International Journal of Advance Research in Science and Engineering
Vol. No.5, Issue No. 09 , September 2016
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

SOFT COMPUTING TECHNIQUES FOR MAJOR ROOF FALLS IN BORD AND PILLAR IN UNDERGROUND COAL MINES USING MAMDANI FUZZY MODEL

Singam Jayanthu[1], Rammohan Perumalla[2]

[1]Professor, Mining department National Institute of Technology, Rourkela, Odisha
[2]M.Tech (R) student, National Institute of Technology, Rourkela, Odisha.

ABSTRACT

Roof falls are common problems in underground coal mines which may have serious effects on miners in the form of injuries, disabilities or fatalities as well as other damages like production delay, interruptions in mining operations, equipment breakdown events. Roof fall and side fall accidents accounted for about 21% and 15% of all fatal accidents during the year 2014,2015 (DGMS 2015,2016). According to the importance of the problem, different researchers were conducted to find the relationship between the area of major roof fall and the effective parameters on occurrences of the roof fall in underground coal mines. So it is mandatory to continue the study of different possible optimistic methods to evaluate the Roof fall area. Many modeling techniques are being used by different investigators and researchers for developing different types of roof fall predictions. In this study fuzzy logic was applied to predict area of major roof fall in coal mines. The predictive fuzzy model was implemented on MATLAB 2014 using Mamdani algorithm and was developed based on expert's knowledge and data base including data sets collected from the mines. The obtained results from the fuzzy model and the actual roof fall were compared it showed that the fuzzy model can predict the area of major roof fall effectively.

Keywords: Roof Fall, Coal Mines, Fuzzy Logic, Mamdani.

I. INTRODUCTION

Roof falls were the frequent issues arise in underground coal mines which may have severe effects on the coal miners in various forms like bruises, impairments, disabilities. These effects not only limited to miners but also extended to machinery in consequences like equipment breakdowns, damages, interruptions to mining operations etc. Therefore, applying a proper technique that can take simultaneously both the complexity and inherent uncertainty connected with roof fall problem into account help investigators analyses the problem more accurate and precise. Fuzzy logic is a useful mathematical tool for modeling the existing uncertainty and complexity. From past two decades, fuzzy logic has been successfully applied to many field related problems especially in modeling complex and imprecise systems in the science and engineering field like pocket hand computers, aircraft aid for helicopters, governing of subway structures to develop driving comfort, accuracy of halting, and supremacy economy, upgraded fuel consumption for automobiles, distinct-knob control for washing

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

machines, automatic motor regulator for vacuum cleaners with acknowledgment of external area condition and mark of soiling, and forecast systems for early acknowledgment of earthquakes etc [1].

II. FUZZY LOGIC

A fuzzy set is a class of objects without a precisely defined criterion of membership. The set is characterized by a membership function which assigns to each object a grade of membership ranging between zero and one [2]. It is to deal with the conception of the uncertainty due to imprecision and vagueness. This theory becomes an important tool in various engineering modeling and replaces the traditional methods of designing and modeling of a system. Imprecision here is meant in the sense of vagueness rather than the lack of knowledge about the value of a parameter. In fact, it is a natural way to deal with imprecision problems by definition of class which represents continuum grades of membership. Therefore, a much wider scope of applicability in the field of pattern classification and information process is accessible by fuzzy sets[1].Moreover, it performs numerical computation by using linguistic labels stipulated by membership functions. In this way, contrary to a classical set in which the elements belong to, or not belong to a set, a fuzzy set degree of membership for each element is assigned in the unit interval between 0 and 1. This theory can also be used for developing rule-based models which combine expert knowledge and numerical data. The typical block diagram of fuzzy logic with different levels is shown in below fig 1.

