South Asian Journal of Mathematics 2013, Vol. 4 (1): 35 ∼ 47
www.sajm-online.com ISSN 2251-1512 RESEARCH ARTICLE

Risk analysis on any disaster level using a new algorithm based on fuzzy number

Kartik Patra ①*, Shyamal Kumar Mondal ①

① Department of Applied Mathematics, Vidyasagar University, Midnapore -721 102, W.B., India,
E-mail: kpatrakp@gmail.com

Received: Dec-1-2013; Accepted: Jan-5-2014 *Corresponding author

Abstract Any kind of natural disaster is one of the major problems causing the huge damages to a society in the world. In this paper a new algorithm $DREM$ has been developed for precaution of saving the public property from the damages due to disaster. The proposed algorithm consists of a new fuzzy number method including analytical hierarchy process and information diffusion method, by which risk estimation and recurrence interval of any disaster level in linguistic form i.e, small, medium, large and extreme can be derived. Then it has been shown that the proposed method is very useful either for large or small size of data whereas usual statistical method is not so. Also this proposed method is compared with the other existing method and it is seen that our proposed method gives the better performance. Finally this method has been applied in a flood disaster in China during the year $1950-2009$. So, this study has a significance to mitigate any kind of disaster problem.

Key Words fuzzy risk analysis, trapezoidal fuzzy number, analytical Hierarchy process, information diffusion

MSC 2010 53B40, 54A05

1 Introduction

Now a days various types of natural disasters such as flood, drought, earth-quake etc. are frequently occurring around the world. In such cases various types of damages are happened such as Buildings are destroyed, many peoples die, cultivation areas highly damages, various type of disease attack to human being. So a huge amount of economic loss and physical problem arise due to a natural disasters. Therefore risk analysis in disaster management has great significance to the government to take the correct decision in time about the protection of the public properties from the damages.

Risk is one type of uncertainty where some of the probabilities involved into a loss or other undesirable outcome. By risk analysis an attempt is made to numerically determine the probability of various adverse events of any system. Normally statistical methods are used to evaluate the risk estimation for any disaster. As long sequence of data is difficult to collect therefore in case of small sample issues the results based on classical statistical method are sometimes unreliable. However risk as a natural and social phenomenon, is neither precise nor certain. In such cases fuzzy set theory (Zadeh, 1965) has some very useful techniques by which data may be defined through vague in linguistic term such as small, medium, large and extreme etc. This linguistic terms can not be defined with precise single value. But using fuzzy set theory this terms can be formally defined in mathematical logic. At first, Schmucker (1984) proposed the fuzzy risk analysis. In many cases there will be a scarcity of data which causes fuzzyness. Huang

Citation: Kartik Patra, Shyamal Kumar Mondal, Risk analysis on any disaster level using a new algorithm based on fuzzy number, South Asian J Math, 2013, 4(1), 35-47.

(2002) deals with fuzzyness of a risk system. Accessing disaster risk is difficult because of the lack of objective measure and scarcity of data. There are many way to fill up the gaps for scanty of data. Many fuzzy methods for flood risk estimation have been developed in this purpose. Wang et al.(2011) and Zang et al. (2011) use the AHP (Analytical Hierarchy Process) for comprehensive evaluation of flood with variable fuzzy sets to integrate the qualitative and quantitative information of the indicator system. AHP was first introduced by Saaty (1980). Wang et. al. (2008)introduced an integrated $AHP - DEA$ methodology for bridge risk assessment. Information diffusion is also one of the more useful way. Li et al (2012) presented a method of flood risk analysis using variable fuzzy set model and information diffusion technique. But in this paper there is some anomalies.

Now to overcome some anomalies in existing methods for risk estimation, in this paper a new algorithm ($DREM$) has been proposed. This algorithm consists of a new fuzzy number method including Analytical Hierarchy Process (AHP) and information diffusion Method (IDM). As a case study this method has been applied to flood disaster problem in China during the period $1950 - 2009$. From this study it has been shown that this method gives nearly same result for either small or large sample but this is not correct for statistical method in the case of small sample size. Again it has also shown that comparing the existing method, our proposed method gives better performance removing all anomalies in the existing method. So, this paper will be very useful to the disaster management to take the precaution about the disaster after knowing the risk of different level of a disaster from previous records.

The rest of the paper is organized as follows. In section §2 a preliminaries is given. In section §3 a new method of fuzzy number has been introduced. In section §4 risk estimation of any disaster level has been discussed using proposed fuzzy number method, analytical hierarchy process and information diffusion method. Also a complete algorithm ($DREM$) for risk estimation has been proposed there. In section §5 a case study of flood disaster in china during the period $1950 - 2009$ has been discussed. In section §6 a conclusion has been drawn.

