DEVELOPMENT OF A PROCESS OF ELICITATION FOR A CENTRIFUGAL PUMP IN THE QUALIFICATION AND RELIABILITY ENVIRONMENT OF OFFSHORE ASSETS IN THE PRE-SALT

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Abstract: In the current context of equipment in an offshore environment, failure histories are mostly incipient, which makes it difficult to elaborate maintenance plans for such assets. Thus, this article demonstrates the procedure for building an elicitation with expert opinion in a research environment to perform quantitative analysis of potential failures that can affect the reliabilit fluid system during the operation phase. The Delphi methodology for qualitative technology prediction was used, which is more suitable when there is no historical data or when quantitative data on the failures of a given asset are lacking. The elicitation results will make it possible to quantify the uncertainties based on previous experience, the elaboration of mathematical models and the management of conflicts to determine the roadmap for improving the assets.

Keywords: elicitation; offshore; reliability; asset; expert opinion.

Resumo: No contexto atual de equipamentos em ambiente offshore, os históricos de falhas são em sua maioria incipientes, o que dificulta a elaboração de planos de manutenção para tais ativos. Assim, esse artigo demonstra o procedimento para construção de uma elicitação com opinião de especialistas em um ambiente de pesquisa a fim de realizar análises quantitativas de possíveis falhas que podem afetar o sistema de fluidos de confiabilidade durante a fase de operação. Foi utilizada a metodologia Delphi para previsão de tecnologia qualitativa, que é mais adequada quando não há dados históricos ou quando faltam dados quantitativos sobre as falhas de um determinado ativo. Os resultados da elicitação permitirão quantificar as incertezas com base na experiência prévia, na elaboração de modelos matemáticos e na gestão de conflitos para determinar o *roadmap* de melhoria dos ativos.

Palavras-chave: elicitação; offshore; confiabilidade; ativos; opinião de esialistas.

1. INTRODUCTION

The success and effectiveness of the production of the Brazilian presalt reservoirs represent the apogee of the accumulation of geophysical, geological, and productive knowledge of the basins of the Brazilian margin in the almost sixty years of exploration and production activities. This was achieved thanks to the exploration competence of the Petrobrás company in the search for the country's oil selfsufficiency, backed by the positive characteristics of the Brazilian Pre-Salt: high productivity, accumulated volume of reserves, quality of natural gas and oil and low exploratory risk and production. Due to the great financial result from this exploration, it is known that

ISSN: 2357-7592

the systems of an oil well contain hundreds of pieces of equipment that are fundamental for the production process to occur with high reliability, which justifies the great need for a high investment for the acquisition of assets and its exploratory study of failure mitigation so that the revenue is voluminous by the company that uses and exploits them.

The exploration of expert opinions has proven to be an area of diligent research in many contexts, such as the study of researchers in human reliability analysis [1], in Bayesian belief networks [2] and their hybridization [3]. Given this scenario, it was necessary to use alternative sources of identification and analysis of failures, such as Failure Mode and Effect Analysis - FMEA and the Elicitation with expert opinions, based on the Bayesian model and the Delphi method. Due to the scarcity of empirical data related to the concepts developed, this dissertation resorts to the elicitation of specialists to obtain failure rate estimates of the concepts developed. It is a direct elicitation method with the possibility of reassessing the responses during the rounds. Based on the Delphi method, each expert answers an electronic questionnaire (Google Forms) assigning a failure rate for an optimistic, most likely, and pessimistic scenario, similar to the work of Droguett & Firmino (2006), in which, later, the probabilities of failure are calculated. The advantage of this method is to avoid potential biases and confrontation between experts, with the main result being the search for consensus among them.

1.1. Asset Tree

For the beginning of the elicitation process, it is crucial to define the hierarchical tree of the process, system or equipment to which answers are sought. Thus, a set of the company's assets organized in hierarchical levels are arranged to allow the identification of the item, relating its physical/geographic location to its functional role within the production, support and administrative areas. In this way, it becomes possible to visualize maintenance costs, production systems, processes and the functions linked to them, as well as manage equipment and services at different levels of the installation independently in the company. The construction of an asset tree is the basis of the entire maintenance management process and has the purpose of ensuring the unequivocal individual identification of each maintenance item, thus enabling the interrelationship with the systems and subsystems involved and the constitution of the maintenance historic data of each item.

In the production process, each facility has its specific functions, and these functions have their relative importance, having in essence a register that allows:

a) to determine the addresses of the intervention points.

b) to associate those addresses to their performed functions.

c) to associate the assets to the productive process.

d) to associate the functions to their relative importance.

e) to control the cost of maintaining the functions.

