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Fuzzy Failure Probability of Transmission Pipelines in the Niger Delta Region of Nigeria: The case of Third Party Activities.

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Abstract

We undertake the apportioning of failure possibility on twelve identified third party activities contributory to failure of transmission pipelines in the Niger Delta region of Nigeria, using the concept of fuzzy possibility scores. Expert elicitation technique generates linguistic variables that are transformed using fuzzy set theory into fuzzy possibility scores that expresses the expert belief and confidence that the identified third party activity would cause transmission pipelines to fail in the Niger Delta region of Nigeria.

Keywords: expert elicitation, fuzzy set, fuzzy possibility score.

1. Introduction:

In the absence of accurate pipelines transmission failure data, it becomes necessary to work with rough estimates of probabilities which are treated as random variables with known probability distributions [9]. This requires that data should be available from which these probability distribution can be reasonably deduced. Fuzzy methods might be the only way little quantitative information is available regarding fluctuations of parameters and probabilities of basic events that are treated as fuzzy numbers [6,8]. In this research, probabilities of basic events of transmission pipeline failures were treated as fuzzy numbers, which is obtained by expert elicitation and theory of fuzzy set.

Study methodology

Ten experts comprising of seven engineers, two academic pipeline researchers and one industrial pipeline researcher labeled J1 to J10 were selected to evaluate reasons for pipeline failure by twelve (i_1 to i_{12}) third party identified activities based on experience and knowledge about pipelines. These activities are indicated in Table 1

Ariavie (2010) heighted the selection and methodology of eliciting responses from experts and adopted the Delphi technique, [1,2]. Clemens and Winkler [3] examine the impact of dependency among experts using a normal model and conclude that three to five experts are adequate. Hora [5] created synthetic group from the responses of real experts and found that three to six or seven experts are sufficient with little benefit from additional experts beyond that point. The experts selected comprise of seven engineers, two academic pipeline researchers and one industrial pipeline researcher. They are to evaluate reasons for pipeline vandalization by third party based on experience and knowledge about pipelines. Each expert is assigned a non-negative "weight" $\omega_i \geq 0$ to reflect his/her relative expertise in the group, and thereafter standardize these so that $\sum_i \omega_i = 1$. If some experts are viewed 'better' than others, the 'better' expert is given a greater weight.

Experts' were mailed the questionnaire with the advisory table via surveymonkey.com, an online tool for collecting and analyzing responses from individual experts (See Ariavie , 2010). Surveymonkey also creates smart, academic research, personalized and professional survey with ease and offers a wide range of survey options that includes Multiple choice, Matrix of choice, Rating scale, Text boxes and Demography. It also assist to randomized/sort answers which eliminates bias (a good factor that makes it suitable for the Delphi technique), provides fields for additional. Monkeysurvey allows response to surveys by Emails, Websites, Facebook Pages, Blogs, Banner Ads and Twitter Posts. Once completed, surveymonkey results can be analyses ontime realtime, and the responses can be viewed and reports can be generated, shared results with others without giving them access to your full account.

The responses is tabulated Table 2 with the weighting score and composition of different experts in Table 3.

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Table 1: : Identified twelve basic events contributory to pipeline vandalization via third party activities

Basic Events	Classification
i_1	Revenge
i_2	Poverty
i_3	Fishing
i_4	Government Neglect
i_5	Get Rich Quickly
i_6	Farming Activities
i_7	Militancy
i_8	Population Explosion
i_9	Aging Pipeline
i_{10}	Company's Operation
i_{11}	Sabotage
i_{12}	Poor Engineering Constructions

Table 2: Expert Response to Questionnaire

Classification	Revenge	Poverty	Fishing	Government Neglect	Get rich quickly	Farming Activities	Militancy	Population Explosion	Aging Pipeline	Company's operations	Sabotage	Poor Engineering Constructions
J1	D	D	A	SA	SA	D	SA	D	D	D	SA	D
J2	A	SA	SD	SA	SA	SD	SD	A	A	SA	SA	SD
J3	A	SA	D	A	SA	SD	SD	A	A	A	SA	SD
J4	SA	A	D	SA	SA	A	A	D	D	SA	A	D
J5	A	A	D	S A	A	D	SA	D	D	A	A	D
J6	A	SA	D	SA	SA	D	A	D	D	D	A	D
J7	D	A	D	SA	SA	D	A	D	D	A	A	SD
J8	A	SA	SD	SA	SA	SD	SA	SD	SD	A	SA	A
J9	D	SA	SA	SA	SA	SA	SA	D	SA	A	SA	D
J10	A	SA	D	SA	SA	D	SA	D	SA	SA	A	D

