

RESEARCH ARTICLE

Development of Adaptive Neuro-Fuzzy Inference System for Assessing Industry Leadership in Accident Situations

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ABSTRACT Petroleum activity is characterized as a high-risk activity due to the probability of accidents with material and human losses. The leaders of this segment assume, besides the complex routine tasks, the challenge of making assertive decisions during an accident. This study aims to present an evaluation model of the Industry Leadership Index for Emergencies Situations (*ILIE*), using the Adaptive Neuro-Fuzzy System (ANFIS). The model was composed of 4 input variables, namely: knowledge, behavior, skill, and attitude; and one output variable, Industry Leadership. The data collection took place in petroleum production units in Brazil, with a sample of 151 respondents through the application of a survey. The observed data were treated in an Excel tabulator and used in the development of the ANFIS model. From this model, it was possible to carry out simulations to predict the impact, which the increase or decrease in the value of each input variable can influence the leader's profile. The model performed satisfactorily in the Root of the Mean Square Error (RMSE) analysis, being 0.199 in data training and 1.217 in data verification. The results suggest that the ANFIS method can be successfully applied to establish a model to analyze industry leaders prepared for assertive responses in crisis scenarios.

INDEX TERMS Leadership, industry, evaluation, emergency, ANFIS.

NOMENCLATURE

ANFIS	Adaptive Neuro-Fuzzy Inference System.
RMSE	Root of the Mean Square Error.
MF	Member Function.
CRM	Crew Resource Management.
GLOBE	Global Leadership and Organizational Behavior.
CEO	Chief Executive Officer.
N	Population size.
n	Sample size.
Z_{α}^2	Degree of confidence in the standard deviation.
p	Probability of success / expected proportional.

q	Probability of failure.
UFBA	Federal University of Bahia.
EF	Executive Function.
WV	Weighted Value.
V_i	Value assigned to each parameter.
V_{max}	Maximal value reached for each parameter.
W_i	Weight assigned to each parameter.
PETROBRAS	Brazilian Petroleum Anonymous Society.
IL	Leadership Index.
X, Y	Input Variables.
F	Output Variable.
$A1,2, B1,2$	Linguistic Variables.
(Π)	Node.
$WI,2$	Impact of Rules.
$WI,2$	Normalization output values.

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- F1,2* Degree of activation of the consequent.
d Maximum Error Allowed.
FIS Fuzzy Inference System.

I. INTRODUCTION

Many researchers have used ANFIS for solving many kinds of engineering problems. In [1], it was developed an hybrid model combining ANFIS and PSO for the estimation of cetane numbers of biodiesel and diesel oils. The novelty of this study was the development of novel correlations and smart models with high accuracies. ANFIS was also used for modelling tobacco seed oil methyl ester production from underutilized tobacco seeds in the tropics. It was made a comparison between the results obtained by ANN and ANFIS [2]. Forecasting issues were also succeed developed using ANFIS, such are the cases of forecasting oil production [3], and wind power forecasting [4]

The quality of an organization's safety climate impacts positively or negatively on task performance. Safety culture has a high influence on safe postures in the employees' performance so that accidents are avoided. When exposed to an emergency, leaders are expected to act with technical, cognitive-behavioral skills, and safety standards established by the organization [5], [6], [7], [8].

The petroleum industry carries out risky operations due to the nature of the processes and this can result in accidents. In industrial scenarios, where there are highly complex procedures, the leadership in facing the crisis guides and performs decisive actions to contain or eliminate the event. For the development of the model proposed in this research, the attributes or variables Knowledge, Behavior, Skill, and Attitude and respective indicators were used, which constitute each variable, considered essential in decision-making in emergencies [9], [10], [11].

The response capacity both from the leader and from his/her team in a crisis scenario requires, in addition to technological safety resources, properly planned barriers, technical knowledge, and cognitive-behavioral processing. In addition, spaces for discussion during the planning of the facilities, simulations in training, and essential compositions in the formation of leaders of highly complex industries [12], [13].

The topic of leadership is approached in a multidisciplinary way, in studies of knowledge and behavior from traits and profiles. Studies are conducted to improve safety actions, focusing on risk analysis, preventive maintenance, identification of occupational accidents, environmental sustainability, precautions, and instructions for emergencies [12], [14]. The emission of reports and observatory data serve as lessons learned for industries, staff, and anyone else interested in industrial safety. The Piper Alpha, Texas City accidents are examples of procedures with non-assertive answers, as well as content to explore manners that should not be used and those which could be used in cases of serious accidents, such as the two recently cited [10], [15].

This research presents a model for evaluating the Industry Leadership Index for Emergencies using the Adaptive Neuro-Fuzzy System (ANFIS) [1]. The model presents four input variables: Knowledge (*K*), Skill (*S*), Behavior (*B*), and Attitude (*A*), as well as an output variable, the Industry Leadership Index for Emergencies (*ILIE*). The data were collected using a Likert scale survey applied to managers, supervisors, and engineers who work in the operational area. The paper is organized into six sections. Section 1 presents the research, the context, and the objectives. Section 2 discusses the literature review. Part 3 highlights the model development process, the variables evaluated, and the measurement tools. Section 4 describes the materials and methods. Section 5 presents results and discussions. And section 6 describes the conclusions, research contributions, and future work.