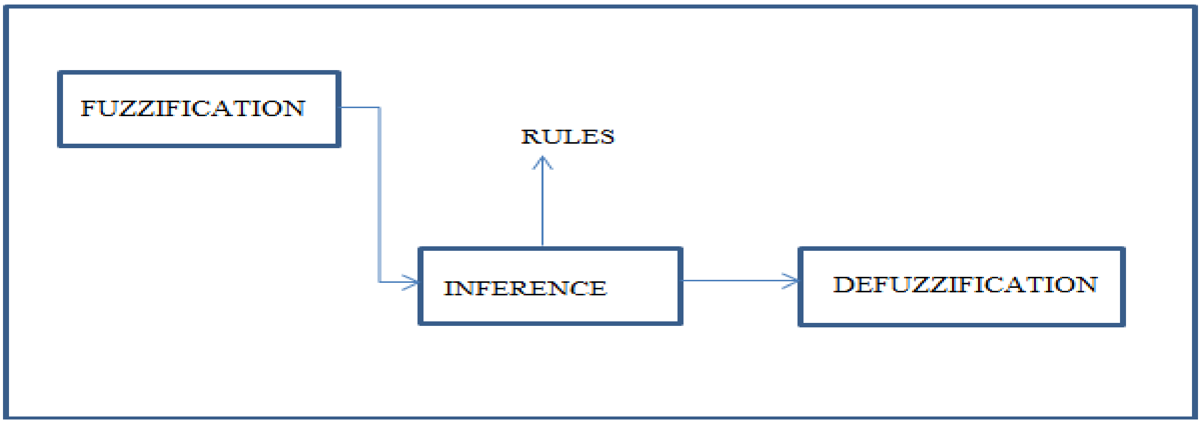


Fig 1: Block diagram a Fuzzy logic system.

2.1 Fuzzification Process

Fuzzy set performs numerical computation by using linguistic labels. Fuzzy set performs numerical computation by using linguistic labels. For each input and output variable selected, we define two or more membership functions (MF), normally three but can be more. As a first part of fuzzy logic system, crisp values of input and output variables should be converted to fuzzy values or linguistic information. first part of fuzzy logic system, crisp values of input and output variables should be converted to fuzzy values or linguistic information.

2.2 Knowledge Base

As presented in fig1.There are various ways to represent knowledge. Perhaps the most common way to represent human knowledge is to form it into natural language expressions of the type. knowledge base includes database and rule base. The database defines the membership functions of the fuzzy sets used in the fuzzy rules,

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

whereas the rule base contains a number of fuzzy if–then rules. IF premise (antecedent), THEN conclusion (consequent) [3]. The structure in expression is commonly referred to as the IF–THEN rule-based form; this form generally is referred to as the deductive form. It typically expresses an inference such that if we know a fact (premise, hypothesis, antecedent), then we can infer, or derive, another fact called a conclusion. This form of knowledge representation, characterized as shallow knowledge, is quite appropriate in the context of linguistics because it expresses human empirical and heuristic knowledge in our own language of communication.

2.3 Fuzzy Inference System

The fuzzy inference system (FIS), also known as the decision-making unit, performs the inference operations on the rules. In fact, fuzzy inference is the process of formulating an input fuzzy set map to an output fuzzy set using fuzzy logic. [4]. It is the process of making a crisp quantity fuzzy. It could be done this by simply recognizing that many of the quantities that we consider to be crisp and deterministic are actually not deterministic at all. They carry considerable uncertainty [3].

The center segment of a fuzzy logic system is the FIS part, which consolidates the facts got from the fuzzification with the rule base and directs the fuzzy reasoning procedure. There are a few FIS that have been utilized in different applications, and the most normally utilized incorporate the accompanying: The Mamdani fuzzy model, the Takagi–Sugenos–Kang (TSK) fuzzy model.

Among distinctive FISs, the Mamdani fuzzy model is one of the most regularly utilized as a part of fuzzy logic for fathoming numerous genuine issue. The Mamdani FIS was proposed by Mamdani to control a steam engine and boiler combination by set of linguistic control rules got from experienced human operators.

2.4 Defuzzification Process

Defuzzification is a procedure to extract a representative numerical (crisp) value of output from a fuzzy set. The application of the defuzzifier is to receive the fuzzy input and provide crisp output. In fact, it works opposite to the fuzzier. There are a number of defuzzification methods in the literature such as Centroid Of
Area (COA).

III. DETERMINING PARAMETERS FOR MAJOR ROOF FALL AREA PREDICTION

Several parameters were studied and observed from different investigators on roof fall prediction. The major contributing roof fall parameters are Area of exposure (AE), Depth Cover (DC), Rock Mass Rating (RMR), Roof convergence (RC), Intersectional span (IS).

