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Unlocking Value Through Disruptive Production Concepts: A Case Study on the Brazilian Offshore Coast

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Abstract

The proper development of an offshore production system requires a thorough evaluation of subsea technologies capable of unlocking innovative field development architectures and delivering maximum economic benefits, while maintaining safety and environmental targets.
As oil and gas production advances into more remote and deeper water regions, disruptive subsea development strategies become increasingly essential. This papers aims to evaluate the impact of using subsea technologies, such as boosting, separation, subsea water injection, and subsea tiebacks, in oil field developments, focusing on the Brazilian Pre-Salt Santos Basin. Evaluating such subsea strategies is an important step of the field development strategy definition due to the potential to address challenges in terms of flow assurance. These challenges encompass pressure drop in long flowlines, thermal management to mitigate hydrate and wax deposition, and the requirement for cost-effective chemical delivery. The advancement of tools and techniques to overcome these challenges and enhance the decision-making process is vital for maximizing the value derived from subsea strategies.
This study employed an Expert System to analyze several conceptual alternatives, through an integrated mutidisciplinary approach. Analysis in terms of Capital Expenditure (CAPEX), Net Present Value (NPV), and GreenHouse Gas Emissions Intensitiy (GHGEI) were conducted. Over 70,000 conceptual alternatives were generated and analyzed using a tradespace method to identify the optimized zone.

Keywords
Subsea technologies; Flowassurance; Field development; Pre-salt; Conceptual alternatives; Expert System

Introduction
The conceptual engineering phase represents a crucial moment when significant decisions are made, involving the generation and evaluation of various development alternatives. The quality of these alternatives plays a fundamental role in creating value in subsequent stages. It is illustrated in Figure 1 that sound decisions made during FEL-1 and FEL-2 stages can significantly impact project value, depending on the quality of project definition.
This paper demonstrates the use of a system that has emerged into the oil and gas industry to revolutionize the conceptual selection of offshore concepts. This system uses an integrated methodology (Model-Based System Engineering) along with artificial intelligence (Expert System) to generate thousands of conceptual alternatives for offshore fields [1,2]. This expert system has revolutionized conceptual engineering for its agility in generating a vast number of concepts in record time. It covers all disciplines required for offshore field development, employing an original model and object-oriented programming (OOP) techniques. The aim is to investigate the most economically robust solutions across different scenarios, where the optimal solution for each technical discipline individually may not be the best solution when it is considered in an integrated way. This approach highlights solutions that could not be identified when each discipline is examined separately or in a semi-integrated way, as is done in the traditional approach [3,4].

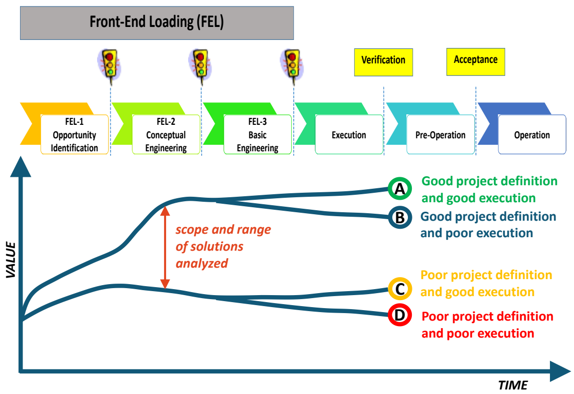

Figure 1. Project Value Impact

This study will consider offshore field development in Brazil´s coast as a case study.
The case studied is in a water depth of around 400 m, an oil volume in place of 5000 MMSTB, and an API of 30. The simulations will encompass a range of processing facility types and locations, including fixed, tension leg, and SEMI platforms, as well as different export destinations. Additionally, the analysis will explore different subsea architecture alternatives and subsea processing options, such as booster pumps, three-phase separators, and raw water injection systems.
The objective is to identify the optimized project zone, where projects yield the highest NPV with the lowest CAPEX, through an analysis known as tradespace exploration. In this specific project, a key focus was placed on analyzing the effects of subsea processing alternatives, including boosting, raw water injection, and three-phase separation. The use of these technologies can significantly impact flow assurance outcomes in the oil industry by enhancing the efficiency and reliability of hydrocarbon flow.

Methodology

In order to perform the simulations, the first step is mapping the main characteristics of the project to be evaluated. Some of the project boundary conditions are shown below:

- Operational lifetime of 19 years.
- Average water depth of 600 m.
- Average reservoir depth of 4500 m.
- Initial reservoir pressure is about 6900 psi.
- Volume of oil in place of 5000 MMSTB.
- Crude oil gravity of 30° API.
- 18 production wells and 12 water injection wells.
- Maximum buildup inclination of 30° for the directional drilling.
- Steel and flexible catenary risers with reference internal diameter of 6 in.
- Steel and flexible pipelines with reference internal diameter of 6 in.
- Topside back pressure of 145 psi.
- Production unit capacity constraints of 300MBBL/d for liquid processing, 450,000 MSCF/d for gas processing, and 450MBBL/d for water injection.

