SPE 121837

An Innovative Tool on a Probabilistic Approach related to the Well Construction Costs and Times Estimation

A. Merlo, Eni-E&P Div., P. D'Alesio, SPE, ProEnergy, T. Loberg, SPE, IRIS, O. Arild, SPE, IRIS

This paper was prepared for presentation at the 2009 SPE EUROPEC/EAGE Annual Conference and Exhibition held in Amsterdam, The Netherlands, 8–11 June 2009.

Abstract

When planning oil and gas wells, the cost and duration uncertainty, related to the well construction process, could be a big concern.

Traditionally, Drilling Engineers, in different geographical areas, have utilized different estimation methods with a consequent difficulty of communication. This tool could represent a common platform on the well construction cost and duration estimation.

In recent years probabilistic well cost estimates have become a requirement as part of the internal procedures of the E&P Companies, e.g. when applying for an Authorization for Expenditure (AFE) approval.

This paper describes the tool and methodology which have been developed upon request by Eni E&P to introduce and strengthen the application of probabilistic well construction cost and duration estimation within the drilling department. The tool offers decision support for well and operation planning and has the potential to make the cost and duration uncertainty analysis an integrated activity of the well planning process.

The software is characterized by a user friendly interface and is tailored to Drilling Engineers' needs, to easily and effectively perform the probabilistic risk analysis and to systematize the corresponding workflow.

It also facilitates both internal and external communication, since it has the potential to be used as a standard tool.

In conclusion, the developed tool allows Drilling Engineers to:

- perform a quantitative risk analysis;
- calculate risked cost and duration;
- identify operations which mostly affect drilling uncertainties;
- evaluate and select alternative technical solutions;
- prepare prevention and mitigation plans for the reduction of both duration and cost.

Introduction

The Oil & Gas Industry is currently facing a mounting pressure to reduce well construction costs. One of the most effective ways of achieving such objective is to reduce the associated uncertainties, i.e. to produce consistent cost and duration estimates during the planning phase of activities.

Traditionally, well cost and duration estimates have been obtained through a deterministic approach; they have relied, to a large extent, only on historical data, i.e. "single values" whose effect has often been to distract the Drilling Engineer from the actual risks which could be likely encountered in the project under evaluation. In addition to the cost and duration related to the operations "as planned", in fact, undesirable events may occur and cause time delays and extra costs.

Such traditional method surely provides quick results, which are easy to communicate; unfortunately, for what said above, this approach does not reflect the inherent uncertainties of well construction operations. Just looking at the historical project cost estimates, the trend has often been to get too optimistic values, as a consequence of ignoring the occurrence of possible undesired events, each having a different/specific probability and impact on the project under evaluation. The result has been an inevitable disappointment on the actual performance of the projects selected on the basis of forecasts which do not manage uncertainties in a probabilistic way, refer to [Chen & Dyer, 2007].

In order to strengthen the basis for decision-making in the well planning phase, a proper well construction cost and duration analysis tool should be able to:

- systematise all the available information;
- quantify well construction cost and duration;
- compare different solutions for construction of a well;
- create nuanced cost and duration pictures based on well-specific input parameter values;
- pinpoint the most critical operations affecting well construction cost and duration uncertainties;
- reflect the implementation of cost and duration reducing measures.

This paper describes the results of a research project, whose aim has been to develop a suitable model and software for the analysis of well construction cost and duration uncertainties. As a result of the project work, an analysis tool has been developed by IRIS (International Research Institute of Stavanger) with a heavy involvement and funding by Eni E&P and support by ProEnergy. Such analysis tool offers a very useful decision support for well construction planning, and has the potential to make the analysis of cost and duration uncertainties an integral activity of the well planning process; consequently it has the potential to contribute to reduce well construction cost and duration.

Probabilistic methodology

Due to well-to-well and field-to-field variations, the well construction should be interpreted as a unique process. A risk analysis based on well-specific construction cost and duration estimates is therefore essential.

The developed software is a user-friendly tool which provides the user with means to analyze the uncertainties associated with well construction cost and duration. The results coming from the tool study provide essential information for the planning phase, as well as assist decision-makers in identifying cost and duration reducing measures. The software can be used as a standard tool for calculation of well construction cost and duration.

A probabilistic approach for the estimation of well cost and duration is used, to reflect the fact that the cost and duration of the various activities in well construction are uncertain, and thus that the final well cost and duration are uncertain and cannot be expressed with a single value.

Based on a fixed Operation Plan, an analysis using the software tool allows the Drilling Engineer to include potential undesirable events and obtain probability distributions for the well construction cost and duration. Due to the large uncertainties involved at the stage when this analysis is performed, a stochastic modelling approach is used by the tool (Monte Carlo simulations, refer to [Ripley, 1987]). This is combined with an adequate model for the Operation Plan build-up. Input to the model is based on expert contribution from different disciplines.

