Abstract
Growing global energy demand and rising price of oil favors the reactivation of oil and gas fields once considered economically marginal and have been deactivated. The reactivation of these known fields, commonly referred to as mature fields, brings a number of uncertainties with regard to production and, consequently, its management efficiently and profitably. This paper aims to propose a hybrid system that assists operations management in the production of oil and gas. From the identification of relevant variables for the operational management, it is proposed a system that uses the concept of a set of techniques (Real Options, Utility Theory, Fuzzy Logic and Decision Tree). In summary, we propose a system that extends from the choice to acquire a production area by conducting sensitivity analysis and projection of production.

Keywords: Oil & Gas exploration; industrial management systems; small and medium enterprises

Introduction
The inherent complexity of the production system in the supply chain of oil and natural gas and their derivatives must be well managed. Investments in the development of an oil field to increase production and sustainability, as well as investments in surface facilities are increasing. According to Babadagli (2007) the cost of the projects oil production always increase, while revenue from the additional oil recovery decreases as age advances the field.
In oil fields that have been producing for a long time, it is quite critical, since it is assumed that the point of economic infeasibility of the operation is not far away. Some obstacles in production management are discussed in the literature, such as the retention and transmission of knowledge between the productive areas of the field (Yero and Moroney, 2010), the absence of a global view and at the same time, integrated field (Rahmawati et al., 2012) and greater detailing and projected costs (Boschee, 2012). The solution to these barriers will allow better management of operations, assets, facilities and wells.

A computer system that allows a more comprehensive and integrated view of the oil field enables an approach that goes beyond individual analyzes of subsystems in an oil field. The use of computational techniques and decision optimizes data analysis of each stage of the production process. Mature fields and areas with economically marginal oil accumulations have been defined in various ways (Terzian, 1995; Pauzi, 1999; Schiozer, 2002). In this paper we use the definition for such areas proposed by Hall (2004). He considers a mature field the one that has produced 40% of the recoverable volume of oil expected. In this paper, we use the term Also “marginal areas” or “fringe field” which is inactive areas were previously exploited by Petrobras or have low productivity and are only economically feasible when methods, techniques or incentives are applied to reduce production costs. It should be noted that not every field is a mature and marginal field, and not all marginal fields are mature fields. However, the current state of exploration and bidding in Brazil combines these two concepts.

This paper proposes a system that aims to support the decision on the purchase of a new area of exploration, defining mechanisms for production wells and monitoring of interventions. Will enable a proper analysis of costs and support integrated decisions, covering the most important aspects of operations in oil fields: logistics, industrial facilities, supply of raw material (the reservoir) and suppliers, taking into account environmental issues and safety.

**Reactivation of economically marginal deposits**

In general, the life cycle of projects of exploration and production of oil fields is expected to last 20 to 30 years. Divided into two major exploratory and production stages, the management of these projects requires careful study of costs and profitability.

The exploration phase includes drilling one or more wells in the contracted area; implementation of appraisal wells of extracted material and obtain provisional licenses. The study of sedimentary basin through coring and generation models and projections of reservoir operations are performed at this stage.

The next step is initiated with production planning and preparation of project production. This step includes the development of the field, start of production and operation. The detailed study of the technical and economic feasibility study will allow the development of the field in a controlled and cost effective manner. The finding of declining production foster investment in new methods of exploitation or even declare economic marginality.

Economically marginal production is characterized by high operational costs, increasing investments in infrastructure and demobilization revenues. These characteristics turn the exploration of these wells not sufficient to pay the costs (Jacinto, 2009).

When a production area can be disabled by being economically marginal at any given time due to the price of oil; lack of investment in new methods of oil extraction or corporate investment strategy, the area is returned to the state so that it can bid for another company.
interested. In case of a reactivation of production, existing data from previous production allows for studies of profitability of the field as a whole.

The reactivation of production in areas considered economically marginal is already a reality in countries like the U.S. and Canada. The United States and Canada are countries with marginal activities on shore and can serve as an example in the process of reactivating areas with marginal deposits in Brazil through small and medium businesses. In these countries, small and medium-sized companies (called independent) are responsible for much of the production and job creation in the sector of fields producing fewer than 15 barrels per day (b/d). In Canada, the presence of independent companies in the oil industry is also important for the dynamics of the productive sector.

