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Rigorous Drilling Nonproductive-Time Determination and Elimination of Invisible Lost Time: Theory and Case Histories

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Abstract

This paper addresses the measuring techniques that involved data quality control and automatic drilling operations detections of routine drilling operations that are available today in modern drilling programs, and goes through examples of how implementation was carried out in the onshore area that drilled a series of similar wells. Measurement accuracy, training, and the development of new work processes were successfully implemented that led to major KPI (Key Performance Indicator) time savings between 31% and 43%.

You cannot improve what you don't measure. And in this case you cannot measure without a proper data quality control (QC) procedure in place.

Introduction

The traditional learn curve theory published by Millheim [1] and Brett [2] analyzed passed performance of drilling complete wells with the objective of capturing the learning and successfully applying them on the next well or well campaign to be drilled. It relied on being able to rigorously QC the drilling morning report data and correlated these events with other well data coming from electric logs, geology and drilling recorded data. Iyoho [3] further took this methodology and came up with a 10 step process that was successfully implemented and he documented the significant savings that came from this approach, and actually one of the key steps to disseminate the knowledge and lessons learned in the company was the obligatory peer review at the planning stage from other departments that allowed for the dissemination of knowledge through discussions rather than data base approaches, therefore human interaction seemed to be the key in his process supported by a database and software based solutions.

Bond and Scott [4] came up with a further step change in improvement by developing the technical limit theory (TL) and practice back in the mid 90's that involved a slightly difference management approach and called upon a technique of questioning current performance, comparing it with what was possible and asking the question of what is needed to get there. Phil Scott further disclosed later during many of his presentations that all this effort was only possible through a rigorous management buy in that adheres to some basic principles that involve everyone in the group and top management to be supportive and never evoke criticism, to really believe that every person's job is as important as the next, equal rights and status for contractors and staff, full disclosure of errors and lost time, clear priorities and shared goals, and the celebration of success. Another peculiarity of TL is the identification of the invisible lost time that has been partially identified in the references above but will be part of discussion in this paper too since there is some breakthrough in this area of research.

The techniques above typically involved a large group of people, a significant amount of resources to collect, QC and organize the data, many workshops and the key element of time. In addition what the authors have noticed is that leadership is also critical, whether through internal management or through specialized consultants that understand how to motivate groups to excel (much like a coach does in sports). Nevertheless, even when implemented properly, these approaches tend to be cyclic and keeping up the momentum has shown to be difficult and the processes seem to break down when certain elements leave the group. Also, in most cases, when it comes to improving the drilling performance of the routine drilling operations, nothing normally happens until the rig does something different, no matter how many meetings and workshops are carried out away from the rig, and even if some rig personnel are involved – until the driller is engaged the final results will not be the best.

The process presented here places the focus on the final element in the improvement food chain that is the driller himself. The idea here is to provide this individual/group with all the information and support necessary to allow the drilling rig group to achieve the required safety practices that come from understanding how to perform the job properly and in a consistent manner.

Automatic Operations Detection of Routine Drilling Operations [Ref. 5]

The work presented here is based on the automatic operations detection of the routine drilling operations that is based on collecting real time (or near real time) data and determining the rig state as shown in Fig. 1. The key here was to have an independent data QC process performed by a different company than the data provider themselves thus ensuring that there is no conflict of goals or interests. Following the QC process, the data is then classified and processed and a rig state is assigned to every time interval as shown below (e.g. Drilling Rotary, Drilling Sliding, Ream and Wash Upwards, etc.). These are the fundamental building blocks for all the classifications and reports performed throughout this paper. Additional information on this process can be obtained in references 6 and 7.

