AADE-25-NTCE-070

Implementation of Lean Methodologies in the Technology Adoption Cycle for MPD Processes in Unconventional Reservoirs

Martin Duarte, Matthew Kvalo P.E Antonio Torrealba P.ENG, Stasis Drilling Solutions

This paper was prepared for presentation at the 2025 AADE Fluids Technical Conference and Exhibition held at the Bush Convention Center, Midland, Texas, April 15-16, 2025. This conference is sponsored by the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers, or members. Questions concerning the content of this paper should be directed to the individual(s) listed as author(s) of this work.

Abstract

While MPD might be seen as being in the early stages of the technology adoption cycle in some basins, in others it is integral to the drilling operations. The Haynesville Shale is one such basin in late stages of the cycle, with the majority of wells drilled utilizing a form of Managed Pressure Drilling (MPD). Early adopters in the basin tried a variety of different MPD technologies and processes, which resulted in identifying the most likely technology to achieve a decrease in wellbore-related NPT. As usage grew, the focus shifted from technology identification to optimization with attention on cost and critical path time reduction, resulting in a quasi-level of standardization being established for several years on equipment and processes used.

At this later stage of the technology cycle, the implementation of Lean Methodologies can lead to the next level of optimization and innovation even within a well-established drilling process. By utilizing this holistic approach, focused on the value stream, it's possible to identify and address potential sources of *Muda* (waste) such as over-processing, over-production, motion, waiting, etc. Real-world examples will be used to highlight how the implementation of Lean Methodologies allowed for a step change in comparison to previous optimization efforts

Introduction

Surface Back Pressure Managed Pressure Drilling (MPD) and its variants represent a critical advancement in optimizing drilling operations. In the Haynesville shale, these methods have become essential for conducting efficient drilling campaigns. Over time, MPD has progressed through the technology adoption cycle (Figure 1) in the Haynesville, moving from initial trials by early innovators and adopters to widespread standardization once its benefits were clearly demonstrated. This shift has led to a significant reduction in drilling days per well—dropping from more than 40 days for a 10,000-foot lateral to an average of 25 days or fewer.

As a result, MPD utilization has surged in the region. Many providers seek a competitive edge by refining equipment, pursuing research and development, or adjusting costs. While these strategies fuel innovation, they often yield only incremental improvements for the end user. This paper asserts that applying Lean Methodologies to MPD workflows, especially when guided by a client-centered approach, uncovers additional opportunities for optimization. These lean principles offer a structured method to eliminate waste, boost efficiency, and drive continuous improvement throughout the drilling process.

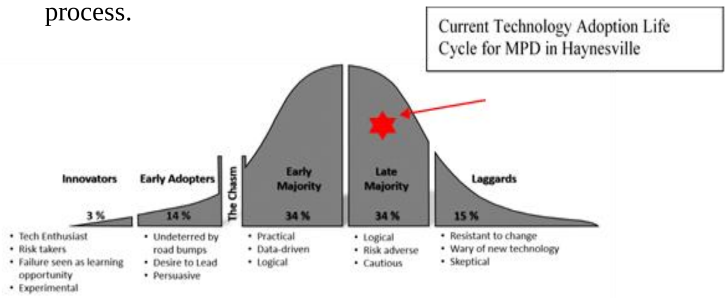

Figure 1 –Technology Adoption Lifecyle Curve and all of its Relevant Stages

Lean Methodologies: Principles and Framework

Lean Methodologies originated within Toyota's production system. These principles have since been adapted across industries due to their universal applicability and efficacy. The core principles are:

Value: Is in lean is any activity or feature that directly satisfies customer needs or requirements, and that the customer is willing to pay for. It is further broken down into the three following categories.

1. **Value-Add:** Directly transforms the product, service, or process in a way that the customer is willing to pay for or Contributes to the desired outcome from the customer's perspective.
   Example**:** Drilling the wellbore deeper into the pay zone, thus transforming the physical properties of the well.

2. **Non-Value (Waste):** Does not transform the product or service in any meaningful way or adds no benefit from the customer's perspective and could be eliminated without affecting final quality.

   Example**:** Excessive circulation time prior to a trip, which does nothing to improve the final drilling outcome.