In 2011, the U.S. began production in fields of 362,734 to 370,315 (b/d) in marginal wells. These wells represent 71.3% of American oil wells (IPAA, 2012). After encouraging production in mature fields, Canada reached third place in natural gas production and sixth in production of crude oil in 2012, according to The Canadian Association of Petroleum Producers' (CAPP, 2013). These data motivate the study of the Brazilian scenario considering that there are many fields and areas considered economically marginal for the production of oil and gas.

**The acquisition process of areas for reactivation**

The acquisition process for reactivation of marginal areas with accumulation described below is the result of compiling all the information from tenders and contracts of the two bidding areas with economically marginal accumulations occurring in Brazil.

The process begins when the ANP (National Petroleum Agency) conducts the survey of areas with marginal accumulations available for the preparation of the bill containing the dates and provisions of the auction. Notification is finalized with the publication of this bill in newspapers, magazines, and websites, besides conducting seminars in different locations to promote the participation of undertakings concerned occurs.

With deadlines, provisions and established dates, small and medium enterprises seek to qualify to participate in the auction. The qualification stage involves the expression of interest to participate in the auction, payment of participation fees and framing company in four aspects: Technical Qualification; Legal Qualification; Financial Qualification and; Tax Qualification.

Every aspect mentioned above includes a number of documents to be issued by the company and public administration bodies, proving the structure of the company under the conditions laid down in the bill. The company may only participate in the auction to ensure the framework in four aspects.

The fee for participation allows the company that expressed interest, access to geological, geochemical and geophysical data about the areas that are being offered. From these data, it is necessary to draw up a document containing the main activities to be performed in case of trimming the area that the company is running. This document is called the Initial Work Program and will be subject to review in the auction, with a note attached to it. For each activity contained in PTI, a financial guarantee is established by identifying the value of planned investment.

The signing of the concession agreement between the company or consortium winner and ANP occurs at the moment it holds the payment of the signing bonus, which was contained in the submitted proposal and presentation of a statement of financial security for the PTI.

With the signing of the contract, the company has two core activities in the period of 2 years: (1) environmental licensing, and (2) sending the ANP ratio of wells that will be part of the
Project for Rehabilitation of Reservoir, document issued in case of be declared commercial area in this 2-year period.

For the environmental licensing of oil producing areas, the law may vary by area location. For example, in the Reconcavo Basin, located in the state of Bahia and where there are a considerable number of mature fields, identifying the depth of existing wells in the field is required.

For areas with wells that require operating license before requesting the issuance of permits for the location (approving the location and design of field activities) and implementation licenses (approving the installation of production facilities) will be required. Completing this step takes about one year (Machado, 2009).

In the phase of environmental licensing, the company may invest resources exclusively for the activities described in PTI. This does not mean that the company cannot operate under its concession area in search of new reserves. The technical and economic feasibility for the reactivation of area studies should be conducted within a maximum period of two years from the signing of the concession contract. This is the final decision to declare commerciality and invest in the production of mature field, or declare abandonment of the area and consequently bear the loss of the capital paid up to date.

With the decision to continue exploring and extracting oil, the company issues a declaration of commerciality to ANP. Upon submission of this statement, the company has 180 days to submit the Project for Rehabilitation of Quarry, containing not only the relationship of wells previously sent, but all the planning for the productive cycle of the area. The ANP will evaluate the project and the dealer will start operations in the production stage, and supervised by the Regulatory Agency.

The stage production has a maximum duration of 15 years stipulated in the contract. However, the utility company may decide to return the area before the completion of this period, when economic sensitivity studies indicate the business economic infeasibility of continuing production. Occurring return area, the ANP shall review the same and finalize the grant process.

Any environmental damage occurring in the area during the contracted period is the responsibility of the company. Thus, conducting environmental assessment is paramount periodically to prevent damage to the environment, fines generation and environmental liabilities.

SOMORe
After learning in detail how a mature field containing marginal accumulations of oil and gas is acquired, we can identify aspects that are related to the whole process: Contractual aspects; Technical aspects; Economic aspects; Environmental aspects.