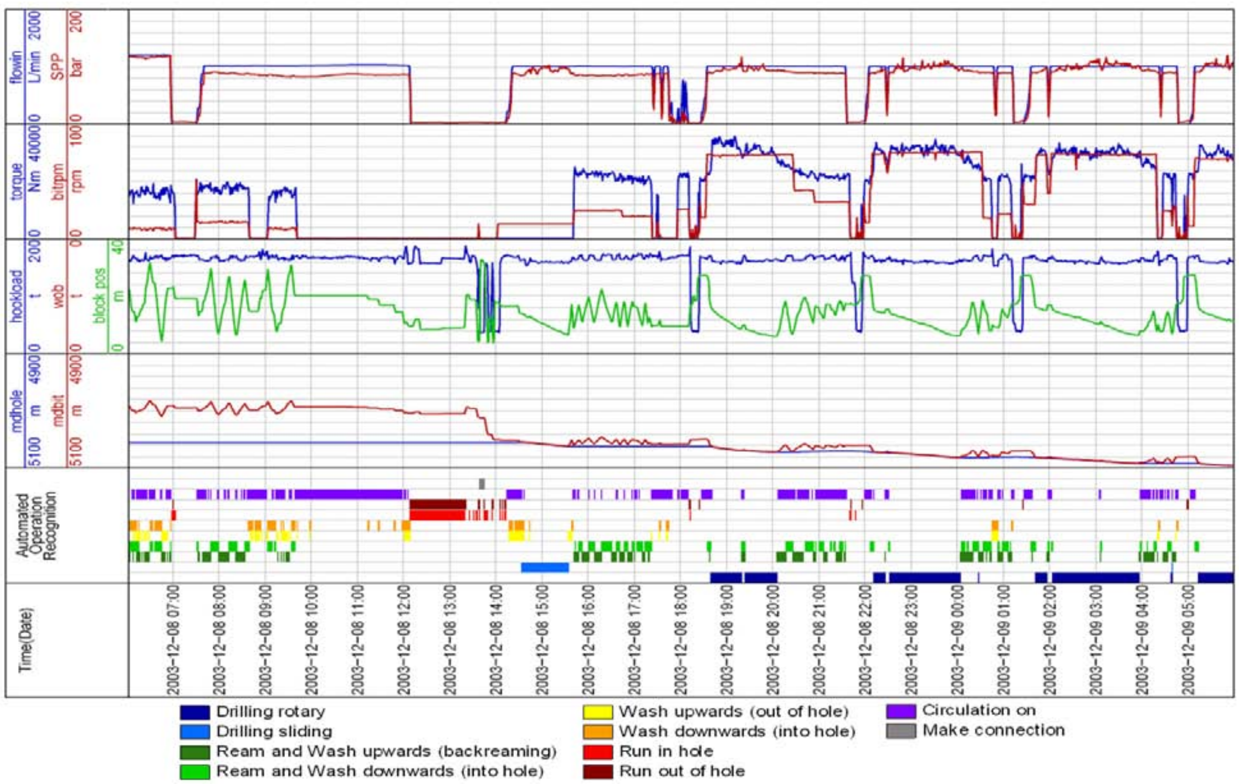
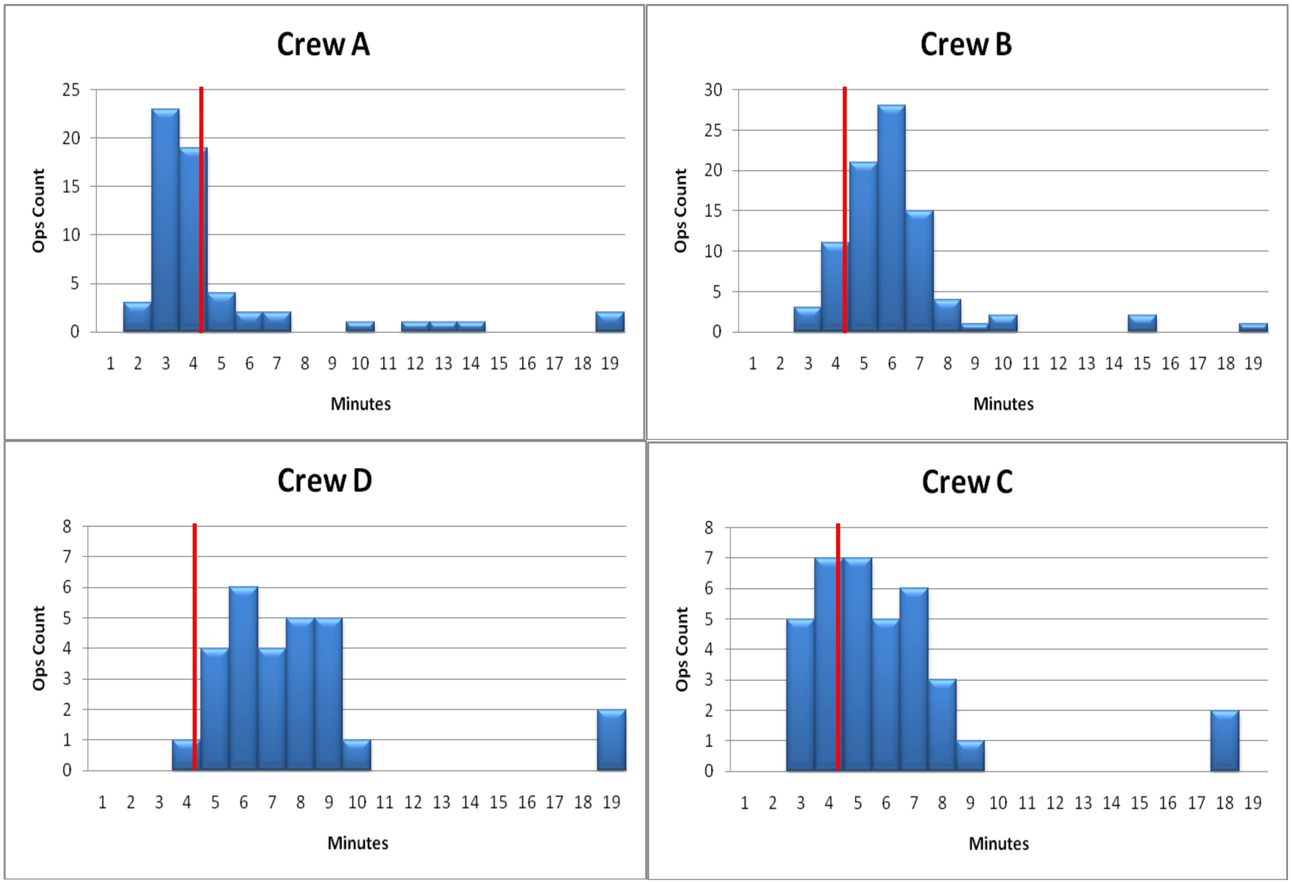


