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Original Article

A Novel Approach for Enhancing Drilling Efficiency through Flat Time Optimization

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Abstract *- Efficient evaluation and improvement of drilling performance are crucial for companies in the oil and gas industry to optimize work plans, scale operations, and allocate financial resources effectively. Drilling operations, which are major expenditure areas, have seen efforts to enhance efficiency and reduce costs. A significant focus has been on optimizing flat time, which accounts for about 30-40% of total well time and significantly impacts well costs. A pioneering project aimed at systematically optimizing flat time analyzed over 2000 flat time sections, establishing a robust baseline and implementing a digital dashboard for real-time performance monitoring across 12 rigs. This approach led to significant time savings of 186 days within two quarters and cost savings of over 150 million dollars over five years. The project's success was also measured by improvements in the Drilling Rate Improvement Index (DRII), showcasing notable efficiency gains. Through data-driven insights and flat-time optimization, this project highlighted the potential for substantial cost savings and operational efficiencies in the oil and gas sector's drilling operations.*

Keywords *- Drilling performance, Drilling management, Flat Time Optimization, Drilling Operation Excellence, Well Cost Optimization.*

1. Introduction

Flat-time operations are of utmost importance and account for 30% to 40% of the overall duration dedicated to good construction. Flat time refers to the period during which various non-drilling activities take place, including static time without drilling, cessation of drilling, Pulling Out Of the Hole (POOH), casing running, cementation, wellhead and blowout preventer (BOP) installation as illustrated in Figure 1 [1]. As shown in Figure 1, flat time is represented by the horizontal sections, indicating no progress in hole depth over time. Historically, a Well Performance Management System (WPMS) has been utilized to reduce the well's flat time by making the learning curve steep and transferable [2]. Contreras et al. introduced a novel methodology to boost cost savings in the oil and gas drilling industry by enhancing the efficiency of tripping operations. They suggested a thorough analysis utilizing Key Performance Indicators (KPIs) to monitor and optimize tripping speeds, connection times, and footage, thus identifying and minimizing Invisible Lost Time. This approach enables real-time performance adjustments and supports a comprehensive historical analysis to monitor and enhance overall rig efficiency. Implementing this method allows operators to significantly cut operational costs, enhance drilling practices, and ensure the timely completion of wells [1]. Goo et al. studied the impact of multiwell operational performance benchmarking in establishing a baseline for each operation executed during well construction. They found that benchmarks should be derived from data that accurately represent the expected operational conditions [3].

Ferrari et al. have developed an Integrated Rig Management System that amalgamates data from rig sensors and daily reports to provide advanced analytics, streamline reporting, and improve operational performance and rig management. Comprising five key modules, namely Reporting, Multi-Wells/Rigs Performance, Real-Time Operations Monitoring, Predictive, and Data Manager, the system offers comprehensive insights for decision-making. Its impartial KPIs have shown potential time and cost savings of up to 8% in well campaigns. Furthermore, it optimizes logistical planning, integrates with third-party solutions, and addresses environmental concerns by analyzing energy consumption and reducing greenhouse gas emissions. Continuous enhancements ensure the system's adaptability and effectiveness in enhancing cost-efficiency, reliability, and environmental sustainability in drilling operations [4]. In their efforts to enhance efficiency, Mohamed et al. founded the Petronas Digital Collaboration Centre (PDCC) as a platform for decision support.

