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INTEGRATED PLUGIN DESIGN FOR ECONOMIC EVALUATION OF OFFSHORE OIL AND GAS CONCEPTUAL FIELD ARCHITECTURES

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Resumo. *O presente trabalho apresenta o desenvolvimento de um plugin para integrar os softwares comerciais PETREL® e FLOCO®, otimizando a análise econômica de reservatórios de petróleo na fase conceitual. O objetivo é automatizar a transferência de dados entre os programas, reduzir erros e aumentar a eficiência na tomada de decisão. A metodologia envolveu a modelagem de reservatório no PETREL®, a elaboração de uma UML para estruturar o desenvolvimento do software e a implementação do plugin para a transferência e visualização dos dados. O plugin foi projetado para capturar parâmetros críticos de reservatório e curvas de produção, enviando-os ao FLOCO® para cálculo de indicadores financeiros como NPV, Payback e IRR. Os resultados indicam que a ferramenta reduziu significativamente o tempo de in e eliminou a necessidade de transferências manuais de dados, permitindo que um único usuário gerencie a simulação e a análise econômica. Essa integração aumenta a confiabilidade dos resultados e melhora a tomada de decisão estratégica na indústria de petróleo e gás.*

Palavras chave: *Análise econômica. Modelagem de reservatórios. Integração de softwares, Linguagem de Modelagem Unificada.*

Abstract. *This paper presents the development of a plugin to integrate the commercial software PETREL® and FLOCO®, optimizing the economic analysis of oil reservoirs in the conceptual phase. The objective is to automate data transfer between the programs, reduce errors, and increase decision-making efficiency. The methodology involved reservoir modeling in PETREL®, the creation of a UML to structure software development, and the implementation of the plugin for accurate data transfer. The plugin was designed to capture critical reservoir parameters and production curves, sending them to FLOCO® for the calculation of financial indicators such as NPV, Payback, and IRR. The results indicate that the tool significantly reduced processing time and eliminated the need for manual data transfers, allowing a single user to manage both simulation and economic analysis. This integration enhances result reliability and improves strategic decision-making in the oil and gas industry.*

Keywords: *Economic analysis. Reservoir modeling. Software integration. Unified Modeling Language.*

1. INTRODUCTION

The feasibility study of economic projects in the oil industry is surrounded by uncertainties throughout its development, including oil price fluctuations, equipment costs, and the volume of hydrocarbons or gas within the reservoir, among others. To minimize calculation errors, each process must be analyzed carefully with the least possible variation. Therefore, handling these data typically requires specialized tools that often lack integration. The exploration and production E&P involve locating and extracting oil and natural gas from underground or underwater reservoirs. Software solutions designed specifically for upstream operations in the oil and gas industry are known as E&P software. These programs help companies analyze geological data more effectively, enabling more accurate modeling and improved production planning.

Building a model of an oil and gas reservoir is complex and challenging due to both the variety of data types involved and the many different stages required. Today, we generally construct 3D geocellular models for volumetric estimation, dynamic simulation, well planning, and production optimization, or to understand the inherent uncertainty of any hydrocarbon reservoir (Cannon, 2018). The reservoir modeling process is shown in Fig. 2. After completing the reservoir study, the engineering team transfers this large amount of data to the economic team for project feasibility analysis. In particular, conceptual subsea engineering is a subsequent stage that focuses on proposing the most efficient architectures for these components, aiming to optimize costs and define viable field development strategies in the upstream segment of the oil and gas value chain. This stage can take months if done manually, and only a few layout options are generated. The softwares used in this study are able to deal with reservoir modeling on one hand and with field development on the other hand, generating hundreds of options for the company within days, with all financial KPIs calculated. However, they lack integration to expand capabilities in reservoir development, modeling, and economic studies under the *Front-End Loading* (FEL) framework.

The FEL approach is divided into three stages. The conceptual phase of the project focuses on FEL 1 and FEL 2. The conceptual engineering phase of FEL is defined as a significant investment effort during the project stages leading to the final investment decision.

