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HOW WE IMPROVED OPERATIONS IN DRILLING PRE-SALT WELLS

Augusto Borella Hougaz[1], Luiz Felipe Martins[2], Carlos Damski[3], Jéssica Lima Bittencourt[2], Luciano Machado Braz[2]

Abstract

The development of pre-salt wells offshore Brazil has been one of the most challenging projects in history of E&P. Facing water depths of 2000+ meters, a salt layer 2000 meters thick to reach reservoirs at 7000 meters below sea level, has to use technological and procedural techniques never used before. In those 2 years of exploration of those fields many technologies were tested and improved. This paper describes the systematic approach was taken to analyze, plan and follow-up the development of drilling operations campaign in those fields, and the case study of overall process improvement. The assumption was to apply a risk analysis tool which uses previous data to analyze the performance and plan future time. The goals of this process are continuous improvement of execution and process control for each operation. Looking into previous performance, new interventions were planned more accurately and further improvements were studied. The frequent follow up of the drilling intervention was done using the statistical base to compare the most recent results. At operational level it was possible to see if the last operation was done in the 1st, 2nd, 3rd or 4th quartile of its related statistical distribution, as well as to verify the difference within P10 and P90, which indicates the control of each operation execution process. The same process was done for some rig related operations and for the whole intervention at end of it. Close contact with the intervention progress was kept and actions taken in any major deviation from the plan.

This paper describes the case study where the process control and optimization of the total time for drilling 10 wells with similar design was measured between March 2009 and May 2011. It resulted in significant improvement in the drilling process.

1. Introduction

Forecasting does not mean avoiding risk or prevent the impact, but to recognize its probability, ensuring the conditions for decisions that maintain the effects to acceptable levels for the business.

Forecasting is based on maintaining dynamic processes to analyze, develop, document and maintain updated scenario studies. One of the most important scenarios under consideration while developing an oil field is the planning of the duration of a well intervention (whether drilling, completion or workover).

All oil companies describe what occurs in a well intervention using daily drilling reports. The methodology presented here transforms the data recorded on the daily drilling report into a Knowledge Base (Figure 1), which is used to draw the risk scenario that predicts the total duration of a new intervention. We also use the concept of "reporting on planning" where the source of operational information shifts from the rig-site to the planning office (Nakagawa 2005).

[1] Ph.D., Senior Petroleum Engineer - Petrobras – Petroleo Brasileiro SA
[2] Petroleum Engineer – Genesis do Brasil
[3] Ph.D., Electronic Engineer – Genesis Petroleum Technologies Pty Ltd

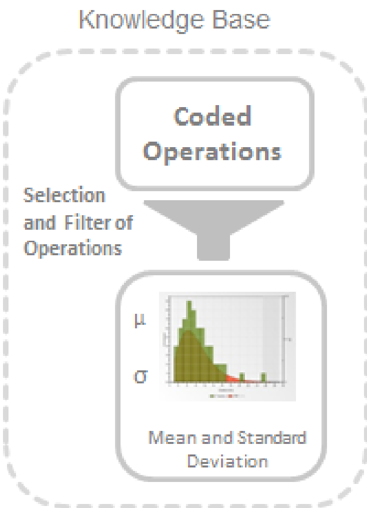

Figure 1. Knowledge Base creation.

The knowledge base is also used to analyze the performance of the execution of the same operations that were planned. That is, the methodology works in the planning and the follow up of well interventions, as shown in Figure 2.

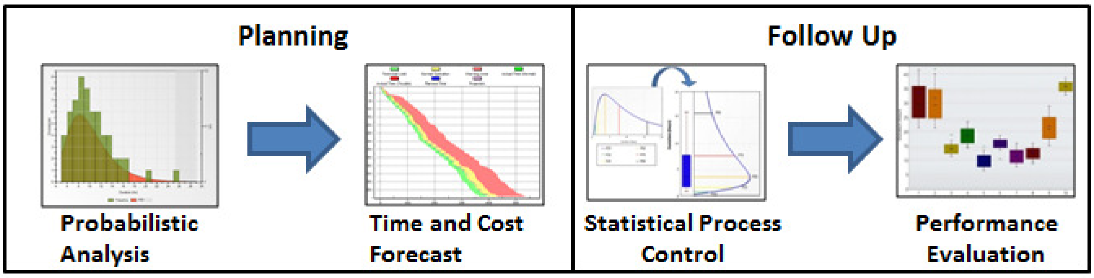

Figure 2. Planning and follow up of well operations

The performance assessment allows the selection of critical operations in each intervention in terms of lengthy durations and in terms of execution process control, indicating to engineers which operations have the potential to reduce the execution time, enabling continuous improvement of its execution.