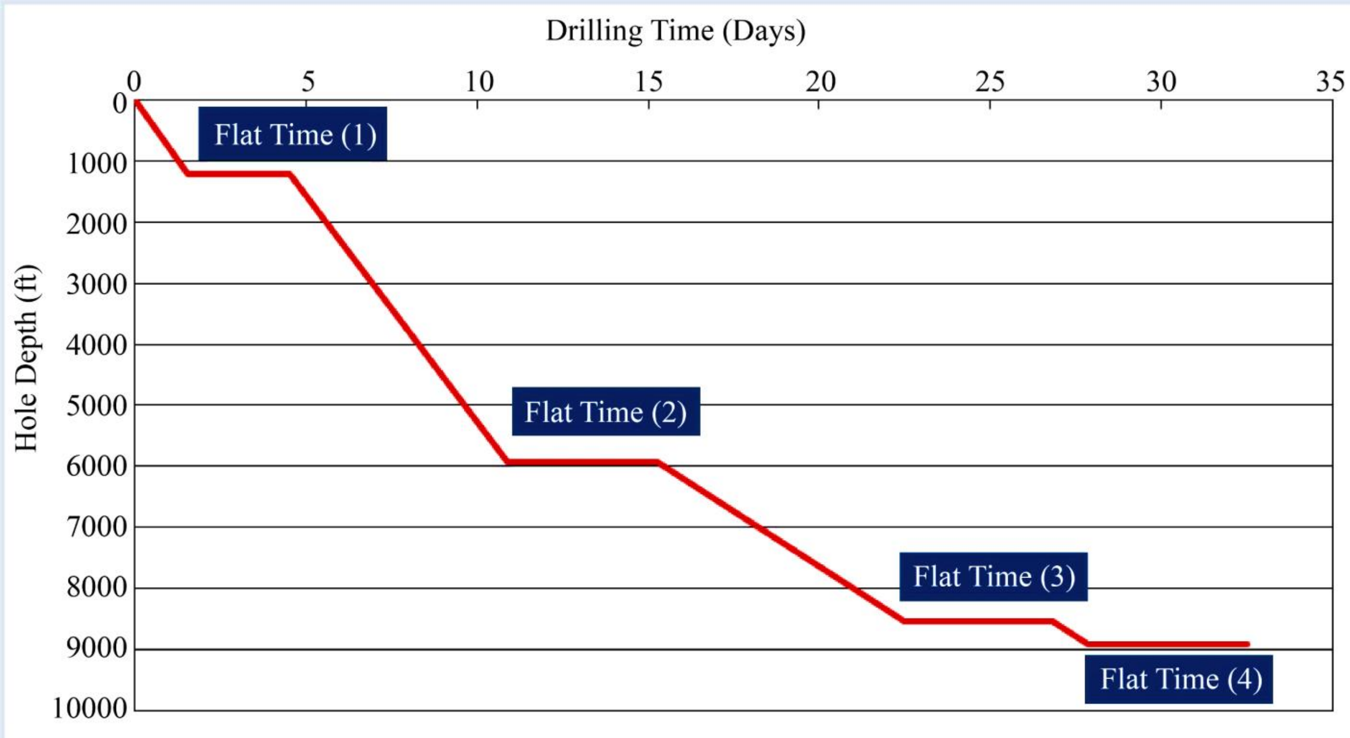

Fig. 1 Time-Depth curve for well drilling highlighting flat time sections

However, they identified a crucial gap in their system: the absence of a method for measuring good activity performance. Previously, reliance on manual logs and Excel spreadsheets hindered proactive measures and real-time interventions. The introduction of an artificial intelligence tool aims to fill these gaps but brings about management challenges concerning personnel, processes, and technology[5]. In their research, Khudari et al. explore the transformative impact of the Aramcolink solution on geo-steering operations at Saudi Aramco. They highlight the shift from disparate real-time data sources to a unified system, utilizing the WITSML protocol to connect with diverse service providers. The main objective is to provide operational geoscientists and engineers with a centralized platform for the simultaneous monitoring of multiple drilling wells. Aramcolink offers advanced functionalities like data quality control, rescaling, filtering, alerting, and communication tools crucial for optimizing production through effective geo-steering. Its standout features include data cross-plotting, azimuthal image dip calculation, petrophysical analysis, and comprehensive well trajectory visualization. The study also underscores how this transition facilitated standardization in real-time log naming, measurement units, and scaling, thereby streamlining operational processes. Finally, the paper concludes with insights on lessons learned and suggestions for future enhancements [6]. In recent years, real-time drilling data has become increasingly recognized for its potential value and widespread application within the oil and gas industry worldwide. This data is crucial for making timely and informed decisions during drilling operations, saving millions of dollars and reducing critical hole incidents. Even in the planning stages of a well, drilling departments rely on real-time and historical data to develop detailed drilling programs based on nearby well histories. Access to both active and historical data facilitates incident avoidance by leveraging insights gained from formation reactions during drilling. To maximize the utility of this data, further analysis is necessary to calculate performance metrics for specific rig activities. This involves developing algorithms to automatically recognize drilling activities based on real-time surface parameters and then using this information to derive Key Performance Indicators (KPIs) from observed operations [7]. To assess the quality of real-time drilling data obtained from rig sensors, the oil and gas operator employs six parameters - completeness, uniformity, sensibility, resolution, structure, and format - to measure data quality. Automated Rig Activity Measurement (ARAM) generates several KPIs, including Footage KPI, Data QC Availability, and Data QC Channels, for evaluating data quality across different vendors. These KPIs are utilized within a Real-Time Data Quality Dashboard, allowing drilling engineers to filter analysis results based on acceptable data quality ranges. This systematic methodology facilitates the identification of high-performing rigs and those in need of improvement [8]. Javed et al. highlighted the critical role of flat-time operations in oil and gas well construction, specifically focusing on the Blowout Preventer (BOP) handling to control costs and enhance safety. A case study of 14 wells in Malaysia found that BOP-related activities significantly contribute to overall flat time. Reducing BOP flat time can considerably decrease well costs. Further research involving 32 Malaysian wells established benchmarks for various BOP activities, revealing that factors such as rig procedures, facilities, BOP configuration, pressure rating, and connection type influence BOP flat time. This emphasizes the potential for operational efficiencies and cost savings through optimized BOP management [9]. A Real-Time Drilling Decision Center (RTDDC) was utilized to optimize drilling operations and improve well planning methodology. By applying advanced data analytics, invisible lost time was identified and addressed, resulting in enhanced performance tracking. Real-time data was combined with daily drilling reports to validate operational phases and calculate rig states. Key performance indicators were used to normalize and compare performance, leading to improved well planning. The methodology was successfully applied to two wells, capturing operational inefficiencies and categorizing root causes. The results demonstrate the application of advanced data analytics in optimizing operational efficiency and achieving cost savings in drilling projects. The connection time was studied using the RTDDC unit. The average connection time for 19 rigs was analyzed; it averaged to 5 min, and the large variation between the rigs could be 16 hours and 53 minutes [10]. Ouahrani et al. studied the impact of invisible lost time on optimizing the total well time. They found that efficient well-time management and cost optimization are essential challenges for drilling operators and service companies. In addition, they introduced an approach that combines real-time rig surface data with daily operation reports to track and compare drilling activities, enabling the identification and measurement of ILT and performance variations [11, 12]

Damski, investigated the integration of high-frequency drilling data from rig sensors with low-frequency daily drilling reports and well plans to improve performance in the well construction process. Their study focused on a fleet of 20 land rigs and employed a systematic approach to monitor and evaluate rig performance. By defining Key Performance Indicators (KPIs) and setting benchmarks, the analysis combines both real-time and historical data to gain insights into rig capabilities, crew performance, operational constraints, and drilling tool efficiency. The computed KPIs and the identification of Invisible Lost Time enable the drilling team to implement continuous improvement principles and optimize operations. The approach also allows for the generation of the best composite times for future wells, extending technical limits and identifying cost-saving opportunities. The performance-based methodology and multi-rig analysis platform prove to be effective tools in enhancing rig performance and can be beneficial for other operators and service companies in the industry [13, 14]. Different approaches have been utilized to enhance drilling operations. The two most common approaches are the PLANE-DO-CHECK-IMPROVE and SIX-SIGMA methods. Each method compromises definitive workflows to enable continuous drilling benchmarking within the project team and contractors [15].

2. Problem Statement and Research Objectives

The optimization of flat time in well construction remains inadequately addressed, presenting significant opportunities for improving specific processes and procedures. Current methods employed by operators to reduce flat time lack clarity and consistency, leading to substantial inefficiencies. Key questions revolve around identifying the specific process gaps and exploring potential improvements. Despite efforts to reduce connection time through Real-Time Data-Driven Decisions (RTDDC), tripping enhancement, and improving Blowout Preventer (BOP) and wellhead timing, there are noticeable inconsistencies across rigs, with over 12 similar rigs in operation exhibiting substantial differences in timing and not adhering to uniform procedures. A critical issue is the absence of specific standards and benchmarks for flat-time optimization. Without established guidelines, consistent and efficient flat time management across different rigs is unachievable. Furthermore, the current database within the open well system is inadequate for effective gap analysis and lacks the necessary data accuracy to identify inefficiencies. Another significant limitation is the absence of a dedicated system to monitor pre- and post-flat time actions. This lack of monitoring makes it challenging to pinpoint and address inefficiencies effectively. Additionally, there is no structured process or workflow to identify gaps and implement best practices, making it difficult to apply effective solutions consistently across all rigs.

The primary objective of this research is to identify the specific gaps in current flat time reduction processes. This involves conducting a detailed analysis to pinpoint inefficiencies that lead to increased flat time. To address these issues, the development and implementation of standards for flat time optimization are crucial. Establishing benchmarks and guidelines will ensure consistent and efficient management across different rigs. Enhancing systems for monitoring and analyzing flat time data is another key objective. Implementing advanced systems will facilitate accurate gap analysis, enabling more effective identification and resolution of inefficiencies. Furthermore, establishing a clear workflow for identifying gaps and integrating best practices is essential. Creating a structured approach will enable the consistent application of effective solutions across all rigs. The ultimate aim of this study is to develop a comprehensive roadmap that answers the research questions, gathers data on gaps, and reduces the rig time spent on a well. This will be achieved by minimizing flat time and controlling invisible and wasted time, leading to a more efficient and standardized approach to flat time optimization.

3. Research Methodology

In this research, a specific process and set of procedures were applied to establish a clear and reliable baseline for the flat time sections and identify the existing gaps. This involved setting Key Performance Indicators (KPIs) through a systematic process and model. By recognizing the aforementioned limitations, the methodology was designed to include three major steps or phases in the workflow aimed at improving the flat time of drilling a well: the planning phase, the implementation phase, and the project review phase.

3.1. Planning Phase

The planning phase is crucial for maximizing improvement opportunities within a project. Without a clear vision, the operations team can lose direction and fail to achieve their goals. To address this, several key points are considered. Firstly, a review of previous activities and performance initiatives related to flat time optimization is conducted to evaluate outcomes and highlight milestones achieved. The following flat-time operations are the main operations that need to be evaluated:

- Circulation after section TD" section Total Depth". At least 3-4 cycles.
- Wiper Trip.
- Circulation before Final BHA" Bottom hole Assembly POOH" Pull out of the hole".
- Final POOH before casing.
- Casing Run.
- Circulation before Casing Cementation.
- Casing Cementation. Perform top job offline.
- BOP Nipple Down + WH Nipple Up + BOP NU & Pressure Test
- Rigging up of the Drilling BHA runs for the next section.
- Shoe Track Drilling (Including Casing Pressure Test)
- FIT" Shoe formation integrity Test"

Next, any gaps in the historical process are identified, and optional process improvements are defined to create a project process map. The timing for each flat-time operational component is studied, and a baseline is established through data acquisition, including both Low-Frequency Data (LFD) and High-Frequency Data (HFD). While ensuring data quality assurance/quality control (QA/QC) measures are in place. The gathered data is then analyzed to identify potential business improvements, assess operational timing savings, and enable cost control.

It is important to note that the gaps between rigs and operational activities provide valuable insights into potential opportunities and areas for improvement. Once the baseline is defined and business opportunities are clearly identified, the project team sets Key Performance Indicators (KPIs), establishes new targets and goals for each specific section/operation, and conducts brainstorming sessions with all participants to gather feedback and leverage their experiences. A dedicated task force team is formed to complete the project phases, and project/study resources are allocated while adhering to a defined timeline outlined in a project charter. During the planning stage, achieving precision involves three steps/ phases: acquiring data with attention, to detail conducting thorough data analysis, and setting strategic goals. This combination guarantees a base of insightful information analysis and well-defined objectives for successful project implementation.