2 Preliminaries

2.1 Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions. It was developed by Thomas L. Saaty in 1980 and has been extensively studied and refined since then. It has particular application in group decision making and is used around the world in a wide variety of decision situations. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations. The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques. In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision.

The pairwise scale preference for AHP is given in the following table:

Table-1: Standard comparison table of AHP

Value(a_{ij})	Comperison description
1	indicator i and j are of equal importance
3	indicator i is weakly more importance than j
5	indicator i is strongly more importance than j
7	indicator i is very strongly more importance than j
9	indicator i is absolutely more importance than j

Of course we set $a_{ii} = 1$. Furthermore if we set $a_{ij} = k$ then $a_{ji} = 1/k$.

2.2 Information diffusion method (IDM)

Information diffusion is a fuzzy mathematical set value method for samples which optimize the use of fuzzy information of samples to offset the information deficiency. Using the information diffusion method the risk estimation value of different degree values can be easily computed. By this method fuzzy information of the samples optimized to balanced the information deficiency. According to this method a single valued sample diffused into a set value sample. The simplest model of information diffusion is normal diffusion model.

Information Diffusion: Let X be a set of sample and V be a subset of universe. $\mu : X \times V \longrightarrow [0,1]$ is a mapping from $X \times V$ to $[0,1]$. $\forall (x,v) \epsilon X \times V$ is a kind of information diffusion of X on V and satisfied the following three conditions (Huang and Shi,2002):

(1) If $\parallel v' - x \parallel \leqslant \parallel v'' - x \parallel$, then $\mu(x,v') \geqslant \mu(x,v'')$, $\forall v', v'' \epsilon V$ where μ is the diffusion function.

(2) Let v^* be the observed value of x, which satisfy $\mu(x,v^*) = max_{v\epsilon V}\mu(x,v)$.

(3) $\mu(x,v)$ is conservative. If and only if $\forall x \epsilon X$, its integral value on the universe is 1, viz. $\int \mu(x,u)du = 1$

Let X= $\{x_1, x_2, ..., x_n\}$ be a sample and U= $\{u_1, u_2, ..., u_r\}$ be the discreet universe of X. x_i and u_j are called the sample point and the monitoring point respectively. If $\forall x_i \epsilon X$, $\forall u_j \epsilon U$, we diffuse the information carried by x_i to u_j at gain $f_i(u_j)$ using the normal information diffusion shown in the following equation:

$$f_i(u_j) = exp[-\frac{(x_i - u_j)^2}{2h^2}], u_j \epsilon U \tag{1}$$

where h is the normal diffusion coefficient calculated as

$$h = \begin{cases} 0.8146(b-a) & if\, n = 5 \\ 0.5690(b-a) & if\, n = 6 \\ 0.4560(b-a) & if\, n = 7 \\ 0.3860(b-a) & if\, n = 8 \\ 0.3362(b-a) & if\, n = 9 \\ 0.2986(b-a) & if\, n = 10 \\ 0.6851(b-a)/(n-1) & if\, n \geqslant 11 \end{cases} \tag{2}$$

where b=$max_{1 \leqslant i \leqslant n}(x_i)$; a=$min_{1 \leqslant i \leqslant n}(x_i)$

Let

$$C_i = \sum_{j=1}^{r} f_i(u_j) \tag{3}$$

A normalized information diffusion on U can be determined by x_i, as shown in the following equation

$$\mu(x_i, u_j) = \frac{f_i(u_j)}{C_i} \tag{4}$$

Adding all normalized information for each monitoring point u_j, the information gain is obtained at u_j which comes from the given sample X. The information gain is shown in the following equation:

$$q(u_j) = \sum_{i=1}^{n} \mu(x_i, u_j) \tag{5}$$

$q(u_j)$ represents that with the information diffusion technique, there are $q(u_j)$ monitoring point in term of statistics averaging at the monitoring point u_j. $q(u_j)$ is not a positive integer but is a number not less than zero. The assumption is:

$$Q = \sum_{j=1}^{r} q(u_j) \tag{6}$$

where Q is the sum of the sample size of all $q(u_j)$. Theoretically Q=n, but due to the numerical calculation error, there is slight different between Q and n.Therefore we can estimate the frequency value of a sample falling at u_j

$$p(u_j) = \frac{q(u_j)}{Q} \tag{7}$$

The frequency value can be taken as the estimation value of its probability. The probability value of transcending u_j should be

$$P(u_j) = \sum_{k=j}^{r} p(u_k) \tag{8}$$

where $P(u_j)$ is the required risk estimation value.

