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Building Trust in AI/ML solutions: Key Factors for Successful Adoption in Drilling Optimization and Hazard Prevention

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Introduction

The use of AI/ML technologies has provided breakthrough performance in automated predictive data analytics. With the increasing amount of data available during drilling operations, data driven AI/ML solutions lay out the future of current technologies for drilling optimization and hazard prevention. Fast adoption and appeal of these technologies to the industry could be explained by a few reasons:

- AI/ML enables digital transformation by using only real-time data without extensive requirements for contextual data so that engineering and data input processes can be fully automated;
- AI/ML solutions predict outputs based on the data trends allowing to solve problems where conventional models are hard to implement or are not sensitive enough to identify subtle anomalies;
- Targeted solutions address specific problems and become more applicable in the modern digital ecosystem,
- Due to previous reasons, such technologies are easier to implement and to scale up in the operational environment.

Successful adoption of AI/ML technologies lies in its validation and trust in the operational environment. Based on the project experience from various parts of the world, prerequisites for building trust have proven to be:

- high performance AL/ML technology;
- matured IT infrastructure with relevant support services to enable digital transformation;
- monitoring specialists in an established RTOC or rigsite team to validate solution decisions;
- good communication protocol and established responsibilities of the RTOC and rig team to validate the impact of the predictions and to apply for operations.

The success factors are consequently related to technology, infrastructure and “soft” aspects like work processes, team interactions and defined roles and responsibilities. Each of these areas will be addressed individually.

The AI/ML Technology solution

Current AI/ML solutions aid users to detect high-risk conditions and hole abnormalities and to suggest optimized drilling parameters in real time earlier than human cognitive abilities would allow. It gives a drilling team additional time to react and take corrective measures.

The drilling machine learning system consumes real-time data (standard drilling operational parameters) by connecting to the real-time data server. Based on the data, it predicts and provides risk awareness ahead of time for potential stuck pipe events. Displayed in the customer preferred real-time data viewer, the solution shares an easy-to-read color coding and text information. As the predictions are provided, their analysis is presented in the monitoring display as trends, warnings, and alarms related to the risk detected. Independent agents address a unique aspect of the well conditions impacting the risk for stuck pipe. It allows monitoring engineers and rig crew to identify the cause of the sticking issues and consequently implement the correct preventive actions. Such novel work processes enabled by AI/ML technologies enhance the utilization of human talent and improve drilling performance. For example, stuck pipe incident occurrence rates with risk monitoring using AI/ML systems show substantial reduction in occurrences of stuck pipes (~20 incidents per

100 wells down to ~2 per 100 wells in 2021 for an Asian Operator) (Payrazyan 2023). Constant improvement of the technology and its implementation in RTOC allowed the same company to achieve zero stuck pipe globally in 2023 (Mokhtar 2024).

Another type of AI/ML solution (self-corrective solution) is ROP optimization technology. In a similar way the drilling machine learning system consumes real-time data and in return shares optimized drilling parameters. Recommended rotary speed, WOB and mud flow rate are shared in the customer real-time data viewer. By following these recommendations, a driller and the operatonal team have an opprotunity to improve their performance by 12-64% (depending on the initial drilling practices and lithologies). The solution provides recommendations based on the best practices, reacts quicker to lithology changes and identifies opportunities for drilling optimization.

Methodology

The first step in building trust is to demonstrate that the AI/ML system would "work on my data and provide value in my organization." The following methodology was proposed in (Payrazyan 2023) for a stuck pipe risk detection system and proven to be successful over different implementation projects. The following steps can be performed using company data:

1. Tests on data from historical wells to verify whether the solution generates valid early warnings prior to known stuck pipe incidents;

2. Blind tests on historical data where information on whether an incident occurred or not was unknown to the tester;

3. Live field tests to verify risks are detected in real time, communicable to monitoring engineers and compatible with operational workflows and practices;

4. Analysis of larger samples of wells, with and without the solution running, for evidence of a change in the occurrence rate of stuck pipe incidents between the sample groups.

Similar steps can be used for ROP optimization technology:

1. Tests on data from historical wells to verify whether the solution generates valid ROP recommendations and offers potential ROP improvements.

