JASEM ISSN 1119-8362

Full-text Available Online at
www.ajol.info and
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J. Appl. Sci. Environ. Manage. *March,* 2012
Vol. 16 (1) 95 - 101

Delphi Fuzzy Elicitation Technique in the Determination of Third Party Failure Probability of Onshore Transmission Pipeline in the Niger Delta region of Nigeria

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ABSTRACT: The Delphi technique via the expert elicitation method becomes extremely handy particularly in view of limited availability of data in determining failure probabilities of onshore transmission pipelines in the Niger Delta region of Nigeria occasioned by third party activity. Using, ten (10) experts opinion elucidated individually via email questionnaires and summarizing their responses in linguistic languages expression that were converted into failure probabilities for twelve (12) identified third part activities in the Niger Delta region of Nigeria using Fuzzy Set Theory tools. The results show that the neglect by government has the highest probability of failure of 0.1698200. @JASEM

Keywords: Delphi technique, onshore transmission pipeline, Fuzzy set theory, third party activities,

The Delphi Fuzzy method proposed by Chang *et al* (2000) is an iterative process to collect and distill the anonymous judgments of experts. It is also is in essence a series of sequential questionnaires or 'rounds', interspersed by controlled feedback, that seek to gain the most reliable consensus of opinion of a group of experts (Linstone and Turoff, 1975).The Delphi process ensures confidentiality, geographical dispersion, exchange and information solicitation via emails, (Dalkey,1972) avoiding downsides associated with group dynamics such as manipulation or coercion to conform or adopt a certain viewpoint can be minimized (Helmer and Rescher, 1959, Hsu and Sandford, 2007).

The Delphi technique, mainly developed by Dalkey and Helmer in 1963 at the Rand Corporation in the 1950s, is a widely accepted method for achieving convergence of opinion concerning real-world knowledge solicited from experts within certain topic areas and is designed as a group communication process that aims at conducting detailed examinations and discussions of a specific issue for the purpose of goal setting, policy investigation, or predicting the occurrence of future events (Ulschak, 1983; Turoff and Hiltz, 1996; Ludwig, 1997). Common surveys try to identify "what is," whereas the Delphi technique attempts to address "what could/should be" (Miller, 2006).

Expert elicitation, being a method for carrying out the Delphi's technique, refers to a systematic approach to synthesize subjective judgments of experts on a subject where there is uncertainty due to insufficient data, when such data is unattainable because of physical constraints or lack of resources (Slottje et al, 2008). According to Hart, 1986 and Walton, 1997, an expert is effective, efficient, credible, reliable and aware of his limitations. Furthermore, an expert is experience in the area of discourse whose opinion is based on sound opinion the domain of the question at hand? Feltovitch *et al*. 2006, provides further generalizations i.e Experts organize knowledge effectively, have superior recall of information and have improved abilities to abstract knowledge to new situations, compared to lay people. They perform the basic operations of their discipline efficiently, and are able to think critically about data and methods in their domain. Usually, attaining expertise requires both study and practical experience (Wiegmann, 2005). In Slottjj et al, 2008, the six building blocks of carrying the elicitation process to involve the screening and re-screening of uncertainties, the selection of experts, gathering and disseminate basic key information to experts, qualitative and/or quantitative expert elicitation session(s) and reporting and communicate the results

MATERIALS AND METHODS

In this study, the expert *a priori* status asserted and evaluated based on the professional characteristics and track record of the person, the qualifications, experience, publications and professional standing are relevant. (Wiegmann, 2005). We ensured potential problems such as bias, cognitive, overestimation of single-event probabilities, conservatism, optimism and fallacies of causal and diagnostic reasoning. (Fenton, 1998). Individually-focused (as opposed to group) elicitation of expert judgment has been widely used in applied Bayesian decision analysis and areas of environmental policy (Morgan *et al.*, 1978a; Morgan *et al.*, 1978b; Morgan *et al.*, 1984; Morgan *et al.*, 1985; Morgan and Keith, 1995; Budnitz *et al.*,1995; Budnitz *et al.*, 1998; Morgan *et al.*, 2001; Garthwaite *et al.,* 2005; Morgan *et al.*, 2006). A panel size of 10 was selected because of the scope of the problem and resources available (Delbecq et al. 1975, Fink et al. 1991, Hasson et al.