Figure 1: Automatic Operations Detection example.

"Invisible" Lost Time related to routine drilling operations

The measurement of Invisible Lost Time starts by analyzing each individual key performance indicator (KPI) that can be produced by a particular crew (drilling crew, casing crew, etc) or by a machine automated operation or a combination of both. The example below will illustrate how this process is carried out with 4 crews by measuring the time each individual crew carries out a particular routine drilling operation over a period of time. The time period is typically selected to allow for different crews to perform the same operation many times under similar conditions, therefore an example of a time interval could be the duration to complete (drilling and flat times) a particular hole size, or the time to complete a particular tubular run and so forth.

Once this data is gathered, individual histograms (Fig. 2) are prepared for each crew for each routine drilling operation.



	A	B	C	D	Total [min]	Total [hrs]
Operations Count	58	96	39	27		
Target Operation Duration [min]	4.85	4.85	4.85	4.85		
Potential Saving [min]	55	270	63	115	503	8.4
Potential Saving [%]	14.8%	35.9%	25.2%	47.1%		

Figure 2: Weight to Weight Comparison of several crews performing the same routine operation for the same hole size section.

Now the decision process for the identification of the target value begins. When analyzing all the crews together, it becomes clear that crew A can perform this operation routinely below 4.85 min. and therefore, for this analysis, the target was selected to be this value, (this is somewhat subjective but is based on the data at hand). This is different than the absolute technical limit value that could be argued to be the left most value (smallest time) performed by any particular group. This selection process for the target makes a difference in the outcome of the analysis and the quantification of results.

Once the target is selected, the invisible lost time is defined here as the cumulative time to the right of the target value as shown in Fig. 3 (or the amount of time left on the table). Therefore the selection of the target basically determines the amount of invisible lost time that is detected. Therefore in this case, the ILT for this study in Fig. 2 was 55 min. for Crew A, 270 min. for Crew B, 63 min. for Crew C and 115 min. for Crew D. To compare the groups amongst themselves it is necessary to divide the ILT for each group by the total amount of time spent KPI for each group since they have performed the same operations a different amount of times. In doing so, this results in 14.8 % for crew A, 35.9 % for Crew B, 25.2 % for Crew C and 47.1% for Crew D. The smallest % value indicates the smallest amount of time left on the table and therefore the better performance for this particular KPI. Before any extrapolation can be made, several KPI's are analyzed to check for best overall performance.