2. Building a Knowledge Base

It is very difficult to compare one intervention with another, even with the same goals and being executed in the same field, but operations can be compared (Figure 3).

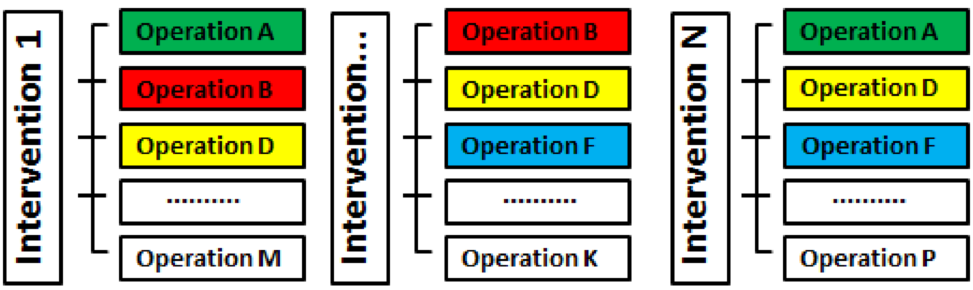

Figure 3: Operations are comparable but whole interventions are not.

To ensure the standardization of coded operations (start and end in the same operational step), even occurring in different interventions, it is necessary to give a structure to the operational data from daily reports. In the methodology presented here, this structure is given by an Ontology of Operations (organization of operations built from consensus among the company's community of practice), which presents the definition of more than 200 well operations, according to the diagram shown in Figure 4:

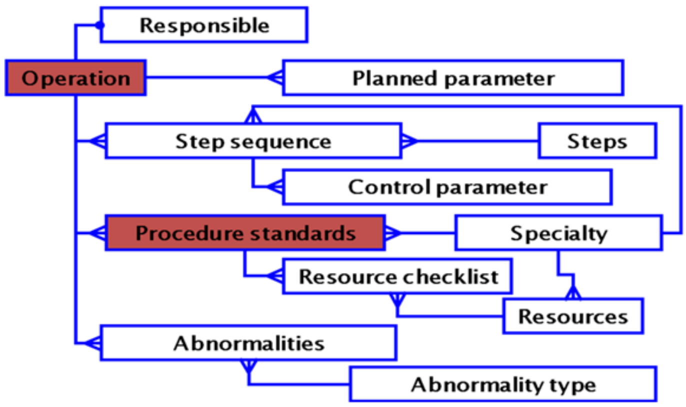

Figure 4: Diagram of the other entities related to the "operation" (Miura 2004).

Figure 4 shows the entities and their relationships. The relationship ending with a "crow's foot" relates to several elements in that entity. For example, an "operation" comprises of a "sequence of steps" (many steps) and also is executed by many "procedure standards". Each "procedure standard" contains a "Resource Checklist" (list of resources) for its implementation. During the execution of an "operation" many "Abnormalities" can occur. For more details see Miura et al. (2009).

When the information from in the daily reports is coded in accordance with this Operations Structure, we create the set of statistical seeds which can be compared to each other, generating the Knowledge Base.

3. Intervention Planning

The durations of each executed operation are grouped and fitted into a lognormal distribution (Figure 5). In order to calculate the cumulative uncertainty of a new sequence of operations, the methodology runs a Monte Carlo simulation for the entire sequence, sampling each operation's distribution. This is normally done for 10,000 samples, which can give a quite accurate prediction for the whole plan. With the simulation, the user can ascertain the risks, ranging from P10 to P90. This allows a clear definition of the expected planned time for each operation and for the whole sequence (Figure 6).