Following are the main benefits coming from the application of this methodology:

- More effective work processes, through:
  - systematized expert input;
  - “easy to do” in-house calculations;
  - automatically generated reports
- Improved internal and external communications:
  - field-to-field comparisons;
  - communication in a license setting;
  - easy communication to decision-makers
- Effective support to technical decisions:
  - risk management in a cost perspective;
  - reduced well construction cost and duration.

Model structure

The model structure of the software is organised to execute the following steps:

- Development of the Operation Plan
- Analysis of costs and durations associated with the planned operations
- Connection of possible undesirable events to the Operation Plan, in order to obtain the Risk Operation Plan
- Modelling of sensitivity related to both cost/duration contributions and uncertainties
- Identification of suitable preventive measures (alternatives to the base case)
- Definition of the most appropriate alternative

Figure 1 shows the tool model structure, i.e. the general existing connection between the Operation Plan and the Risk Operation Plan, through the addition of undesirable events to the planned operations.

In more detail, a case study can contain several wells; each well can then have several design alternatives, consisting of:

- Architecture description;
- Operation Plan (not including undesirable events);

- Risk Operation Plan (including undesirable events);
- Simulation results.

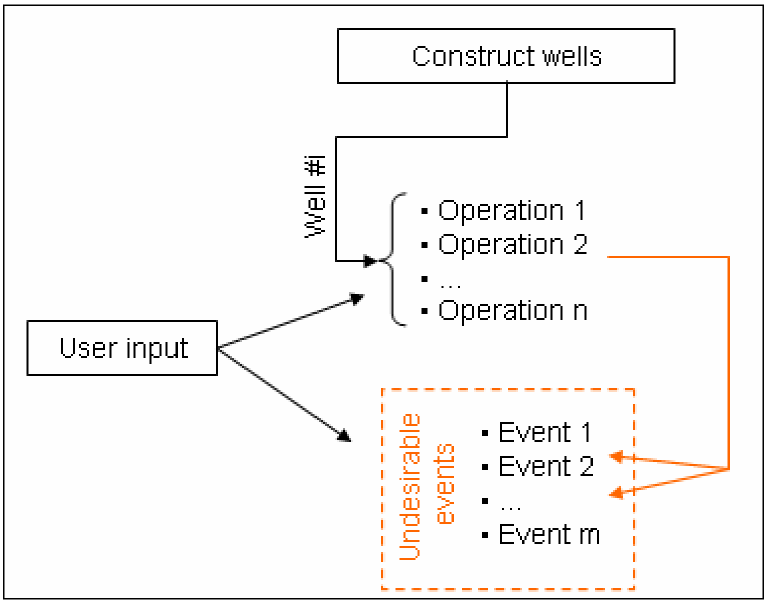

Figure 1 The tool model structure

The well construction process can be defined as a set of chronologically ordered phases:

- Mobilization of rig
- Spudding
- Placement of BOP
- Drilling of hole sections
- Abandonment.

Each phase includes several operations, which are automatically generated by the software; the resulting Operation Plan can then be edited by the user by adding/removing operations.

Duration- and cost-related information for each operation are combined by the software in order to simulate the cost and duration picture for the whole well construction process. This modelling allows all the available deterministic data and the associated uncertainties, to be expressed at an appropriately detailed system level.

In other words, the well construction process is divided into several operations, whose cost and duration are expressed in terms of probability distributions. The probabilistic total cost and duration will be obtained as the sum of the costs and durations of the single operations, refer to [Aven, 2003]. This is mathematically described in equations (1) and (2) below:

$$C = C_1 + C_2 + \ldots + C_n \quad (1)$$

where C is the total well construction cost, $C_1, C_2, \ldots, C_n$ are the costs of operation 1,2, …, n respectively.

$$D = D_1 + D_2 + \ldots + D_n \quad (2)$$

where D is the total well construction duration, $D_1, D_2, \ldots, D_n$ are the durations of operations 1,2, …, n respectively.

For each operation, a set of undesirable events can occur. The extra cost and duration of possible undesirable events are added in the same manner as in equations (1) and (2).

The results are provided in terms of both expected (most probable) values and the associated uncertainties (probability distribution). This allows the identification of the most critical operations/undesirable events, which can be optimized/avoided or reduced by using appropriate preventive measures for both operational and contractual aspects.

Assessment of input data is a crucial and considerable part of the tool analysis process. Some input may be supported by relevant documentation related to the drilling operation, e.g. the drilling program. However several parameters, especially the probability values and distributions, are assigned based on subjective considerations in combination with the available hystorical data.

