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Reliability criteria estimation of O&G Industry Equipment in the concept selection process

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The design and development of new products are complex processes. After defining potential alternatives, frequently called “concepts”, that fulfil most criteria, they must be compared, ranked, and/or selected. The concept selection becomes even more challenging at an early stage of development, when a limited amount of data is available, making it difficult to quantify some criteria, such as reliability. However, there is little to non-existent reliability data at the concept selection stage. Also, many studies do not detail the reliability criterion when estimating it. We can obtain a prior reliability distribution for each concept, by using data from generic sources, such as expert opinion. This study proposes a method to estimate reliability criterion in the concept selection process. The criterion is quantitative, considers the reliability with an associated probability distribution, accounts for the reliability uncertainty, and based on probabilistic reliability models, specified using experts’ opinions. We apply the Weighted Rating Method (WRM) for multicriteria decision-making regarding the concept selection. Three different concepts of oil well equipment is compared. Besides the reliability criteria, costs, flexibility, integration, and time are also evaluated. The results can help the parties involved in the process to base decisions on more robust reliability criteria, enabling the selection of more credible equipment to contribute to the industry’s end activities’ efficiency.

Keywords: Concept Selection, Oil and Gas Industry, Oil Well Equipment, Reliability Criteria, Bayesian prior distribution, Weighted Rating Method.

1. Introduction

Selecting concepts that meet organizations' criteria is a crucial step in new technology development. However, this is a complex task as the performance and relevance of each concept against the criteria must be carefully considered. Additionally, the relevance of each criterion can vary across projects.

Reliability-based approaches are increasingly used to assess new product specifications (Jia and Guo 2022). However, reliability is not deeply explored as a criterion. Despite limited reliability data available during concept selection, alternative sources like expert opinions and databases of similar equipment can be utilized to establish a prior distribution of each concept's reliability. Therefore, the uncertainty incurred should be considered in the analyses. (Maior et al. 2022).

Thus, this study introduces a methodology that quantitatively incorporates reliability into the selection process, accounting for concept uncertainty. We present a case study comparing three oil well equipment concepts, evaluating reliability, costs, flexibility, and development.

3. Methodology Overview

Here we apply the Weighted Rating Method for multicriteria decision-making to concept selection. As it is a simple methodology to understand, experts are able to critically analyze the results, identify inconsistencies, and reassess concepts if needed. Additionally, a simpler method facilitates the systematization and formalization of the concept selection process. To define the reliability criterion, we perform an elicitation step where expert j provides the probability of failure estimate of concept c, x_{cj}. A simple way to aggregate the experts data is by linearly pooling the experts' opinions as $x_c = \sum_{j=1}^{N} p_j \times x_{cj}$, where x_c is an estimate of the probability of failure of concept c, p_j is the weight of expert j, and N is the number of experts involved. Biases can occur when experts assign weights to criteria due to limited knowledge or overconfidence. To address this, we conducted a virtual elicitation without expert interaction, allowing each expert to provide individual opinions. An analyst then assigned weights based on their knowledge levels.

We assume that x_c is the mode (b) of the triangular distribution that describes the real values of the reliability of concept c, $R_c(t)$, and that the optimistic (a) and pessimistic (d) reliability values are respectively 1 and 0 (maximum uncertainty was associated with expert opinion due to the very early stage of development). Then, we calculate the expected value of the distribution using $E[R_c(t)] = \frac{a+4\times b+d}{6}$. After computing $E[R_c(t)]$ for all concepts, we determine the baseline $\bar{E}[R(t)]$ and the reliability criterion score (S_{R_c}) values of each concept.

$\bar{E}[R(t)]$ corresponds to 50% of the scale, concepts with expected reliability values up to 25% higher have S_{R_c} equal to 4. Concepts with an expected reliability value between 25 and 50% greater than the reference value have $S_{R_c} = 5$. Concepts with an expected reliability value up to 25% lower have $S_{R_c} = 2$, while concepts with an expected reliability value between 25 and 50% lower than the reference value have $S_{R_c} = 1$. To illustrate the applicability of the proposed methodology, we present an example applied in a Brazilian oil company.

4. Case Study

The problem consists of concept selection for developing a new subsea interface for intelligent electrical well completion. More specifically, three concepts were evaluated: concept (1) consists of a system integrated with the subsea control module (SCM) of the wet Christmas tree, concept (2) has no redundancy in SCM and has a Central Process Unit (CPU) and Electric Power Unit (EPU) pair for each well in the control and supervision system (SCS), and concept (3) has two redundant CPUs and two high voltage supplies in SCM and shares one set of CPU and EPU for each well in SCS.

Five criteria were evaluated: cost (the price of developing the equipment), time (required to develop the technology), flexibility (capacity to adapt to different equipment), integration (capacity, to guarantee interoperability), and reliability (ability to perform satisfactorily during a specific mission time). Firstly, the experts evaluated the relevance of the criteria (w), provided the values for each criterion (S), adopting the same scale from 1 to 5 (see Table 1) and provided x_{cj}. After eliciting the estimated failure probability in 15 years of each concept we computed their respective expected reliability. Then, the mean value $\bar{E}[R(15)] = 85.88\%$ was adopted as baseline, and the reliability criterion values of each concept were set using the scale described previously.

Table 1. Criteria scores for each concept.

Criteria	Relevance	Concepts 1	2	3
		$w \times S$	$w \times S$	$w \times S$
Cost	$w_c = 3$	3	9	15
Time	$w_t = 4$	12	16	20
Flexibility	$w_f = 3$	6	9	12
Integration	$w_i = 5$	10	15	25
Reliability	$w_r = 4$	8	8	12
Total	-	35	65	88

Finally, the scores of each criterion were computed for each concept by multiplying the criteria, the results are summarized in Table 1, and indicates that concept (3) is the more suitable to the organization.

5. Conclusion

This study's results can support the individuals involved in the decision-making process to base the concept selection, despite the data limitation, on more robust reliability criteria that consider a quantitative estimation aligned with other critical criteria, as cost and flexibility. In this sense, the selected equipment can be more credible and aligned with the organization main objectives. This research focuses on equipment development in the O&G industry, but its applicability can extend to other contexts and equipment types.

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