3 Proposed Fuzzy Number Method (FNM)

In this method disaster and its indicators are expressed as a level such as small, medium, large and extreme which are fuzzy number in nature. The fuzzy number corresponding to each level h for j^{th} indicator is considered as a trapezoidal fuzzy number, denoted by $T_{\tilde{hj}} = (a_{\tilde{hj}}, b_{\tilde{hj}}, c_{\tilde{hj}}, d_{\tilde{hj}})$, whose membership function $\mu_{\tilde{hj}}(x)$, can be formulated as:

$$\mu_{\tilde{hj}}(x) = \begin{cases} 0, & if\ -\propto < x \leqslant a_{\tilde{hj}} \\ \frac{x - a_{\tilde{hj}}}{b_{\tilde{hj}} - a_{\tilde{hj}}}, & if\ a_{\tilde{hj}} < x \leqslant b_{\tilde{hj}} \\ 1, & if\ b_{\tilde{hj}} < x \leqslant c_{\tilde{hj}} \\ \frac{d_{\tilde{hj}} - x}{d_{\tilde{hj}} - c_{\tilde{hj}}}, & if\ c_{\tilde{hj}} < x \leqslant d_{\tilde{hj}} \\ 0, & if\ d_{\tilde{hj}} < x < \propto \end{cases}$$

where $h = 1, 2, 3, 4$ denote the level small, medium, large and extreme respectively and $j = 1, 2, ..., m$. After construction of membership function, for each year the level of the value of each indicator can be determined and after that individual effect due to each indicator can be obtained by evaluating the degree of belongingness of the value of indicator in the corresponding level. If the levels corresponding to the value (x_{ij}) of j^{th} indicator for i^{th} year are h_{j1} and h_{j2}, then the individual effect, η_{ij} of x_{ij} can be calculated as

$$\eta_{ij} = h_{j1}\mu_{\tilde{h_{j1}}}(x_{ij}) + h_{j2}\mu_{\tilde{h_{j2}}}(x_{ij}) \tag{9}$$

After calculation $\eta_{ij}, j = 1, 2, ..., m$ the collective effect i.e, degree value ζ_i of all indicators can be determined by the following formula

$$\zeta_i = \sum_{j=1}^{m} w_j.\eta_{ij}, i = 1, 2, ..., n. \tag{10}$$

where w_j is the weight of the j^{th} indicator obtained by AHP.

4 Proposed Disaster Risk Estimation Method ($DREM$)

Natural disaster causes a huge amount of damage every year around the world. So, disaster risk analysis is a very essential mater as a social problem. The types of natural disaster are usually mentioned in linguistic form. Generally disasters are classified into four levels: small, medium, large and extreme. As the classified levels are in linguistic form, hence in nature they are fuzzy numbers. In this study it is considered as a trapezoidal fuzzy number. To estimate the risk of the disaster levels from the previous records, a sample of n years is considered in a matrix from as follows:

$$X = \begin{pmatrix} x_{11} & x_{12} & .. & .. & x_{1m} \\ x_{21} & x_{22} & .. & .. & x_{2m} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ x_{n1} & x_{n2} & .. & .. & x_{nm} \end{pmatrix}$$

where m is the number of effected items (indicators) due to disaster, n is the number of years and x_{ij} is the value of the j^{th} indicator of i^{th} year. Since this is a multidimensional information sets so it can be converted to one dimensional degree value for the classification of disaster in linguistic form. For doing so Analytical Hierarchy Process (AHP), proposed fuzzy number method (FNM) and information diffusion method (IDM) have been used.

4.1 Proposed $DREM$ algorithm

For evaluation of risk for any disaster level (small, medium, large and extreme) from previous statistical data, the $DREM$ has been proposed using FNM, AHP and IDM . The necessary steps for evaluation of risk value are described by the following algorithm.