Table 3: Weighting Score and Constitution of Different Expert

SN	TITLE	ASSIGN SCORE FOR TITLE OF EXPERT	SERVICE TIME (years)	ASSIGN SCORE FOR SERVICE TIME OF EXPERT	EDUCATIONAL LEVEL	ASSIGN SCORE FOR EDUCATIONAL LEVEL OF EXPERT	AGE OF EXPERT (years)	ASSIGN SCORE FOR AGE OF EXPERT	WEIGHTING SCORE	WEIGHTING FACTOR, w_j
J1	ENGINEER	3	> 20	5	BSC	5	>46	5	18	0.11764706
J2	ENGINEER	3	< 5	1	BSC	5	28 - 36	3	12	0.07843137
J3	ENGINEER	3	< 5	1	BSC	5	28 - 36	3	12	0.07843137
J4	INDUSTRIAL RESEARCHER	5	< 5	1	MSC	6	37 - 45	4	16	0.10457516
J5	ENGINEER	3	15-20	4	HND	4	> 46	5	16	0.10457516
J6	ACCADEMIC RESEARCHER	6	5 -10	2	PHD	7	37 - 45	4	19	0.12418301
J7	ENGINEER	3	< 5	1	BSC	5	28 - 36	3	12	0.07843137
J8	ENGINEER	3	10 -15	2	MSC	6	37 - 45	4	15	0.09803922
J9	ACCADEMIC RESEARCHER	6	15 - 20	3	MSC	6	37 - 45	4	19	0.12418301
1J0	ENGINEER	3	<5	1	MSC	6	37 - 45	4	14	0.09150327

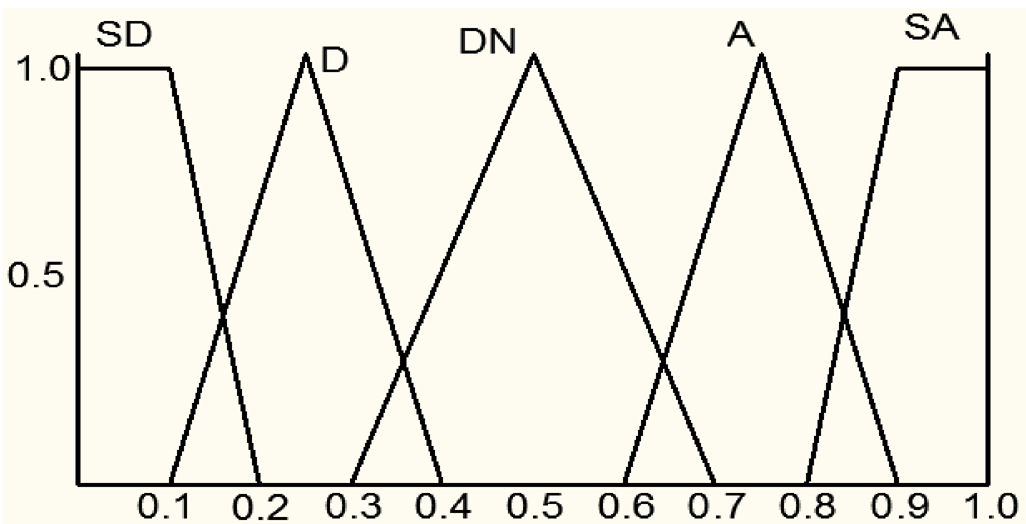

Figure 1 Schematics of scale membership function using a combination of both trapezoidal and triangular membership function.

In converting the linguistic terms expressed by the experts, numerical approximation system converts linguistic terms to their corresponding fuzzy numbers using the extension principle of the $\alpha - cut$ of the membership functions which could be triangular, trapezoidal or a combination of both [4]. In this paper, we adopt the figure shown in figure 1 with the corresponding membership function of the different linguistic terms in equation (1a to 1e)

$$f_{SA}(x) = \begin{cases} 0 & x < 0.8 \\ \dfrac{x-0.8}{0.1} & 0.8 < x \le 0.9 \\ 1 & 0.9 < x < 1 \end{cases} \qquad (1a)$$