2. Live field tests to verify recommendations are provided in real time, communicated to monitoring engineers and rig team to allow timely update current drilling parameters with recommended values.

3. Analysis of larger samples of wells, with and without the solution running, for evidence of consistent ROP improvement in the groups with the solution.

Going through one or more of these steps in the process of adoption of a new AI/ML solution is crucial. During this journey the following factors should be evaluated and addressed to build the trust in the technology at the initial stage:

- AI/ML solution is compatible with the company's data;

- AI/ML solution provides valid timely warnings and recommendations leading to positive outcomes;

- the number of false positives[1] is within an acceptable range;

- initial training and knowledge about the solution is shared to the key project personnel who can further contribute as solution champions and advocates;

- further implementation risks are known, assessed and minimized;

- a strong business case is created based on the company's data which is essential for further adoption and acceptance of the technology.

Results and Discussion

Use cases of solution implementation

With an operator in Oman, the 3rd step in the proposed methodology for a stuck pipe risk detection was selected to verify risks in real time. A technical set up which is commonly used for described AI/ML solutions is presented in figure 1 and was established for this project. The system was running in real time. The dashboard could be accessed using a web-based system, while the data was kept on

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[1] False Positives are used to calculate performance metrics such as Precision, False Positive Rates and accuracy for a subset of machine learning models (classification systems). In order to get a reading on the true performance of a model, it must have some notion of "ground truth", i.e. the true state of things. Performance metrics can then be directly calculated by comparing the outputs of models with this "ground truth".

the WITSML server in Oman. The software was capable of ingesting mud logging WITSML data and providing output compatible with the customer's needs in terms of connectivity and ability to read, write, and display.

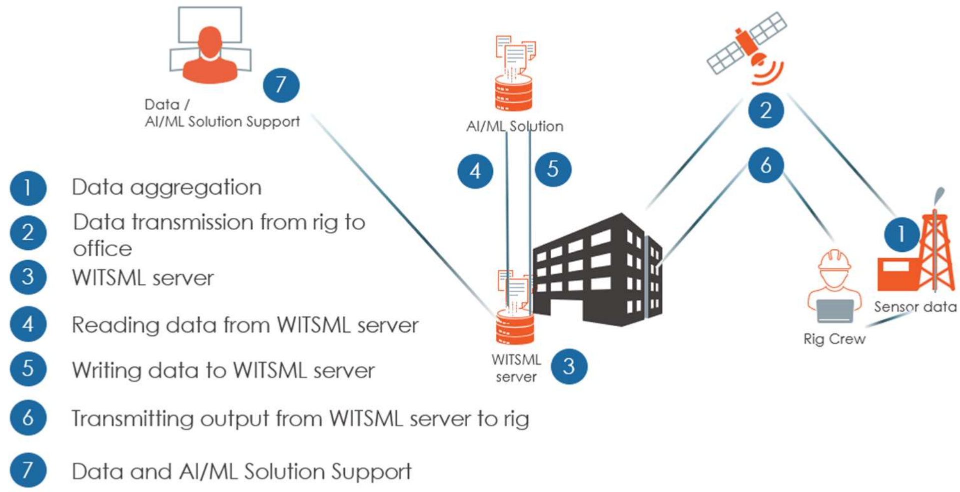

Fig. 1—Typical technical set up of the services: Data Transfers between Wellsite, Office, WITSML Providers, and Drilling Mud Logging Providers

There were 3 parties to monitor the dashboard: the drilling supervisor/wellsite engineer and the rig manager/driller, both were on site, and the well planner/engineer in town (Muscat). The system was run on land rigs with limited internet connectivity. During the implementation period, some technical issues were encountered which were resolved by the following steps:

1. Upgrading the data transfer bandwidth from 512 kbps to 3 Mbps;

2. Adding an additional screen dedicated for the drilling AI/ML dashboard outputs;

3. Opening the operator firewall to allow internet access to the mud logging unit.

The operator followed good drilling practices in mitigating the stuck pipe risks. This is manifested via frequent reaming after drilling a stand during the drilling operation and fast tripping speeds while running casing (mitigating the risk of differential sticking). The use of the drilling AI/ML stuck pipe solution was able to improve the mitigation through the early warnings.