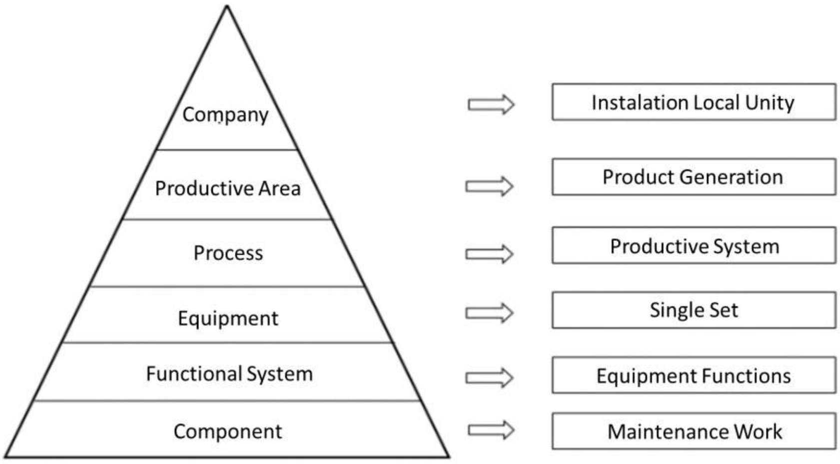
ISSN: 2357-7592

f) to control the availability of the assets.

g) to facilitate the definition of the priorities to care.

Figure 1 illustrates the hierarchical levels of the assets.

Figure 1 – Asset Hierarchical Tree



Source: Authors

1.2. ABC Criticality Analysis

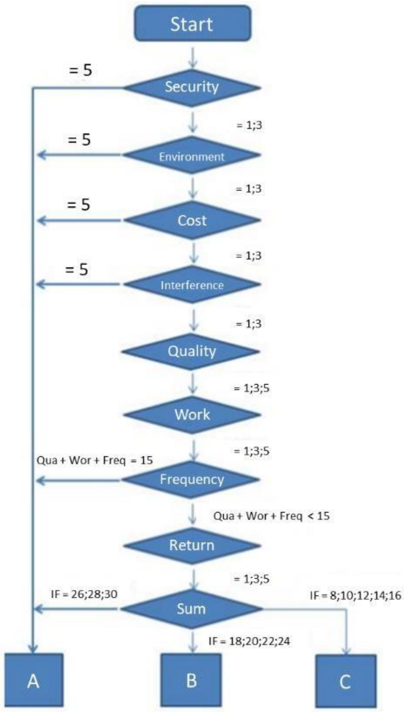
The ABC criticality analysis aims to determine and quantify the universe of critical assets in each plant/process to provide the best guidance regarding the possible maintenance techniques to be used, as well as the focus on maintenance activities that must be carried out. This last step, in turn, seeks as a result the operational guarantee of the plant/process and the optimization of employed resources.

The equipment, functional systems and components determined by the asset tree can be classified into three groups according to specific characteristics – A, B or C. These classifications essentially address the importance of each asset within the production process, their priority level in the various activities associated with the operation of this equipment, the forms of engineering approach, service programming, maintenance, etc.

All assets - with the exception of the first 3 levels highlighted in Figure 1 - must be classified, also containing the result in graphic form. When submitting assets to the criticality algorithm (Figure 2), the family to which they belong is not considered, but their specific function within the production process.

ISSN: 2357-7592

Figure 2. Logic for asset criticality analysis



Source: Authors

1.3. FMEA (Failure Modes and Effects Analysis)

Subsequently, an FMEA form was elaborated, which is a tool that aims to define, identify, and eliminate potential system failures even in its early stages of design. The analysis cannot be performed on an individual basis, and therefore, the team that forward it must be appropriate for the specific project [4]. The FMEA consists of collecting information about the functions, mode, cause and effect of failures, as well as detection methods and their respective indices. Its main objectives are to identify and classify failure modes according to their effects on the system to prioritize design improvements; to identify actions at the project level to eliminate or reduce possible failure modes; to document and justify changes in product design; and to serve as a source of knowledge for analysis and evaluation in a relevant environment.

According to [4], FMEA is an effective tool for risk assessment at the beginning of a DFR project, as it identifies potential failure modes for the product/process, assesses the risks associated with these failure modes and identifies and indicates actions to minimize or eliminate the causes of failures. In addition, the FMEA can aggregate requirements, customer usage, and application environment (relevant environment) into its analysis as input and, through group interactions during completion, can report initial results regarding the physics of the failure, reliability prediction, and life testing.