3. **Non-Value, but Required:** Does not directly add value to the product or service but is required for regulatory, safety, or operational reasons.
   Example: Tripping the drill string out of hole for casing does not transform the wellbore, but is required for the next step in the operation.

Value Stream: Value stream mapping (VSM) involves identifying and categorizing all process steps by their type of value. It can be applied at both a high-level (macro) scale and a detailed (micro) scale, and it may include multiple layers or iterations. Often, several smaller value stream maps feed into one overarching process aimed at a single objective. Each map focuses on what the client perceives as valuable, classifying everything else as either waste or necessary waste. By making the flow of work visible, value stream maps help identify removable waste and reduce the time associated with tasks deemed necessary but non-value-adding.

Respect for People: Lean emphasizes creating a workplace where everyone feels empowered to propose improvements, especially those closest to the process. These individuals are most affected by any changes, so their insights should be sought out and given proper consideration. When ideas are dismissed or not taken seriously, valuable opportunities may be lost. Lean also acknowledges that not all ideas will succeed; however, it promotes an environment where suggestions are encouraged for the sake of continual process improvement—free from fear of retribution if the idea does not work as intended.

Pursuit of Perfection: Continuously seeking improvements to eliminate waste and optimize efficiency. This is done through experimentation with the goal of zero waste. This is why this principle is a "pursuit". It is an ongoing initiative.

Combining these principles, Lean encourages a culture of continuous improvement and innovation which can be used for addressing the dynamic challenges found in drilling. This philosophy emphasizes the identification and elimination of waste, empowering teams to streamline processes and enhance operational efficiency. In the context of MPD, this approach is particularly valuable for optimizing equipment performance, refining operational procedures (improving SOPs or reducing time associated to MPD SOPs), and ensuring seamless collaboration of stakeholders (communication between parties). With this in mind, Drilling can now be analyzed through the eyes of lean**.**

Types of Waste in Well Construction.

Lean identifies eight types of *Muda* (Japanese for waste). Each value stream will have some combination, if not all, of these, which vary based on the operation that is being analyzed. These eight types of waste can be remembered using the acronym DOWNTIME. Here is an example of waste identified by Lean found in traditional drilling operations:

1. **Defects:** Errors in wellbore stabilization/ EMW mismanagement.
2. **Overproduction:** Preparing excess drilling fluid volumes.
3. **Waiting:** Delays in equipment setup and testing.
4. **Non-Utilized Talent:** Lack of input from operational staff in process optimization.
5. **Transportation:** Inefficient movement of materials on-site and between locations.
6. **Inventory:** Overaccumulation of drilling fluids, consumables, and rental equipment.
7. **Motion:** Unnecessary movements of personnel and equipment.
8. **Excess Processing:** Redundant circulations of Kill Weight Mud (KWM).

Figure 2 – Wastes of Lean

Value Stream Mapping of Drilling Process

Value Stream Mapping is a cornerstone Lean tool, applied to visualize and analyze workflows. For figure 3, a basic VSM of drilling operations while utilizing MPD can be observed. Through this visual depiction, it's easier to identify bottlenecks, redundant steps, and opportunities for streamlining. Ironically, when first preparing a VSM, it is not uncommon for less than 10% of activities to actually create value. For example, in Drilling operations, the only value add activities are:

1. **Drilling Ahead:** Bit is on bottom and making new hole.
2. **Running Casing:** Rig is running production casing to TD.
3. **Cementing:** Rig is cementing production casing in place.