Implementation of the drilling AI/ML for stuck pipe prevention enabled successful completion of the drilling of 4 wells with no stuck pipe events, with 2 wells having zero NPT and the other 2 wells being drilled ahead of schedule, enabling a potential estimated DDR cost savings of around USD 1.1 million. Achieved time/cost savings on the land rig justified the required investments in the technical interface mentioned above. Therefore, improvement of technical infrastructure in the office and on the rig should be an essential step on the digitalization journey of a company planning to work with AI/ML.

A similar project was run in India on 5 wells. The technical performance of the AI/ML system was excellent: 7 stuck pipe incidents were pre-warned, and preventative actions were taken in many cases. Unfortunately, the internet connectivity to the rig was relatively poor (85-90% uptime dependent on well location). In one instance the AI/ML technology provided repeated warnings, but at the time, the internet connection was not available, preventing the rig from seeing the warnings. The pipe got stuck 5 hours after the first warning, resulting in a sidetrack. Despite the good performance of the AI/ML technology and an overwhelmingly positive business case, this single event caused by poor internet connectivity deprived the trust in the solution. Such events could be mitigated by choosing suitable technical solutions where local rig deployment could be one of the possibilities.

In one of the cases, ROP optimization technology was used on the rig in West Africa (Robinson 2022, Al Riyami 2023). First, the technology was applied to the historical data of various well sections. This step together with blind tests (step two) often become a valuable demonstration tool of the technology to the team. Even though it is impossible to implement recommended drilling parameters on the historical data, such process allows to validate AI/ML solution based on the feedback and analysis of engineering team. In this case it was passed successfully, and AI/ML solution was further implemented on the ultra-deep water well. The novelty of the solution and the strong attention from the technical management and technical expertise ensured that the advice provided by the AI/ML solution was precisely followed. This resulted that bit on bottom time (BOBT) was reduced by 40% to 70% and the well was drilled 2.6 days ahead of technical limit (24 days ahead of plan).

The model was validated on 9 independent wells of various complexity, from different fields and regions, showing a strong ability to upscale to new wells and to support the use of a single model across a broad range of operations. On subsequent wells, when the technology adoption was matured and the attention from the technical management decreased, rig teams started to overrule the AI/ML advice, introducing cautious safeguards that resulted in poorer performance. This is an example of how culture and KPIs can negatively impact the uptake of a new technology and cause significant ILT. Benchmarking exercises on individual sections indicate that rig-imposed deviations from drilling procedures, best practices and AI/ML advice cost the company more than 100 million USD per year. To capture this value and mitigate such cost losses in the future, a change management process has been implemented by the operator in this case.

Adoption Barriers

For successful adoption of AI/ML solutions there are a few main barriers which should be overcome. These barriers could be divided into three major groups: technical, organizational, and personal. Which type of barrier would be a holdup for a solution adoption, is specific to a company and is often defined by the digital maturity of that company; but all the barriers should be resolved and overcome to be able to fully realize the AI/ML solution benefits.

Some of the frequently mentioned technical barriers (for example, data quality or its frequency) can pose significant risks. However, with recent technological developments they are often not the biggest issue for AI/ML solutions, as they could be resolved with the use of one of the available technologies on the market or by local installation. What is more damaging to the implementation of AI/ML solutions is the lack of constant availability of the data, poor data handling practices and the lack of data support services which prevents the resolution of data issues on the spot. Such "instability" of the provided data could be more damaging to adopting the solution compared to other technical issues.

Organizational barriers are another main type of barrier in most companies. For the predictive solutions to provide the best results, they should be monitored 24/7 by specialists in the RTOC or on the rig. These new types of solutions change the dynamics and role of the RTOC centers going away from monitoring of surface parameters (as properly set up smart alarm could do it more efficiently than a human) towards consuming the outputs of AI/ML solutions, evaluating provided risk warning together with other factors and acting on it in a proper manner. An established RTOC with monitoring specialists or trained specialists on the rig site can become a key success factor on the company's digitalization journey as they provide:

- validation and quality control of decisions at the initial stages of implementation of a solution;
- successful implementation of solution recommendations in operation enabled by proper use of communication protocol between the RTOC and the DSV/rig team;
- close ties of the monitoring team with the planning and operational teams to share the knowledge of the operational recommendations and vice versa: situational awareness of operation limitations and objectives upfront to achieve the best results with the solution.