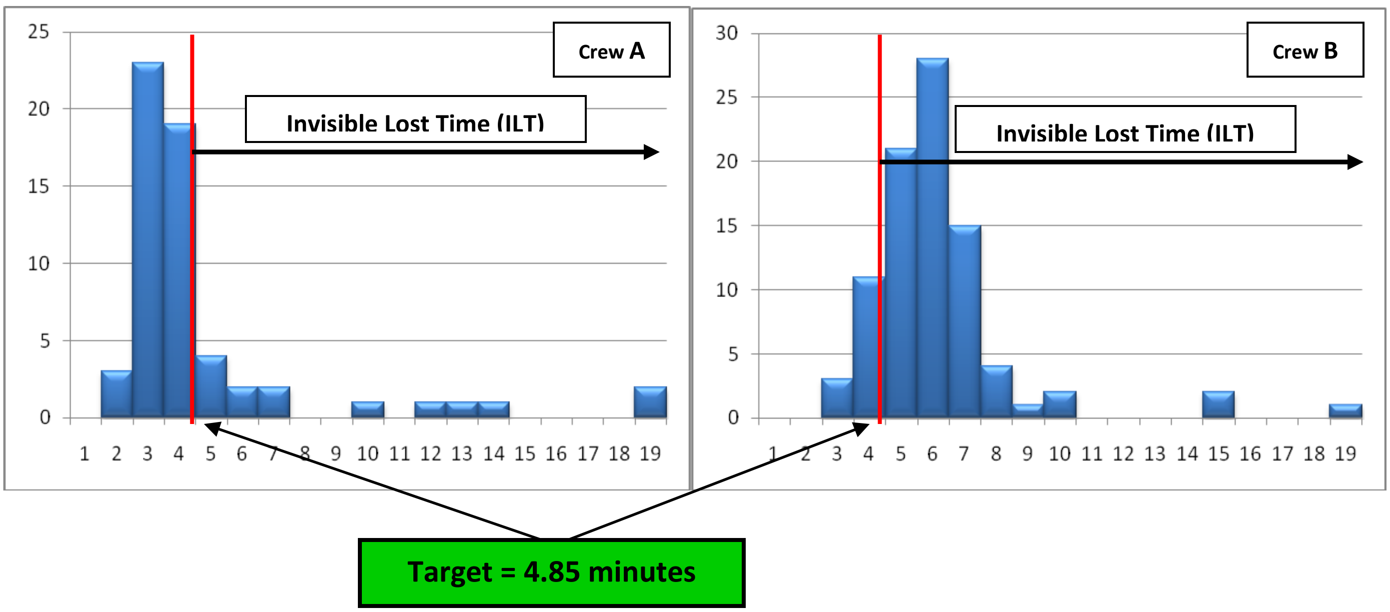


Figure 3: Invisible lost time determination example.

Safety related to routine drilling operations

Looking again to Fig.2, it can be seen that the histograms present quite a different spread behavior, meaning that Crew A has most of its routine values concentrated between 3 and 4 minutes, while Crew D has it spread out between 4 and 9 min. which is quite a significant difference that leads to investigate the reason for such a difference in consistency. It should be noted that one KPI alone would be hard to justify such suspicion regarding inconsistency, but if this is observed on several different KPI's, further investigation of the routine drilling practices might be justified. Consistent performance, as shown by crew A, was also observed to be safe. In Fig.3 above, Crew A is consistent in making drilling slip-top-slip connections more so than the other crews.

"Near" Real Time Learn Curves and Benchmarking

Typically nearly all data streams are delayed even if for a fraction of a second. In the case of this study, near real time learn curves were produced from the drilling data that was captured between the rates of once per second and once every ten seconds and the results were generally provided at every crew change (either every 12 or 24 hours) so that the crew could get immediate feedback. The idea here was to work with the possibility of daily improvement that showed to be the appropriate time span for the problem at hand, namely the driller's safety/performance improvement.

The measurement part of the process of safety and improvement involved the following:

- Receiving the common recorded drilling channels collected every second or so for the common drilling channels. Most companies already collect this data even in real time.

- Quality controlling the data since there can be errors, especially at the beginning of a job that would otherwise skew the results of future calculations rending them useless.
- Processing this data to automatically detect the common drilling operations [Ref 5]. These routine drilling operations are: rotary drilling, slide drilling, reaming and washing up and down, washing up and down, time in slips, circulating and flagging operations that cannot be measured using this system due to lack of data or the drilling operation is stopped (e.g. the bit could have been retrieved or there is some problem on the rig and so forth).
- Presenting the results in such a way that the driller's and directional drillers can easily grasp the content and act on them appropriately.

The implementation part of the process of safety and improvement involved the following:

- Proceeding with the measurement part without any involvement of the crews to begin with.
- Establish the present benchmark for each rig and crew for several Key Performance Indicators (KPIs). Benchmark (or Base Value) in this context is defined as the point where the crews started from (as opposed to target values that is the desired value to be achieved).
- Present the information to the groups (drillers) involved and get their feedback and thoughts on the process and measurements and listen to their concerns and ideas. This was necessary as the groups have never been measured this way and their buy in was invaluable if any positive results were to be expected, otherwise the measurements were simply ignored and there was no positive action taking place. This will be further illustrated in the case histories.
- For simplicity, the reports were divided out into two groups, the driller's group and the directional drilling group.