Step 1: Find the membership value ($\mu_{\tilde{hj}}(x)$) of each disaster level for each indicator.
Step 2: Calculate the individual effect η_{ij} of j^{th} indicator of i^{th} year as

$$\eta_{ij} = \sum_{h_j} h_j \mu_{\tilde{h_j}}(x_{ij}), h_j = 1, 2, 3, 4. \tag{11}$$

Step 3: Decide disaster indicator weights w_j using AHP.
Step 4: Calculate the disaster degree value for i^{th} year as

$$\zeta_i = \sum_{j=1}^{m} w_j \eta_{ij}, i = 1, 2, ..., n. \tag{12}$$

Step 5: The n number of degree values are diffused into $r\,(r < n)$ number of monitoring points defined by decision maker. Then calculate the probability estimation of each monitoring points which is the required risk value of the disaster level corresponding to the monitoring point. The flowchart of the above algorithm is given as following:

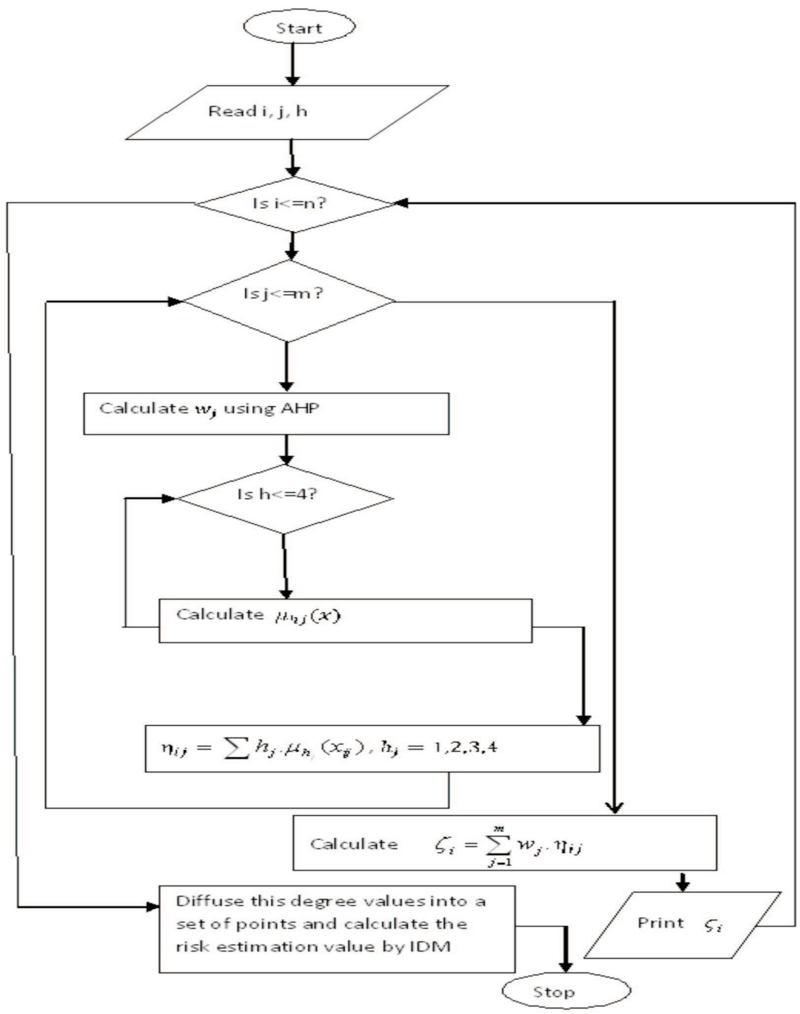


Fig 1: Flowchart of *DREM*

5 Numerical Example

In this paper, for illustration of our proposed method ($DREM$), a historical data (Li et. al. 2012) of a flood disaster in China has been taken to calculate the risk estimation of different flood levels. There are 60 records of successive 60 years as a sample set. **Four indicators** involved in this data sets are **Damage area, Inundated area, Dead population and Collapsed houses**. According to our method flood are classified into four classes i.e, levels such as **small, medium, large and extreme** and these levels are identified with h=1, 2, 3 and 4 respectively.

These flood levels are expressed with trapezoidal fuzzy numbers for different flood indicators. For this data set the trapezoidal fuzzy numbers for different flood levels are classified as follows:

In the case of Damage area, the trapezoidal fuzzy numbers of different flood levels are

small flood=$(0, 0, 1095, 9045)$, medium flood=$(1095, 9045, 11732, 14197)$,

large flood=$(11732, 14197, 17297, 20388)$ and extreme flood=(17297,20388,80000,80000)

In the case of Inundated area, the trapezoidal fuzzy numbers of different disaster levels are

small flood=$(0, 0, 932, 4989)$, medium flood=$(932, 4989, 6534, 8216.7)$,

large flood=$(6534, 8216.7, 10954, 13000)$ and extreme flood=(10954,13000,50000,50000)