Subjective probability assessment is a difficult task, which requires consistency in several sub activities:

- Correct parameter interpretation
- Thorough consideration of all the available information
- Quantification of the performed assessment, i.e. the uncertainty related to the chosen parameter values.

Preliminary work meetings, involving experts from various disciplines, are important to stimulate constructive discussions and ensure that relevant conclusions are consistently taken into consideration.

After assessing the input parameters required for well construction evaluation, the tool analysis is performed. The results provided by the well specific analysis are listed below:

- **Mean duration and cost vs. drill depth**. Curves representing the mean duration and cost, obtained analytically from the input distributions vs. the deterministic drill depth.
- **Drill depth vs. time curves.** The 5-, 10-, 20-, 25-, 30-, 40-, 50-, 60-, 70-, 75-, 80-, 90- and 100-precentile plots for drill depth vs. time.
- **Well construction duration.** The probability distribution for the total well construction duration is given using a histogram, also providing the minimum and maximum values, mean, standard deviation, 10-, 50- and 90-percentiles and the CDF curve.
- **Well construction cost.** The probability distribution for the total well construction cost is given using a histogram, also providing the minimum and maximum values, mean, standard deviation, 10-, 50- and 90-percentiles and the CDF curve.
- **Cost and duration limits.** The probabilities of performing the well construction within user defined cost and duration limits.
- **Sensitivity analysis based on cost and duration contribution**. A rank of the most critical phases, operations and events based on the mean portion of the total well construction cost and duration.
- **Cost breakdown**. The mean costs categorised according to Eni E&P cost coding standards.
- **Comparison of well construction plans**. A comparison of the total well construction cost and duration histograms, the drill “depth vs. time” and the “cost vs. time” curves for different alternatives.

The effect of uncertainty contributors may be evaluated by preparing proper adjustments of the model input through different alternatives. Re-analysis with the adjusted input provides a basis for ranking and selection of the candidate measures to reduce both the expected cost and duration and relevant uncertainties.

By briefly summarising, the work flow can be described as follows:

1) Expression of the uncertainties related to operational and contractual aspects by means of probability distributions
2) Auto-generation of a default Operation Plan
3) Adjustment of the auto-generated Operation Plan
4) Definition of the potential undesirable events
5) Execution of the Monte Carlo simulations
6) Investigation of results
7) Adjustment of operational and/or contractual parameters
8) Execution of a “re-analysis”.

Comparison between cost estimates for two possible well designs can in some cases indicate that the plan with the lower estimated expected cost has a large uncertainty about this value, compared to the estimated expected cost value for the other plan. An example is shown in Figure 2; the main question here is regarding the risk one is willing to take: a small risk of experiencing extremely high cost can in some cases be more critical than planning for a relative high cost.

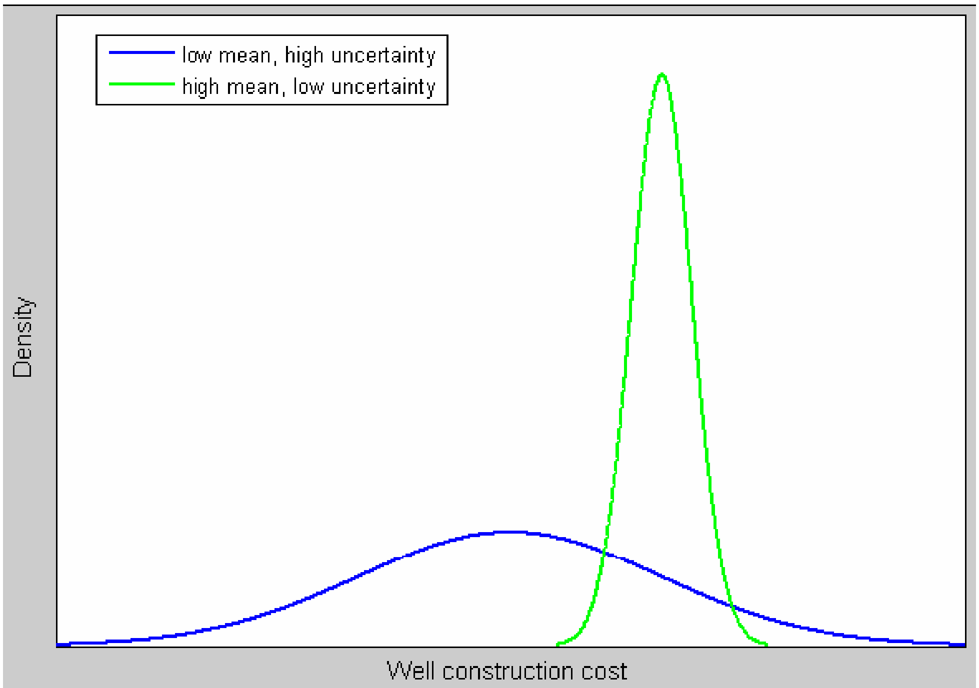

Figure 2 Comparison of two probabilistic project cost estimates. The blue curve shows the cost probability distribution for a project with low expected cost and high uncertainty. The green curve shows the cost probability distribution for a project with high expected cost and low uncertainty

Example case

After the Drilling Engineer has finished the Drilling Programme for an onshore well, with RKB elevation 12 m and total depth 4645 m, he has to provide the probabilistic well cost and duration estimation.