Case Histories

The Case histories bellow address the concepts explained above.

First we demonstrate how the automatic operation detection process complements the daily morning report. Shown below in Fig. 4 is a Weight to Weight connection KPI performed by two different crews for the same 24 hour period. For this particular example in Fig.4 we only show one KPI out of a possible 60-80 KPI's that proNova measured automatically every day.

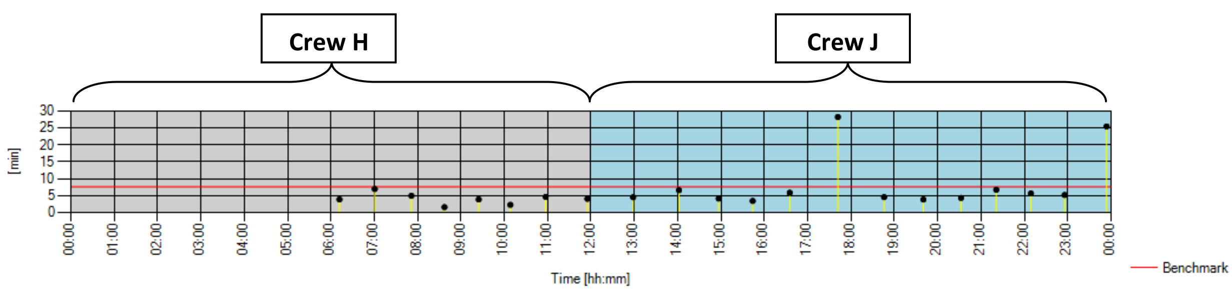


Figure 4: A daily Weight to Weight KPI needle plot report that complements the daily morning report.

The crew change happened at noon and midnight and the two different crews are shown in the grey (crew H) and blue (crew J) highlighted areas respectively. From 2h40m to 6h10m the morning report helped explain some rig activities tacking place, and for the routine operations the automatic report precisely shows the rig state for the corresponding times. This plot demonstrates that at the meal time, 17:30 and right before crew change at 23:30 there was excessive time in making a weight to weight connection only for crew J. In talking to the crews, the problem was resolved by the crews themselves. It was noticed that Crew J was unaware that their relief crews weren't doing the same procedure for lunch and before crew change, and seeing how in this case Crew H operated, Crew J immediately changed their actions to meet the standards of other crews on their rig. This simple solution saved in excess of 40min. per day of rig time (or around a rig day every 1 ½ months).

To document a learning process, we have selected an example of the average weekly Drilling Slip-to-Slip KPI time from 2 similar rigs, drilling in the 6 ¼" hole section, drilling similar directional wells, over a period of 2 consecutive wells each shown in Fig.5.