II. THEORETICAL FRAMEWORK

A. INDUSTRY LEADERSHIP

There is a specific leadership for each organization or situation, whether formal or informal, based on factors such as knowledge, techniques, and behaviors. These characteristics help in the engagement, motivation, and cooperation of his/her followers, besides the performances according to individual and group skills, and experiences [8], [14], [16].

The accidents at the Three Mile Island nuclear power plant and the Piper Alpha Oil Platform in 1979 and 1988, respectively, led the scientific community to discuss new concepts about process safety in the industry, from procedures arising from human factors, which interfere in the responses of leaders in a crisis. These events caused fatalities and economic losses, and the lessons learned were not enough to prevent accidents from recurring. It can be observed that failures persist, and in this context, leadership is an approach little discussed when it comes to industry leaders. Leading teams in highly complex spaces, such as the petroleum industry, requires deepening attributes and indicators that can assess industry leadership for emergencies [17].

In an industrial environment, personal and group characteristics impact decision-making in serious situations, among these characteristics there are commitment, cooperation, competence, and communication. Regarding leadership style, other characteristics are highlighted, and they are: practical knowledge, control, interpersonal relationship, inclusion, humbleness, determination, experience, technique, safe behavior, and emotional intelligence [18], [19], [20].

There are principles to be met to attribute to the leader, the effectiveness in the activities developed in the process industry to maintain a safe environment. Communication, the skill to make decisions, responsibility and self-recognition, simplicity, and humbleness are indicators of attributes of leadership prepared to face an unexpected event that can lead to victims and property damage. These are also important attributes for the expansion of the safety culture [21], [22], [23], [24].

B. LEADERSHIP EVALUATION

The studies on leadership evaluation pointed out the 360° method as one of the most used tools to evaluate leadership and for the investigations of measurement methods for leader development. It was observed that although evaluations that measure leader increment are carried out, these are not yet specific and validated by science. Because they are designed and applied empirically, they do not always achieve the expected objectives. This is also the understanding of researchers [25], [26]

The leadership evaluation of the Level 5 Leader, a theory by Collins and Change [27], an expert in leadership, considers two attributes as the most important, humbleness, and determination, a “fierce” will for assertive answers. Collins, after evaluating through interviews, 11 CEO leaders considered high competence, concluded that leaders considered Level 5 present these two attributes (Humbleness and Determination) in prominence, qualities that directly impact the performance of an industry leader, as pointed out in the observed data [28], [29], [30], [31].

Research has been conducted in the search for a successful profile for leadership and characteristics are pointed out for some leaders specifically. In the military structure, a leader who presents attributes such as courage, the ability to make decisions, expresses confidence and resistance in adversities, enthusiasm for what he/she does, the initiative for assertive responses, and competence in the activities performed by technical and practical knowledge [32], [33], [34].

High-risk segments adopt CRM (Crew Resource Management), such as healthcare, military, and maritime. CRM training, mandatory in the aviation industry, is presented as a piece of remarkable background knowledge to meet the gaps in emergencies. However, the petroleum industries do not adopt this training, although they indicate the importance of human factors in event occurrences. Human errors are treated as responsible for accidents, in the face of inadequate decisions made by leadership in an accident. Knowledge, non-technical skills, attitudes, behavior, cognitive processes, communication, and interpersonal relationships are part of the CRM method content [35], [36], [37]

A study presents the GLOBE (Global Leadership and Organizational Behavior), a research program on social, organizational, leadership culture and effectiveness for business executives. This project is conducted in 62 countries, to present concepts, develop, test, and validate theories that point to the integrated relationship between culture and social-organizational effectiveness, and the attributes for an effective CEO (Chief Executive Officers) leadership. The GLOBE is composed of 112 behavioral attributes, among them modesty, decisiveness, autonomy, and confidence. In this research, 21 characteristics of those that make up the GLOBE were used to evaluate and indicate leadership styles in militarism as well. In light of this exposure, it is important to discuss, in addition to the characteristics, the culture, the relationships, and both the leaders’ behaviors and the led’s. In GLOBE, the evaluation of the degree of confidence,

decision-making power, and innovation are elements inserted in the case study of the consultation with experts and leaders in this paper [38], [39], [40]

The methods for leadership evaluation have a self-assessment format with the application of surveys. These discussions restrict the activities in an environment of sectorial accidents, as well as behaviors and procedures that ensure the leader’s competence to act in these circumstances. The literature consulted contributed to the identification of the variables and indicators used for the development of the model specifying the leader’s activity area and how to respond to emergencies.

C. VARIABLES AND INDICATORS FOR THE ANALYSIS OF THE INDUSTRY LEADERSHIP INDEX FOR EMERGENCIES SITUATIONS

1) KNOWLEDGE

Knowledge is a set of information and beliefs that can generate various interpretations, according to what is intended to be related. Opportunities to learn about organizations and technologies, to avoid small failures and disasters when it comes to risks and accidents. Knowledge adds value to the individual when there is a direct relationship between the cognitive world and the real world, “knowing” and “understanding”, related to cognitive processing [41].

Theoretical knowledge is part of learning concepts, principles, and fundamentals, to identify characteristics and rules according to what they represent for learning, with specialized information and content. Procedural knowledge is defined as that which corresponds to the exercise of the activity and its specificity, a set of techniques, strategies, and methods of performing the task [42], [43].