3.1.1. Data Acquisition Phase

Accurate and comprehensive data gathering is a critical step in ensuring the success of any scientific project. It is important to carefully select and gather relevant data that aligns with the project's specific goals and objectives while eliminating extraneous information that may introduce noise during the subsequent analysis phase. In this regard, several key steps were undertaken during the data acquisition phase.

Firstly, a systematic model was developed to collect data from a substantial dataset comprising 650 wells and over 2000 flat-time sections drilled within one of the largest assets of a leading Middle Eastern company. Data extraction was performed from the EDM Halliburton database system using customized queries specifically designed to retrieve the essential data elements required for the project. A sample of the database used in this study is summarized in Table 1.

Secondly, the identification and categorization of essential column titles and primary data fields were conducted. This encompassed vital information such as well name, asset name, rig name, section start and end dates, temporal characteristics, Non-Productive Time (NPT) during each section, section and event types (drill or flat), main well types, and other relevant attributes. It should be noted that the selection of these primary data fields may be tailored according to the specific analysis requirements and organizational objectives of the company.

Rigorous data quality assurance/quality control (QA/QC) procedures were implemented to ensure data integrity and cleanliness. A meticulous review process was undertaken to validate and verify the accuracy of the baseline data for all rigs, fields, and operational aspects. Emphasizing data cleanliness and accuracy is crucial to facilitate informed decision-making during subsequent analysis stages.

Prior to commencing the data analysis phase, comprehensive data review sessions were conducted with the involvement of project focal points. These collaborative sessions aimed to refine and validate the collected data, ensuring its relevance and appropriateness for the subsequent analysis steps.

3.1.2. Data Analysis Phase

The data analysis stage requires a professional team with expertise in data science and drilling experience to drive operational excellence. Benchmarking is used to compare current performance with a dataset, identifying gaps for improvement. Variances among rigs and operations indicate areas where performance can be optimized.

Table 1. A sample of the comprehensive database used in this study

Well	Rig	Section	Activity	Depth in	Depth out	Depth (Drilled)	Section time (Hrs)	Section NPT (Hrs)	Days/1000ft (with NPT)	Days/1000ft (without NPT)
W-348	Rig-28	22	Drill	58	1245	1187	43	0	1.51	1.51
		22	Flat	0	1245	1245	75	0	2.51	2.51
		16	Drill	1245	6007	4762	190	0	1.66	1.66
		16	Flat	0	6007	6007	89	0	0.62	0.62
		12.5	Drill	6007	7105	1098	232.5	1.5	8.82	8.77
		12.5	Flat	0	7105	7105	113	1	0.66	0.66
		8.5	Drill	7105	7825	720	28.5	0	1.65	1.65
		8.5	Flat	0	7825	7825	109.5	2	0.58	0.57
		6.125	Drill	7825	12133	4308	192	2	1.86	1.84
		6.125	Flat	0	12133	12133	69.5	1	0.24	0.24
		6.125	COMP	0	12133	12133	182.5	13	0.63	0.58
W-359	Rig-42	22	Drill	60	1215	1155	39	0.5	1.41	1.39
		22	Flat	0	1215	1215	108	14	3.70	3.22
		16	Drill	1215	5916	4701	208.5	9.5	1.85	1.76
		16	Flat	0	5916	5916	123.5	1	0.87	0.86
		12.5	Drill	5916	7060	1144	104.5	2.5	3.81	3.72
		12.5	Flat	0	7060	7060	193.5	0	1.14	1.14
		8.5	Drill	7060	7850	790	48	0.5	2.53	2.51
		8.5	Flat	0	7850	7850	82.5	0.5	0.44	0.44
		6.125	Drill	7850	11026	3176	182.5	0	2.39	2.39
		6.125	Flat	0	11026	11026	30	0	0.11	0.11
		6.125	COMP	0	11026	11026	194	6.25	0.73	0.71
W-380	Rig-42	22	Drill	64	1222	1158	30.5	0	1.10	1.10
		22	Flat	0	1222	1222	58.5	0	1.99	1.99
		16	Drill	1222	6115	4893	569.5	419	4.85	1.28
		16	Flat	0	6115	6115	54.5	0	0.58	0.58
		12.5	Drill	6115	7438	1323	69	4	2.17	2.05
		12.5	Flat	0	7438	7438	76.5	0	0.43	0.43
		8.5	Drill	7438	8250	812	52.5	2	2.69	2.59
		8.5	Flat	0	8250	8250	77	0	0.39	0.39
		6.125	Drill	8250	11540	3290	145.5	1	1.84	1.83
		6.125	Flat	0	11540	11540	40	0	0.14	0.14
		6.125	COMP	0	11540	11540	0.5	0.5	0.25	0.25

For this study, a specialized well-flat-time planning tool, referred to as the "Digital Flat Time Performance Tool", has been developed and implemented. The tool serves as a user-friendly dashboard, generating planning charts for all well sections, automatically preparing planning timing, and presenting actual timing upon section completion. It also functions as an After-Action Review (AAR) tool.

Baseline Identification

Establishing the baseline for such a specific operation was a complex task. After filtering and cleaning the data, different baselines were utilized to establish the SMART KPIs. These baselines included the Top Quartile (TQ) baseline, the Best in Class (BIC) baseline, and the Median baseline, which were determined using percentiles. The input data for the digital performance tool includes well profile, number of sections, section size, drilling/flat activity, depth in/depth out, total depth, and target formations. Upon completion of each section, the drilling engineer records the actual section timing. The output data provides the number of samples drilled from the same well type, indicating the strength of the database based on the available sample size for subsequent calculations. Note that a higher number of samples increases baseline reliability; field experience recommends at least five samples to create a trusted baseline. The tool provides both field-specific timing (well-type timing per field) and rig-specific timing (well-type timing per rig). Additionally, it includes Best in Class (BIC) timing, top-quartile (TQ) timing, and median timing. The tool automatically compares the median construction timing of the field with the construction timing of the rig. If the field performance is lower than the rig performance, the rig performance will be selected as the target for the next well. Conversely, if the rig performance is less than the field performance, the field performance will be used as the target level for the next well. The rig target timing and the time saving per section are calculated using equations one and two, respectively. The timing saves per section, and the team can track the gaps for each section completed.

$$Rig\ Target\ Timing = Minimum\ of\ (well\ type\ timing\ per\ field\ \&\ Well\ Type\ Timing\ Per\ Rig \qquad (1)$$

$$Time\ Saving\ per\ Section = Rig\ Target\ Timing - Actual\ Time \qquad (2)$$

The phase dashboard of the Digital Performance Tool, including a sample calculation, is presented in Figure 2. The Digital Performance Tool also provides a days versus depth graph for actual sections, along with the target baseline and a comparison between the actual and target timing for each section, as shown in Figures 3 and 4, respectively.

Asset	Rig	Field	Target Formation	Trajectory	Shape	Number of sections
ASSET-1	Rig-26	X-29	Formation-E	H	J	5

Flat Time Digital Dashboard

Input Data					Out Put Data								Final Details			
					Field specific (Days)				Rig Specific (Days)							
Hole size	Activity	Depth In	Depth Out	Total Depth	Sample size	BIC	TQ	Median	ig Sample siz	Rig BIC	Rig TQ	Rig Median	Rig Target	Actual	Saving	Best Section
22.00	Drill	50	1209	1159	121	0.64	1.26	1.55	6.00	0.81	1.00	1.37	1.37	1.20	0.17	0.55
22.00	Flat	0	1209	1209	121	1.38	2.65	2.98	6.00	1.82	2.99	3.52	2.98	2.60	0.38	1.14
16.00	Drill	1209	5940	4731	121	2.36	5.29	6.34	6.00	2.36	5.47	6.76	6.34	4.30	2.04	0.50
16.00	Flat	0	5940	5940	121	2.32	3.92	4.40	6.00	2.78	4.06	4.86	4.40	3.00	1.40	0.39
12.25	Drill	5940	8527	2587	121	1.99	5.53	7.22	6.00	2.51	4.18	4.85	4.85	5.80	-0.95	0.77
12.25	Flat	0	8527	8527	121	3.05	3.93	4.34	6.00	3.05	4.12	4.21	4.21	3.20	1.01	0.36
8.50	Drill	8527	8906	379	121	0.53	0.86	1.04	6.00	0.66	0.69	0.73	0.73	1.10	-0.37	1.39
8.50	Flat	0	8906	8906	121	2.90	3.94	4.66	6.00	3.10	3.52	4.31	4.31	3.60	0.71	0.33
6.13	Drill	8906	9299	393	121	0.24	0.53	0.72	6.00	0.28	0.52	0.61	0.61	0.60	0.01	0.60
6.13	Flat	0	9299	9299	121	0.03	0.72	0.87	6.00	0.57	0.62	0.76	0.76	0.70	0.06	0.00