International Journal of Advance Research in Science and Engineering
Vol. No.5, Issue No. 09 , September 2016
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Table 1: Statistics of the collected mine data

S.No	Parameter	Symbol	Min	Max	Mean	SD
1.	Area of exposure (m^2)	AE	6000	11404	9291	2571
2.	Depth of cover	DC	61.5	120	91.3	27.82481
3.	RMR	RMR	58	58.1	58.01	0.05477
4.	Intersectional Span	IS	1.5	7.1	4.2	2.27
5.	Roof Convergence (mm)	RC	0.5	1.5	1.12	0.445
6.	Area of major roof fall	AMRF	1600 m^2	3400 m^2	2500 m^2	670.82 m^2

The purpose of the paper is to enhance the application of a Fuzzy model to mining industry predict the area of major roof fall in coal mines. The data from Indian coal mines were used. Results of the basic descriptive statistical analysis performed on available database as shown in table 1.

The selected parameters with their testing data and actual data is clearly shown in table 2. Each parameter with the calculation of mean, median, SD, actual and predicted values with error rate were also given in table2.

Table 2: Testing data set used for evaluating proposed model.

S.no	Area of exposure (AE) sq m	Depth of cover (DOC) m	RMR	Intersectional Span (IS)	Roof Convergence (mm)	Actual Roof fall area	Predicted	Error
1.	6253	61.5	58	1.5	0.5	1600	1423	
2.	9503	93.8	58.1	3.5	1.14	2200	2163	
3.	9873	96.7	58	4.5	1.27	2500	2453	
4.	10404	101	58.1	6.5	1.34	2800	2723	
5.	11404	120	58	7.1	1.5	3400	3073	
Mean	9291.4	91.3	58.03	4.2	1.12	2500	2367	

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Median	9873	96.7	58	4.5	1.27	2500	2453	
SD	2571.4747	27.82481	0.05477	2.27	0.44533	670.82	625.56	
R error		-	-	-	-	-		0.98477
R^2error		-	-	-	-	-		0.9598

IV. FUZZY MODEL TO PREDICT AREA OF MAJOR ROOF FALL

Fuzzy logic is a logical system it is a prolongation of multivalued logic. It is a theory which relates to classes of objects with un sharp boundaries in which membership is a matter of degree. This theory occupies major portion in different engineering modeling and becomes substitute for traditional methods of designing and modelling of a system. In this model max min composition was selected. It is conception of defining the existence of a relational chain between elements of input and output. It is the most adoptable technique [5].

$$\mu_A(x) = \max\left[min\left[\frac{x-a}{b-a}, \frac{c-x}{c-b}\right], 0\right] \quad (1)$$

$$\mu_A(x) = \max\left[min\left[\frac{x-a}{b-a}1, \frac{d-x}{d-b}\right], 0\right] \quad (2)$$

The proposed fuzzy models include five input variables – AE, DC, RMR, IS, RC and output variable – Area of major roof fall. It is shown in fig 2.

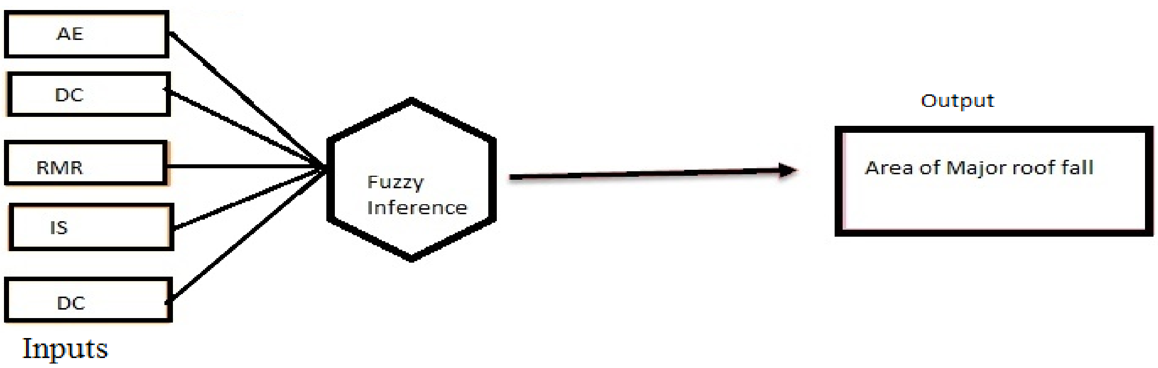
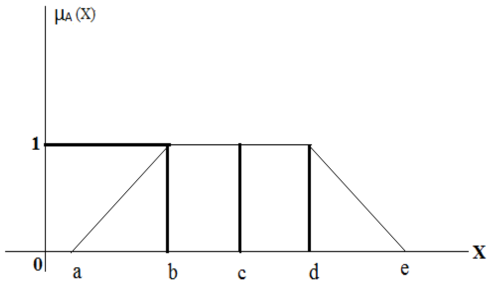


Fig 2: Schematic diagram of major Roof fall Fuzzy model.