When the impact of a threat occurs during routine activities, knowledge is not always isolated, leading to the best decision and response to the event. There is a high probability of initiating high-impact, low-visibility failures during the progressive stress stage in an accident occurrence. Cognitive functions are altered: memory, attention, logical reasoning, perception, and decision, that is why they react with the inclusion of auxiliary memory through notes, documents, mind maps, and safety systems, to achieve successful decisions [13], [44].

The indicators were identified and subjected to analysis as to the degree of importance for an industry sector leader in an emergency, according to the presentation in Table 1.

2) BEHAVIOR

It is possible to demonstrate and act with determination and emotional control to achieve safe behavior. One of the pillars of leadership is confidence, the values, and beliefs that inspire conscious actions in environments vulnerable to accidents [48].

Inappropriate behaviors can be mapped by the leader’s psychological factors and the group’s. It is observed that the unconscious arises without warning, and preventive measures

TABLE 1. Indicators for the variable knowledge.

Variable	Indicators	References
Knowledge	TH	[6]
	IN	[7]
	LR	[8]
	EX	[45]
	RA	[46]
	SA	[33]
	SY	[18]
	TR	[46]
	SP	[47]
PR	[12]	

Meaning: K-Knowledge; TH-Technique; IN-Intelligence; LR-Logical Reasoning; EX-Experience; RA-Rationality; SA-Safe; S-Systematics; TR-Transformation; SP-Specialty (Expertise); PR-Practice. Source: research data.

cannot be triggered. When leadership has unique hazard control functions, the causes and possibilities for assertive actions generate positive effects in case of failure. It is necessary that the Executive Function (EF), which represents a set of defined and structured procedures with resources that impact the performance on the task, efficiently and aligned to the actions directed to each situation to predict the expected response [49]

Although indicators such as sympathy, sense of humor, and empathy are part of studies on leadership characteristics, they are applied to segments in the educational area, health, and business environment, due to the need for behaviors that impact the response to a specific scenario of the areas that involve segments such as health, marketing, and business. In a crisis, these attributes do not stand out in the same format but are representative of the leader’s performance in routine activities. The indicators of the Behavior variable have a direct effect on the response to an emergency. However, this approach to human factors in the dynamics of the industry is still little discussed. This variable is considered essential in all speeches related to safety [41], [50]. Table 2 presents the indicators.

3) SKILL

In the study about safe behavior, the development of skills and knowledge that are non-technical, but only contribute to situations that depend on specific actions to conduct decisions, management, control, and command of the team in a stressful environment, are part of CRM (Crew Resource Management)

In this context, the importance of perception and recognition of events comes through cognitive skills. The CRM program seeks social skills: cooperation, interpersonal relationship, commitment, and recognition [35].

Activities performed at the same time require auxiliary memory, auxiliary processing, and signaling to activate attention at critical moments. These procedures are part of a skill

TABLE 2. Indicators for the variable behavior.

Variable	Indicators	References
Behavior	HS	[51]
	EC	[19]
	AC	[52]
	DE	[15]
	ST	[53]
	EM	[54]
	SY	[55]
	SE	[56]
	VI	[27]
	HU	[20]
	RE	[22]
	PA	[57]
	SI	[58]
DT	[59]	

Meaning: HS-Humor sense; EC-Emotional control; AC-Aggressive challenges; DE-Demanding; ST-Strict; EM-Empathy; SY-Sympathy; SE-Steadfast; VI-Vibrant; HU-Humbleness; RE-Reliable; PA-Patronizing; SI-Simple; DT-Determine. Source: research data.

set. In an uncertain event, risk perception, creativity, and resilience are part of this construct.

Enabled people keep track of their activities step by step, with steps memorized and repeated to accomplish the tasks. An individual may be able to manage a crisis, with the development of a mind map. It is important not to rely on automation, because of the unconscious forgetfulness that can be part of a high-stress environment

Skill is not a substitute for the rule, they are complementary attributes that allow the action to be performed, with the ability to formulate the rules that are validated with the consensus of pairs. Those who routinely experience the same practical situations and adopt automatic behaviors, even repeating the work rituals, cannot always be considered safe. Knowledge, skill, and intuitive learning for high-stress situations must come together to structure leadership suitable for quick and assertive decisions in industry emergencies [23].

The leader mobilizes, aggregates, and encourages. If these skill indicators, as well as creativity and organization, democratize learning for impactful execution, in managing an emergency in the industry. Assertive behaviors and responses influence driving stress control and cognitive memory activation [42], [60].

Table 3 presents the variety of indicators that are associated with the variable Skill. The fields of education, health, politics, business, psychology, and administration discuss the impact of this attribute, and correlations with other variables are discussed in this paper.

4) ATTITUDE

The mental disposition related to the specific situation, and the subject, comparing scenarios with customized reactions, can be one of the definitions of attitude. According to

TABLE 3. Indicators of the variable skill.