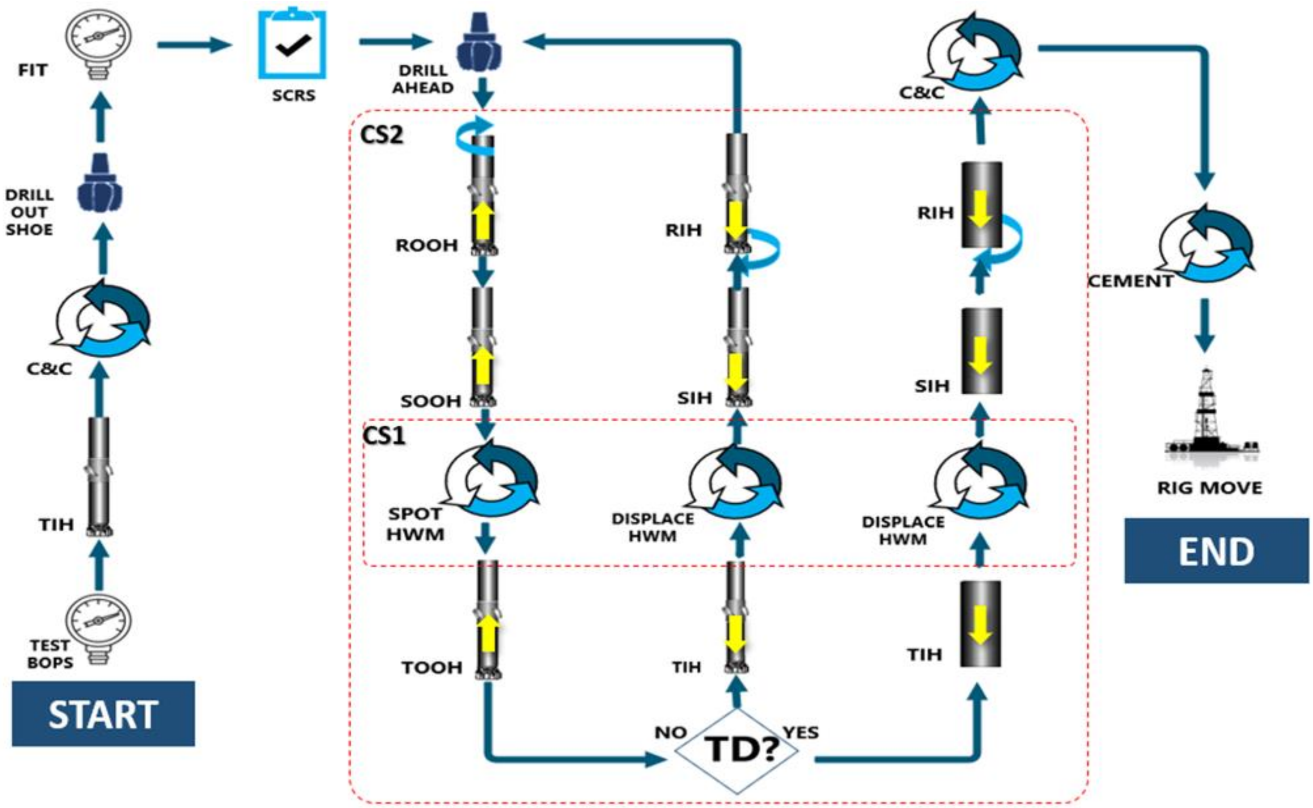

Figure 3 – Value Stream Map of the Drilling process utilizing MPD

This is not to say all other activities should be or can be removed. Testing BOPs do not transform the wellbore, being a non-value but required waste as this activity is both a regulatory and an operational safety requirement. The goal of lean is to minimize the amount of time it takes to perform both the value add and the non-value but required, and eliminate all non-value add activities. Utilizing the VSM two areas where initially. Identified for optimization.

- **Mud Circulation Optimization (CS1):** Mapping fluid placement and displacement workflows to reduce unnecessary circulations.
- **Anchor Point Selection (CS2):** Reduction in the magnitude of pressure fluctuations while drilling and casing the production hole section.

Background

The Haynesville Shale is a high-pressure, high-temperature (HPHT) unconventional reservoir that presents unique challenges, such as temperatures up to 380°F (195°C) and hole stability issues in extended laterals. Before MPD adoption in the basin, wells often took more than 40 days from spud to rig release, a timeline reduced to under 25 days on average with the introduction of MPD techniques.

(CS1): Mud Circulation Optimization

Original Practice: When tripping out using MPD with hydrostatically underbalanced MW, in order to maintain static overbalance in the well, a high density/ low volume pill is typically spot at the casing shoe. This Heavy Weight Mud (HWM) would then require multi-stage circulations to displace when tripping back in, which resulted in several hours of displacement time to remove HWM and condition the wellbore.
Waste: Three types of waste were identified in this process.

1. **Motion** associated to the reduction of trip speed when tripping back in to displace HWM.

2. **Waiting** times associated for fluid processing of interface of HWM and active fluid when displacing.

3. **Extra Processing** due to the need of swapping back and forth between tripping and circulating operations, as well as circulations that would not normally take place in conventional drilling.

