat transportation and received Thesis Dissertation Award from IEOM society in March 2015, Dubai, UAE. He has published near 60 journal or international conference papers and one book chapter published in the field of industrial engineering, transportation, traffic and road safety. He teaches transport and industrial engineering courses at universities and has around 25 years of executive experiences on traffic and road safety planning in developing countries. He has also strong cooperation with national and international agencies traffic safety and more with international agencies in the field of industrial engineering. Some national transportation projects have been implemented under his supervisory roles with the results of fatality reduction in intercity transportation.

Seyyede Mahsa Saleh has Bachelor and Master of Science degrees in Industrial Engineering. She graduated from MehrAstan University, Guilan, Iran in July 2016. Her thesis dissertation is on studying risk evaluation in civil engineering projects and published some papers in Persian language in this field.