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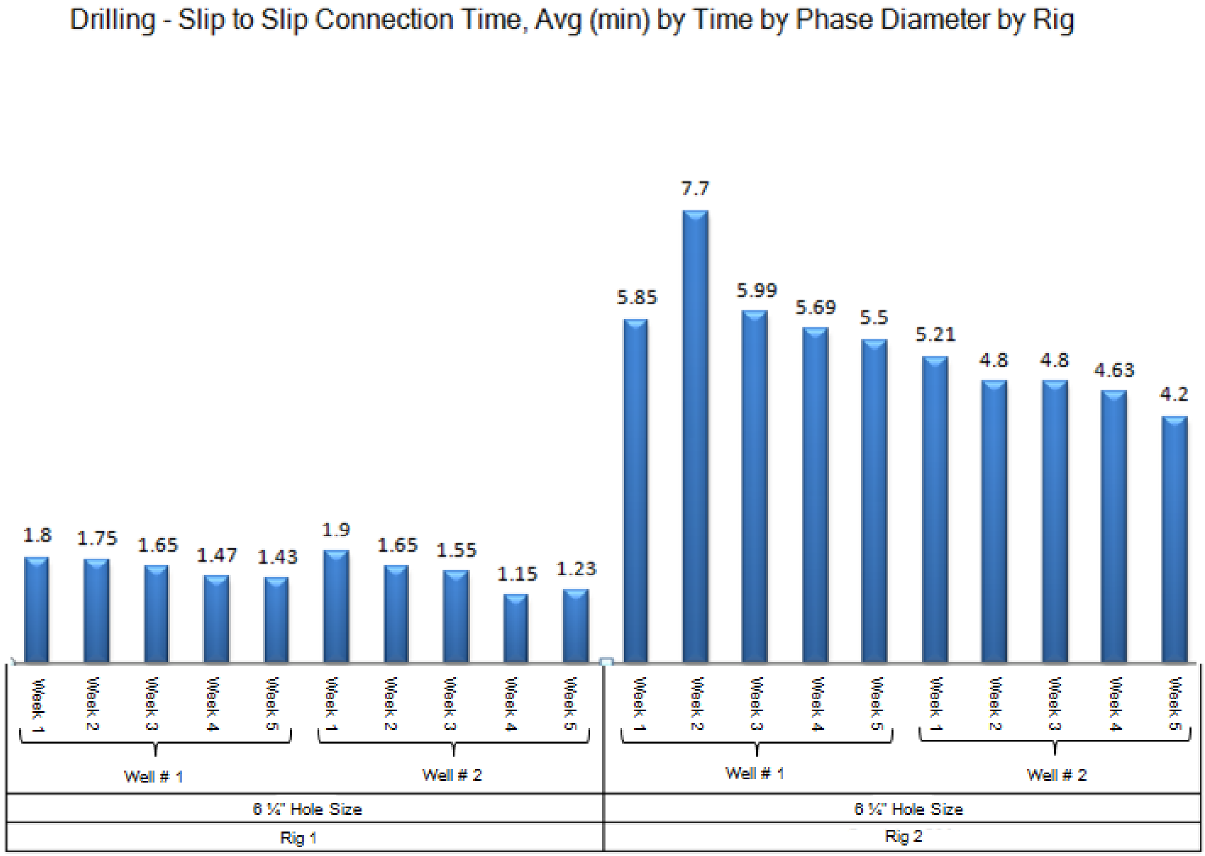

Figure 5. (Drilling Slip-to-Slip Connection time for 2 Similar Rigs, Drilling 2 similar consecutive wells each in the 6 ¼" hole size)

As seen above, Rig 1 was making drilling slip-to-slip connections roughly 3.5 times faster on average per week than Rig 2. The Drilling Slip-to-Slip connection presented here is the time it takes the driller and his roughneck crew to connect drill pipe at the surface using manual tongs and chain tongs or an iron roughneck, and also the time taken to stab the drill pipe to the top-drive. Rig 1 was using manual tongs and chain tongs to connect drill pipe in this case, and Rig 2 was using an iron roughneck to connect drill pipe while drilling. For each of the two rigs listed above, there were a total of 4 different crews for each drilling rig while in the 6 ¼" hole size. In this case Rig 1 is more efficient in making drilling slip-to-slip connections compared to Rig 2. For Rig 1, the 4 crews that were involved had a lot of experience, worked well together, and were well accustomed to using manual tongs and chain tongs, thus constituting a much faster drilling slip-to-slip time. On Rig 2, the iron roughneck slowed down the connection times greatly, however the question was: could they improve?

The phenomenon that can be seen in Fig.5 is that regardless of Rig 1 or Rig 2, both showed a great deal of improvement from start to finish of each 6 ¼" hole size drilled. Rig 1 improved from 1.8 minute weekly average to 1.43 minute weekly average for well 1 and 1.9 minute weekly average to 1.23 minute weekly average for well 2, moreover Rig 2 improved from 5.85 minute weekly average to 5.5 minute weekly average in well 1, and 5.21 minute weekly average to 4.2 minute weekly average in well 2. So in conclusion Rig 1 improved their drilling slip-to-slip time by 31% and Rig 2 improved theirs by 32.5%. In this study both Rigs, regardless of their differences were able to improve their operations over a period of 2 wells each, and this was accomplished because they were able to visually see the improvement through rigorous automatic operations recognition measurement and the fact that the operator management supported the move to commence measuring routine drilling performance.