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2000) even though between 10 to 1685 is allowed (Powel, 2003).

Three rounds of questionnaires were sent to a preselected expert panel viz: first round of pilot testing of questionnaires is sent to help to identify ambiguities and improve the feasibility of administration, with the second and third round rounds being more specific, with the questionnaires seeking quantification of earlier findings, usually through rating or ranking techniques. Feedbacks from previous rounds tend to help convergence to a consensus of opinion (Jairath and Weinstein 1994).

Expert selection: In selecting experts to participate in an expert elicitation, representatives from across all the relevant disciplines and schools of thought, which process is fundamentally different from that of drawing a random sample to estimate some underlying true value. In the case of expert elicitation, it is entirely possible that one expert, perhaps even one whose views are an outliner, may be correctly reflecting the underlying physical reality, and all the others may be wrong. For this same reason, when different experts hold different views it is often best not to combine the results before using them in analysis, but rather to explore the implications of each expert's views so that decision makers have a clear understanding of whether and how much the differences matter in the context of the overall decision (Morgan and Henrion, 1990).

Ten experts, seven engineers, two academic pipeline researchers and one industrial pipeline researcher were chosen to evaluate reasons for pipeline vandalization by twelve (i_1 to i_{12}) third party identified activities based on experience and knowledge about pipelines. The identified events for this study are 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 Poor and i_{12} =Engineering Constructions. They were to respond in linguistic terms of Strongly Disagree (SD), Disagree (D), Don't Know (DN), Agree (A) and Strongly Agree (SA) to whether the identify third party activity are responsible for pipeline failures (Table 1). The experts were labeled J1 to J10.

Table 1: Response from 10 experts on 12 identified third party activities using

Classification	Revenge	Poverty	Fishing	Government Neglect	Get quickly rich	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

Legend: **SA**-Strongly Agree **A**- Agree **DN**-I don't know **D**- Disagree. **SD**-Strongly Disagree

RESULT AND DISCUSSION

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 $\sum_i \omega_i = 1$. Experts that are viewed 'better' than others, the 'better' expert is given a greater weight. Experts' were mailed the questionnaire with the advisory table (Table 2) via surveymonkey.com, an online tool for collecting and analyzing responses from individual experts via emails. Surveymonkey also assist to randomized/sort answers which eliminates bias (a good factor that makes it suitable for the Delphi technique). Once completed, a surveymonkey result is analyzed on time real-time with the responses viewed and reports generated. Generated results can be shared with others without access to the sender account details.

Table 2: Advisory table for Experts

Title of Expert	Assigned Title Score	Service years of Expert	Assigned Service Score	Educational Level	Assigned Educational Level Score	Age bracket of Expert	Assigned Age Score
Academic Researcher	6	less than 5 years	1	Ph.D	7	10 - 18 years	1
Industrial Researcher	5	between 5 and 10 years	2	Master degree	6	19 - 27 years	2
Scientist	4	between 10 and 15 years	3	Bachelors degree	5	28 - 36 years	3
Engineer	3	between 15 and 20 years	4	Higher national diploma	4	37 - 45 years	4
Technologist	2	above 20 years	5	Ordinary diploma	3	Above 46 years	5
Pipeline Operator	1			Senior secondary school certificate	2		
				Technical college	1		

Weighted score, w_c= Assigned title score + Assigned service score + Assigned educational score + Assigned age score………………………………. (1)

For expert J1, weighted score, w_{c1}=18 (an engineer who is over 46 years with a service history of over 20 years) while for expert J2, weighted score, w_{c2},=1 2 (an engineer whose age bracket is between 28 – 36 years with a service history of less than 5 years). Similarly, calculations for weighting score for expert 3 to expert 10 would give the result shown in Table 3. The weighting factor is hereafter calculated for individual expert as a ratio of the weighting score of the expert to the sum of the weighting score for all the experts.