Variable	Indicator	References
Skill	MO	[24]
	CR	[23]
	CA	[61]
	EN	[62]
	AR	[63]
	OR	[15]
	IN	[64]
	LI	[65]
	PE	[66]
	RE	[29]

Meaning: Mobilization-MO; Creativity-CR; Dynamics-DY; Catalysis-CA; Encourage-EN; Articulation-AR; Organized-OR; Insight-IN; Listening-LI; Peace-making-PE; Resilience-RE. Source: research data.

researchers, when faced with a situation that requires a decision and no contest, attitude is a choice. This requires a sense of balance so that the choice leads to the desired response. For this, it is necessary to be a participative agent [9].

The outcome is a consequence of this choice, and the tendency is the presence of an action conditioned to cognitive processing. Tolerance and emotion go hand in hand with aspects related to command, courage, and positioning in the face of adversity that involves risks and contingency in emergencies [67].

These characteristics differ from personal constructs, which identify situational responses rather than natural preferences or characteristics. The chosen attitudes can happen from different influences, which depend on the scenario. Leadership in a psychological construct has cognitive and emotional functioning and requires mastery of strategies and decision-making power to perform successfully in emergency environments. A leader needs to involve people in the routine and mobilize them in times of uncertainty [41], [68], [69], [70]. Table 4 presents the variable Attitude and indicators.

TABLE 4. Indicators of the variable attitude.

Variable	Indicator	References
Attitude	PA	[71]
	SO	[12]
	EM	[30]
	CS	[72]
	TO	[31]
	CM	[73]
	CR	[37]
	PO	[74]
	ED	[60]

Meaning: Participation-PA; Sociability-SO; Emotion-EM; Conservation-CS; Tolerance-TO; Command-CM; Courage-CR; Positioning-PO; Education-ED. Source: research data.

D. ANFIS - ADAPTATIVE NEURO FUZZY SYSTEM

The application of computational intelligence-based tools has proven efficient in Engineering, Health Sciences, and Humanities, in studies that aim to evaluate subjective dynamics as well. Neuro-diffuse systems can be used to recognize patterns, functions, predictions, and control [75], [76]

The ANFIS is an intelligent system with the learning capability of neural network architecture. Thus, the ANFIS simultaneously processes linguistic variables and learns from the environment in which it is inserted.

It is an architecture that adjusts the parameters of a fuzzy set of inputs and outputs, and the observed data is used in the process of developing the System and brings together two types of modeling of fuzzy sets, based on the Takagi-Sugeno fuzzy inference system. This model was chosen because it interprets the system simpler [1], [77].

The Takagi-Sugeno fuzzy inference system uses a mapping system for each fuzzy IF-THEN rule output. This function maps the input and output of the rule from a combination of the inputs. The fuzzy rules from the SUGENO model do not use the fuzzy set, but rather a mathematical function from the inputs. The most common rules format is: IF x is A and Y is B , THEN z is k , where k is a constant. Thus, the output of each fuzzy rule is a constant, and the consequent member functions are represented by single points. During training, the rule parameters include both antecedent and consequent parameters and should have outputs with minimum error (RMSE) [1].

i) ANFIS Architecture

In the ANFIS architecture, the neural networks are composed of specific processing units and functions gathered in each of the 5 layers, as illustrated in Figure 1. The outputs of the previous layers serve as inputs to the next layer.

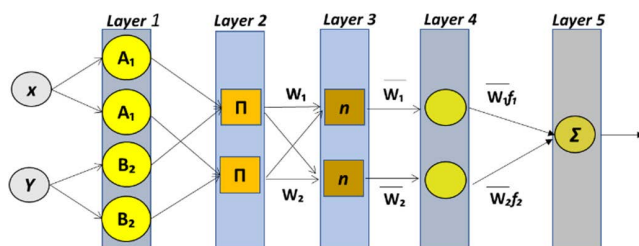


FIGURE 1. ANFIS Architecture. Source: Adapted from [3], [4].

The input of this model (Fig. 1) is composed of two variables (x and y) and an output variable (F). The first layer (1) represents the fuzzification stage, and each input node (\dot{I}) is ‘an adaptive node, i.e., the degree of adherence to the linguistic term, calculated based on the premise of each rule, represented in A_1, A_2, B_1 , and B_2 . In the second layer (2), each node (Π) represents a rule. At this step, the result is calculated which will determine the consequent degree of the rule that will be achieved. The impact of each rule is represented by W_1 and W_2 . In the third layer (3), the normalized value of the activation degree of each rule is calculated. Each node in this layer is identified with the letter N , and the normalized output

TABLE 5. Measurement likert - scale.

Measurement Scale									
Check Scale					Weight (degree of importance)				
(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Totally Inadequate	Inadequate	Medium	Adequate	Very adequate	Any	Little	Medium	Important	Very Important

values are represented by W_1 and W_2 . In the fourth layer (4), the output of each neuron is calculated by the normalized output from the previous layer (W_1 and W_2) and the activation degree of the consequent rule (F_1 and F_2). And the fifth layer (5) is formed by a single node represented by the symbol \sum . At this stage, the calculation of the overall sum from the output of the received signals takes place, to obtain the precise output of the System (F). The model answer is the weighted average derived from the rules. This is the representative scenario for each step of the development of the System [4].

The Neuro-fuzzy system (FIS) is applied to different non-linear relationship parameters and presents predictive results analyzed and compared to the conclusive data. The parameters are well defined considering the training and adjustments performed by the system. It is observed that hybrid systems, such as ANFIS, make use of fuzzy engineering and neural networks. This is one of the advantages of its use since it unites the positive aspects of FIS linguistic processing and the adaptation as well as learning of neural networks.