Role and responsibility assignments for those who monitor data and timely communicate risks come into focus in the present business environment as it is tightly related to contractual obligations. Competing interests can often hinder the application and success of the new solution.

Another big organizational barrier is the autonomy of the rig: Unpublished data from McKinsey recommends strengthening the role of the central team based in the office to ensure the implementation of best practices across teams. Such strengthening of the central office helps to ensure that shared recommendations are listened to and implemented. Convincing a rig team to trust and rely on a new solution (which is closely connected with personal barriers) can quickly become one of the main challenges on the way.

The third type of barrier is personal (or human). Even though we are all surrounded by new technologies and use AI/ML solutions every day, there are still a few personal human misperceptions to overcome. Those can include:

- trusting the "black box" (of the unknown which AI/ML technology and provided recommendations may represent to an average oil and gas operator);
- a fear of AI/ML replacing a human in the workplace;
- a "refusal attitude" to accept new technology due to a preference to rely on a person's professional experience rather than augmenting tools.

Many of these personal fears and barriers could be resolved by conducting regular training, establishing clear communication protocols and action guidelines, and the regular sharing of use cases from rig operations. During the initial period of technology adoption, it is also essential to have a focal person available to the users to assist with familiarization with the solution. Active use of new technology and positive feedback from other users in the company can also help to boost trust.

With the rapid advances in modern technology and new targeted AI/ML solutions automatically solving more everyday tasks, success in the workplace becomes not only about a person's professional experience, but more about being able to embrace new technologies and the opportunities that they open. AI/ML solutions augment existing business processes, becoming a powerful tool to enrich a person's work experience, improve one's efficiency and assist the users. Therefore, the role of humans becomes even more important where their collected experience should be further used to improve the solution and elaborate on the use cases. The testing steps in methodology such as blind tests, de-risking and establishing a strong internal business case are also crucial to overcoming such type of barriers.

Communication protocol

The use of communication protocol has proven to be a successful practical tool on the road towards AI/ML implementation in RTOC and on the rig. A schematic of a communication protocol is presented in figure 1. Table 1 shares an example of communication protocol messages and when such messages should be communicated to the rig. Similar structured communication protocols have been developed for all companies where AI/ML solution is implemented and have shown good results with various monitoring teams.

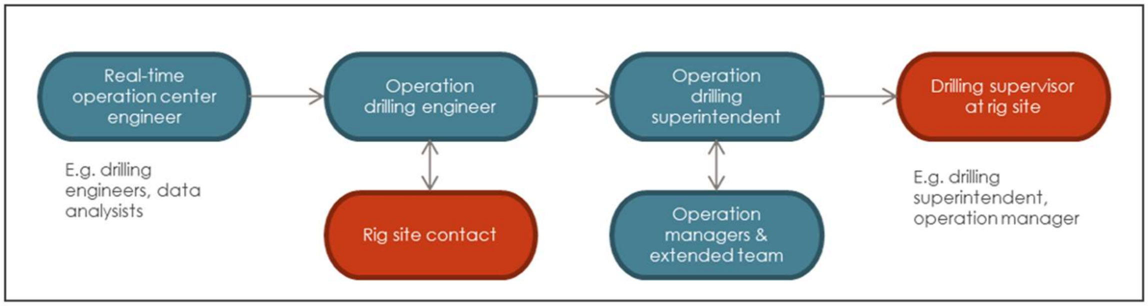

Fig. 2 — An example of communication protocol.

Table 1: An example of communication protocol messages for Stuck Pipe risk warnings.