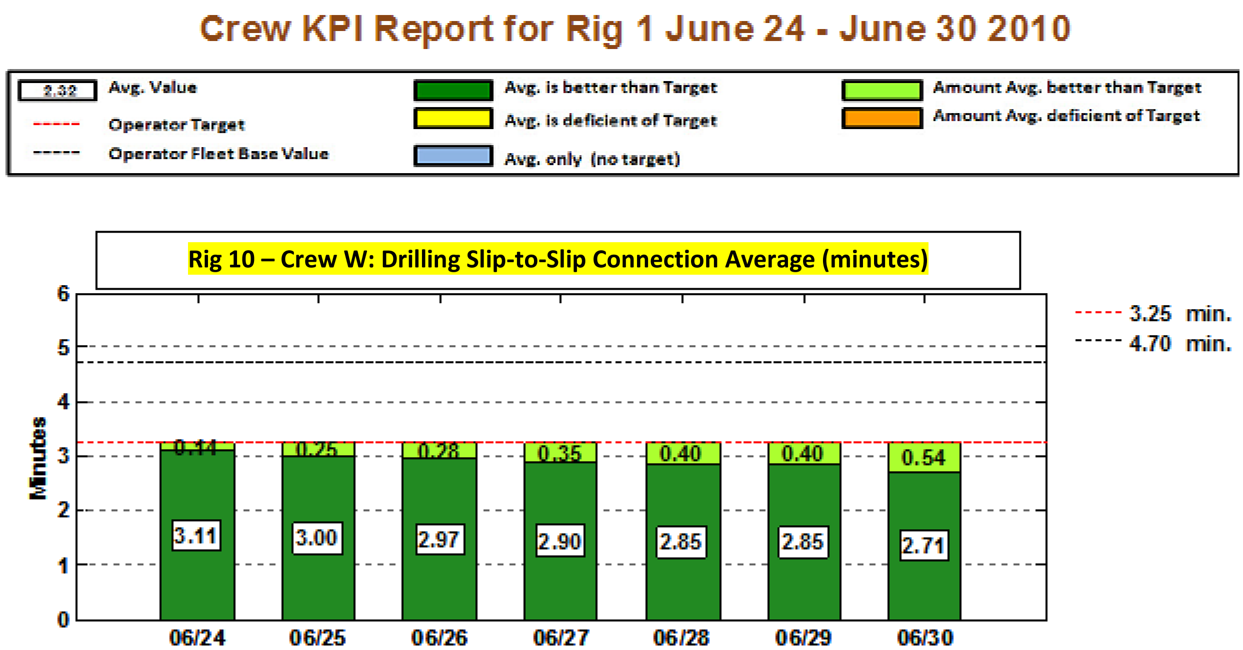

Figure 6. Daily Crew Performance Report. In this case, this report represents Crew W's Drilling Slip-to-Slip Connection Averages per day for an entire week for Rig 10)

To document a "near" real time learning process we have selected Crew W as seen on Fig. 6 above that continuously showed improvement over the 7 day period they were making drilling slip-to-slip connections on Rig 10. The base value for Rig 10 (denoted as the black dashed line on the 4.7 minute marker) is the average Drilling Slip-to-Slip connection time that Rig 10 was taking 4 weeks prior to 6/24.

The target marker (denoted as the dashed red line in Fig. 6 at 3.25 minutes) was calculated in this example by using historical data from previous wells prior to the implementation of the Automatic Operations Recognition. A series of historical development wells (almost identical in trajectory) were processed by prior to commencing in near real time, and after the processing of those historical wells had been completed, the operator was able to visualize through histograms that 3.25 minutes was a very doable and a safe target marker for Rig 10 since many crews in the fleet were able to consistently beat it.

The key to this operator's success was to include everyone in their planning process. This included personnel from the Drilling Contractor, Operator, and the supplier of services for the automated operations measurement part. Operations managers, drilling managers, Superintendents, Company Men, Rig Managers, Directional Drillers, Drillers, Derrickmen & Roughnecks were all heavily involved in this effort.

The way to read the report in Fig. 6 is such:

- The operator target is set to 3.25 minutes for Drilling Slip-to-Slip connections.
- Crew W's base value is 4.7 minutes, and this value represents the average Drilling Slip-to-Slip connection time for Crew W on Rig 10 for the first 3 weeks of automatic operations detection processing.
- The Crew base value is the marker to show how Crew W on Rig 10 used to performance compared to today.
- There are 7 days on this report, each day representing the average KPI value for a particular crew, in this case Crew W.
- This report was generated on a daily basis and handed to all personnel involved in this initiative so that everyone kept track of performance. If the bars show green, this means that crew is beating the target value set by the operator for that particular day. If the bars show yellow and orange, this means the crew is deficient of the target for that particular day, so it's very straight forward and to the point.
- The deviations from the target in yellow were addressed at the morning safety & operations meetings.
- Crew W, took less than 7 weeks to average drilling slip-to-slip connections on 6/24 of 3.11 minutes (se Fig.7 below). This is an average daily improvement of 1.59 minutes. By the end of the week, on 6/30, Crew W averaged 2.71 minutes, almost 2 minutes on average per day below their base value 5 weeks prior. This improvement in daily averages for drilling slip-to-slip connection time only occurred because Crew W, and other crews for this particular operators entire rig

fleet were completely aware of their daily performance levels, and the Crews themselves worked out how they could improve in time. This is one KPI example out of many that each crew in this study were able to improve due to automatic operations recognition.