For this scope, the software tool is used.

First, the well architecture is to be specified by entering casing design data: a wellbore schematic is automatically generated (refer to Figure 3).

Then, the Operation Plan has to be established based on the Drilling Programme. In our example the following phases have been included:

- Mobilise
- Drill 36" hole
- Drill 26" hole
- Install BOP
- Drill 17 $^{1}/_{2}$" hole
- Drill 14 $^{3}/_{4}$" hole
- Install BOP/MPD
- Drill 12 $^{1}/_{4}$" hole
- Drill 10 $^{5}/_{8}$" hole
- Drill 8 $^{1}/_{2}$" hole

The Operation Plan is constructed based on input parameters for each phase, which are related to cost and duration of the operations included in the phase.

The input parameters are specified as probability distributions in order to reflect uncertainties.

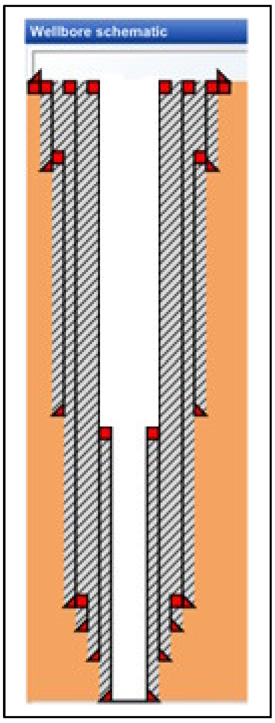

Figure 3 Architecture of the example well

An example, shown in Figure 4, is the ROP when drilling the 14 $^{3}/_{4}$" hole. Available information on reference wells and geological characteristics have induced to express the ROP as a triangular distribution with minimum value 2 m/h, most probable value 6 m/h and maximum value 10 m/h.

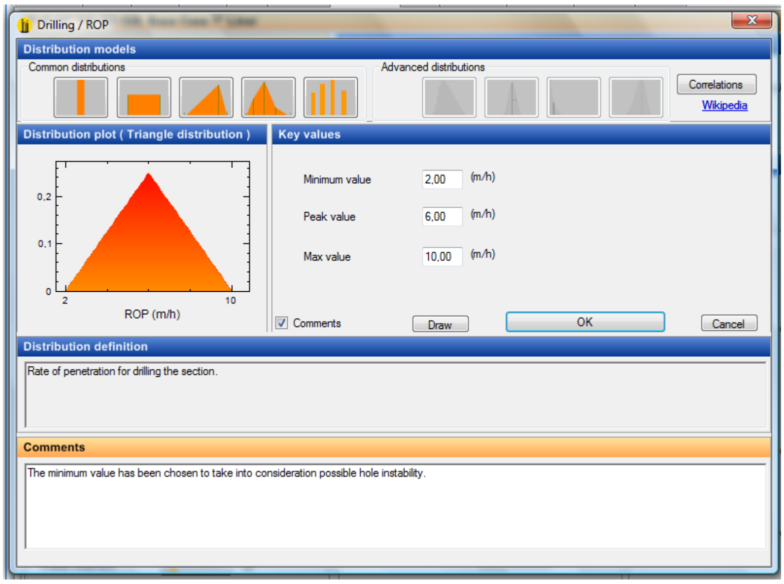

Figure 4 Probability distribution for the ROP when drilling the 14 $^{3}/_{4}$" hole section in the example case

The Operation Plan, together with the phase input for constructing the 14 ¾" hole section, is shown in Figure 5. It can be noticed that the Operation Plan for constructing the 14 $^{3}/_{4}$" hole section includes three bit changes. As a matter of fact, the section length is 1437 m and the expected bit life, i.e. the drilled length before the bit has to be changed, is 400 m.

Operations related to one change of the bit are automatically generated.

The auto-generated Operation Plan has been manually edited to insert the specific "Installation of E-CD" operation foreseen for this phase.