$$f_A(x) = \begin{cases} \frac{x-0.6}{0.15} & 0.6 < x \le 0.75 \\ \frac{0.9-x}{0.15} & 0.75 < x \le 0.9 \\ 0 & otherwise \end{cases} \quad (1b)$$

$$f_{DN}(x) = \begin{cases} \frac{x-0.3}{0.2} & 0.3 < x \le 0.5 \\ \frac{0.7-x}{0.2} & 0.5 < x \le 0.7 \\ 0 & otherwise \end{cases} \quad (1c)$$

$$f_D(x) = \begin{cases} \frac{x-0.1}{0.15} & 0.1 < x \le 0.25 \\ \frac{0.4-x}{0.2} & 0.25 < x \le 0.4 \\ 0 & otherwise \end{cases} \quad (1d)$$

$$f_{SD}(x) = \begin{cases} 1 & otherwise \\ \frac{0.2-x}{0.1} & 0.1 < x < 0.2 \\ 0 & x \le 0.2 \end{cases} \quad (1e)$$

Combining or agrregating the different opinion of the ten experts over the twelve identified events into a single one, we would apply the linear opinion pool method given in equation (2).

$$N_i = \sum w_j B_{ij}, \qquad j = 1,3,\ldots,n \quad (2)$$

where

N_i *represents combined fuzzy number of basic events i*

m represents the num,ber of basic events,

w_j *represents the weighting factor of* exp*ert j*

B_{ij} *represents the linguistic* exp*ression of a basic event i given by* exp*ert j, and*

n represents the number of exp*erts*

Equation 2 is subject to fuzzy maximizing and minimum set defined by [4] as

$$f_{\max}(x) = \begin{cases} x & 0 \le x \le 1 \\ 0 & otherwise \end{cases} \qquad f_{\min}(x) = \begin{cases} 1-x & 0 \le x \le 0 \\ 0 & otherwise \end{cases} \quad (3)$$

Membership values can be interpreted as possibilities and integrating the fuzzy ratings to the fault problem, the final ratings are also fuzzy numbers [1] which would require conversion into crisp score called *Fuzzy Possibility Score (FPS).*

A *fuzzy number* $\bar{M}$ is of *LR-type* if there exist reference function *L* (for left), R (for right), and scalars $\sigma > 0, \beta > 0$ with

$$\mu_i(x) = \begin{cases} L\left(\dfrac{m-x}{a}\right) & for\ \ x \le m \\ R\left(\dfrac{x-m}{\beta}\right) & for\ \ x \ge m \end{cases} \qquad (4)$$

Where m, called the mean value of $\overline{M}$, is a real number and $\sigma\ and\ \beta$ are called the left and right spreads, respectively. Symbolically $\overline{M}$ is denoted by $(m, \sigma, \beta)_{LR}$

The fuzzy possibility score of the fuzzy number N is can then be calculated from

$$FPS == \mu_T(N)[\mu_R(N)+1-\mu_L(N)]/2 \qquad [9] \qquad (5)$$

Also, the fuzzy failure probability, as defined by Onisawa, [7], is given as

$$FFP = \begin{cases} \dfrac{1}{10^k} & FPS \ne 0 \\ 0 & FPS = 0 \end{cases} \qquad where \qquad (6)$$

$$k = [(1-FPS)/FPS]^{(1/3)} \times 2.301$$

Results obtained and Discussion

For event $i_1 =$ Revenge and applying equation (2), and applying the $\alpha - cut$ of different membership function, we have

$$N_1 = w_1B_{1,1} + w_2B_{1,2} + w_3B_{1,3} + w_4B_{1,4} + w_5B_{1,5} + w_6B_{1,6} + w_7B_{1,7} + w_8B_{1,8} + w_9B_{1,9} + w_{10}B_{1,10}$$

$$N_1 = \max\left(w_4 \cdot f_{SA}(x) \wedge (w_2 + w_3 + w_5 + w_6 + w_8 + w_{10}) \cdot f_A(x) \wedge (w_1 + w_7 + w_9) \cdot f_D(x)\right)$$

$$N_1 = [0.5176341 - 0.0862723\,\alpha,\ \ 0.08627235\,\alpha + 0.3450894\,] \qquad (7)$$

The corresponding membership function of the fuzzy number N_1 is gotten from equation (7) to give

$$\mu_{N_1}(x) = \begin{cases} \dfrac{0.5176341 - x}{0.08627235} & 0.4313617 < x \le 0.5176341 \\ 1 & 0.4278084 < x \le 0.4313617 \\ \dfrac{x - 0.3450894}{0.08627235} & 0.3450849 < x \le 0.4278084 \\ 0 & otherwise \end{cases} \qquad (8)$$