In the case of Dead population, the trapezoidal fuzzy numbers of different disaster levels are

small flood=$(0, 0, 1012, 3446)$, medium flood=$(1012, 3446, 4367, 5113)$,

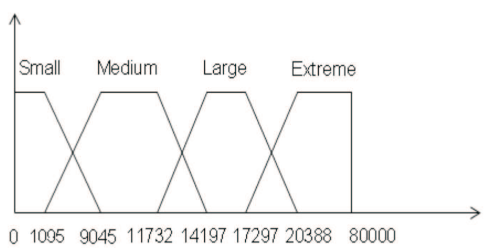
large flood=$(4367, 5113, 7829, 10676)$ and extreme flood=(7829,10676,100000,100000)

In the case of Collapsed houses, the trapezoidal fuzzy numbers of different disaster levels are:

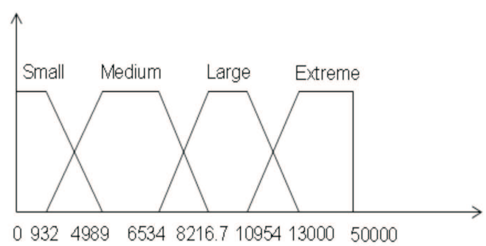
small flood=$(0, 0, 50.2, 112.1)$, medium flood=$(50.2, 112.1, 182.5, 247.7)$,

large flood=$(182.5, 247.7, 500.9, 754.3)$ and extreme flood=(500.9,754.3,5000,5000)

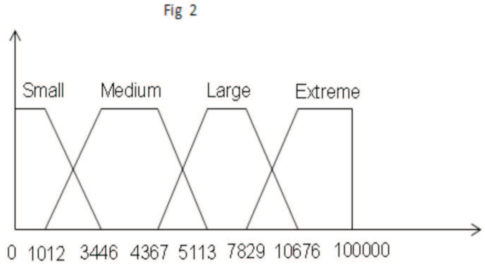
The geometrical representations of the membership functions of all these fuzzy numbers are shown in the following figures (Fig $2-5$).



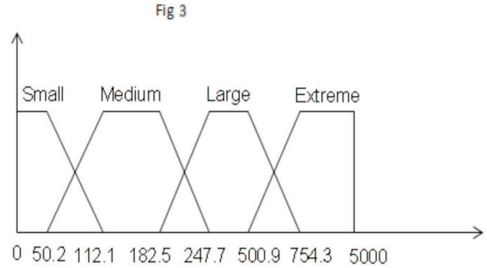
Damage area
Fig 2



Inundated area
Fig 3



Dead population
Fig 4



Collapse houses
Fig 5

The sample data for 60 years in China is given in Table 2.

Table-2: 60 years records of flood disaster

Year	Damage area(1000 hectors)	Inundated area(1000 hectors)	Dead population(persons)	Collapse houses(10000)
1950	6559.00	4710.00	1982	130.50
1951	4173.00	1476.00	7819	31.80
1952	2794.00	1547.00	4162	14.50
1953	7187.00	3285.00	3308	322.00
1954	16131.00	11305.00	42447	900.90
1955	5247.00	3067.00	2718	49.20
1956	14377.00	10905.00	10676	465.90
1957	8083.00	6032.00	4415	371.20
1958	4279.00	1441.00	3642	77.10
1959	4813.00	1817.00	4540	42.10
1960	10155.00	4975.00	6033	74.70
1961	8910.00	5356.00	5074	146.30
1962	9810.00	6318.00	4350	247.70
1963	14071.00	10479.00	10441	1435.30
1964	14933.00	10038.00	4288	246.50
1965	5587.00	2813.00	1906	95.60
1966	2508.00	950.00	1901	26.80
1967	2599.00	1407.00	1095	10.80
1968	2670.00	1659.00	1159	63.00
1969	5443.00	3265. 00	4667	164.60
1970	3129.00	1234.00	2444	25.20
1971	3989.00	1481.00	2323	30.20
1972	4083.00	1259.00	1910	22.80
1973	6235.00	2577.00	3413	72.30
1974	6431.00	2737.00	1849	120.00
1975	6817.00	3467.00	29653	754.30
1976	4197.00	1329.00	1817	81.90
1977	9095.00	4989.00	3163	50.60
1978	2820.00	924.00	1796	28.00
1979	6775.00	2870.00	3446	48.80
1980	9146.00	5025.00	3705	138.30
1981	8625.00	3973.00	5832	155.10
1982	8361.00	4463.00	5323	341.50
1983	12162.00	5747.00	7238	218.90
1984	10632.00	5361.00	3941	112.10
1985	14197.00	8949.00	3578	142.00
1986	9155.00	5601.00	2761	150.90
1987	8686.00	4104.00	3749	92.10
1988	11949.00	6128.00	4094	91.00
1989	11328.00	591.00	3270	100.10
1990	11804.00	5605.00	3589	96.60
1991	24596.00	14614.00	5113	497.90
1992	9423.30	4464.00	3012	98.95
1993	16387.30	8610.40	3499	148.91
1994	18858.90	11489.50	5340	349.37
1995	14366.70	8000.80	3852	245.58
1996	20388.10	11823.30	5840	547.70
1997	13134.80	6514.60	2799	101.06
1998	22291.80	13785.00	4150	685.03
1999	9605.20	5389.12	1896	160.50
2000	9045.01	5396.03	1942	112.61