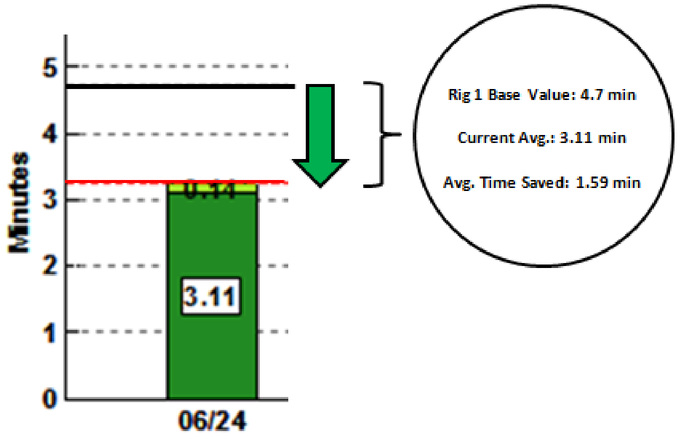

Figure 7. (Improvement in Daily Average for Drilling Slip-to-Slip connection time for Crew W based on Rig 10 Base Value)

On 6/24, the average drilling slip-to-slip connection time for Crew W on Rig 10 was 3.11 minutes. This value beat the target for this KPI (Key Performance Indicator) by 0.14 minutes, thus the bar on the graph is denoted as green (beating the target value set by the operator).

The reason this performance reporting methodology works is due to the fact that the crews have daily feedback on how they are performing. Green means better than target set by the operator and yellow means deficient of the target set by the operator, and the feedback that was given by the crews themselves was positive, they found it easy to follow allowing them to analyze themselves areas where they can improve for their routine daily operations.

Conclusions

The automatic operations detection technology, preceded by a rigorous data QC process was a means to help prepare meaningful reports to flag opportunities to improve safety and performance. Some solutions and improvements were very simple and easy, e.g. tour shift changes in Fig. 4 that saved 40 min. per day, and some require more planning and closer contact with the drilling crews, such as in Figure 6. that provided savings of 43% on some important key performance indicators.

Acknowledgements

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References

1. Millheim, Keith; Maidla, Eric; Kravis, Simon; An Example of the Drilling Analysis Process for Extended Reach Wells, SPE 49111, presented at the 1998 SPE Annual Technical Conference and Exhibition held in New Orleans, USA, 27-30 September 1998.
2. Brett G.F. and Millheim, K.K: The Drilling Performance Curve: A Yardstick for Judging Drilling Performance, paper SPE 15362 presented at ATCE, New Orleans, LA, October 5, 1986.
3. A.W. Iyoho, SPE, K.K. Millheim, SPE, B.K. Virginillo, M.J.Crumrine, "Methodology and Benefits of a Drilling Analysis Paradigm", IADC/SPE 87121, presented at the IADC/SPE Drilling Conference held in Dallas, Texas, U.S.A., 2-4 March 2004.
4. Bond, D.F., Scott, P.W., Page P.E., and Windham, T.M., "Applying Technical Limit Methodology for Step Change in Understanding and Performance", SPE/IADC 35077 presented at the 1996 SPE/IADC Drilling Conference, New Orleans (USA), March 1996

5. US Patent 6,892,812, Niedermayr, Michael, “Automated method and system for determining the state of well operations and performing process evaluation”, assigned to TDE Thonhauser Data Engineering GMBH, May 17, 2005.
6. vanOort, E., Taylor, E., Thonhauser, G., Maidla, E., “Real-time rig-activity detection allows to indentify and minimize invisible lost time”, World Oil April 2008, Page 39ff
7. Case History: Automated Drilling Performance Measurement of Crews and Drilling Equipment Ketil Andersen, Per Arild Sjøwall, StatoilHydro, Eric Maidla, Buddy King, Nexen Data Solutions Inc., Gerhard Thonhauser, Philipp Zöllner, TDE Thonhauser Data Engineering GmbH Copyright 2009, SPE/IADC Drilling Conference and Exhibition This paper was prepared for presentation at the SPE/IADC Drilling Conference and Exhibition held in Amsterdam, The Netherlands, 17–19 March 2009.