Hole Size	Flat Time (Field Median)	Flat Time (Rig Median)	Target	Actual	Savings
22	2.98	3.52	2.98	2.60	0.38
16	4.40	4.86	4.40	3.00	1.40
12.25	4.34	4.21	4.21	3.20	1.01
8.5	4.66	4.31	4.31	3.60	0.71
6.125					
Total Savings, Days (Flat Time)					3.50

Fig. 2 Automated planning tool interface

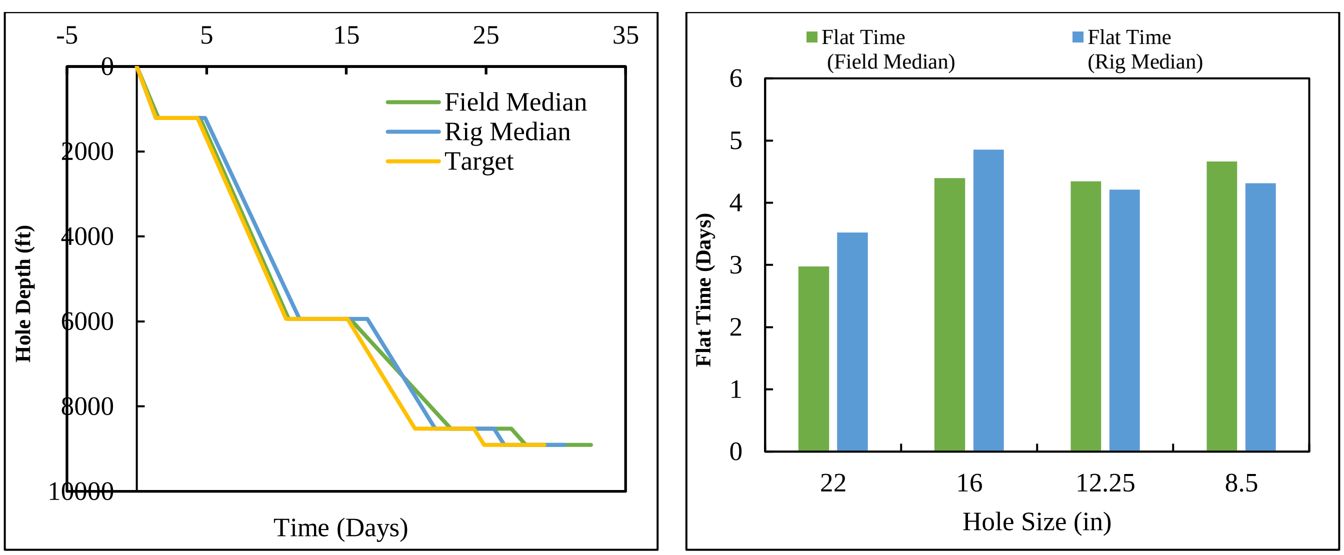

Fig. 3 Planning tool output, time versus depth

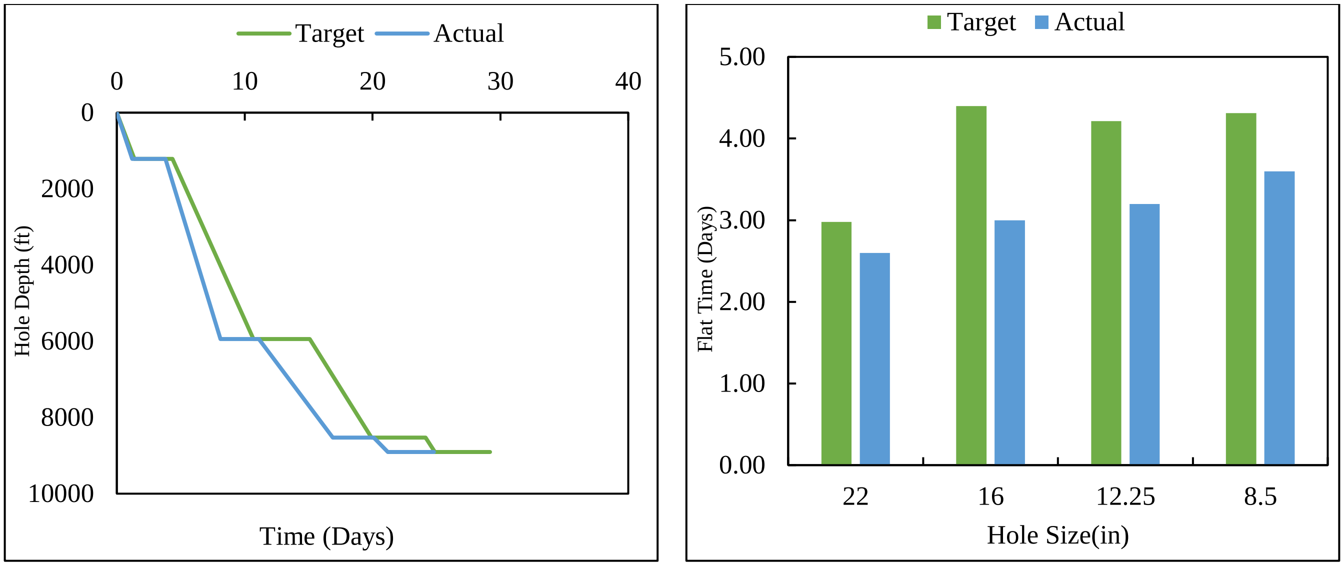

Fig. 4 Comparison between the actual and target timing for each well section

3.1.3. Setting the Project Targets

Upon data acquisition and data analysis phase, One of the most important elements in any performance optimization project is to settle the project goals and targets that match the team and organization's capabilities; goals and objective statements provide the direction for planning and execution, and the goals must be SMART.

Specific, Measurable, Acceptable, Realistic, Timely bound, basically Goals and objectives can guide action.

- Specific: the basic project goals were setting targets for each rig based on the historical baseline field/rig timing, building new project processes, improving flat time for 12 rigs, providing best practices for activities, and monitoring project performance.
- Measurable: The goal statement should clearly state what will be achieved and when it will be completed; if the goals can be measured, then it will be easy to determine whether the project was achieved or not; in the flat time reduction project, the goals were to reduce the timing by 15 % and to measure the timing section by section, to provide the gaps/ best practices section by section.
- Acceptable: Does everyone in the drilling organization agree that the goals are necessary and desirable? Are the objectives accepted by all project participants, and what are the limitations, if any? For the flat time project, several meetings were conducted with all stockholders, drilling engineers, drilling supervisors, drilling management, all service providers, and rig contractors to highlight the performance opportunities and the gaps, process and project road map, and all the team agreed on.
- Realistic: the goals can be accomplished with the current organization's capabilities but are probably challenging and need more effort. This can be an answer to whether the goals are achievable. For the flat time project, a realistic goal was settled because the best timing had been achieved, and the main idea was to share the best practices/ timing with all the rigs and observe future operations for improvements.
- Timeline: The goals should be controlled by the deadline and within the time horizon. The project team will follow up on the actions with the planned timing and measure the plan/actual action timing close out. In the flat time project, the team settled for one year for the project to achieve the goals and target.