Continued Table-2:

Year	Damage area(1000 hectors)	Inundated area(1000 hectors)	Dead population(persons)	Collapse houses(10000)
2001	7137.78	4253.39	1605	63.49
2002	12384.21	7439.01	1819	146.23
2003	20365.70	12999.80	1551	245.42
2004	7781.90	4017.10	1282	93.31
2005	14967.48	8216.68	1660	153.29
2006	10521.86	5592.42	2276	105.82
2007	12548.92	5969.02	1230	102.97
2008	8867.82	4537.58	633	4.70
2009	8748.16	3795.79	538	55.59

The weight of the indicators evaluated by AHP using the preference table (Table 3) with the help of pairwise scale preference (Table 1) described in the section §2.1 for each indicators, can be obtained by Table 4.

Table-3 : Comparison table of flood indicators

	Damage area	Inundated area	Dead population	Collapse houses
Damage area	1	1/2	1/9	1/3
Inundated area	2	1	1/5	1/2
Dead population	9	5	1	3
Collapse houses	3	2	1/3	1

Table-4: Weights of the flood indicators

	Flood impact weight
Damage area	0.0655
Inundated area	0.1189
Dead population	0.6043
Collapse houses	0.2113

Using the data in Table 2, $DREM$ algorithm of section §2.4 is used to calculate the flood degree values for given 60 years, which is given in the Table 5

Table-5: Degree values for corresponding 60 years

Sample	Degree value	Sample	Degree value	Sample	Degree value	Sample	Degree value
1	1.607851	16	1.469056	31	2	46	2.373578
2	2.249906	17	1.232853	32	2.571069	47	3.155048
3	1.636323	18	1.046922	33	2.794546	48	1.838957
4	2.111791	19	1.114479	34	2.733692	49	2.733631
5	3.836003	20	2.16279	35	2	50	1.615182
6	1.520342	21	1.381111	36	2.1844	51	1.642316
7	3.6043	22	1.365405	37	1.82995	52	1.32399
8	2.242231	23	1.257125	38	1.902836	53	1.677362

Continued Table-5:

Sample	Degree value	Sample	Degree value	Sample	Degree value	Sample	Degree value
9	1.737286	24	1.762075	39	1.933732	54	2.112121
10	1.801004	25	1.515981	40	1.915338	55	1.349262
11	2.476216	26	3.568229	41	1.949003	56	1.741036
12	2.571582	27	1.345247	42	3.1844	57	1.688066
13	2.2113	28	1.719793	43	1.831988	58	1.441846
14	3.763546	29	1.208859	44	2.1844	59	1.170688
15	2.391812	30	1.707898	45	3.064213	60	1.162949

A graph of degree values for 60 years for the flood disaster has been shown in Fig 6. Now the recurrence interval i.e, interval of small flood, medium flood, large flood and extreme flood during the certain years can be calculated easily from this graph.

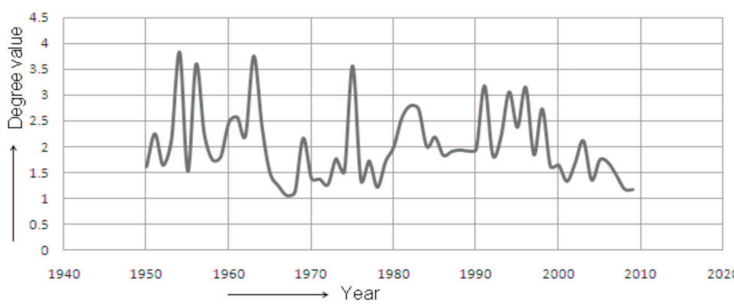


Fig 6 : Flood degree curve of 60 years sample

According to Chen (2009) the degree values of flood lie between 1 to 4. Now the risk estimation for different degree values can be obtained using the information diffusion method. In this method 60 degree values for 60 years in Table 5 are diffused into some monitoring points. In this problem the monitoring points are taken from the set $U = \{0, 0.1, 0.2, 0.3, ..., 3.9, 4.0\}$. Using equations 3 to 10 the risk estimation values of these monitoring points are calculated and it is depicted by the curve (black) in the Fig 7 when the given data about the flood disaster is large in size. Again if data is small, in this case it is taken 35 as for example, then risk estimation at the same monitoring points have been shown by the curve (blue) in the Fig 7.