III. MATERIALS AND METHODS

For this study, three meetings were held with 12 specialists in industry safety (Manufacturing, Chemical, and Petrochemical industries) for the adequacy of the linguistic variables and their indicators. As well as the report on the experiences of these leaders contributed to understanding the discussions of authors about disasters in the industry, leadership procedures, human error, and other human factors that may interfere with emergency responses. The variables: Knowledge, Behavior, Skill, and Attitude, and the indicators correspond to the content of the survey applied in petroleum production units in Brazil, for data analysis through ANFIS.

A. VARIABLES AND INDICATORS FOR ANALYZING THE LEADERSHIP INDEX

The variables observed were 4: Knowledge (K); Behavior (B); Skill (S); and Attitude (A). The indicators for the evaluation of Knowledge were 10; for behavior, 14 indicators; for Skill, 11 indicators; and for Attitude, 10 indicators. Tables 1, 2, 3, and 4 present the variables and their indicators.

B. DEVELOPMENT OF THE DATA COLLECTION INSTRUMENT, DEFINITION OF THE SAMPLE SIZE, AND DATA COLLECTION

To measure the 4 variables from the survey, the Likert Scale was used to obtain quantitative data in evaluations of

subjective content. The instrument consists of a 5-point scale (1 to 5) and the degree of importance (1 to 5) of the explored phenomenon. Table 5 shows the measurement criteria used in this research [78].

The sample size was calculated based on Equation 1. The error probability formula, 0.05 for α , and 0.95 for p (success probability) [79]:

$$n = \frac{N \cdot Z_{\alpha}^2 \cdot p \cdot q}{d^2 (N - 1) + Z_{\alpha}^2 \cdot p \cdot q} \tag{1}$$

where:

n : population sample.

N : whole population.

Z_{α}^2 : confidence level of 95% (1.96 according to the Normal distribution table).

p : probability of success or expected proportion (in this case 50% = 0.5).

q : probability of failure (1- p , in this case 1 - 0.5 = 0.5).

d : maximum error allowed (0.03%).

The result was 89 respondents as a sufficient sample. However, 151 leaders on the shop floor participated in the survey in the positions of coordinators (29.19%), supervisors (85.54%), managers (16.1%), petroleum engineers (11.7%), and operators (10.7%). The profile is predominantly male, with 145 (96%) men, and 6 (4%) women. Among the respondents, 89% had high school, and 11% had postgraduation.

Twenty-three forms were applied on-site at one of the petroleum production units in the Northeast of Brazil.

After this test, 177 forms were sent by e-mail, distributed among 5 petroleum production units in Brazil, 160 of which were returned, and 9 blank surveys were excluded.

To verify the consistency of the survey as to its reliability, Cronbach's alpha coefficient was used, with a criterion of 0.7 to 0.9 for being considered adequate. This is one of the statistical procedures for measuring internal consistency, which refers to the degree to which the survey items are correlated with each other and with the research result.

C. DATA TREATMENT IN EXCEL TABULATOR

The data were processed in an Excel tabulator and separated into variables and their respective indicators, then added the weighted value (WV) of the answers corresponding to the degree of each indicator's importance.

Considering that, in the literature, no studies were found for the evaluation of industry leadership for emergencies, the evaluation criteria were based on a scale from 0 to 100% in the questionnaire applied in the case study, from the discussions

with specialists. The scale defined by the specialists considered unsatisfactory values below 59%, regular from 60% to 69%, and satisfactory above 69%.

The calculation of the industrial sector leadership index for an emergency is represented in Equation 2.

$$LI = \sum \left(\frac{WV}{WV_{max}} \right) \cdot 100\% \quad (2)$$

where:

LI: Leadership Index.

WV: Weighted Value.

WVmax: maximum Weighted Value.

D. ANFIS PROCEDURE

The model was developed in the Neuro-fuzzy Designer application, MATLAB software, in 4 steps: *Load data*, *Generate FIS*, *Train FIS*, and *Test FIS*. In this way, the system accuracy and the development of the codes generated in the MATLAB environment are evaluated [80].

1) LOAD DATA

In the first stage, values resulting from the treatment of the collected data were used as input data for the system. The separation of data to feed each system input phase (*Test*, *Training*, and *Checking*), followed the standard measurement criteria of the MATLAB/Simulink editor and was adopted in published studies, where the random division of data prevails at 70% for the trainer input data, 15% for the tester, and 15% for the checking [81].

2) GENERATE FIS

In the second stage, the grid partition method was used to generate the FIS. At this step, it starts with the adjustment of the consequent parameters by the Ordinal Least Squares method and fixed antecedents. Then, the consequent parameters are adjusted by the Descending Gradient method, and fixed consequents. To generate the FIS, it was necessary to define the type of member function of the input variables and the type of output variable. For this, the RMSE values were used to determine the best member function and the epoch number to select the best fitting model. Tests were performed with the types of member functions available in the Neuro-Fuzzy Designer. This way, the Gaussian function presented the most satisfactory result [81]. Figure 2 presents the ANFIS structure defined.

The structure of the proposed model is composed of four input variables and one output variable. The application automatically created eighty-one “AND” rules.