3.2. Implementation Phase

The implementation phase holds immense importance in project management. During this phase, the team focuses on translating the initial plan into actual execution. It involves a series of activities, including the safe delivery of planned tasks, measuring the achieved deliverables, and evaluating the outcomes. The implementation phase ensures that the project progresses as intended and allows for adjustments and improvements as needed. For effective implementation of the proposed workflow, an effective communication and coordination plan should be set up. Effective communication plays a critical role in the success of any project. It ensures that all participants involved in the project are aligned and have a clear understanding of the project's goals, expectations, requirements, and timeline. The communication process involves sharing best practices, addressing gaps, conducting performance reviews, exchanging feedback, and ensuring that everyone is on the same page. To facilitate effective communication, the project team establishes clear processes, guidelines and best practices. This enables regular updates to be provided to management and stakeholders regarding the progress of the project. By emphasizing effective communication and implementing appropriate communication strategies, the project team can enhance collaboration, streamline processes, and ensure that all project stakeholders remain informed and engaged. The proposed communication workflow protocol is shown in Figure 5. In this project, the following actions are conducted:

1. Provide a pre-section planning document containing flat time targets per each section. Each section target is calculated considering a 15% improvement in either field median or rig median values, whichever is less. This document is handed over to the concerned drilling team for review, discussion, and follow-up.
2. Periodic rig visit to attend the pre-spud section meeting with all drilling team members.
3. Daily communication and follow-up through the group email communication updating the number of sections completed for that day, with the detailed breakup and analysis of each operational step in the flat time.
4. Conducted Weekly meetings through MS teams (30+ meetings were conducted) with the group to identify GAPS/Best performance per section, gather the feedback from rig supervisors and drilling engineers, share the knowledge, appreciate good performers rigs, brainstorm the areas of improvements, discuss best practices and the way forward. Assign action items from these meetings and maintain an action tracker.

3.3. Results and Discussion (Project Review Phase)

In this section, the main actions that have been taken to reduce the flat time and the results of each action taken will be discussed.

3.3.1. Optimization of Condition trips with Proper Risk Assessment

In order to cancel condition trips, a thorough risk assessment is required, which involves evaluating the condition of the wellbore comprehensively. If the drilling practices have been implemented effectively and the wellbore is in good condition, it may be possible to cancel the condition trip. This decision can lead to significant time savings, with some rigs saving approximately 10-12 hours of round-trip time. The main contributor is the hole stability. If the hole is stable, then the wiper trip is avoidable, and the casing can be smoothly and speedily run. Below are contributing factors that will affect the cancelling decision as Follow:

- Hole Trajectory (Inclination & Azimuth)
- Mud type Selection (OBM for sensitive shale) and Mud Weight Selection
- Geophysical features such as faults and loss zones
- Improper Hole Cleaning
- Effect of weak and low-pressure formation, if any

3.3.2. Drill Pipe Tripping Speed Enhancement

Significant differences in the speed of drill pipe tripping (in the cased hole) were observed across various rigs, ranging from 9 standard stands per hour (stds/hr) to 18 stds/hr. These variations were identified during weekly meetings, prompting a request for rigs with lower tripping speeds to enhance their performance in this regard. The utilization of High-Frequency Data (HFD) and Real-Time Drilling Data Center (RTDDC) units for simulating connection time and tripping speed proves crucial in projects of this nature.

3.3.3. Optimization of the Tripping Hydraulics

To manage the surge and swab effect, restrictions were imposed on tripping operations within the open hole. However, it was noticed that surge and swab calculations were not carried out before Running in Hole (RIH). In response, in-house training sessions were organized to provide technical refresher courses to all Drilling Engineers (DEs) on conducting surge/swab analysis, hydraulic analysis, torque and drag calculations, and other relevant aspects. Furthermore, a Gap analysis was conducted for each rig to identify areas for improvement in tripping speed and connection time. This analysis aimed to enhance the tripping speed for the Drill Pipe (D/P) from 13 to 15 stands per hour, as shown in Figure 6. These efforts were undertaken to optimize tripping operations and ensure more efficient drilling practices. Improvements in the tripping speed and time-saving are clearly summarized in Table 2. It is clearly shown that 145 hours could be saved per well for each rig conducting 500 stand trips if they improved their tripping speed to 20 Stands per Hour.

3.3.4. BOP Handling Time Optimization

A comprehensive analysis of operational protocols related to Blowout Preventer (BOP) and wellhead management was conducted, with a focus on identifying efficiencies to optimize time utilization. The study also explored the viability of conducting BOP tests in situ on the stump, necessitating an in-depth risk assessment and the development of standardized methodologies for stump-based BOP testing. The primary aim was to enhance operational efficiency and safety within BOP and wellhead systems. The investigative process included a rigorous examination of average Nipple Up (N/U) and Nipple Down (N/D) durations alongside the timeframes required for conducting pressure tests on various BOP components, as delineated in Table 3. This dataset provides insights into the operational dynamics of different systems and sections, categorizing "N/U times" as the duration needed to assemble the BOP components, "N/D Bop Lift time" as the timeframe required for disassembly, and "Pressure Test time" as the duration dedicated to verifying the BOP's pressure integrity. These empirical findings, encapsulated in Table 3, serve as a critical foundation for delineating operational efficiencies and facilitating safety enhancements in BOP and wellhead operations by elucidating the temporal variations associated with the assembly, disassembly, and testing of distinct components and systems.

3.3.5. Wellhead Installation Timing Optimization

Initially, rigs faced a waiting time of 4 hours for the baseplate weld to cool down, specifically for the 22" section. To minimize this waiting time, some rigs began using infrared thermometers to monitor the temperature of the weld joint and expedite the cooling process. Additionally, in certain cases, the number of welders assigned to weld the wellhead was increased from 1 to 2 to accelerate the overall welding process.

This optimization of timing was achieved by implementing simultaneous operations, such as picking up drill pipes while the wellhead was being cooled off. It is important to note that proper risk assessments were conducted for offline operations and simultaneous operations to ensure the safety of the operations.

3.3.6. Utilization of Pneumatic Wrenches in all the Rigs

The utilization of pneumatic wrenches has resulted in significant time savings when it comes to the tightening and loosening of BOP bolts.

3.3.7. Makeup and Laying Down Drill Pipes/BHA

This timing optimization efforts were focused on PAD rigs, specifically regarding the load capacity during skidding operations. The rigs' ability to skid with different loads of drill pipe on the derrick was evaluated.

Some rigs demonstrated the capability to skid with a load of 40 stands of drill pipe, while others were able to handle a load of 100 stands. As the project progressed, it was noted that the drill pipe pick-up and lay-down time significantly decreased across most of the rigs.