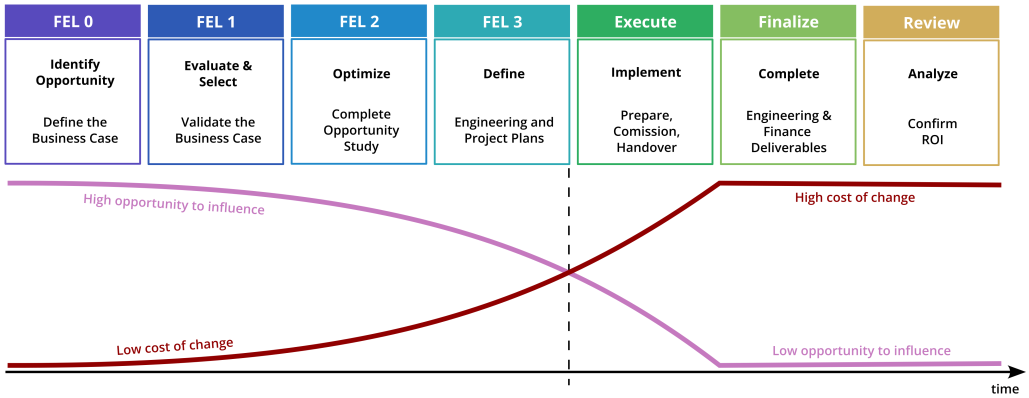

Figura 1. Phases of a capital project according to FEL principles. Source: own authorship based on (Chakrabarti, 2005) and (Neal, 2024).

In the literature, from the perspective of project management consultants (Independent Project Analysis, IPA) and the reality of the oil and gas industry, FEL is considered essential to reducing the likelihood of a project failing to meet its promises (Van der Weijde, 2008). At this stage, financial indicators such as Net Present Value (NPV), Payback, and Internal Rate of Return (IRR) are calculated, serving as key references for project decision-making.

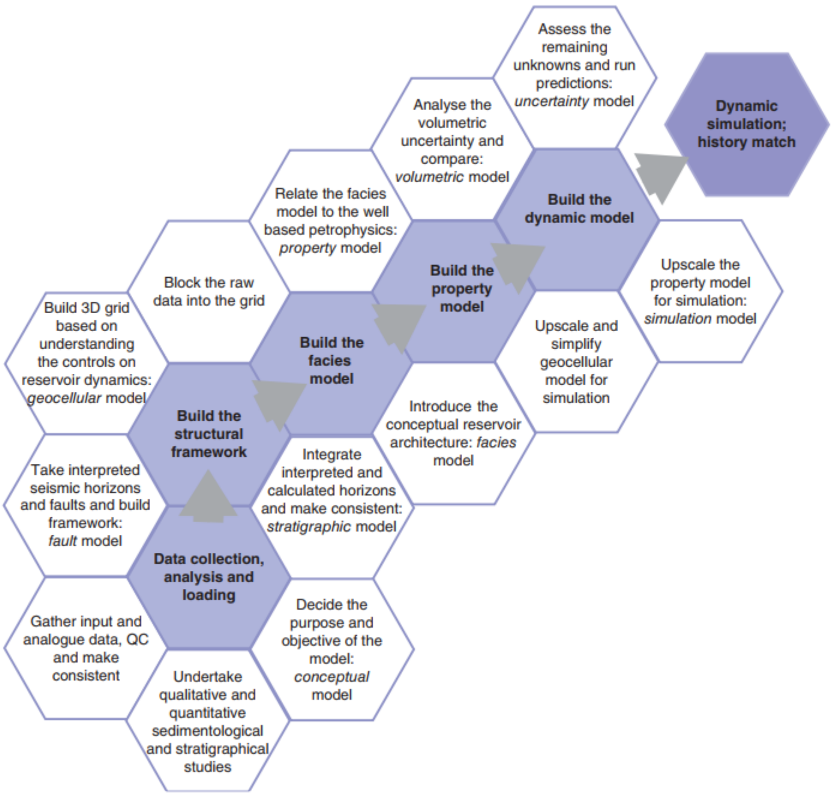

Figura 2. Reservoir modelling steps (Cannon, 2018)

To optimize workforce efficiency and improve project accuracy, an integrated plugin design was proposed to bridge two commercial expert systems: PETREL® and FLOCO®. The plugin is expected to create an interface to facilitate data exchange mainly related to reservoir parameters and production curves required for economic evaluation.

2. METHODOLOGY

The work was divided into: Reservoir modeling in the PETREL® software, calculate the Vertical Flow Performance (VFP) curves to represent the pressure loss along the flow through the subsea pipeline, development of a UML for managing the software creation process, and support for the development team to verify the accuracy of the transferred data and the financial indicators calculated by the concept optimization software, FLOCO®.

2.1 Reservoir modeling

The project begins with the modeling of a reservoir to be selected as a case study. For this purpose, the UNISIM I model, developed by CEPETRO-UNICAMP, was chosen as the reference reservoir. Defining the exploitation strategy of an oil reservoir requires understanding the fluid movement dynamics in the porous medium, considering critical geological heterogeneities and the viscous, capillary, electrical, and gravitational phenomena that influence fluid flow within the reservoir (Machado, 2023). This process necessitates collaboration between geophysicists, geologists, and reservoir engineers, aiming to represent the field as accurately as possible by creating static and dynamic models.