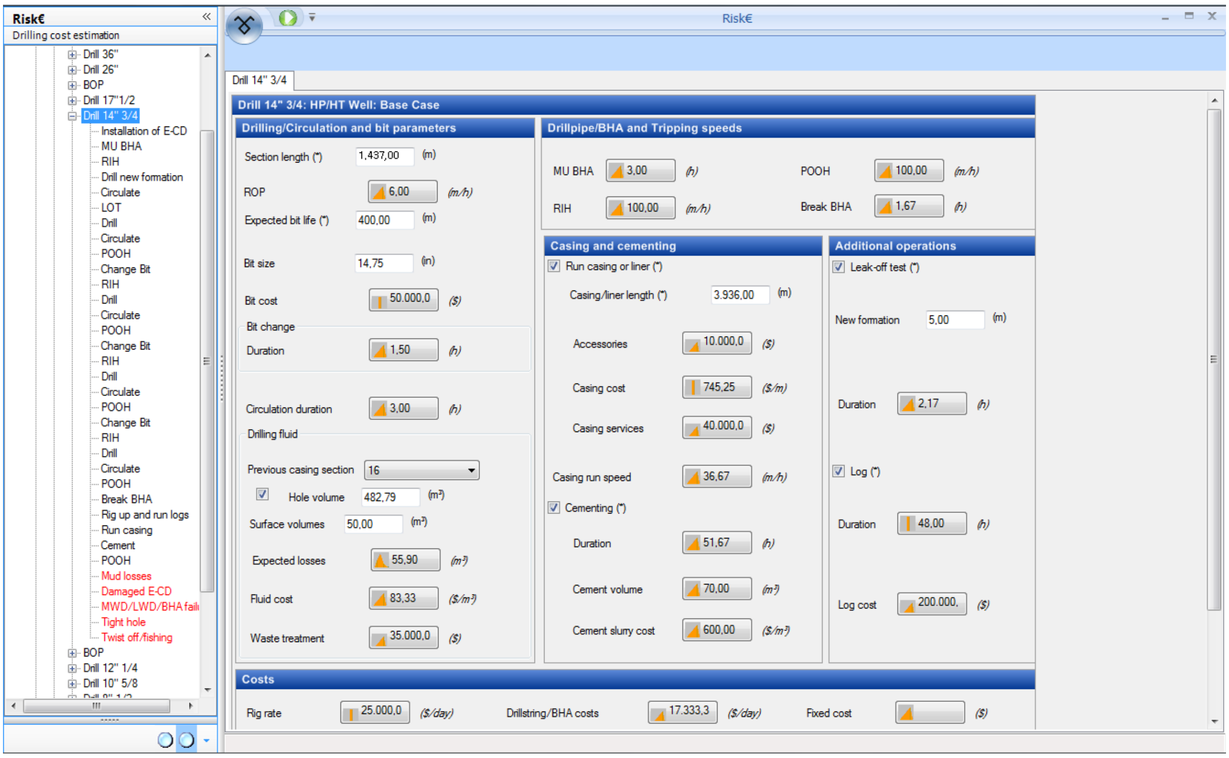

Figure 5 The phase input window for the construction of the 14 $^{3}/_{4}$ " hole section in the example well (base case)

The red incidents in Figure 5 are the possible undesirable events for the 14 $^{3}/_{4}$" phase; such events have been specified with the relevant probability of occurrence, extra duration and cost.

An example of an event specification is shown in Figure 6. This event has the potential to occur during the selected operations of the considered phase.

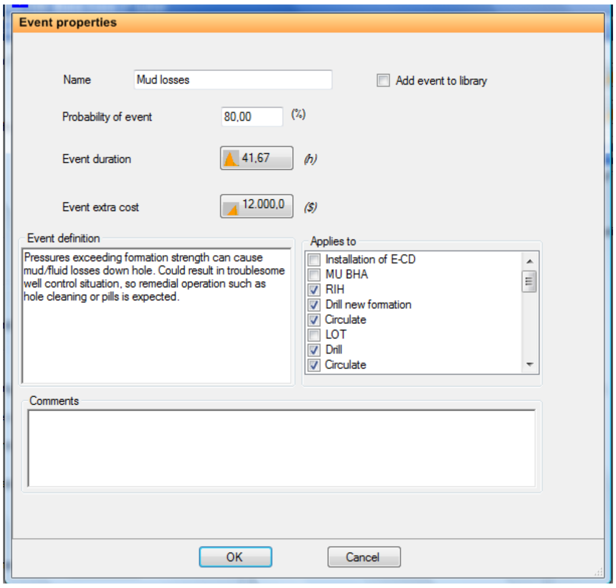

Figure 6 - Example of assessment of the undesirable event "Mud losses"

After the Drilling Engineer has completed the operation plan and undesirable events have been specified for all phases, a Monte Carlo simulation is run. Results can be presented both for the standard Operation Plan (i.e., excluding undesirable events) and for the Risk Operation Plan (i.e., including undesirable events). Figure 7 shows several (risked) results:

- Probability for constructing the well within given duration and cost limits; the Drilling Engineer is free to vary the limits.
- Percentile curves for the drill depth vs. time.
- Histograms showing the distributions of total well construction duration and cost.