In this work, the FMEA was applied by a multidisciplinary team of specialists responsible for the innovation project, integrating the disciplines of mechanics, automation/electrical, materials and reliability. During the FMEA, the failure modes of

ISSN: 2357-7592

each component were listed, taking into account potential human and process errors, assuming the system operation in a relevant environment

1.4. Elicitation of expert opinion

Expert opinion elicitation is a technique that aims to reduce and control the cost uncertainty associated with the industrial scale by collecting opinions from different experts about the functioning of an asset. Therefore, the implementation of this technique allows us to gather information that helps the planning, operation, and maintenance areas to correctly allocate the necessary resources to keep production and systems running at high levels, which will directly affect corporate profits. Currently, reliability encompasses different methods and techniques, including technological advances that help predict and diagnose failures in industrial equipment.

For reliability analysis, the probability distributions are the main substitute for model judgments, and a variety of extrapolation methods designed to compute an expert's opinion on a given unknown have been established. Requesting experts is essentially a scientific consensus method and is often used in the study of rare events. Its specialized form allows parameterization of the individual objects under study, a "contextualized hypothesis" to quantify uncertainty. [5] conceptualizes arousal as a carefully organized set of steps that must be overcome in the search for truth, scientific research or the achievement of some goal. [3] used Bayesian analysis to estimate the reliability of industrial equipment under development using data from similar systems and expert opinions on the impact of design change.

The Delphi elicitation tool prescribes a systematic and interactive method of analysis that, based on the free and independent opinion of a group of experts, tries to form an opinion opposite to the general opinion of the analyzed subject. Delphi is a method of stimulation that, according to [6], achieves consensus by repeatedly submitting to a panel of experts and asking others to provide arguments in support of the point of view. It is a qualitative forecasting technique in which expert judgment is combined in a series of repetitive/repeated steps. The results of each iteration are used to develop the next iteration to gather expert feedback.

2. METHODOLOGY

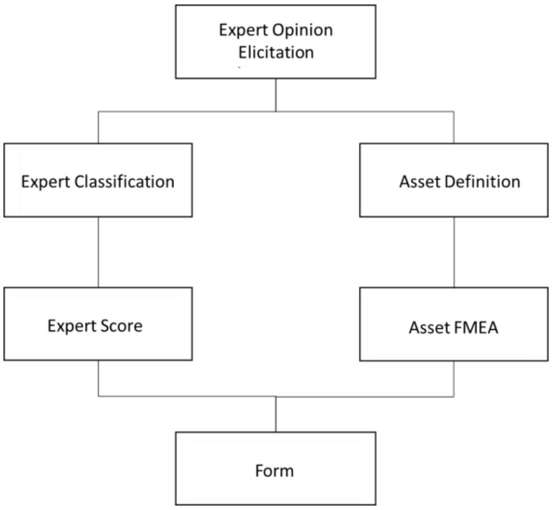
The methodology to identify potential failures that affect reliability using expert opinion – the elicitation - used the following steps: study of process flowcharts; graphics; equipment list; information on the Maintenance Policy adopted; similar equipment; database containing the history of failure occurrences, with the date, time, the equipment in which it occurred (including the component that failed), the failure root cause, the losses caused and the time and resources for the repair; and analysis of FMEA results.

Based on this analysis, the expert's elicitation and qualification forms were elaborated, which were later sent for them to fill out. Then, from the collection of data

ISSN: 2357-7592

from the answers to the forms and the attribution of a score to each participating specialist, a treatment of the data was carried out to obtain quantitative information about the failures of the asset. Finally, the elicitation results were documented. Figure 3 illustrates the applied methodology.

Figure 3. Methodology diagram



Source: Authors

As in the elicitation the possibility of many opinions is given, the calibration of the answers with assignment of scores to each expert becomes an important activity to guarantee the quality of the elicitation results. In the qualification of the specialists, the criteria according to [7] were used.

3. RESULTS AND DISCUSSION

Initially, a survey of projects/works with methodologies and objects of study similar to those presented in this article was carried out. The research results showed that no other projects and/or elicitation questionnaires were found as a model for the family of offshore assets, such as the pump under study.

Then, the forms were designed based on a division into two sections: qualitative responses and quantitative responses. The qualitative response section sought to determine the relative probability of a failure occurring due to a specific cause. Thus, the specialists who filled in the forms had to assign a percentage probability for the occurrence of the event, which could vary from a very unlikely scenario to an extremely probable one. The answers in this section would then allow us to determine which failure mode is most likely to occur among all those listed.