According to (Baker *et al.*, 2015), understanding a reservoir model requires considering the fluid type (bitumen, heavy oil, conventional oil, volatile oil, retrograde condensate, gas), reservoir architecture (size and structure; petrophysical properties), drive mechanism (expansion, solution gas, gas cap, water), and fluid characterization. Once these factors are determined, dynamic simulation can be conducted to estimate field production. However, constructing a dynamic model first requires static model development. One of the primary objectives of reservoir modeling is to describe the complexity and heterogeneity of the reservoir. In reservoir studies, the only recorded data typically available, apart from well positions, are seismic amplitudes. However, seismic data do not directly provide reservoir property measurements (Grana *et al.*, 2013), requiring additional tests and probabilistic calculations to determine these properties. This model will include information related to lithology, porosity, saturation, thickness, and permeability of the reservoir (Soleimani and Jodeiri Shokri, 2015).

Modern reservoir simulators are computer programs designed to model fluid flow in porous media. Applied reservoir simulation refers to using these programs to solve reservoir flow problems. Flow modeling operates within the context of reservoir management functions (Fanchi, 2005). Oil reservoir simulation is essential for calculating the probability of hydrocarbon presence in a given region and estimating its economic feasibility. Once the reservoir is modeled and the production flow simulation is performed in PETREL®, the data is read by the plugin and transferred to FLOCO® for concept calculations and financial parameter estimation.

2.2 Vertical flow Performance (VFP)

Vertical Flow Performance (VFP) analysis is a crucial methodology in petroleum engineering used to understand and optimize the flow of fluids from the reservoir to the surface. VFP curves represent the relationship between pressure drop in the well and the flow rate of produced fluids. Essentially, they describe how efficiently the reservoir's natural energy or artificial lift mechanisms can transport fluids to the surface (Saeten, 2015). In oil and gas wells, hydrostatic pressure is typically the dominant component—especially in multiphase flows, where the fluid mixture density varies along the wellbore. Frictional pressure loss occurs due to the resistance between the fluid and the pipe wall, as well as interactions between the different fluid phases (gas, oil, and water). Acceleration pressure loss is usually negligible, except in wells with high gas flow rates or in pipe segments with significant changes in diameter. Figure 3 represents the VFP curve and the main losses.

The pressure drop required to lift the reservoir fluid from the bottomhole through the tubing can be written as:

$$\Delta p^{\text{pipeline}} \simeq \Delta p_{PE} + \Delta p_{KE} + \Delta p_F \tag{1}$$

where Δp_{PE} is the loss due to change in potential energy, Δp_{KE} is the loss due to change in kinetic energy (often ignored), and Δp_F is the loss due to friction.

In this context, the Beggs & Brill correlation (Beggs and Brill, 1973) remains one of the most widely adopted methods for modeling pressure drop in pipelines and tubing under steady-state, multiphase flow conditions. When applied to VFP curve generation, the Beggs & Brill correlation enables the computation of bottomhole pressure (BHP) as a function of surface pressure (THP), flow rate, and gas-liquid ratio (GLR) for a given tubing configuration. By discretizing the wellbore into segments and solving the pressure gradient iteratively along the vertical or inclined profile, it becomes possible to generate a table that describes the well's hydraulic behavior over a range of operating conditions.

In this work, the VFP curves were calculated using the Beggs & Brill method as implemented in a dedicated microser-

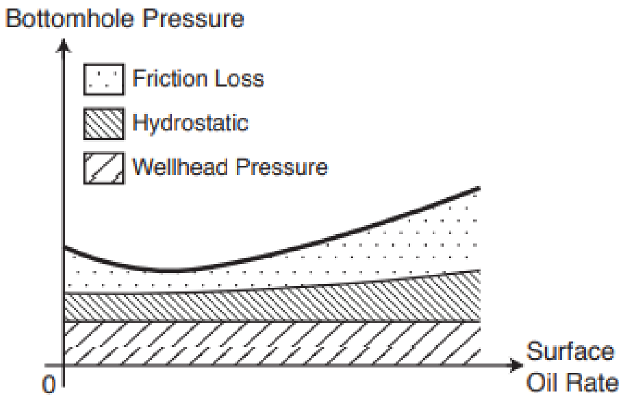

Figura 3. Illustration of the VFP curve for two-phase flow (Saeten, 2015)

vice, which receives well geometry, fluid properties, and operating parameters extracted from the Petrel reservoir model. The resulting VFP tables are then reintegrated into the simulation environment to improve the accuracy of production forecasting, particularly by incorporating pressure losses along the entire subsea system, from the reservoir to the topside facility.