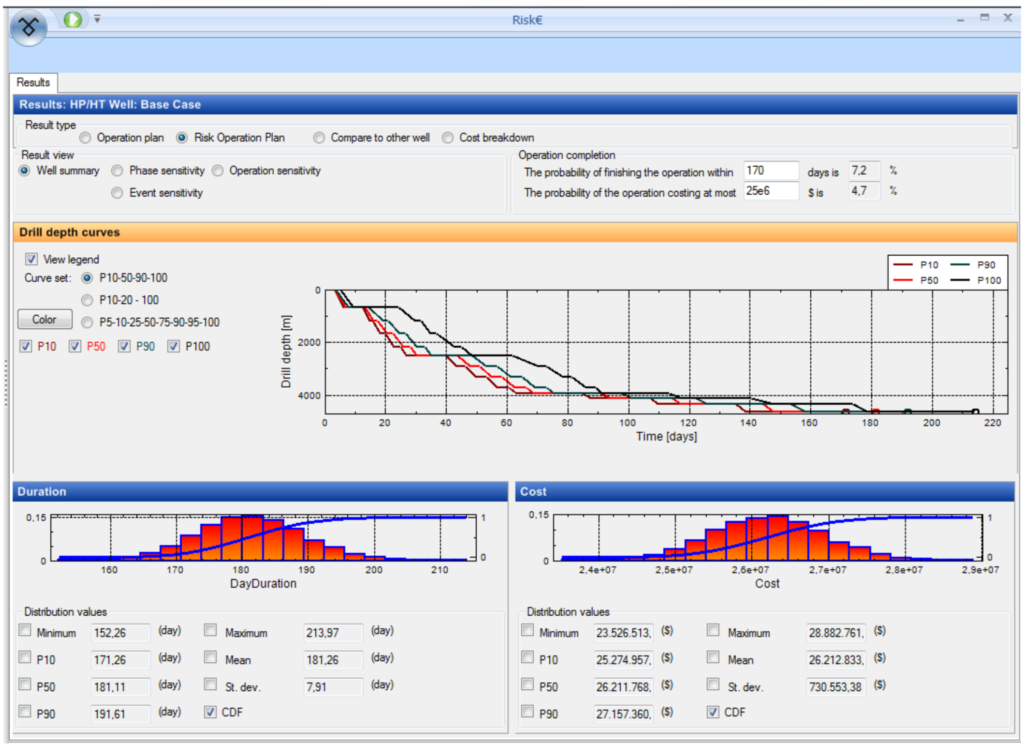

Figure 7 Results for the Risk Operation Plan of the example well (base case)

By using the tool, the Drilling Engineer has the opportunity to identify those phases and operations with the highest impact on total duration and cost (refer to Figure 8), as well as to visualize the cost breakdown for both the well and each single phase (Figure 9).

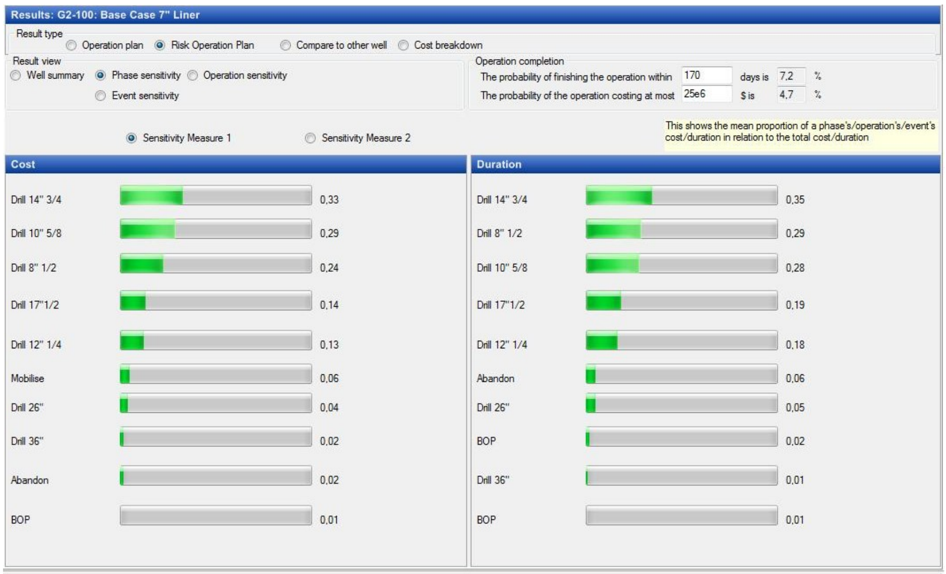

Figure 8 Most critical phases of the example well (base case)