The next step to improve system usability is to define scenarios for simulations. At this stage, the project team determines their evaluation priorities, making setting the simulation matrix an essential step in defining project execution options.
The simulation matrix will consider four key aspects: facility type, subsea architecture, subsea processing options, and different oil export locations. The fixed facilities include Jacket-200m and Jacket-300m, installed at water depths of 200 and 300 meters, respectively. For the floating facility, the Tension Leg Platform (TLP), Floating Production Storage and Offloading (FPSO), and Semi-Submersible (SS) will be considered.
Regarding subsea architecture, two options will be considered: full and satellite with manifold. The full option allows all archetypes (satellite, manifold, loop, and trunkline) for the system's subsea algorithm to generate alternatives. In contrast, the satellite with manifold option excludes loop and trunkline configurations and tests only satellite options and other configurations that mix manifolds with satellite wells.
The subsea processing alternatives include raw water injection (RWI), booster with and without RWI, and 3-phase separator with and without RWI. The impact of using subsea processing technologies is assessed by analyzing the trade-off between the initial investment required to implement them and the improved flow assurance, reflected in the resulting hydrocarbon production curves.
For oil export, three options will be considered in addition to scenarios where there is no oil storage, particularly for FPSOs where oil storage is inherently included. These options are: a Floating Storage and Offloading (FSO) unit, Location A offshore at an average distance of 12 km, and Location B onshore at an average distance of 120 km.
The simulation alternatives are summarized in Table 1.

Table 1. Simulation alternatives

Facility Type	Subsea Architecture	Subsea Processing	Export Line
Jacket 200m	Full	No	Location A
Jacket 300m	Satellite + Manifold	RWI	Location B
TLP		Booster // Booster + RWI	FSO
SS		3P-Separator // 3P-Separator + RWI	
FPSO			

All combinations generated from the alternatives in Table 1 resulted in a total of 70 setups for analysis. Each of these setups generates hundreds of conceptual alternatives. Once the simulations are completed, it's possible to plot all concepts together to analyze the optimized zones.
To compare and find the optimized zone, it's necessary to create a chart known as tradespace exploration [2]. There are two possibilities for generating a tradespace exploration:

1. Plotting NPV against CAPEX: In this plot, the goal is to find the concept with the lowest CAPEX and the highest NPV.
2. Plotting NPV against profitability (NPV divided by PVI – Present Value of Investment): many oil companies use profitability metrics to determine the worthiness of a project.

The financial indicator calculations are outputs generated by the expert system for each conceptual alternative simulated according to the simulation matrix. To perform these calculations, the software includes a proprietary database with over 320,000 items, encompassing all the equipment necessary for the construction of an offshore field. Each item is characterized by its technical-operational specifications and unit cost. The development of this database is based on three pillars: consultation of public information available in literature, market surveys, and cost engineering.

Results and Discussion

Over 70,000 concepts were generated for the 70 different setups, and the tradespace analysis plot is depicted in Figure 2.

NPV was plotted against profitability, allowing for the grouping of concepts into distinct zones. These zones include the TLP zone, the FPSO zone, the SEMI zone, and the Jacket zone. From the chart, the blue points represent the best strategy, once they exhibit the highest profitability.

In this study, these points are related to the jacket-200m strategy, with full (mix of satellite, manifold, loop, and trunkline) subsea architecture, no subsea processing, and export lines to Location A.

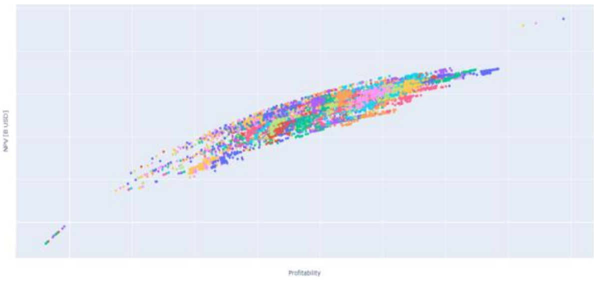

Figure 2. Tradespace Profitabiliy vs. NPV

An example of a conceptual alternative resulting from this strategy is presented in Figure 3, which consists of using a loop architecture for production wells and a manifold architecture for water injection wells.

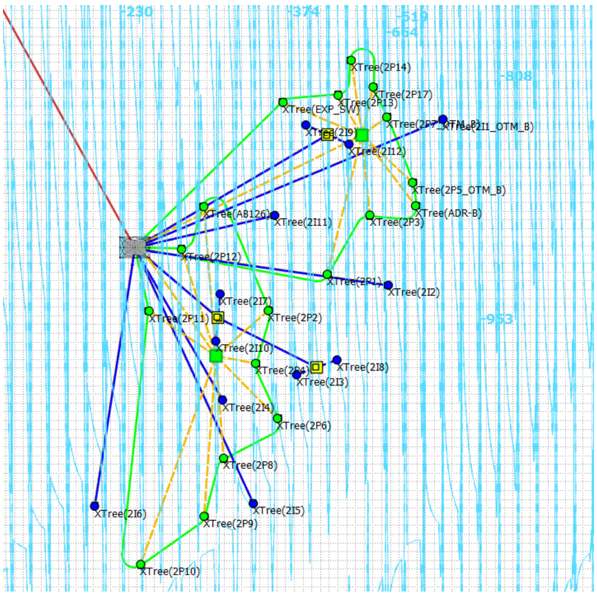

Figure 3. Conceptual alternative from Jacket-200m strategy

Conclusions

The use of a system that allows for the rapid evaluation of dozens of development alternatives for a field, along with the generation of thousands of associated concepts using an analysis tool (tradespace exploration), presents a significant opportunity for oil companies to develop fields in a more profitable and efficient manner. In the conceptual phase where these decisions are made, this has the great potential to increase companies' awareness of new technologies that may be immature and require investment, better guiding research, and development investments.

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Responsibility Notice

The authors are the only responsible for the paper content.

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