2.3 UML specification

UML (Unified Modeling Language) is a visual language used to model software based on the object-oriented paradigm. It is a general-purpose modeling language that can be applied across all application domains (Guedes, 2018). Its diagrams allow the representation of critical parameters in software modeling capable of calculating flow rate and pressure in dynamic models. For this purpose, class and activity diagrams, as well as use cases, are utilized. A class diagram defines the structure of the plugin with parameterized attributes, such as tolerance and operational limits. Behavioral diagrams map decision flows to mitigate risks, such as pressure loss in the pipeline.

In use case modeling, the functional requirements of the system are defined in terms of use cases and actors. Static modeling provides a structural view of the system. Classes are defined in terms of their attributes, as well as their relationships with other classes. Dynamic modeling provides a behavioral view of the system. The use cases are realized to show the interaction among participating objects. Object interaction diagrams are developed to show how objects communicate with each other to realize the use case (Gomaa, 2011).

In software development projects, UML supports the design phase by formalizing technical requirements and functionality criteria. This ensures that parameters are validated during processing and that all steps are mapped for future maintenance.

2.4 Economic analyses

Economic models are used to evaluate production strategy schemes and are designed to simulate the development and operation of real projects. To estimate annual revenue, some of the following parameters are required: CAPEX, OPEX, weighted average cost of capital (WACC), oil revenue, gas revenue, water disposal cost, gross revenue, net revenue, royalty rate, and production taxes. If the project's primary decision parameter is the Net Present Value (NPV), then the simulation with the highest positive NPV is considered economically viable and should be executed. NPV represents the project's discounted cash flow based on the given discount rate, as shown in Eq. (2). The pay-out (investment return period) is also useful in determining the expected number of years required to recover the initial investments—therefore, the shorter, the better (Onwukwe, 2019).

$$NPV = \sum_{i=0}^{t} \frac{\text{Cash Flow} - \text{OPEX}}{(1 + \text{WACC})^i} - \text{CAPEX} \tag{2}$$

Based on the generated concepts, FLOCO® calculates each financial indicator of the project and provides a financial report at the end of the process, allowing the best project to be selected according to the company's assumptions.

2.5 Plugin development

Modern scientific modeling software often needs to handle large amounts of data from different sources. A typical example is flow or process simulators, where phenomena at different time and space scales must be connected, and data must be exchanged. If relevant sub-models or experimental data are available, it would be highly efficient to connect such models or data and have them accessible within a simulator with minimal effort. The interoperability between two or more scientific simulators involves taking input from one simulation tool, producing output, and transforming the data into a suitable format that can be read and interpreted by the second simulator. Data is often stored on disk, but it can also be exchanged directly between two simulations running simultaneously via RPC, MPI, and others (Hagelien *et al.*, 2017).

A software life cycle is a phased approach to developing software, with specific deliverables and milestones within each phase (Gomaa, 2011). To integrate the two software applications, a user interface was proposed, allowing the user to run a reservoir simulation, add additional information in a custom tab within the plugin, and then proceed with financial analysis and concept generation. The information is collected within PETREL® and processed by the plugin. The collected data is then processed and used for economic simulation and concept optimization.

3. RESULTS

Figure 4 presents the UML diagram designed for the project, illustrating two possible user workflows: running the simulation entirely within Petrel, or using the Petrel-based simulation to gain more autonomy in FLOCO for adjusting project parameters. Figure 5 shows one of the interface screens that handles the integration of Petrel data with user-defined inputs.

The development of the plugin eliminated redundant manual processes, reducing data entry time and enhancing the efficiency of using FLOCO® as a decision-making system. Before the plugin, the two software operated independently, requiring manual data exports and imports. Now, communication is more seamless and direct, ensuring greater reliability of the information. Previously, two separate users were needed to exchange data between the tools, but now a single user can manage the entire simulation process. The use of UML for the plugin's modular architecture enables scalability for new software versions, updates, and ease of maintenance.