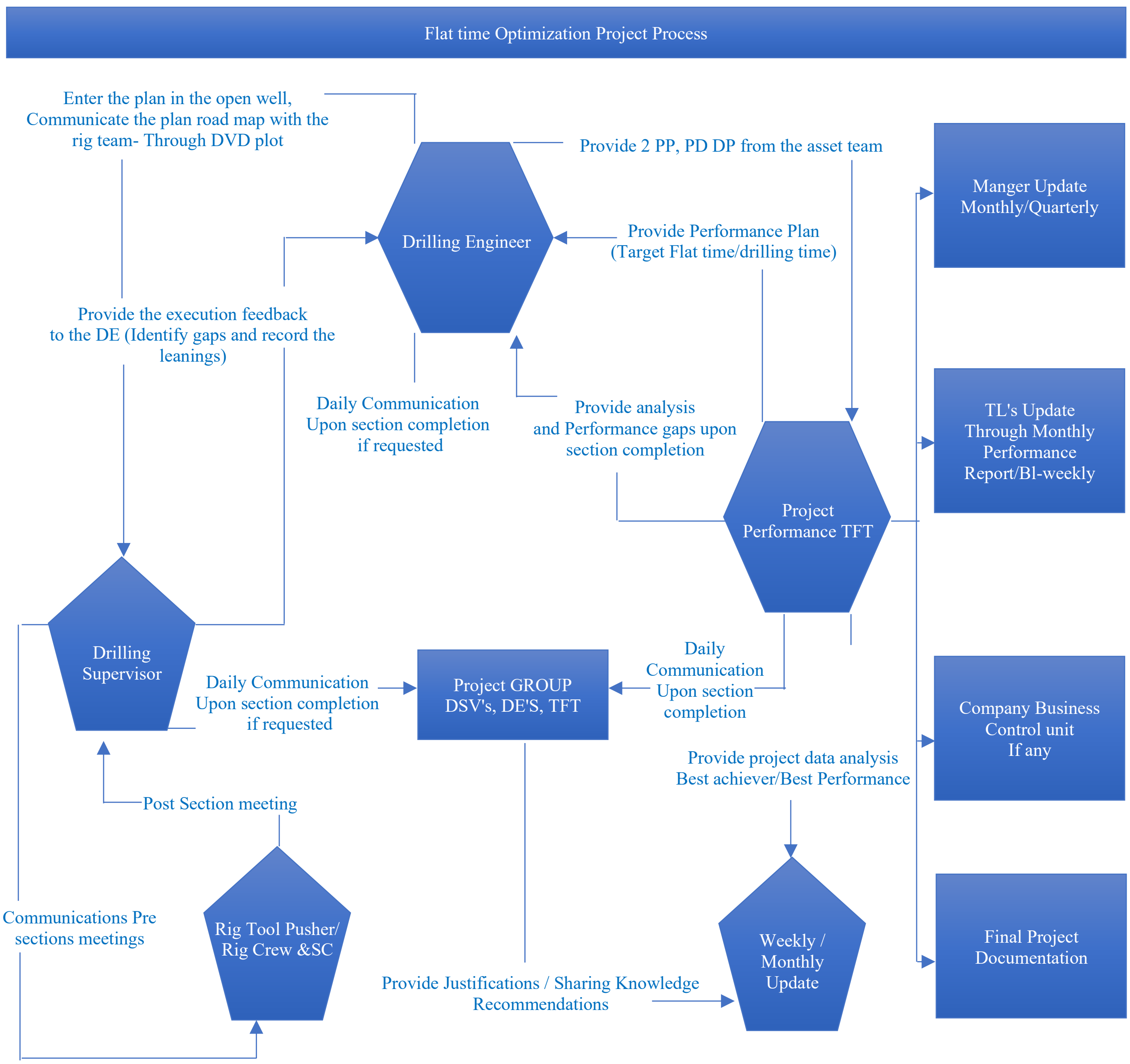

Fig. 5 Project process and communication protocol

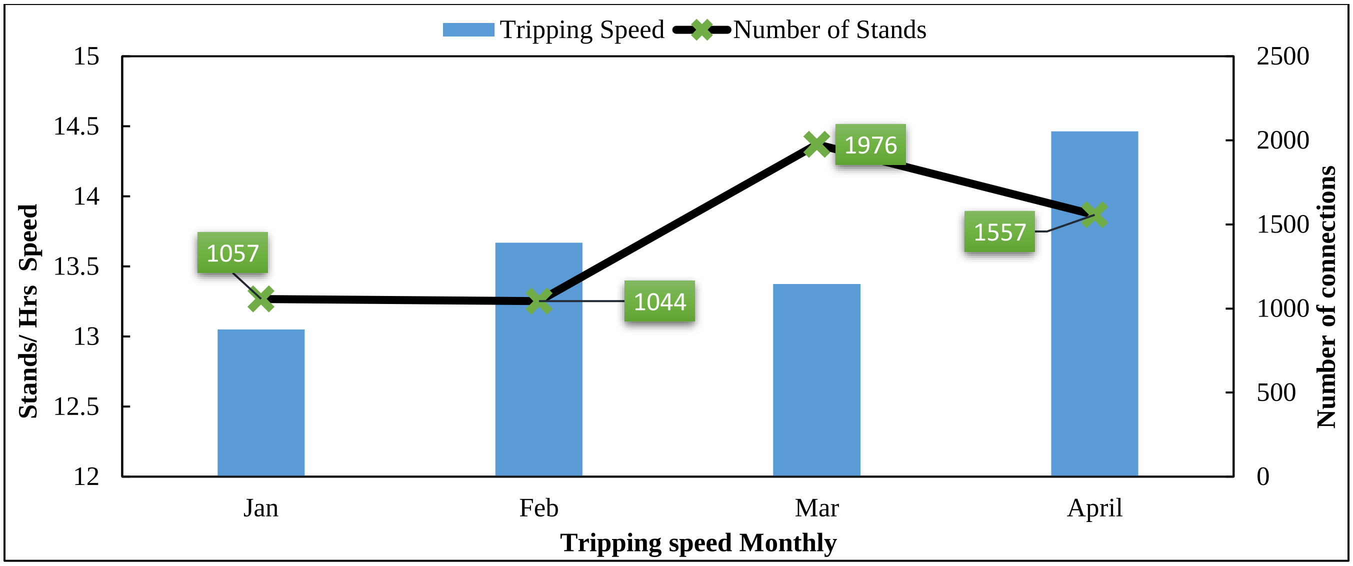

Fig. 6 Monthly drill pipe tripping speed improvement

Table 2. Tripping speed improvement and potential time saving for each rig

Rig	Number of stands	Avg. Tripping Speed	Number of stands per well	Total Time Taken for Tripping based on 500 stands, Hrs	Potential Saving per well (From Best Rig 15.63 stands/hr), Hrs	Potential Saving per well (From Best Tripping speed of 20 stands per hour), 500 Stands per well
Rig-21	724	15.63	500	32.00	0.01	7.00
Rig-29	517	15.50	500	32.26	0.28	7.26
Rig-6	245	15.00	500	33.33	0.66	8.33
Rig-12	273	14.85	500	33.67	0.92	8.67
Rig-20	564	14.60	500	34.24	2.54	9.24
Rig-30	135	14.50	500	34.48	0.67	9.48
Rig-32	118	14.00	500	35.71	0.88	10.71
Rig-42	194	12.25	500	40.82	3.42	15.82
Rig-7	437	11.61	500	43.08	9.69	18.08
Rig-28	177	11.00	500	45.45	4.77	20.45
Rig-14	91	9.10	500	54.95	4.18	29.95
Total	3475	13.46	500	420.00	28.02	145.00

Table 3. Average Nipple Up (N/U) and Nipple Down (ND) times

Description	N/U times, Hrs	N/D Bop Lift time, Hrs	Pressure Test time, Hrs
29.1/2” x 500 psi Diverter system	NA	1.5	NA
21-1/4” BOP, 3K	3	2.5	3
13- 5/8” BOP, 5 K	2.5	2.5	3
Section A 20.3/4” x 18 5/8”, 3 K	2.5	NA	0.5
Section B 20 ¾” X 13 5/8” 5 K	2	NA	0.5
Section C 13 5/8” X 11” X 5 K	1.5	NA	0.5

3.3.8. Optimized Shoe Track Drilling Time

Significant variations were observed in the shoe track drilling time across different rigs and Bottom Hole Assemblies (BHA) types, including Rotary Steerable Systems (RSS), Motor, and Rotary BHAs. To address this issue, a detailed study was undertaken to optimize the drilling time for the shoe track. Parameters and procedures were carefully examined and optimized for each BHA type. As a result of these optimization efforts, the shoe track drilling time was reduced by a minimum of 40-50% for most rigs, leading to improved operational efficiency.

Shoe Track drilling procedure should be followed. If possible, use the same directional BHA to drill the shoe track, which will be used for drilling the next section of the open hole. The optimum parameters should be applied, and the shoe track should be drilled within 1-2 hours. The Drilling Engineer should discuss the shoe track drilling parameters with the DSV before each job. After the plug bump during casing cementation, raise the pressure to casing test pressure and hold for 10 minutes. This helps in the proper locking of the plugs with a float collar. Precautions need to be taken while drilling the float shoe. Do not break the shoe, which leads to the risk of being stuck with stabilizers against the casing.

To overcome this problem, a minimum Rat hole should be kept. Optimal field practices and drilling parameters for each section's shoe track have been systematically gathered from the project and are presented in Table 4 for comprehensive illustration.

3.3.9. Combining Scrapper and Shoe Track Drilling Trip

During meetings, the risks and benefits associated with combining the Scrapper and Shoe track Drilling trips were thoroughly discussed. After conducting a detailed risk analysis and specific risk assessment, certain rigs agreed to merge these two operations. This decision resulted in significant time and resource savings by eliminating the need for an additional trip.