3) TRAIN FIS

In this third stage, the inference system was trained with the hybrid optimization method, considered highly efficient for training ANFIS systems. Hybrid optimization is composed of a combination of methods associated with the estimates of the parameters of the input membership functions, called backpropagation, and methods associated with the estimates

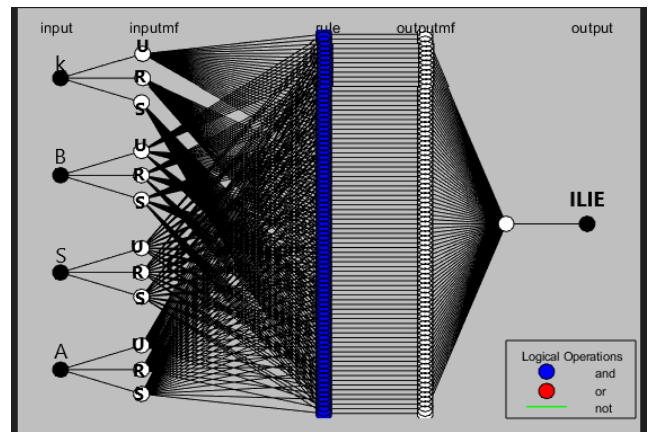


FIGURE 2. ANFIS Structure.

of the output parameters and least square membership functions. The hybrid algorithm demonstrates efficient training of the ANFIS system [82].

The defined stopping training criteria were the error tolerance equal to 10^{-7} and the number of epochs equal to 150. After 6 tests, the number of epochs with the lowest RMSE was identified, according to the type of function of Gaussian relevance. Table 6 shows information from ANFIS after training the input data in the Fuzzy Inference System.

TABLE 6. ANFIS information.

ANFIS information	Data
Number of nodes	193
Number of linear parameters	81
Number of nonlinear parameters	24
Total number of parameters	105
Number of training-data pairs	105
Number of checking-data pairs	22
Number of fuzzy rules	81

Source: research data

4) FIS TEST

The Fuzzy Inference System tests were performed with the observed data separated three times: training, test, and validation, according to the linguistic variables, to measure performance values: unsatisfactory, regular, and satisfactory. The Gaussian inference with Activation Function represented by Equation 3 was used in the system [83].

$$y_i^{(1)} = e^{-\frac{1}{2} \left(\frac{x_i - c}{\sigma} \right)^2} \quad (3)$$

where:

x_i : network non-fuzzy input.

$y_i^{(1)}$: fuzzified output of Layer 1 node i.

σ_i and c_i : parameters that control the width and the center of the function.

5) DEFINITION OF FIS PROPERTIES

The fuzzy inference system (Figure 3) has 4 input variables which are: Knowledge (K) Behavior (B); Skill (S); and Attitude (A).

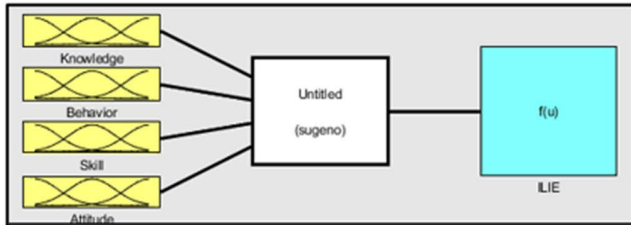


FIGURE 3. Fuzzy inference system.

The member functions of the Gaussian type were classified as unsatisfactory, regular, and satisfactory in the four input variables. An example with the variable Knowledge is presented in figure 4.

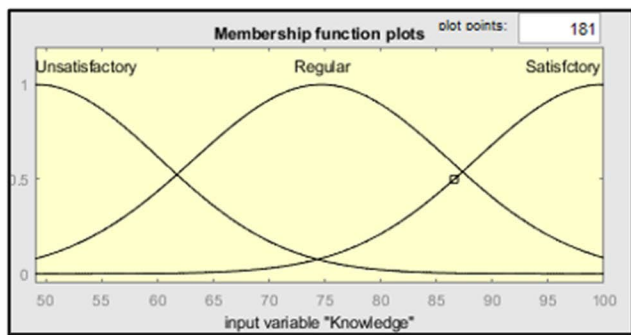


FIGURE 4. Member function.

The Gaussian membership function offered a better adjustment according to the average error and standard deviation. In order to select the membership function, some tests were carried out with the available functions at the “Neuro fuzzy Designer” toolbox of MATLAB. This type of function is used for activation of the neurons in the intermediate layer and linear in the output layer. And the member functions parameters of the four variables are shown in Table 7. This membership function was divided into three categories: Unsatisfactory, regular and Satisfactory for all the input variables as it is shown in figure 4, using as example the input variable named Knowledge.

Having made the definitions presented in this section, the model results were analyzed and discussed.

IV. RESULTS AND DISCUSSIONS

The study was divided into two stages, the first being the data analysis using the Excel tabulator, and the second being the model development using the adaptive Neuro-fuzzy Inference

TABLE 7. Parameters of member functions.