The quantitative responses section, in turn, was filled in later and asked the experts to assign a numerical value to each event, which would represent its occurrence (e.g., one occurrence per year). The answers in this section would then allow us to determine the failure rate of each failure mode listed.

The elicitation process was carried out with a group composed of specialists with theoretical and practical knowledge acquired both through training and professional experience. These specialists were categorized based on four criteria: education level, professional experience, position/occupation and age, as shown in Table 1.

Table 1: Composition of experts

Composition	Classification	Punctuation
Office	Adjunct Professor/Specialist III	5
	Technical Leader/Specialist II/Consultant II	4
	Specialist I/Consultant I	3
	Specialized Technical	2
	Scholarship/Intern	1
Years of professional experience	>30	5
	20-30	4
	10-20	3
	5-10	2
	<5	1
Level of education	Doctor	5
	Teacher	4
	Specialist	3
	Graduate	2
	Technician/Medium level	1
Age (in years)	>50	5
	40-50	4
	30-40	3
	25-30	2
	<25	1

Source: Adapted from OLOWOYIN, Richard (2017)

The experts selected to assess the probability of failures by completing the elicitation form were from the Process, Instrumentation/Electrical/Automation and Mechanical areas, and a score ranging from 1 to 3 was assigned according to the punctuation of each expert, as shown in Table 2.

Table 2: Score adopted for a given specialist's punctuation

Punctuation	Score
4, 5, 6, 7, 8, 9	1
10, 11, 12, 13, 14,	2
15,16,17,18,19,20	3

Source: Authors

These scores were then used to analyze the quantitative responses. Expert responses with a score of 2 were considered twice, and responses with a score of 3

ISSN: 2357-7592

were considered three times to calculate a weighted median value, which represents the failure rate of a given event.

4. CONCLUSION

This article presents a method to structure the acquisition of expert opinion in the context of historical scarcity of fault layers in the offshore environment. This approach introduces the integration of subjective information generated by experts during the development process, aiming to gain insight from it to provide the development team with a basis for decision making, particularly in terms of design review and suitability for requirements established with customers. While this method does not produce accurate reliability predictions, it does provide a baseline for starting reliability analysis in the early stages of innovative design. A disadvantage of the proposed method is the lack of mathematical and statistical applications, which cannot be deepened due to lack of empirical data, either from similar systems or from accelerated life tests or in a relevant scenario. This method will serve to identify project failures in the early stages of development, as it eliminates or minimizes the patterns of potential defects identified, helps to incorporate actions into the project, and increases the maintainability and availability of the oilfield assets. Thus, as the project develops, new reliability analyses can be performed, aiming to guarantee the quality and technological maturity of the final project.

5. REFERENCES

[1] HALLBERT, B. et al. **“The use of empirical data sources in HRA. Reliability Engineering & System Safety ”,** v. 83, no. 2, p. 139-143, 2004.

[2] J.Pearl. _ **“ Probabilistic Reasoning in Intelligence Systems”.** Morgan Kaufmann, San Mateo, CA, 1988.

[3] E.L. Droguett _ and A. Mosleh, **“Bayesian Analysis of Reliability of Products in Development,” Management & Production**, vol. 13, no. 1, pp. 57-69, Apr. 2006. doi: 10.1590/S0104-530X2006000100006.

[4] FOGLIATTO, FS; RIBEIRO, JLD **“Reliability and Industrial Maintenance”.** Rio de Janeiro: Elsevier: ABEPRO, 2011.

ISSN: 2357-7592

5 GALLIANO, AGO "Scientific method: theory and practice". Sao Paulo: Habra, 1979.

6 Aspinall, WP, & Cooke, RM (2013). Quantifying scientific no from expert judgment elicitation. In J. Rougier, S. Sparks, & L. Hill (Eds.), **"Risk and uncertainty assessment for natural hazards "** (pp. 64–99). Cambridge, UK: Cambridge University Press.

7 Olawoyin R**.** (2017). **"Risk and Reliability Evaluation of Gas Connector Systems Using fuzzy theory and Expert Elicitation "**. cogent Engineering, 54: 1372731

8 OP Yadav, N. Singh, RB Chinnam, and PS Goel, "A Fuzzy logic Based Approach to Reliability improvement pet during Product Development, " Reliability Engineering & System Safety, vol. 80, no. 1, pp. 63–74, Apr. 2003. doi: 10.1016/s09518320(02)00268-5.

ISSN: 2357-7592