In the model Trapezoidal membership functions were adopted for describing for input and output variables.

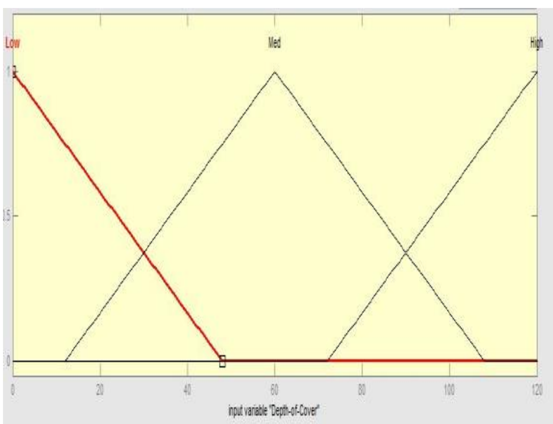
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346



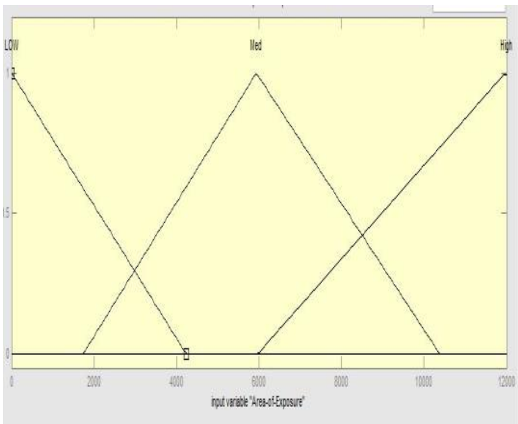
$$\mu_a = \begin{cases} 0 & if\ x \le a \\ \frac{x-a}{b-a} & if\ a < x \le b \\ 1 & if\ b < x \le c \\ \frac{d-x}{d-c} & if\ c < x \le d \\ 0 & if\ x > d \end{cases}$$

Fig 3: Model of Trapezoidal membership function.

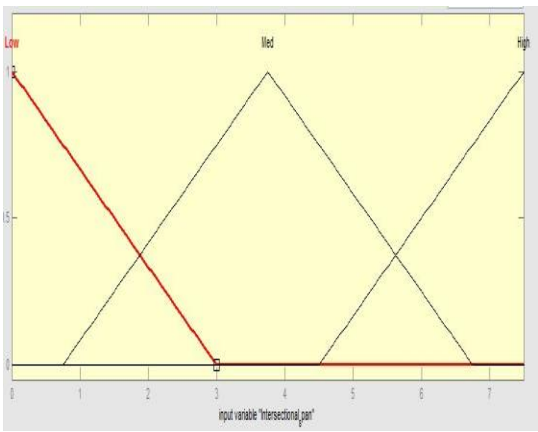
In the model trapezoidal membership functions were adopted for describing input and output variables because of their computational efficiency. In the figure a,b,c,d and e are the parameters of the linguistic values and x is the range of the parameters. The graphical pics of the membership functions of different input and output variables are shown in fig 4.



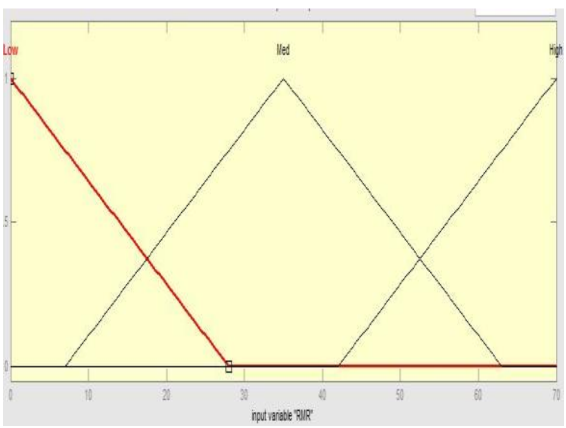
a) Area of exposure



b) Depth cover



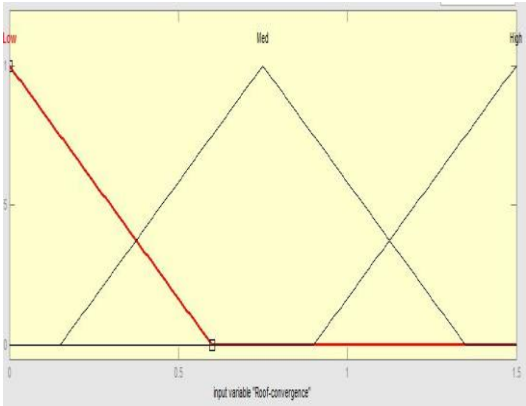
C) Intersectional Span



d) RMR

International Journal of Advance Research in Science and Engineering
Vol. No.5, Issue No. 09 , September 2016
www.ijarse.com