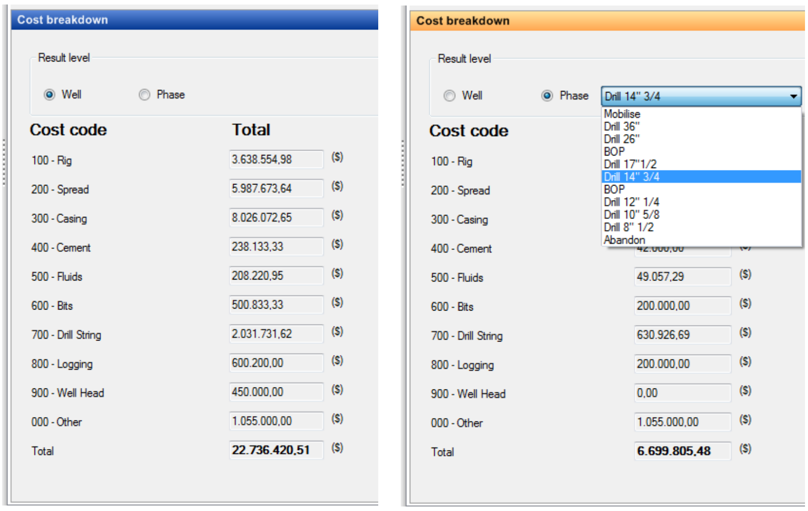

Figure 9 Cost breakdown for the well and the 14 $^{3}/_{4}$" phase (base case)

Based on the simulation results, the Drilling Engineer can identify preventive and mitigation measures (from both the technological and contractual points of view) which could have the best impact for the reduction of total duration and cost. Such measures are taken into consideration, thus generating alternatives to the base case.

In our example, the Drilling Engineer has identified bit performance and mud characteristics to be the factors whose optimization could provide the best improvement opportunities. A detailed study has been carried out to analyse characteristics of the rocks to be drilled and to select the most suitable bits and muds for the first five phases listed in Figure 8. Figure 10 shows the results of the Risk Operational Plan for the "optimised" alternative; in particular, it should be noted that the probabilities of constructing the well within the same duration and cost limits of Figure 7 are now 100% and 90,1% (compared respectively with 7,2% and 4,7% of the base case).

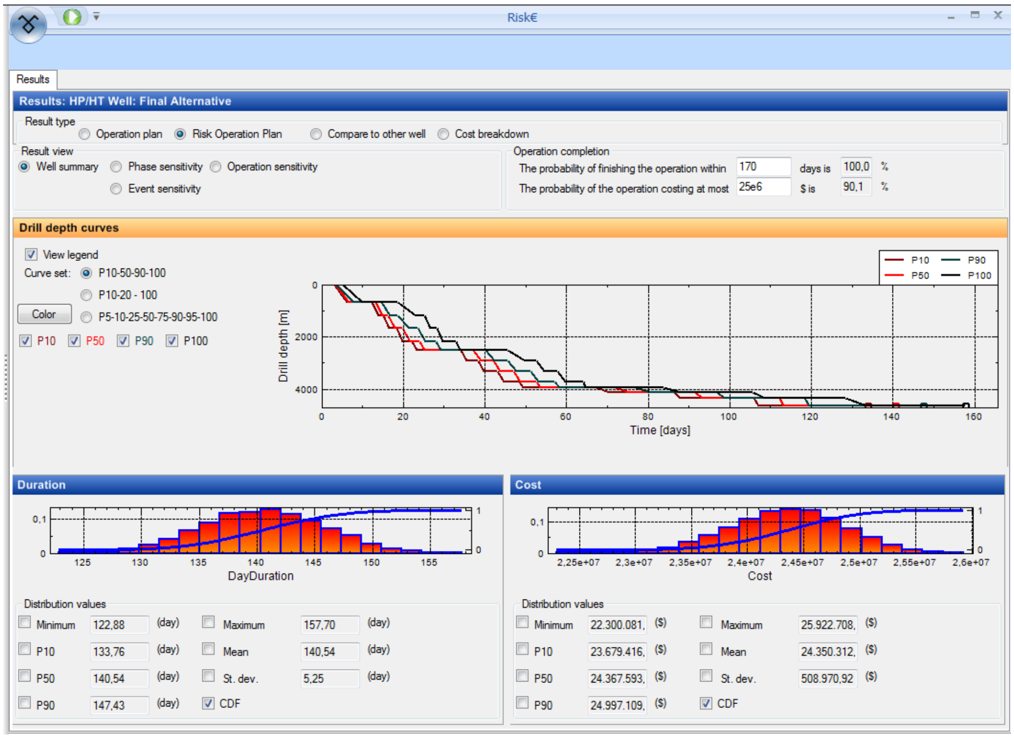

Figure 10 Results for the Risk Operation Plan of the example well (alternative case)

Finally, the estimated costs and durations for the two options have been compared. Figure 11 shows that the estimated mean duration and cost are lower and the distributions are narrower than those for the base case.