3.3.10. Reduction of Several NPT-Related Issues

Various Non-Productive Time (NPT) incidents occurred during the Flat Time operations, including challenges such as unstable hole conditions during Running in Hole (RIH) of the Liner, liner pullout, bit balling in the 22" section, and the liner wiper plug getting stuck during cementing. The root causes of these events were thoroughly examined and discussed, leading to the implementation of Non-Conformance Reports (NCRs) to address and prevent similar issues from occurring in the future; a specific process was created for reducing liner hanger issues, i.e. pre-post liner job checklist signed with all involved parties, this process reduces Liner hanger problems significantly.

3.3.11. Change of Mud Design in some Sections

A recurring issue was identified on certain rigs regarding the Running in Hole (RIH) of 13-3/8" casing, which had a significant impact on the flat time. To address this problem, a thorough review of the mud parameters was conducted, and optimizations were made in the subsequent wells. These adjustments resulted in time savings of 6-8 hours and effectively prevented the occurrence of casing getting stuck.

Table 4. Recommended parameter to drill shoe track

Size	Parameter	Rotary BHA	Motor BHA
18- 5/8"	WOB (KLBS)	10-25	10-20
	Flow Rate	600-700	500-600
	RPM	70-90	30
	DRPM	70-90	80-100
	Torque KFT-LB	2-4	4-6
13-3/8"	WOB (KLBS)	10-25	10-20
	Flow Rate	800	550-650
	RPM	70-90	30
	DRPM	70-90	80-90
	Torque KFT-LB	2-6	2-6
9-5/8"	WOB (KLBS)	10-25	10-20
	Flow Rate	>600	>500
	RPM	80-90	40
	DRPM	80-90	90
	Torque KFT-LB	2-6	2-6
7"	WOB (KLBS)	5-15	5-15
	Flow Rate	300	300
	RPM	90	60
	DRPM	90	90
	Torque KFT-LB	2-5	2-5

3.3.12. Introduction of a Detailed Breakdown of Operational Steps

A few top-performing rigs offered valuable insights by providing a comprehensive breakdown of all their operations during the flat time process. This breakdown served as a reference or benchmark for other rigs that were not performing as well. By following the timing and practices set by the best rigs, significant improvements in performance were achieved among the non-performing rigs. The aforementioned measures resulted in a substantial enhancement of flat-time operations, leading to a reduction in overall well delivery time. The improvements yielded impressive results, including savings of over 186 days, a cost reduction of 5 million dollars, and a remarkable improvement of 15.2%. A total of 232 sections were successfully completed, with 10% of those sections setting benchmark records. Furthermore, all 12 operating rigs demonstrated outstanding performance improvements, as illustrated in Figure 7, which depicts significant enhancements in the average timing for the major key six elements of flat timing for all the project rigs. Moreover, there was a substantial improvement in the Drilling rate improvement index, which witnessed a remarkable shift from -10% to 19%, indicating a significant enhancement of more than 29%, as depicted in Figure 8. This improvement was achieved by reducing the overall well timing through the addition of more wells without increasing the number of rigs. Furthermore, there was an increase in the number of wells drilled within the benchmark and Top Quartile (TQ) performance range, while the percentage of wells falling behind the median was drastically reduced from 63% to 10%.\

4. Results and Discussion

The project savings can be attributed to the implementation of new, project-specific processes and procedures, which have significantly enhanced flat time optimization compared to previous methods. Effective communication, facilitated through regular meetings to continuously address gaps, played a crucial role.

The new system and process provide several key advantages over existing methods, which can be summarized as follows:

1. Comprehensive Systematic Data Model: Establishing a data model with rigorous QA/QC standards creates a robust roadmap, baseline, and SMART KPIs, ensuring precision and reliability in flat time management.
2. Enhanced Communication and Audit Hub: Introducing a dedicated communication process and an operational audit hub enables swift identification of gaps and the prompt implementation of corrective actions, leading to more efficient operations.
3. Innovative Performance Procedures: The new system captures and documents updated performance procedures, ensuring they are shared with all project team members and subsequently with other directorates, promoting consistency and continuous improvement across the organization.
4. Streamlined Operations: The structured approach fosters a more organized and systematic method of handling flat time, leading to significant time and cost savings.
5. Improved Accountability and Transparency: With clear processes and standards in place, accountability and transparency are enhanced, leading to better overall project management and performance.
6. These improvements demonstrate the superiority of the new system and process in optimizing flat time, offering a more efficient and effective approach compared to previous methods.