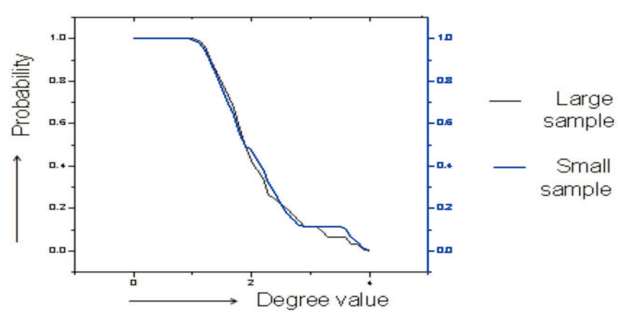


Fig 7: The comparison curve of large and small sample

5.1 Comparison with previous method

It is seen that according to the method in Li et al.(2012), the all values of flood indicators for sample number 5 are greater than the sample number 14. But the degree value for sample number 14 is the greater than the degree value for the sample number 5 and it means that there is the larger flood in the year 1963 than in the year 1954. But it is not coincide with the given data because the larger values of the all indicators in one sample compared to the other sample indicate the larger degree value than other respectively. Hence this is a drawback for this method and this drawback has been overcome by our proposed method which is confirmed numerically by Table 5. Also from AHP method it is seen that the indicator dead population has most impact about 60%. Again from the given statistical data of 60 years it is seen that (i) there are 3 years in which dead population indicator crosses the extreme flood level and other three indicators are about to cross the extreme level, (ii) again there is also another one year in which the indicator collapse houses with second highest impact on flood disaster crosses the extreme level and other three indicators are also about to cross the extreme level. Hence from these observations in statistical data it is clear that the flood disaster is of extreme level about 4 years out of these 60 years. Therefore it is concluded that extreme flood occurs in about every 15 year interval. Again from the method in Li et al (2012) it's about 37 years interval which is not correct according to the observations in statistical data. **But this type of drawback has been minimized by our proposed method** $DREM$.

5.2 Discussion

Now from the Fig 7 it is observed that the two curves (black and blue corresponding to the large and small sample respectively) are nearly equal. Hence it is concluded that our proposed method is very effective either for large or small data sample in flood disaster though it is not correct for usual statistical methods when data size in the sample is small. Now the recurrence interval (N) of any monitoring point u_j can be measured by the formula $N = 1/P(u_j)$, where $P(u_j)$ is the risk estimation value of the monitoring point u_j. The risk estimation values of the monitoring points for the large and small sample shown in Table 6 and 7 respectively.

Table-6: Risk estimation value for large sample

$P(u_j)$	probability value	$P(u_j)$	probability value	$P(u_j)$	probability value	$P(u_j)$	probability value
j=1	1.0000	j=11	0.9999	j=21	0.428	j=31	0.1167
j=2	1.0000	j=12	0.9904	j=22	0.3835	j=32	0.1133
j=3	1.0000	j=13	0.9614	j=23	0.3458	j=33	0.093
j=4	1.0000	j=14	0.8974	j=24	0.2641	j=34	0.0667
j=5	1.0000	j=15	0.8453	j=25	0.2481	j=35	0.0667
j=6	1.0000	j=16	0.7862	j=26	0.2155	j=36	0.0667
j=7	1.0000	j=17	0.7348	j=27	0.1962	j=37	0.0641
j=8	1.0000	j=18	0.6748	j=28	0.1667	j=38	0.0335
j=9	1.0000	j=19	0.5726	j=29	0.1389	j=39	0.0297
j=10	1.0000	j=20	0.4923	j=30	0.1167	j=40	0.0035
j=41	0.0000						