These aspects influence decision-making related to the field, starting from the participation in the auction until the period that the area is returned to the ANP. To facilitate the understanding of the different types of variables and relate them to Fuzzy logic was used. Besides the conventional logic (Boolean, binary or clear), where a given statement is either true or false, there is a set which is an extension of this: the fuzzy set, also known as Fuzzy.

The use of adjectives to associate specifications, such as full, empty, middle, shows the need for assessment that is not necessarily an exact value or, an affirmation, at a given moment, to be false from a particular point of view, while true from another viewpoint. Thus, the fuzzy set values to a crisp together determine the possible outcomes (0 and 1), represent the limit of
accuracy, assuming the existence of others in this range. However, fuzzy logic is not a bias of mathematical logic or a new theory of data sets. It is a form of representation or evaluation of information and various areas use to optimize the results (Lashgari, 1991; Adebowale et al, 2008; Guo et al, 2009; Anifowose and Abdurahim, 2011; Masoudi, 2012; Singha, 2013).

A linguistic variable can take multiple values or adjectives representing cloudy or fuzzy set on the variable. Example: a variable depth of drilling has P linguistic terms [shallow, deep, ultra deep]. These terms are a set solution to the variable P. The sets are associated with membership functions, which is the ability to be a great answer. The membership function has the following representation:

$$\mu_\text{(TO)}: y \rightarrow \{0,1\}$$

where: $$\mu_\text{(TO)} = \text{degree of membership of any value } y \in Y;$$

The values of relevance $$\mu_\text{(TO)}$$ can be in any specified interval. In the decision making process reactivation of areas, some variables that will be modeled using Fuzzy are:

- Recoverable oil volume (V);
- Selling price of a barrel (Pb);
- Licensing (Li);
- Tax (I);
- Risk of Exploitation of new wells in the area (Re).

Until the completion of the work, more variables will be cataloged and modeled following the specified topic in this principle.

**Real options**

Several studies in the area of addressing energy price fluctuations and market instability indicate that these factors adversely affect investment and, consequently, production. Several theoretical models of investments that have been published dealing with uncertainties, example given: Brennan and Schwartz (1985); Majd Pindyck (1987); Brennan (1990) and Bredin; Elder and Fountas (2011). The price difference has attracted considerable interest in the literature Kogan, Livdan and Yaron (2009); Wang, Wu and Yang (2008); and Chang Wang and Daouk (2009).

Black and Scholes (1973) uses the technique of financial options under uncertainty and is cited as one of the precursors in this mode. Real Options may cover multiple decisions within the productive industrial scenario: hiring, training and firing of labor and expenses for short-term materials and machines that are not fully recoverable (Dixit, 1994).

The real options approach can bring flexibility and strategic value for the evaluation of investments in the oil (Fan and Zhu, 2010; Detert, 2013; Reniers *et al*, 2011).

According to Antikarov and Copeland (2002), the main options to reactivation in marginal areas, are:

- Abandonment Options: The option to terminate the operation by closing the production wells and declaring abandonment to ANP;
- Contraction Option: This option would cover only the activities listed in the implementation of ITP;
- Expansion Option: In this option, we consider the application of investment in exploration, evaluation and drilling new wells within the bid area;
- Conversion Option: cover investment applied to types of operations. For areas with marginal accumulations, this option would encompass changes in recovery methods;
- Deferral Option: This option applies after the declaration of commerciality, when, for lower prices per barrel, decides the closing of producing wells and freezing activities until
they have favorable conditions for reopening. Making a historical review, this option is less likely today;
- Option Composed: include options resulting from successive phases of the project. For each milestone, and options are taken depend on the previous. This example applies to the process of rehabilitation of areas with marginal accumulations as a whole;
- Composed Option Type Rainbow: is similar to the previous option. But in this case, each option has many uncertainties and hence the resulting combinations of these options are uncertainties.

In this work, the scenarios in which the system will be tested cover all options mentioned above. In general, however, the compound option that is closest to the reactivation process as a whole. How the Theory of Real Options already has representation similar to a tree, in this work form, combines the two theories for decision making.

**Decision tree**

Having at least two possible ways to go is the reality in environments with uncertainties such as oil and gas. The decision tree is a tree structure consisting of internal and external nodes connected by branches. Each internal node is associated with a decision function to determine the next node. The last we are considered terminal or sheet and indicate a departure (CHO and Kurup, 2011).