WARNINGS OBSERVED	RISK INTERPRETATION	MESSAGE TO RIG	ADVISED ACTION
Combination of HC & DS warnings. DS warnings may be raised based on observed breakover hookload and/or breakover torque values.	**This combination indicates one of two scenarios:** - **Either a sticky/swelling clay constraining pipe movement** - **Losses building a filter cake and preventing full returns to surface.** Both scenarios will increase static & dynamic friction. Swelling/sticky clay will cling to the pipe during connection and when moving the pipe, increasing both static & dynamic friction in the wellbore. During losses, DS is common, due to the pressure differential between wellbore and permeable formation often resulting in a filter cake build-up. HC warnings are often provided due to anomalies in the flow pattern and mud's reduced lifting capability due to the losses.	Before alerting rig, we advise to check for a **sticky clay** or **mud losses**: **Sticky clay**: "Observe from Spotter that there are problems related to formation - probably sticky clay @ X m" **Losses:** "We observe an increased risk for DS, and potentially poor hole cleaning due to losses."	**Sticky clay**: Ream after each stand. Ream and circulate bottoms up at the end of the drilling section. **Losses:** Actions must be determined on a case to case basis but consider reaming and avoiding long connection times.

The first column summarizes the outputs that the monitoring specialist could see in the dashboard. With several AI/ML agents (or even solutions) providing warnings it can quickly become overwhelming to remember different combinations of risk factors, and a monitoring specialist needs to be assisted with interpretation of the incoming information. This field should be clear and unambiguous and quickly refer the specialist towards correct type of risk.

The "risk interpretation" column reminds a monitoring specialist what current risk is involved. This field provides him/her with solid background information on the risk to start acting upon or to investigate the issue further if necessary. Using AI/ML solutions adds another dimension to the risk awareness and interpretation, and this field helps to capture these multiple dimensions and to create a full picture immediately.

The "message to rig" column states a clear message that should be communicated to the rig. Due to the personal barriers mentioned earlier and high level of intensity of operations, the message should be short and understandable. All users in the office and on the rig should be in alignment with what the message means and ready to act on it. These messages as well as other fields of communication protocols should be standardized to provide the simplicity and usability of communication protocol.

The “advised action” column describes recommended actions on some of the risks. Such actions can be generic but often summarize the knowledge of an oil company and are based on its previous experience. This field should be constantly updated with the new lessons learned from the operations. Therefore, the protocols should be constantly updated, and the personnel regularly trained in them.

Such types of communication protocols should be established before the start of operations and constantly validated by real use cases. It is important to consider the organization and personal barriers specific to a company when creating communication protocols. Some roles in the teams might not take the proposed actions or follow the proposed advice from the RTOC or monitoring specialist. To ensure that the solution reaches its benefits in the field, they should be regularly trained and reviewed. Similar types of protocols and checklists are common in other crucial and high tech industries such as medicine and airspace. This tool could be successfully transferred to oil and gas AI/ML solutions if properly implemented.

Conclusions

The use of AI/ML solutions over the past four years with different teams over the world has demonstrated the value of this tool for real-time operations and emphasized the key learnings for successful adoption of such solutions:

- Data driven AI/ML solutions allow the data to tell the story in real time (or historically for analytics). Accurate records of drilling parameters, proper infrastructure and adequate data storage are valuable in themselves and provide a way forward for any digitally mature company;

- Documented value of AI/ML solution implementation benefits justifies a further investment in technical infrastructure and work processes changes;

- AI/ML adds a dimension to the interpretation of data and brings an enhanced focus of its use at the RTOC by real-time monitoring specialists;

- AI/ML is a tool that increases the value of people in their work environment creating an AI drilling engineer with new AI/ML solutions assisting the team in recognition of higher risk patterns and provides it with recommendations that would not be feasible earlier;

- Key success factors for AI/ML solutions lie in overcoming three types of barriers: technical, organizational, and personal. Available data, together with well-established communication processes between teams, act as key enablers of new AI/ML technologies allowing them to reveal and achieve their maximum potential.

Nomenclature

AI	Artificial Intelligence
DDR	Daily Drilling Report
DS	Differential Sticking
DSV	Drilling Supervisor
HC	Hole Cleaning
ML	Machine Learning
ILT	Invisible Loss Time
NPT	Non Productive Time
ROP	Rate of Penetration
RTOC	Real-Time Operation Center
WITSML	Wellsite Information Transfer Standard Markup Language
WOB	Weight On Bit

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