Input Variable	Linguistic Variable	Parameters (Gaussian)
Knowledge	Unsatisfactory	[11.02 49.05]
	Regular	[11.26 74.56]
	Satisfactory	[11.07 99.86]
Behavior	Unsatisfactory	[10.31 43.93]
	Regular	[10.84 68]
	Satisfactory	[10.62 91.82]
Skill	Unsatisfactory	[10.27 43.89]
	Regular	[10.69 67.67]
	Satisfactory	[10.34 91.93]
Attitude	Unsatisfactory	[9.335 44]
	Regular	[9.455 66.04]
	Satisfactory	[10.2 87.61]

Source: research data

System, to observe the impact of each variable on the industry leader’s performance for an emergency.

The Cronbach’s Alpha value was 0.7, which represents the result reliability, considered adequate for studies presenting subjective data and a questionnaire based on the Likert scale used in this study [84].

In the Excel Tabulator, on a scale from 0 to 100, the index for the variable Knowledge was 80%, Behavior 73%, Skill 66%, and Attitude 61%. Given the criteria adopted by the experts, the variables Knowledge and Behavior were considered of satisfactory values and the variables Skill and Attitude obtained regular ones, while the leadership index of 70% was considered adequate or satisfactory as a parameter for evaluating an industry leader in emergencies.

The model showed the lowest RMSE at the 150th epoch, outperforming the other models in the tests performed. The results obtained by the ANFIS model showed that, when reaching the defined stopping criteria of error tolerance and number of epochs, the RMSE values were 0.199 in the data training, and 1.217 in the data validation. The model performance was satisfactory considering that the RMSE value, the smaller the difference between the estimated and the real values [85], [86].

According to the Rule Viewer results (Figure 7), the influence of input variables in determining the output index can be measured. By moving the red line in the center of each input variable to its maximum value, it is possible to verify the positive impact of this variable on the leadership profile.

The Rule Viewer results were compared to the calculations performed in the Excel Tabulator to present the percentage errors between real data and the simulation through ANFIS. In the Neuro-fuzzy Designer application, the model results can be seen in the Rule Viewer and the Surface Viewer. Based on the Rule Viewer results, the percentage errors considering the real values and the simulated values were calculated. The percentage errors were calculated using the model input data (real or observed values), and the results of each variable in the Rule Viewer (simulated values). The percentage errors

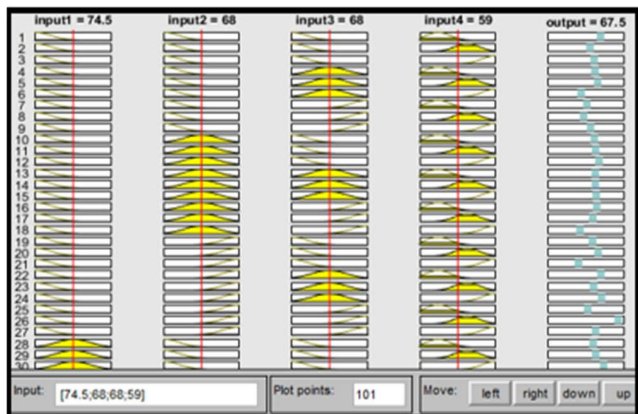


FIGURE 5. Rule Viewer Source: research data.

observed in the input variables Knowledge and Behavior were 7% in both, Skill 3% and Attitude 5%. The percentage error in the model’s output was 4%. This represents 90-95% accuracy between simulated and real data.

In the simulation, considering the variable Knowledge at its maximum value, the Industry Leadership Index increased by 10%. Considering the variable Behavior at its maximum value, the leader profile increases by 37%, while the variables Skill and Attitude are influenced by a positive impact of 4% on the Leadership Index when considered at their maximum values.

Similarly, considering the minimum values assigned to each input variable, a negative impact on the leadership profile can be observed. In the simulation with the variable Knowledge at its minimum value, the Industry Leadership Index decreases by 12%. Considering the other variables at their minimum values, the negative impact on the Leadership Index was 9% in the three simulations.

The Surface Viewer results graphically demonstrate that the four input variables impact the leader profile (Figures 6, 7, 8, and 9).

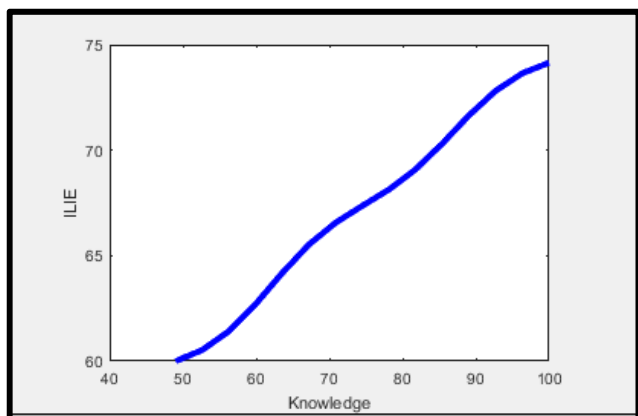


FIGURE 6. Impact of variable K on ILIE.

The graphs show that the greater the Knowledge, the greater the ability to respond assertively in emergencies.