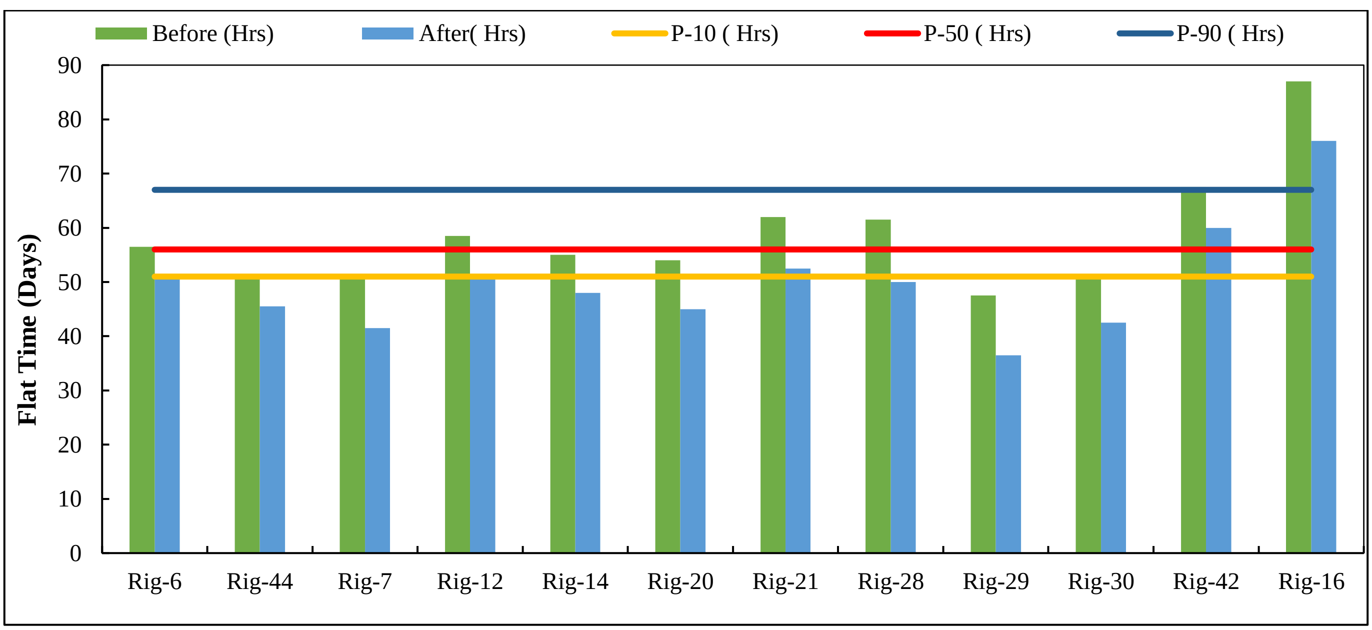

Fig. 7 Rigs flat time performance improvement during the project

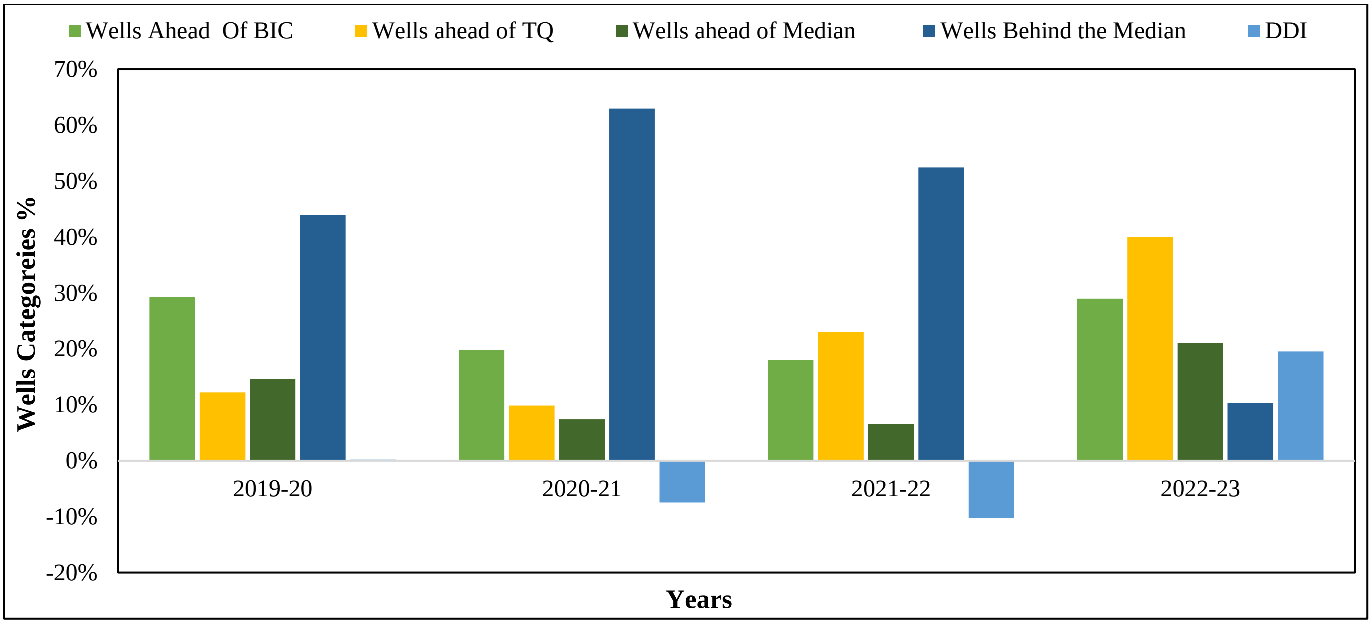

Fig. 8 Drilling rate improvement and wells performance trend yearly, performance impact

5. Conclusion

In conclusion, the implementation of a robust drilling management system is paramount for improving all drilling and non-drilling activities and reducing the overall time required for well construction. One key component of this system is optimizing flat time operations, as it significantly contributes to minimizing both visible and invisible lost time in drilling operations. This study yielded impressive results, with substantial savings of over 186 days and a cost reduction of 5 million dollars. The overall performance saw a notable improvement of 15.2%. A total of 232 sections were successfully completed, and an impressive 10% of these sections achieved benchmark records. Additionally, all rigs showed enhanced performance, thanks to the establishment of clear goals and objectives, as well as the introduction of an excellent digital tool for identifying baselines specific to each rig and field. Setting a clear baseline and defining efficient goals and targets, supported by SMART (Specific, Measurable, Achievable, Relevant, Time-bound) KPIs, is crucial for initiating any drilling project. The identification of gaps between rigs or operational activities is a key element in implementing effective savings strategies. By sharing best practices and optimizing offline operations, operational teams gain better control over timing and achieve substantial time savings. Furthermore, effective and transparent communication plays a vital role in the success of the project. It ensures that the entire team remains focused on the objectives and follows a clear roadmap. By aligning team members' efforts and maintaining effective communication channels, significant time and cost savings can be achieved for oil and gas companies. Consequently, the reduction in well deliverability time leads to increased production levels, enabling these companies to accomplish their goals, fulfil their vision, and align with their mission.

References

[1] William Contreras et al., “Tripping Performance Analysis and Quantifying Invisible Lost Time,” *International Petroleum Technology Conference*, Dhahran, Kingdom of Saudi Arabia, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[2] Naser Al-Barazi et al., “Implementation of Well Performance Management System WPMS Leads to Significant Cost, Time Reduction,” *SPE International Heavy Oil Conference and Exhibition*, Kuwait City, Kuwait, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[3] Jia Jun Goo et al., “Multiwell Operational Performance Benchmarking: A Continuous Drilling Optimization Approach for a Brownfield Drilling Project in Malaysia,” *SPE Intelligent Oil and Gas Symposium*, Abu Dhabi, UAE, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[4] Flavio Ferrari et al., “Integrated Rig Management Platform,” *Abu Dhabi International Petroleum Exhibition & Conference*, Abu Dhabi, UAE, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[5] Azlan Mohamad, Raihana Radzlan, and Wan Helmi Wan Hassan, “Dare to Change: PETRONAS New Approach to Implement Artificial Intelligence of Wells Activity Performance and Benchmarking Tool,” *Abu Dhabi International Petroleum Exhibition & Conference*, Abu Dhabi, UAE, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[6] Musab Khudiri et al., “Utilization of Single Real Time Data Visualization and Transmission Solution in Oil and Gas Field Development,” *Abu Dhabi International Petroleum Exhibition and Conference*, Abu Dhabi, UAE, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[7] Musab Khudiri et al., “Saudi Aramco Real-Time Drilling Operation Activity Recognition & Analysis Engine,” *SPE Middle East Intelligent Oil and Gas Conference and Exhibition*, Abu Dhabi, UAE, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[8] William Contreras Otalvora et al., “A Comprehensive Approach to Measure the RealTime Data Quality Using Key Performance Indicators,” *SPE Annual Technical Conference and Exhibition*, Dubai, UAE, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[9] Javed Akbar Khan et al., “Quantitative Analysis of Blowout Preventer Flat Time for Well Control Operation: Value Added Data Aimed at Performance Enhancement,” *Engineering Failure Analysis*, vol. 120, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[10] Sulaiman Marzoug Al-Ghunaim et al., “Operations Efficiency: Improved Well Planning Methodology Based on Invisible Lost Time Smart KPIs,” *SPE Middle East Oil & Gas Show and Conference*, Manama, Kingdom of Bahrain, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[11] Syed Ali Raza et al., “Performance Enhancement of Drilling and Completions Operations in Giant Offshore Field Abu Dhabi by Tracking and Monitoring Invisible Lost Time and Defined KPIs,” *Abu Dhabi International Petroleum Exhibition & Conference*, Abu Dhabi, UAE, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[12] Louanas Ouahrani et al., “Invisible Lost Time Measurement and Reduction Contributes to Optimizing Total Well Time by Improving ROP and Reducing Flat Time,” *SPE Kingdom of Saudi Arabia Annual Technical Symposium and Exhibition*, Dammam, Saudi Arabia, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[13] Carlos Damski, “Systematic Management for Drilling Process Improvement,” *SPE/IATMI Asia Pacific Oil & Gas Conference and Exhibition*, Bali, Indonesia, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[14] Ahmad Al Ady et al., “Operation Efficiency and Rig Performance Improvements through Data Analytics,” *Gas & Oil Technology Showcase and Conference*, Dubai, UAE, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[15] Tim Croucher, and J.G. Combo, “Creative Changes in Phillips Petroleum Norway's Drilling Management Philosophy Leads To Significant Improvements in Drilling Performance,” *IADC/SPE Drilling Conference*, New Orleans, Louisiana, 1996. [CrossRef] [Google Scholar] [Publisher Link]

Nomenclatures

Assy.	Assembly	GPM	Gallon per Minute
Bbl.	Barrel	HFD	High frequency data
BHA	Bottom Hole Assembly	HWDP	Heavy Wall Drill Pipe
BIC	Best In Class	ILT	Invisible lost time
BOP	Below out preventers	Klb	Kilo Pound
BPH	Barrel per Hour	LFD	Low-frequency data
DDI	Drilling deliverability index	LMS	Learning management system
DDI	Drilling deliverability index	LTA	Less Than Adequate
DE	Drilling Engineer	MS	Mud Supervisor
Deg	Degree	NPT	Nonproductive Time
DP	Drill pipe	OBM	Oil Base Mud
DSV	Drilling supervisor	OP	Over Pull
DTL	Drilling team leader	PCF	Pound per Cubic Feet
ECD	Equivalent circulating density	POOH	Pull Out Of Hole
ERD	Extended reach drilling	PPG	Pound per Gallon.
FD	Field development	PSI	Pound per Square Inch
Ft	Feet	QA	Quality assurance