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346



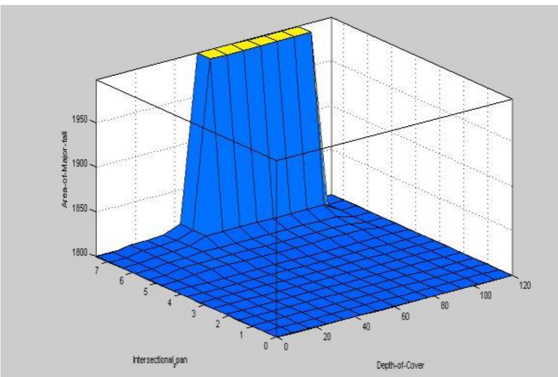
e) Roof convergence

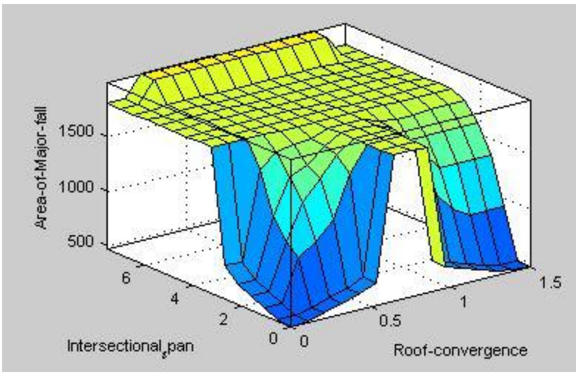
Fig 4: Fuzzy representation of input and output variables

The following next level of the Fuzzy inference system is the developing of the if–then rules, which are used to represent the fuzzy relationships between input and output fuzzy variables. In this paper for constructing the rule base of fuzzy model, a total of 80 rules were utilized based on experts' experiences and data compiled from the mines. The fuzzy model developed here can provide an estimate of area of major roof fall when proper input data were entered into model. For instance as can be seen in table 2 if the input parameters were entered into data like AE = 9503, DC = 93.8, RMR = 58.1, IS = 3.5, RC =1.14, the output predicted area of major roof fall is 2163 m^2 whereas actual area of area of roof fall is 2200 m^2.

V. RESULTS AND DISCUSSIONS

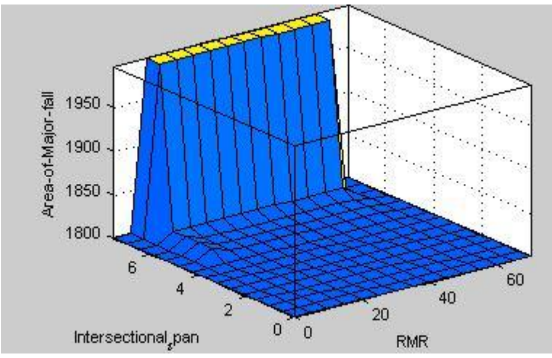
There are 05 data sets which were used for the model. The resultant output of the constructed proposed model each dataset is converted into qualitative information like Low, Medium, High. The constructed model predicted the area of major roof fall approximately in every case. The response plots from Matlab 2014 have been shown in fig 4 a-d. It can be concluded from the fig 4 the constructed fuzzy model is capable of predicting major roof fall area in the experimental.

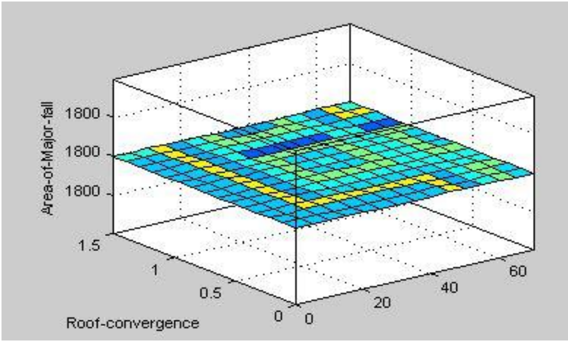




a) IS and DC **b) IS and RC**

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346





c) IS and RMR **d) RC and RMR**

Fig 4 Surface plots of a area of major roof fall with Intersectional span IS and DC, b IS and RC, c IS and RMR, d RC and RMR.