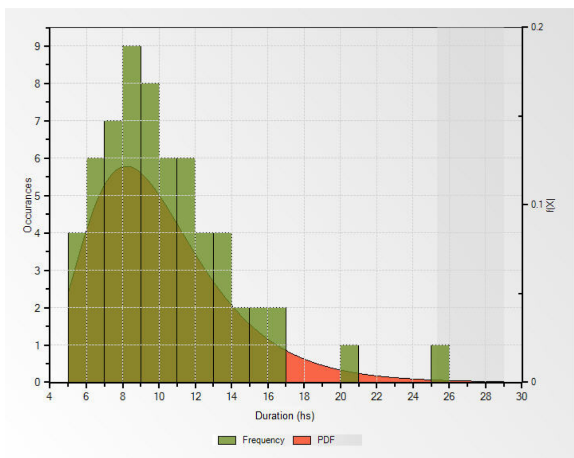

Figure 5: Example of well's operation duration fitted into a lognormal distribution.

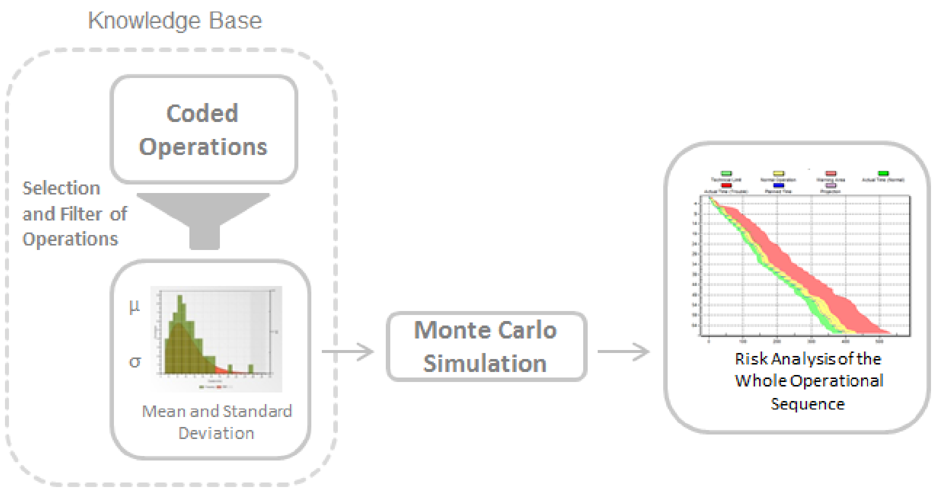

Figure 6: Flowchart from the data collection until the risk analysis of the whole operational sequence.

4. Intervention Follow up and Continuous Improvement

The box plot is an interesting chart for the evaluation of operations because it provides two types of visual information: performance and process control. The performance is indicated by comparison of the last executed operation's duration against the statistical distribution of the same operation already executed in previous interventions (executed quartile). The indication of process control of the operation over time is represented by the distance between P90 and P10, or easier to visualize, the height of the rectangle as shown in Figure 7.

As a current operation has been executed, the duration is placed in a quartile based on the probability distribution. This information is conveyed to the group of interest by a specific color code in terms of KPI.

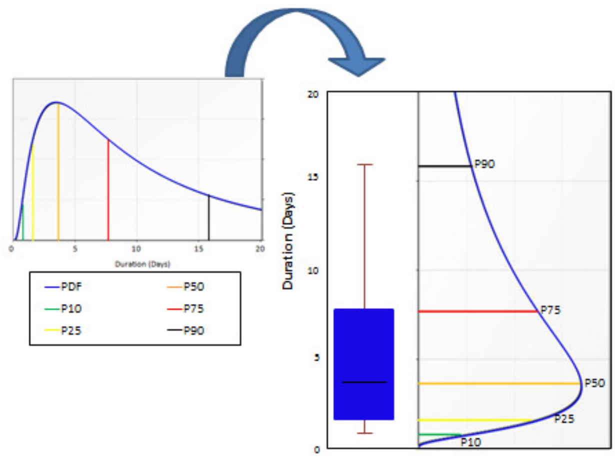

Figure 7: Representation of the probability distribution of the operation's duration in a box plot graph.

The same process applies to monitor operations which are rig-dependent (tripping speed, BOP assembly and casing run speeds).