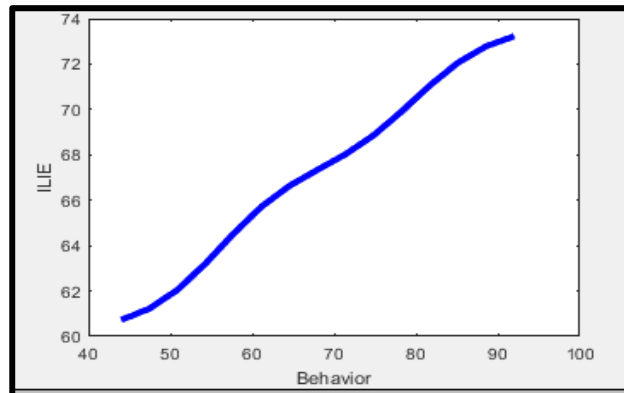


FIGURE 7. Impact of variable B on ILIE.

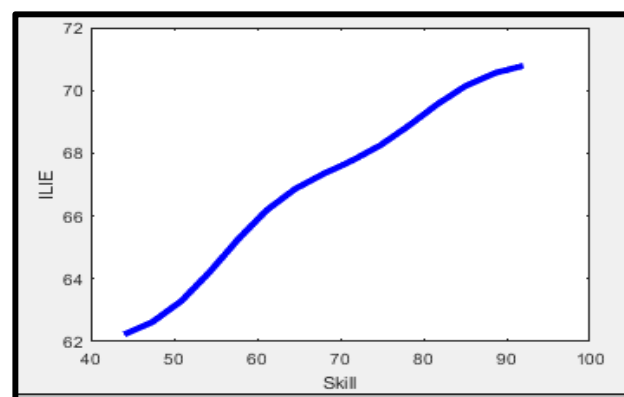


FIGURE 8. Impact of variable S on the ILIE.

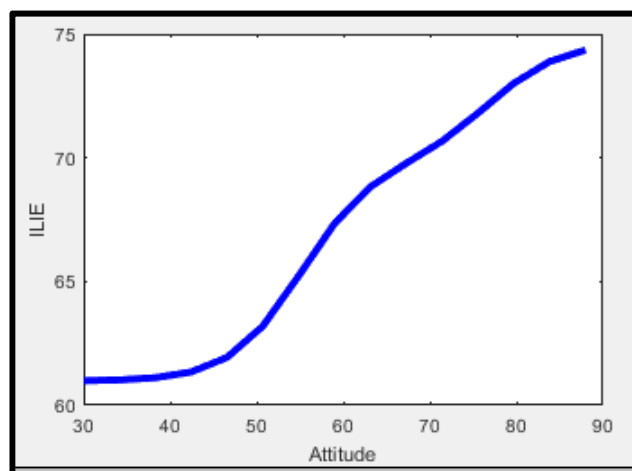


FIGURE 9. Impact of variable A on ILIE.

The same occurs with Safe Behavior. Regarding Skill, the indicators values increase the contingency actions and the more assertive the Attitudes and the efficiency in the leaders’ performance in emergencies.

In the analysis of the variables’ positive and negative impact on the leader’s profile, the greatest negative impact presented is the lack of knowledge, which implies in the

leader's decisions and, consequently, impacts the team's performance. Knowledge enables a greater tendency toward safe behavior when making decisions, while Skill and a Positive Attitude prevail for good responses in an emergency scenario.

V. CONCLUSION AND CONTRIBUTIONS

In this paper, an industry leader evaluation model for emergencies was developed using ANFIS. The study filled a gap identified in the literature by presenting a model to identify determinant variables in the decision-making process in an emergency. In this analysis, the RMSE accuracy between real and predicted values determined the ANFIS models' performance.

In the literature review, a preliminary evaluation model was proposed. To this end, the research grouped variables and indicators through an exploratory approach by elaborating the conceptual model. The model is composed of 4 input variables, Knowledge, Behavior, Skill, and Attitude, and 43 indicators distributed according to the variables. Data collection was carried out in petroleum production units, using an instrument based on a 5-point Likert scale. The instrument applied presented acceptable reliability and internal consistency according to the result of Cronbach's alpha coefficient. The errors presented in the steps of training and testing of the fuzzy inference system indicated the good performance and fit of the model.

The model showed how each input variable impacts the leadership profile in the industry. According to the ANFIS modeling results, the variables Knowledge and Behavior had the greatest effect on leadership performance for emergence.

The Knowledge based on technical and specific learning, and the team's preparedness when facing an unexpected event, can be controlled, and associated with Safe Behavior. In this context, safety behavioral factors help decision-making with more assertive responses, while leadership's Skills and Attitudes determine the procedures that contingency an accident.

As a contribution from a theoretical perspective, this work can fill a gap in identifying industry-specific leadership indexes and emergency responses. The model development and the identification of variables and indicators that impact the leader's professional profile add to multidisciplinary work to approach and discuss the object of investigation.

In practice, the model can be used in the process of selection and professional admission of leaders, and for the evaluation of leaders who are in activity. The model collaborates in the identification of weaknesses in the leadership profile, and thus helps the planning of training for contingency response conditions for an emergency.

Based on the literature review, a theory for the evaluation of an industry leadership in emergencies was not found. In this sense, the paper contributes with new content, that specifically addresses the evaluation of the industry leader. In addition to emerging further discussion and theories on the topic of this paper. Assertive responses in a crisis scenario

also depend on the execution of procedures by the leader and teams that can contingency an accident.

For future work, this research should be applied to other organizations with similar characteristics to the oil and gas industry for validation of the tool.

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