Converting the fuzzy ,

Converting the Fuzzy number using the left and right utility score of fuzzy number is calculated as

$$\mu_{L1}(x) = \sup_x\left[\mu_{N_1}(x) \wedge f_{\min}(x)\right] = 0.5279\ and\ \mu_{R1}(x) = \sup_x \mu_{N_1}(x) \wedge f_{\max}(x) = 0.37767$$

Hence, the fuzzy possibility score of the fuzzy number N_1 is calculated as

$$FPS_{N1} = \mu_T(N_1) = [\mu_R(N_1) + 1 - \mu_L(N_1)]\big/2 = 0.424885$$

The *Fuzzy Failure probability* FFP_{N1} according to equation is given by

$$FFP_{N1} = \begin{cases} \dfrac{1}{10^{k}} & FPS \neq 0 \\ 0 & FPS = 0 \end{cases} \quad \textit{where}$$

$$k = \left[(1 - 0.424885)/0.424885\right]^{(1/3)} \times 2.301$$

$$\Rightarrow FFP_{N1} = \frac{1}{10^{2.54533}} = 2.8489 \times 10^{-3}$$

A Fuzzy probability score of 2.8489 X 10^{-3} for the event revenge implies that the probability of revenge being the cause of pipeline failure as a result of third party activity is 2.84894 X 10^{-3} . Similar failure probability for all the twelve identified events responsible for transmission pipeline failures are computed and shown in Table 3.

Table 4: Fuzzy Failure Probability for identified third party activities

Basic Events,i	Classification	Fuzzy Failure Probability
1	Revenge	0.0028490
2	Poverty	0.0142000
3	Fishing	0.0448750
4	Government Neglect	0.1698200
5	Get Rich Quick	0.0096940
9 6	Farming Activities	0.1138200
7	Militancy	0.0581430
8	Population Explosion	0.0054450
9	Aging Pipelines	0.0566200
10	Company's Operation	0.0032970
11	Sabotage	0.0089722
12	Poor Engineering Construction	0.0097220

Conclusions

We have applied the concept of fuzzy set theory to determine the failure probability of transmission pipelines in the Niger Delta region in Nigeria occasioned by third party activities. This would enhance the development of a Probabilistic Risk Assessment process for Oil and Gas Transmission Pipelines and greatly assist in the development of Risk Assessment model.

Reference

[1] Ariavie G.O, Ovuworie G.C and Ariavie S.S (2010) “On Expert Elicitation Method in the Determination of Transmission Pipeline Failure occasioned by Third Party Activities in the Niger Delta region of Nigeria”. Proceedings of the International Conference on Engineering Research and Development (ICER&D 2010) held at the University of Benin, Nigeria. 7th – 9th September, 2010.

[2] Ariavie G.O (2010) “A Fuzzy Risk Analysis of Pipeline Failures: The Case of Third Party Activities in the Niger Delta Region”. A PhD Thesis submitted to the School of Postgraduate School, University of Benin, Benin City.

[3] Clemens R. T and Winkler R.L (1985) “Limits for the precision and value of information from dependence sources”. Operation Research, 33, 427 – 442.

[4] Chen L and Hwang C.L (1995). “Fuzzy multiple attribute decision-making methods and applications”. Springer, Berlin, pp 138 – 150

[5] Hora S.C (2004) “Probability Judgements for Continous Quanties: Linear Combinations and Calibration”. Management Science, 50, 597 – 604.

[6] Misra K.B and Weber G.G (1990). “Use of Fuzzy set theory for level 1 studies in Probabilistic Risk Assessment”. Fuzzy Sets and Systems 37, pp 139 – 160.

[7] Onisawa T (1988) “An Approach to Human Reliability in man-machine systems using error possibility”. Fuzzy Sets and Systems 27, pp 87- 103.

[8] Suresh P.V, Babar A.K and Raj V.V (1996) “Uncertainty in a Fault Tree Analysis: A Fuzzy Approach”. Fuzzy Sets and Systems 83, pp 135- 141.

[9] Yuhua D and Datao Y (2005). “Estimation of Failure Probability of Oil and Gas Transmission Pipelines by Fuzzy Fault Tree Analysis’ Journal of Loss Prevention in the Process Industries. Vol. 18, pp 83 - 88