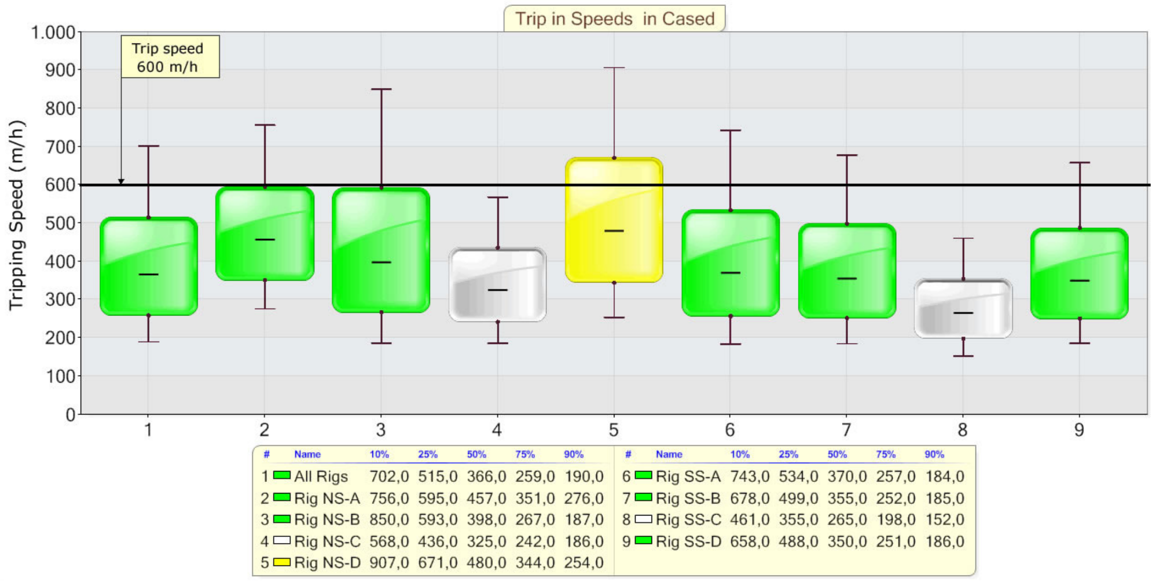

Figure 8: Performance measurement of rig operations

In Figure 8, the **"**trip in" speeds in cased well in each rig are plotted as individual box plots, as well as the trip in speed of all rigs are plotted in a single box plot. The trip in speed of the last executed operation by the monitored rig (at 600 m/h) is compared with the box plot and all rigs and for each rig operating in the field (including boxplot of the rig being monitored). Finally the plot also indicates in which quartile the "trip in" operation was executed in relation to the lognormal distribution contained in the knowledge base.

It is important to notice that the lognormal distribution is applied to the inverse of the velocity (relative time – seconds/meter). In order to facilitate the representation, we perform the calculations with the relative time and then turned back to speed. For this reason, the box plot is shown inverted.

5. Case Study

The case study was done with 10 wells drilled between 2009 and 2011. Figure 9 shows 5 box plots of total time of 6 drilling interventions grouped in sets of 6 wells. The first box plot grouped the 6 first wells ordered by start date, on the second box plot we removed the first well and added the 7th well, and so forth, producing the effect of moving average. The red line is the trend line of P50 which shows a clear decline over time indicating an overall optimization. In addition, the blue lines are trend lines of P10 and P90 respectively which demonstrate an improvement in the process control, reducing uncertainty over time.

The case study was based on the following assumptions and criteria:

- The work deals with the drilling total time of 10 wells drilled in the pre-salt area in Santos Basin
- Chosen wells which had the following phases: 36", 26", 14 3/4" and 8 1/2"
- The drilling time was assumed as per international criterion: from the first meter drilled to the last meter drilled (without coring and without logging).
- Wells were grouped 6 to 6 in chronological order so that there is a relevant set of data and we could apply the concept of moving average to generate at least 5 box plots.