Hypothesis: Circulation time associated with MPD can be eliminated, while increasing trip speed, by the modification of pill placement depth and utilizing fluid flow associated with steel displacement.

Method:
During tripping operations, tripping in displaces a certain amount of fluid volume at a relative to tubular OD and trip speed. This displaced fluid volume can be converted to "flow out" in gpm. This calculated flow at nominal tripping speeds was equivalent to the displacement rates that had been used in the past.

The desired volume of HWM was converted to an height. This provides the minimum spot depth required to achieve the desired EMW. (In the example in figure 4, the minimum required depth for this HWM was roughly ~4,400 ft. to surface - green trace.) Next, the deepest spot depth for the base of the HWM wherein it was possible to displace most if not all HWM by the time the casing shoe was reached was calculated. (In figure 4, this is the red trace at about ~6,000 ft.)

As seen in figure 4, the displacement technique that produces the least amount of strain (in terms of highest EMW) at the casing show is the minimum placement depth. In a weak shoe scenario this is the most favorable spot depth. Conversely, if utilizing the maximum spot depth (6,000 ft.), the strain on the shoe increases due to HWM stretching as DP displaces HWM to surface. This might be a preferable option if slugging the pipe prior to tripping is desired.

In figure 4 these two methods where compared with a 2 and 3 stage circulation in which the conventional spot depth of the shoe had been used. As expected, the 2-stage circulation has the highest EMW at the shoe, while the 3 stage has a slight reduction. If compared to the other two purposed methods mentioned earlier, it can be seen that the EMW seen at the shoe can be reduced and the time in which tripping speeds can be increased is shallower as well. When coupled with the elimination of pumping times, the value of the purposed methods can be seen.

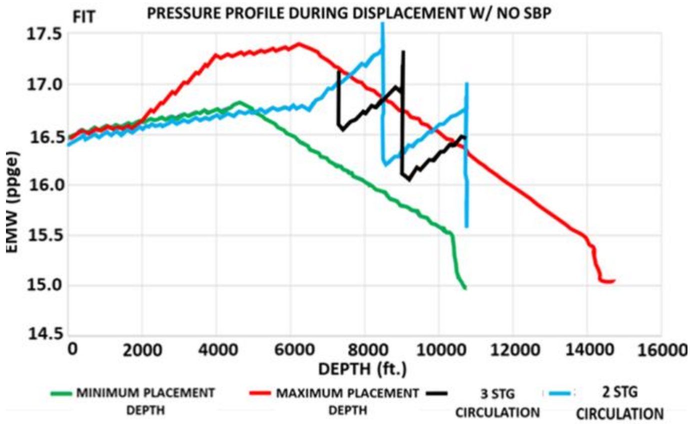

Figure 4 – Pressure Profile During Steel Disp.

Results: The change in method had the following results on the wastes, which resulted in 2 to 6 hours per trip, depending on the number of circulations**.**

1. **Motion** Trip speeds where increased up to conventional tripping speed, thus minimizing time in motion.

2. **Waiting** times where eliminated, all that changed over conventional tripping was that the trip tank where circulated back to HWM frac tanks instead of the active system once full.
3. **Extra Processing** was eliminated, as no more pumping was taking place.

(CS2): Anchor Point Selection

Original Practice: When drilling an extended reach lateral with MPD, a single ESD was selected and held constant (unless dictated by the well) while drilling the section.
Waste: Three types of waste were identified in this process.

1. **Motion:** Backreaming instead of tripping.

2. **Extra Processing:** Holding a higher pressure EMW earlier in the lateral with no effect on value.

3. **Overproduction:** Heavier muds to handle higher targets prematurely

Hypothesis: Increasing target EMW w/ lateral length instead of holding constant EMW will be the same or improve hole stability while improving tripping efficiency, allowing for the capability to round trip faster, by not having to backreaming after the clean-up cycle.

Method:
As lateral length grows in horizontal wells, annular pressure loss (APL) at the bit increases because of increased hole length. This results in an ever increasing bit EMW, which is directly related to hole length.