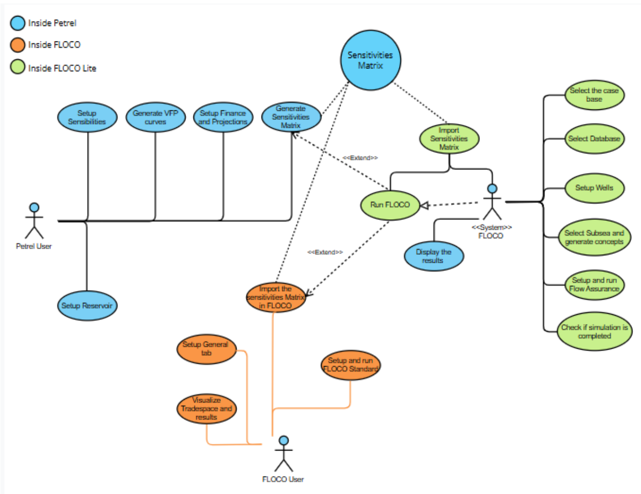

Figura 4. UML development (Author)

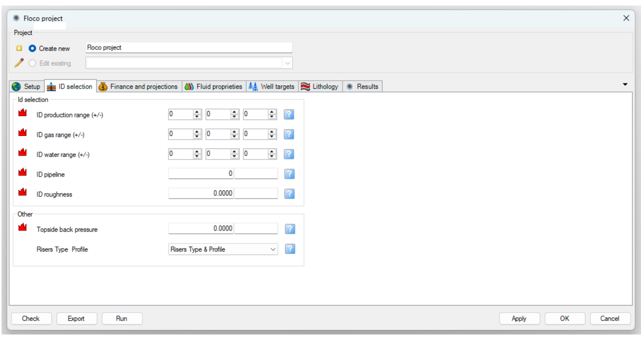

Figura 5. Plugin screen (Author)

4. CONCLUSION

The integration of two powerful software solutions enabled the best functionalities of each to be combined, creating a comprehensive decision-making tool. The plugin represents a significant advancement for economic analysis within reservoir teams, granting them greater autonomy in selecting optimal oil and gas exploration and production scenarios. Additionally, with this integration, the reservoir calibration process in FLOCO® achieves higher accuracy, as it now utilizes production data calculated directly by PETREL®.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Baker, R.O., Yarranton, H.W. and Jensen, J., 2015. *Practical reservoir engineering and characterization*. Gulf Professional Publishing.

Beggs, D.H. and Brill, J.P., 1973. "A study of two-phase flow in inclined pipes". *Journal of Petroleum technology*, Vol. 25, No. 05, pp. 607–617.

Cannon, S., 2018. *Reservoir modelling: A practical guide*. John Wiley & Sons.

Chakrabarti, S., 2005. *Handbook of Offshore Engineering (2-volume set)*. Elsevier.

Fanchi, J.R., 2005. *Principles of applied reservoir simulation*. Elsevier.

Gomaa, H., 2011. *Software modeling and design: UML, use cases, patterns, and software architectures*. Cambridge University Press.

Grana, D., Paparozzi, E., Mancini, S. and Tarchiani, C., 2013. "Seismic driven probabilistic classification of reservoir facies for static reservoir modelling: a case history in the barents sea". *Geophysical prospecting*, Vol. 61, No. 3, pp. 613–629.

Guedes, G.T., 2018. *UML 2-Uma abordagem prática*. Novatec Editora.

Hagelien, T.F., Chesnokov, A., Johansen, S.T., Meese, E.A. and Løvfall, B.T., 2017. "Soft: a framework for semantic interoperability of scientific software". In *Proceedings of the 12th International Conference on Computational Fluid Dynamics in the Oil & Gas, Metallurgical and Process Industries*. SINTEF Academic Press.

Machado, M., 2023. *Modelagem numérica de reservatórios de petróleo: Prática integrada de simulação*. ISBN 9786588763070.

Neal, M., 2024. "10 trends shaping the future of front-end loading (fel)". URL `https://www.stratexonline.com/blog/future-of-front-end-loading/`. Acceso em 17/04/2025.

Onwukwe, S.I., 2019. "Economic analysis of oil rim reservoir development in the niger delta". *J. Adv. Res. Pet. Technol. Manag*, Vol. 4, No. 3, pp. 13–19.

Saeten, S., 2015. *Production Allocation of Oil and Gas: A case Study of the Skarv Field*. Master's thesis, NTNU.

Soleimani, M. and Jodeiri Shokri, B., 2015. "3d static reservoir modeling by geostatistical techniques used for reservoir characterization and data integration". *Environmental Earth Sciences*, Vol. 74, pp. 1403–1414.

Van der Weijde, G., 2008. "Front end loading in the oil and gas industry". *Unpublished master's thesis). Delft University of Technology, Netherlands*.

7. RESPONSIBILITY FOR INFORMATION

The authors are solely responsible for the information included in this work.