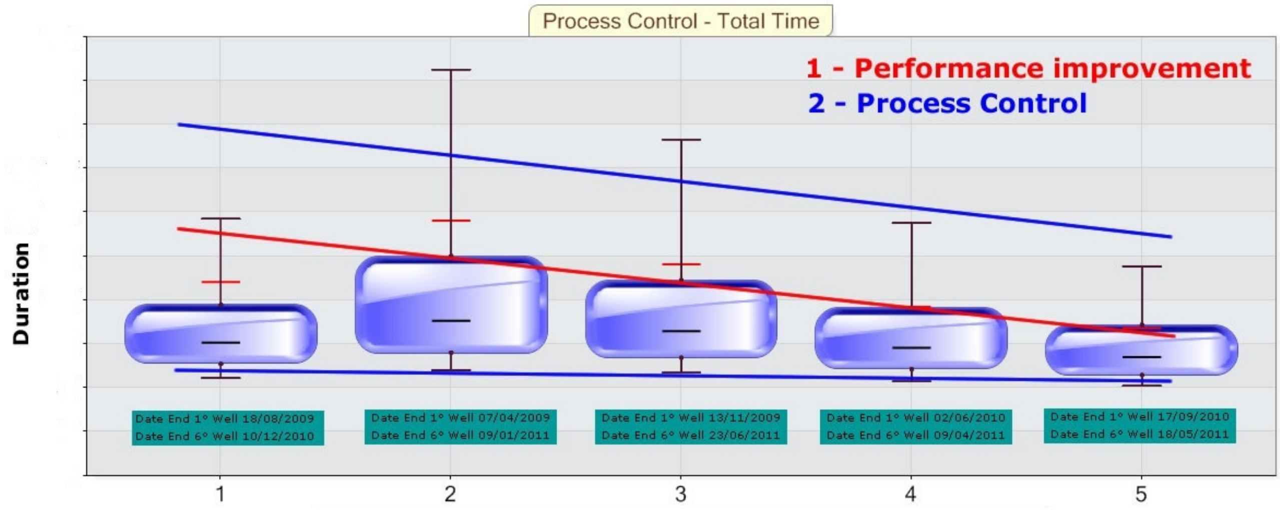

Figure 9: Demonstration of performance improvement and process control in the 10 wells drilled. The methodology presented here has helped this improvement.

Figure 10 helped to identify the most important operations (highest time) and most critical (large standard deviation) based on historical data. With this information the engineers can mitigate the risks and take action to reduce the time and uncertainty of few selected operations with highest impact in the total time.

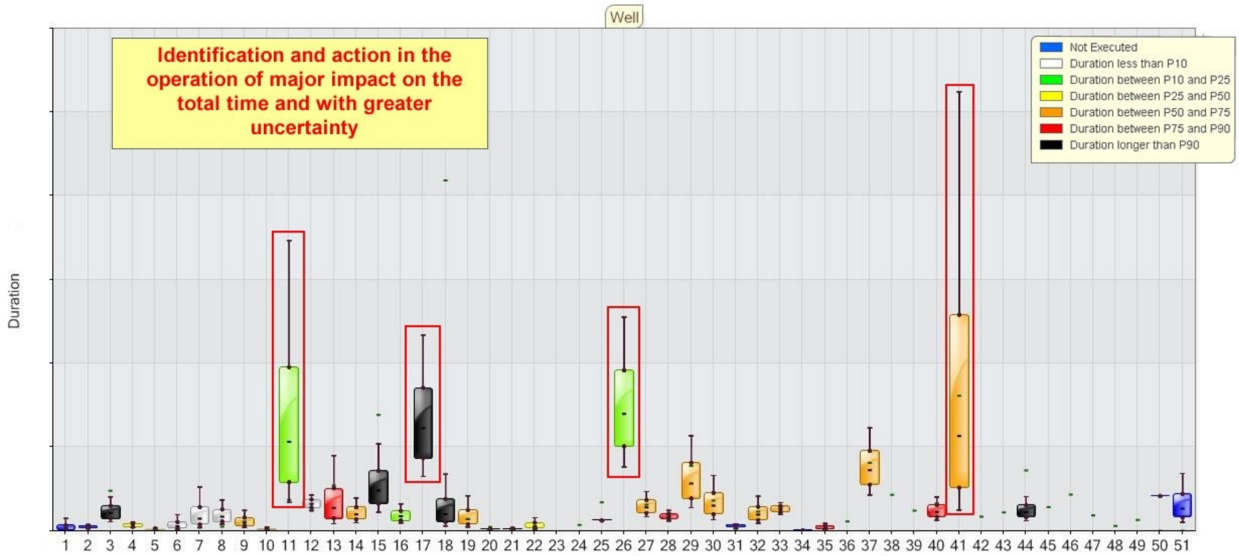

Figure 10: How the methodology helped improved the performance and process control.

Figures 11 and 12 show how the methodology is helping to improve performance of “trip in/out” operations in the rigs (few rigs have not shown the expected improvement, but are on the way with the application of the methodology).