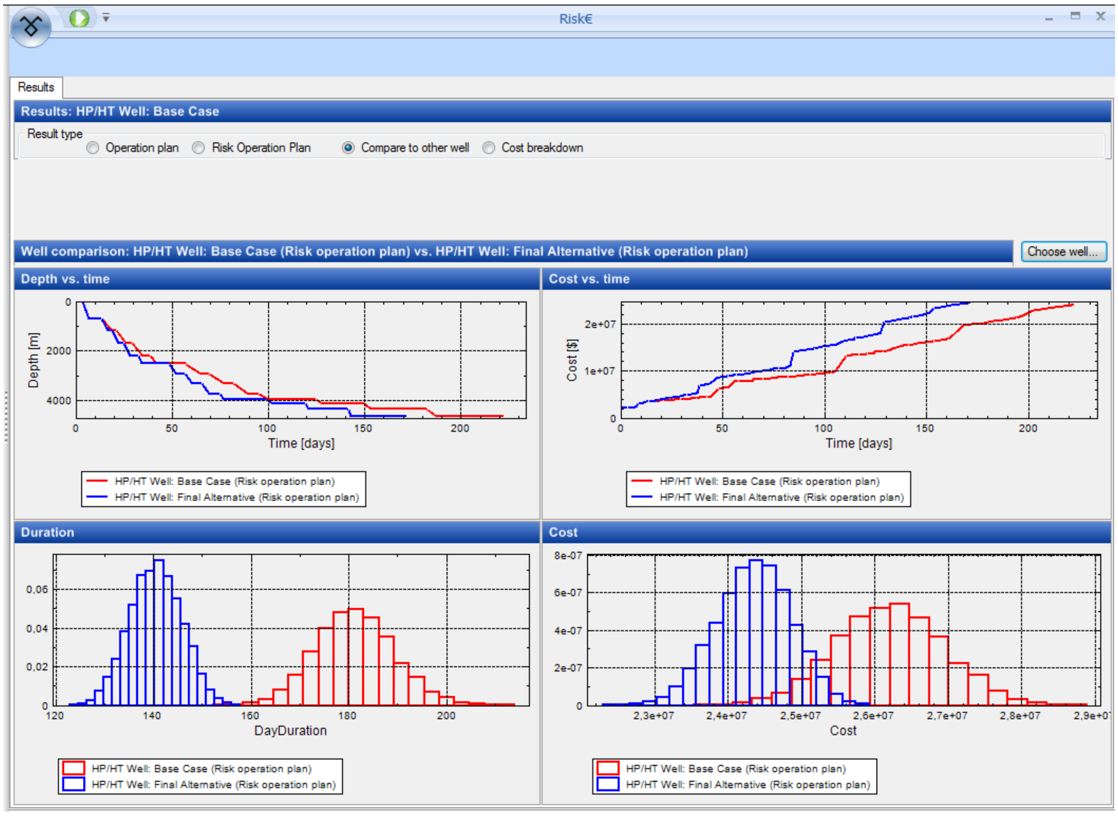

Figure 11 Comparison of durations and costs between the base case and the alternative

Conclusions

A new probabilistic approach related to the well construction cost and duration estimation has been shown. Based on this probabilistic methodology, an innovative tool has been developed.

The advantages of the new probabilistic approach vs. the traditional deterministic approach have been investigated. The probabilistic method provides more informative results both for the well cost analysis team and the involved decision-makers.

The tool not only allows the computation of risked cost and duration, but also gives the opportunity to optimise the well costruction process.

The performance of the developed tool has been shown through a detailed example case.

References

Aven, T.: "Foundations of Risk Analysis – A Knowledge And Decision-oriented Perspective", John Wiley & Sons., New York (2003)

Chen, M. and Dyer, J.: "Inevitable disappointment in projects selected based on forecasts", paper SPE 107710 presented at the 2007 SPE Hydrocarbon Economics and Evaluation Symposium, Dallas, Texas, U.S.A., 1 – 3 April 2007

Ripley, P. D.: "Stochastic Simulation", John Wiley & Sons, USA, 1987