According to Chen (2009) the usual 4 levels (grades) of the flood are defined as follows
small flood: $1 \leqslant \zeta \leqslant 1.5$
medium flood: $1.5 \leqslant \zeta \leqslant 2.5$

large flood: $2.5 \leqslant \zeta \leqslant 3.5$
extreme flood: $3.5 \leqslant \zeta \leqslant 4$
where ζ is the degree value of flood. Now the recurrence intervals of different flood levels i.e, small, medium, large and extreme on the basis of the statistical data in Table 2 can be measured using above formula taking the lower bounds of the above ranges as a monitoring point and as a result it is seen that the recurrence interval for the small flood level is equal to 1, medium flood level is 1.27, large flood level is 4.64 and extreme flood is 14.99. So our proposed method gives the occurrence of extreme flood to be 14.99 i.e, near about 15 years of interval which coincides with the observations in statistical data in Table 2. But Li et al. (2012) gave the recurrence interval to be about 37.5 years which is incorrect with the observation. **Therefore from the above discussions it is clear that our proposed method has better performance compared to other existing methods.**

Table-7: Risk estimation value for small sample

$P(u_j)$	probability value	$P(u_j)$	probability value	$P(u_j)$	probability value	$P(u_j)$	probability value
j=1	1.0000	j=11	0.9993	j=21	0.4773	j=31	0.1143
j=2	1.0000	j=12	0.9824	j=22	0.4338	j=32	0.1143
j=3	1.0000	j=13	0.945	j=23	0.3906	j=33	0.1143
j=4	1.0000	j=14	0.8878	j=24	0.3193	j=34	0.1143
j=5	1.0000	j=15	0.8247	j=25	0.2812	j=35	0.1143
j=6	1.0000	j=16	0.7609	j=26	0.2119	j=36	0.114
j=7	1.0000	j=17	0.697	j=27	0.1731	j=37	0.1006
j=8	1.0000	j=18	0.6384	j=28	0.1483	j=38	0.0629
j=9	1.0000	j=19	0.5518	j=29	0.118	j=39	0.0451
j=10	1.0000	j=20	0.4915	j=30	0.1143	j=40	0.012
j=41	0.0003						

6 Conclusion:

In this paper we define a new method ($DREM$) of risk estimation of different disaster levels in linguistic forms. This proposed method ($DREM$) is comprised with the trapezoidal fuzzy numbers, analytical hierarchy process and information diffusion. Finally in this paper it is applied in the risk analysis of a flood disaster occurred in China during the years $1950 - 2009$. From this study the risk estimations and the recurrence intervals of different flood levels i.e, small, medium, large and extreme can be determined which will be very beneficiary to the disaster management. Comparing with the other existing method it has shown that our proposed method gives better performance. Also it is seen that the risk analysis by this method can be successfully done when there is a scanty of data though usual statistical method fails in such case. Hence with this study a government in any province or country will be very useful to mitigate or protect any kinds of disasters i.e, flood, drought, earthquake etc.

References

1 Chen,S.2009. Theory and Model of Variable Fuzzy Sets and its Application, first ed. Dailan Universityof Technology Press, Dailan.

2 Huang,C.,2002. Information diffusion techniques and small sample problem, International Journal of Information Technology and Decision Making.1, $229 - 250$.

3 Huang,C.,Shi,Y.,2002. Towards Efficient Fuzzy Information Processing: Using Principle of Information Diffusion, Physica Verlag.

4 Li,Q.,Zhou,J.,Liu,D.,Jiang,X.,2012. Research on flood risk analysis and evaluation method based on variable fuzzy sets and information diffusion, Safety Science. $50, 1275 - 1283$.

5 Saaty,T.,1980. The Analytical Hierarchy Process,McGraw-Hill,New York.

6 Schmucker,K.J.,1984. Fuzzy sets, natural language computations, and risk analysis. MD: Computer science press.

7 Wang,Y., Wang,D., Wu,J.,2011. A variable fuzzy set assessment model for water shortage risk: two case studies from China, Human and ecological Risk Assessment. $17, 631 - 645$.

8 Wang,Y.M., Liu,J., Elhag,T.M.S., 2008. An integrated AHP-DEA methodology for bridge riskassessment ,Computers & Industrial Engineering, $54(3), 513 - 525$

9 Zadeh ,L. A.,1965. Fuzzy Sets. Information and Control. $8, 338 - 356$.

10 Zang,D.,Wang,G.,.Zhou,H.,2011. Assessment on agricultureal drought risk based on variable fuzzy set model. Chinese Geographical Science. $21, 167 - 175$.

11 Zimmerman,H.J., 1987.Fuzzy Sets, Decision-Making and Expert system Kluwwer Academic Publishers, Boston.