Figure 5 displays the Pressure Variance Frequency experienced by the well during a single bit run. Red represents the variance when there is no MPD. As seen, there is a high frequency variance in the amplitude of pressure in the range of +800/-500 psi. This pressure fluctuation is a cause of cyclic fatigue failure of the well bore. This fatigue has become more pronounce as lateral length extend. Cyclical fatigue often manifests in difficultly in tripping in and out when extending a lateral past an given depth.

are some of the biggest challenges during conventional drilling in the Haynesville shale. Wellbore collapse / instability often leads to increased time spent on hole cleaning, extended back reaming times, stuck pipe and in worst case scenario loss of the well.

This pressure variation is offset by the utilization of MPD, through using a single target value at the bottom of the curve to minimize these fluctuations as seen in blue in Figure 5, the range in pressure variance is now +300/-200 psi. Compared to the +800/-500 psi. This reduction in frequency and amplitude of pressure variance, leads to lower fatigue on the wellbore and less wellbore failure.

It was hypophysis that by steadily increasing target EMW at the bottom of the curve as the TD is increased, instead of holding the EMW required at TD, would reduce the frequency and amplitude further. This was then simulated and shown in green in figure 5, which resulted in pressure variance amplitude to +100/-200 psi. a further decrease in the frequency of high amplitude pressure fluctuations in the wellbore.

By gradually stepping up EMW instead of selecting a larger target from the beginning, would reduce the pressure required on the equipment, decrease the HWM consumption throughout the well, and maintain a higher buffer in the MPD matrix for longer in the lateral. All of these positives in addition to the pressure amplitude and frequency reduction drove the trial of this method.

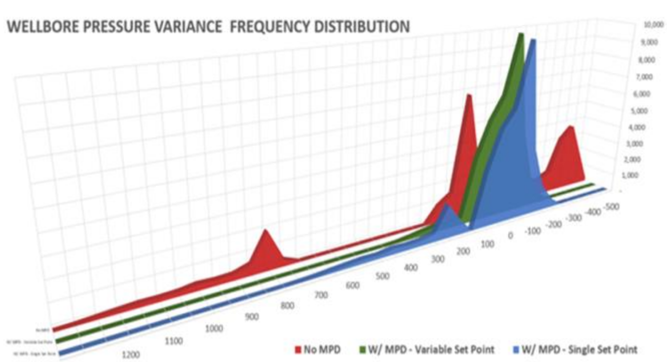

Figure 5 – Frequency Distribution for Downhole Pressure Variance

Results: The change in method had the following results on the wastes, which resulted in 6 to 12 hours per trip, through the elimination of backreaming.

1. **Motion:** Tripping speeds increased with the ability to pull the Drill string off bottom instead of having to Backream 5,000-10,000 ft.

2. **Overproduction:** Utilizing variable EMW target minimizes overproduction by using precise MWs, reducing the need for heavier muds when not required.

3. **Extra Processing:** Reduced premature high target EMWs. This prevents the well from experiencing unnecessary pressure variance.

Conclusion

As we advance through the later stages of the technology adoption cycle, implementing Lean Methodologies becomes increasingly essential for promoting waste reduction within MPD operations. By meticulously identifying and eliminating waste, organizations can streamline processes, leading to substantial time savings and cost efficiencies. This approach not only aligns with Lean's core principle of maximizing value for clients but also cultivates a culture of continuous improvement, significantly enhancing overall customer satisfaction. As the energy industry continues to evolve, the opportunity to uncover operational efficiencies is expanding. Now is the perfect time to integrate Lean principles, focusing on waste reduction not just in research and development, but also in everyday workflows. Prioritizing continuous improvement and fostering a respectful environment for all involved in the drilling process will be crucial for establishing lean practices that yield benefits for all stakeholders, while truly taking advantage of all benefits MPD has to offer.

Nomenclature

MPD: Managed Pressure Drilling
BHA: Bottom Hole Assembly
PPG: Pounds Per Gallon
EMW: Equivalent Mud Weight
MW: Mud Weight
HWM: Heavy Weight Mud
VSM: Value Stream Mapping
ERD: Extended Reach Drilling
ESD: Equivalent Static Density
APL: Annular Pressure Loss
CS: Case Study one or two

References

Batti, K. 2023. “Technology Aoption Curve: 5 Stages of Adoptioin.” https://whatfix.com/blog/technology-adoption-curve/

Jones, D.T. and, Womack, J.P. 2003. “Lean Thinking – Banish Waste and Create Wealth in Your Corporation.”

Monden,Y. 2012. “Toyota Production System – An Integrated Approach to Just-In-Time.”