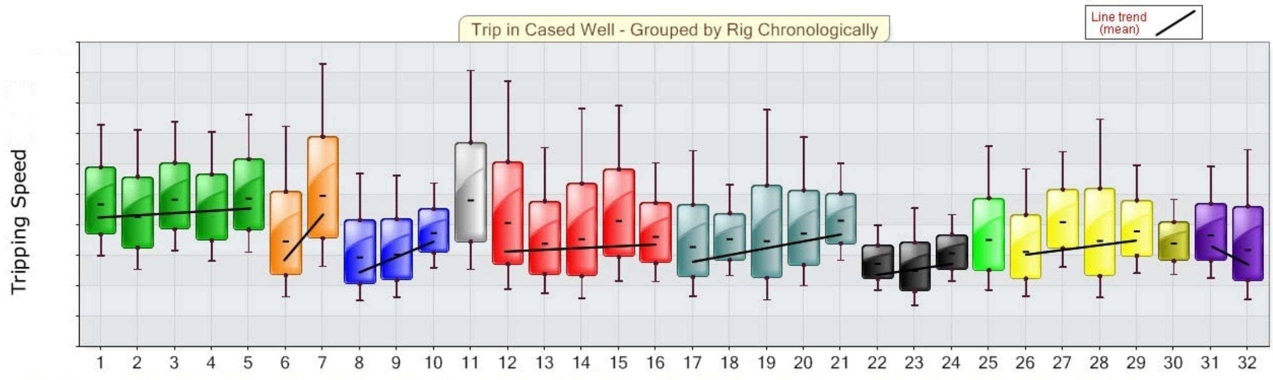

Figure 11: Improvement in **tripping in** operation in cased well from one particular rig. Notice improvement in all rigs, except the rig in purple colour (31-32).

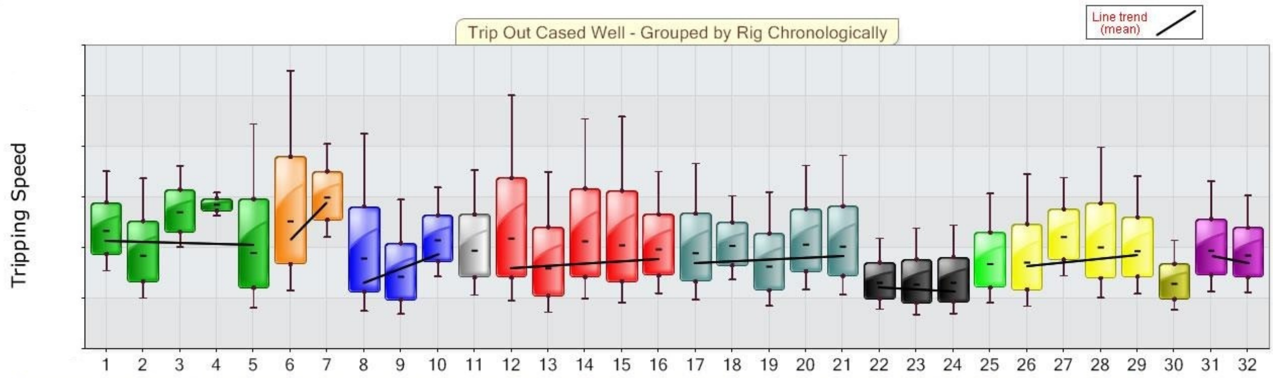

Figure 12: Improvements in **tripping out** operations in cased well for many rigs.

Figure 12 shows a significant improvement in rigs coloured in orange (6-7), blue (8-10)**,** red (12-16), medium green (17-21), and yellow (26-29). Also shows a slight worsening of rigs in green (1-5), fuchsia (22-24) and purple (31-32).

6. Conclusions

The implementation of this methodology in the Pre-Salt area of the Santos Basin is aimed to:

- Automate and systematize the probabilistic estimation of duration of interventions in wells PPSBS (Pre-Salt Pole of the Santos Basin)
- Identify opportunities for improvement at the operation level incorporating them in the planning of future interventions

The progress made with the methodology is listed in Table 1 and the results can be seen in the case study presented in section 5.

Table 1. Progresses made with the methodology

Before the Methodology	After the methodology
Deterministic approach for planning	Probabilistic Planning
Time estimation was dependent of the planner's experience	Times estimation based in the knowledge base
NPT analysis at phase level	NPT analysis at operation's level
Intervention follow up using TxD plot (deterministic)	Intervention follow-up using risk analysis (probabilistic)
No systematic rig performance follow up	Systematic and probabilistic rig performance evaluation
Intervention performance only at planned vs executed level	Intervention performance using quartiles' concept

7. Acknowledgements

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8. References

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