Field as the rule covers larger decision surface. The results show that fuzzy logic is useful and powerful tool for estimating area of major roof fall in coal mines. The output of the fuzzy model can be taken into account as a preliminary assessment of area of major roof fall based on which mining under managers and engineers can take necessary decisions and mitigation measures for controlling and prevention of injuries, fatalities that occurs in mines.

VI. CONCLUSIONS

Roof falls are the regular hazard in coal mines and it is inherently complex and unvaticinate due to dubious and variability in mining and geological parameters. Hence in this paper using fuzzy logic method, a model was established for prediction of area of major roof fall.This model was constructed using five inputs: AE, DC, RMR,IS,RC. Total if - then 80 rules and Centre of area (COA) method for defuzzification process. The fuzzy results show that Fuzzy method is a useful and powerful tool for the safety of mining engineers. The significant advantage of fuzzy model is the human decision and cognizance can be effectively used for the prediction of area of major roof fall in coal mines. It is a lucid that the fuzzy model can be improved with big data that can be obtained from larger recorded data.

VII. ACKNOWLEDGEMENTS

The authors would like to express their thanks to Coal India mine managers for their kind co-operation in permitting to visit the mines. They also thanks the editor of ICRISEM-16 for their co-operation and constructive suggestions. They also thank Mr. Datrika Srinivas Rao for his kind co-operation in guiding for Fuzzy model development.

REFERENCES

[1] Zimmermann, Hans-Jürgen. Fuzzy set theory—and its applications. Springer Science & Business Media, 2001.

[2] Ghasemi, E, and Mohammad Ataei. "Application of fuzzy logic for predicting roof fall rate in coal mines." Neural Computing and Applications 22.1 (2013): 311-321.

[3] Research gate 2016, https://www.researchgate.net/topics.QuestionsAsked.html

[4] Bertoncini, CA., and Mark K. Hinders. "Fuzzy classification of roof fall predictors in microseismic monitoring." Measurement 43.10 (2010): 1690-1701.

[5] Rezaei, Mohammad, Abbas Majdi, and Masoud Monjezi. "An intelligent approach to predict unconfined compressive strength of rock surrounding access tunnels in longwall coal mining." Neural Computing and Applications 24.1 (2014): 233-241.

[6] Ataei, M., R. Khalokakaei, and M. Hossieni. "Determination of coal mine mechanization using fuzzy logic." Mining Science and Technology (China) 19.2 (2009): 149-154.

[7] Azimi, Y., et al. "Prediction of the blastability designation of rock masses using fuzzy sets." International Journal of Rock Mechanics and Mining Sciences 47.7 (2010): 1126-1140.

[8] Deb, D. "Analysis of coal mine roof fall rate using fuzzy reasoning techniques." International Journal of Rock Mechanics and Mining Sciences 40.2 (2003): 251-257.

[9] Ethesis Btech Siva Prasad 2013, http://ethesis.nitrkl.ac.in/5142/1/109MN0505.pdf

[10] Mohammad, R, et al. "Prediction of representative deformation modulus of longwall panel roof rock strata using Mamdani fuzzy system." International Journal of Mining Science and Technology 25.1 (2015): 23-30.

[11] Palei, Sanjay Kumar, and Samir Kumar Das. "Logistic regression model for prediction of roof fall risks in bord and pillar workings in coal mines: An approach." Safety Science / 47.1 (2009): 88-96.

[12] Razani, Mojtaba, Abdolreza Yazdani-Chamzini, and Siamak Haji Yakhchali. "A novel fuzzy inference system for predicting roof fall rate in underground coal mines." Safety science 55 (2013): 26-33.

[13] Ross, Timothy J. Fuzzy logic with engineering applications. John Wiley & Sons, 2009.

[14] Wen-Xiu, Li, and Li Hai-Ning. "Fuzzy system models (FSMs) for analysis of rock mass displacement caused by underground mining in soft rock strata." Expert Systems with Applications 36.3 (2009): 4637-4645.

[15] Zadeh, Lotfi A. "Fuzzy sets." Information and control 8.Deb 3(1965): 338-353.