Table 3: Weight 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
J10	ENGINEER	3	<5	1	MSC	6	37 - 45	4	14	0.09150327

These opinion which are expressed in linguistic terms is converted to fuzzy numbers by Chen et al.'s Left and Right Scores (1989). Generally, this conversion is viewed as a searching method for the fuzzy mean value in a fuzzy set as the fuzzy mean value does not necessary have to be the value that obtains the highest membership grade. In order to determine the crisp score, Hwang et al. (1992) compares the fuzzy sets with a maximizing fuzzy set (fuzzy max) and a minimizing fuzzy set (fuzzy min) and defined as:

$$\mu_{\max}(x) = \begin{cases} x, 0 \le x \le 1 \\ 0, \ otherwise \end{cases} \quad and \quad \mu_{\min}(x) = \begin{cases} 1-x, 0 \le x \le 1 \\ 0, \ otherwise \end{cases} \tag{2}$$

The right and left scores refers to the intersection of the fuzzy logic set M with the fuzzy max. and the intersection of the fuzzy logic set M with the fuzzy min respectively given by

$$\mu_R(M) = \sup_x [\mu_M(x) \wedge \mu_{\max}(x)] \ and \ \ \mu_L(M) = \sup_x [\mu_M(x) \wedge \mu_{\min}(x)] \tag{3}$$

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 (4).

$$N_i = \sum w_j B_{ij}, \qquad j = 1,3,\ldots,n \tag{4}$$

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*

For a scenario of twelve basic events with ten experts' linguistic expression and applying equation 4 and applying the various membership function as depicted in figure 2, the generated combined fuzzy number would given as follows:

$$N_1 = \max\left(w_4 \cdot f_{SA}(x) \wedge (w_2 + w_3 + w_5 + w_6 + w_8 + w_{10}) \cdot f_A(x) \wedge (w_1 + w_7 + w_9) \cdot f_D(x)\right)$$
$$N_2 = \max\left((w_2 + w_3 + w_6 + w_8 + w_9 + w_{10}) \cdot f_{SA}(x) \wedge (w_4 + w_5 + w_7) \cdot f_A(x) \wedge w_1 \cdot f_D(x)\right)$$
$$N_3 = \max\left((w_9 + w_{10}) \cdot f_{SA}(x) \wedge w_1 \cdot f_A(x) \wedge (w_3 + w_4 + w_5 + w_6 + w_7) \cdot f_D(x) \wedge (w_2 + w_8) \cdot f_{SD}(x)\right).$$
$$N_4 = \max\left((w_1 + w_2 + w_4 + w_5 + w_6 + w_7 + w_8 + w_9 + w_{10}) \cdot f_{SA}(x) \wedge w_3 \cdot f_A(x)\right)$$
$$N_5 = \max\left((w_1 + w_2 + w_3 + w_4 + w_6 + w_7 + w_8 + w_9 + w_{10}) \cdot f_{SA}(x) \wedge w_5 \cdot f_A(x)\right)$$
$$N_6 = \max\left(w_9 \cdot f_{SA}(x) \wedge w_4 \cdot f_A(x) \wedge (w_1 + w_5 + w_6 + w_7 + w_{10}) \cdot f_D \wedge (w_2 + w_3 + w_8) \cdot f_{SD}(x)\right)$$
$$N_7 = \max\left((w_1 + w_5 + w_8 + w_9 + w_{10}) \cdot f_{SA}(x) \wedge (w_4 + w_6 + w_7) \cdot f_A(x) \wedge (w_2 + w_3) \cdot f_{SD}(x)\right)$$
$$N_8 = \max\left((w_2 + w_3) \cdot f_A(x) \wedge (w_1 + w_4 + w_5 + w_6 + w_7 + w_9 + w_{10}) \cdot f_D(x) \wedge w_8 \cdot f_{SD}(x)\right)$$
$$N_9 = \max\left((w_9 + w_{10}) \cdot f_{SA}(x) \wedge (w_2 + w_3) \cdot f_A(x) \wedge (w_1 + w_4 + w_5 + w_6 + w_7) \cdot f_D(x) \wedge w_8 \cdot f_{SD}(x)\right)$$
$$N_{10} = \max\left((w_2 + w_4 + w_{10}) \cdot f_{SA}(x) \wedge (w_3 + w_5 + w_7 + w_8 + w_9) \cdot f_A(x) \wedge (w_1 + w_6) \cdot f_D(x)\right)$$
$$N_{11} = \max\left((w_1 + w_2 + w_3 + w_8 + w_9) \cdot f_{SA}(x) \wedge (w_4 + w_5 + w_6 + w_7 + w_{10}) \cdot f_A(x)\right)$$
$$N_{12} = \max\left(w_8 \cdot f_A(x) \wedge (w_1 + w_4 + w_5 + w_6 + w_9 + w_{10}) \cdot f_D(x) \wedge (w_2 + w_3 + w_7) \cdot f_{SD}(x)\right)$$