Some studies use decision trees in various kinds of application and examples show applicability to the research context (Quinlan, 1986, 1987, 1993). An example in oil and gas is the work of Martinellia (2013), which aims to develop a strategy for optimal selection of wells, which incorporates a utility function chosen within a dynamic programming scheme and a decision problem for drilling reservoir (Martinellia et al., 2013).

From the use of Real Options and the business process model, the decision tree will be developed. With the complete decision tree, reactivation activities that allow a qualitative evaluation of the decision by the utility theory to be presented the following process will be verified.

**Utility Theory**

A utility function is constructed by assigning a value to each possible outcome, identifying the best possible outcome and the least preferable. The achievement of intermediate values enables the construction of the curve of the utility function. The utility function can be chosen from the following (SON and Suslick, 2000):
- Linear: $U(x) = cx$
- Exponential: $U(x) = e^{-cx}$
- Logarithmic: $U(x) = \ln(x + c)$, $c > 0$, $x > -c$
- Square root: $U(x) = \sqrt{x + c}$, $c > 0$, $x > -c$

where:
- $x$ = monetary value of the variable;
- $c$ = coefficient of risk aversion = 1/risk tolerance;

The exponential formula applies best to oil exploration, according to Wall (1994). Thus, utility theory allows evaluating complex alternatives. The concept of utility structure array with the decision alternatives attributes and weight. The latter (weight) will reveal the position of the
decision maker or the trend according to the criteria used. Attributes may be quantified through the use of various scales (TORGERSON, 1985):

- Verbal or nominal: uses terms for classification, used in exclusive options;
- Cardinality: when a scale is established and for each option is necessary to associate a value;
- Ordinal: generates a set of possible positions;
- Range: the distance between the values direct the decision maker at your option;
- Scale of reasons: when a ratio is related to a value indication;
- Multidimensional: combination of two or more stops.

During this work, in order to relate the variables, more than one scale will be used.

**Representation of the flow system**
The SOMORE was therefore divided into 5 modules: licensing, environmental, evaluation and exploration, production and projection of return. Each module brings the integration of the techniques presented. Also available are 3 additional areas for reporting of registered transactions of funds allocated for operations, joined the variables and system parameters, such as the dollar, oil prices setting investment ceiling for design exploration and production. The following figure with the main screen.

The module list and licensing deals with issues that include the steps of qualification and the company needs to fulfill to participate in the auction of economically marginal areas with accumulations.

The module will deal with environmental variables and possible paths for environmental licensing. Are various licenses and licensing process requires much of the period established for the declaration of commerciality.

In the area called “Exploration and Evaluation” of areas with marginal accumulations will be granted to the company raised the variables of technical and operational order. These variables will populate the database so that the “Projected Production” module, the relationship
between the projected costs, strategies and development, from north to serve the project execution and monitoring withheld. Managers can project the demand for supply of materials, equipment and interventions in the wells. In the final module, “Return”, are compiled data on the packing of wells, calculation of environmental liabilities and infrastructure that will be returned to the ANP.

When completed the postings in each module, it changes color, becoming blue. In the figure above, Licenses and Environment modules has been released, while the modules in fill or no data are available in gray, indicating the progress of releases of data operations.

Conclusions
Companies need all the information (external and internal) for good decision making regarding investments in their production. The use of computational systems for planning, operations management and decision support is a strategic issue. Investments in exploration and production of oil and gas are very high. A wrong decision can lead a company into bankruptcy.

 Reactivation of mature oil producing areas is becoming a way to meet the growing energy demand and develop technologies, human resources and production strategies. However, SMEs have limited resources for investment. The right to explore or return a hydrocarbon producing area of the state decision requires a grouping of information in different areas of production: technical, fiscal, economic and environmental aspects.

Computational systems to reactivate producing areas of oil and gas need to be specific. Meet specific requirements applicable to areas that have low production. The cost of production is high and revenues must meet the disbursements made by companies. Often, new recovery methods need to be deployed during the production cycle to ensure the profitability of operations.

The SOMORE aims to structure the managerial and operational information allowing based on tangible and projections that reflect the reality of production decisions. This information will allow a competitive edge over competitors and give support to decision making faster and more consistently. The quality of information and how it is established, the application of decision techniques and correct treatment of the variables that influence the decision are observed in the proposed system.

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