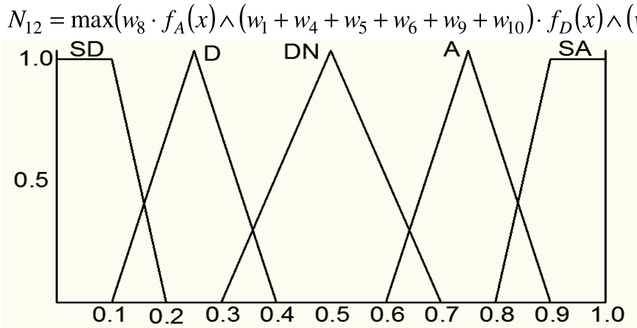

Fig 1: Schematics of scale function using a combination of both trapezoidal and triangular membership functions

The corresponding membership function of the fuzzy number N_1 to N_{12} is modeled according to figure 1 (see Ariavie et al 2010 and Ariavie 2010) is given by

$$f_{SA}(x) = \begin{cases} 0 & , \quad x < 0.8 \\ \dfrac{x-0.8}{0.1} & , \quad 0.8 < x \le 0.9 \\ 1 & , \quad 0.9 < x < 1 \end{cases} \qquad (5)$$

$$f_A(x) = \begin{cases} \dfrac{x-0.6}{0.15} & , \quad 0.6 < x \le 0.75 \\ \dfrac{0.9-x}{0.15} & , \quad 0.75 < x \le 0.9 \\ 0 & , \quad otherwise \end{cases} \qquad (6)$$

$$f_{DN}(x) = \begin{cases} \dfrac{x-0.3}{0.2} & , \quad 0.3 < x \le 0.5 \\ \dfrac{0.7-x}{0.2} & , \quad 0.5 < x \le 0.7 \\ 0 & , \quad otherwise \end{cases} \qquad (7)$$

$$f_D(x) = \begin{cases} \dfrac{x-0.1}{0.15} & , \quad 0.1 < x \le 0.25 \\ \dfrac{0.4-x}{0.2} & , \quad 0.25 < x \le 0.4 \\ 0 & , \quad otherwise \end{cases} \qquad (8)$$

$$f_{SD}(x) = \begin{cases} 0 & , \quad x \le 0.2 \\ \dfrac{0.2-x}{0.1} & , \quad 0.1 < x < 0.2 \\ 1 & , \quad otherwise \end{cases} \qquad (9)$$

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

$$FPS == \mu_T(N)[\mu_R(N)+1-\mu_L(N)]/2 \qquad (Yuhua\ and\ Datao\ (2005)\ and\ Lei\ (2005)) \qquad (10)$$

Also, the fuzzy failure probability, as defined by Onisawa, (1990), is given as

$$FFP = \begin{cases} \dfrac{1}{10^k} & FPS \ne 0 \\ 0 & FPS = 0 \end{cases} \qquad (11), \quad where \quad k = [(1-FPS)/FPS]^{(1/3)} \times 2.301$$

Solving equations 1 through 11 would give the fuzzy probability for the twelve identified events as (Ariavie, 2010, Ariavie et al, 2010 and Ariavie et al, 20110) indicated in table 4.

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
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

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