DEVELOPMENT OF DRILLING NON-PRODUCTIVE TIME REDUCTION FRAMEWORK USING LEAN SIX SIGMA METHODOLOGY FOR BUNTAL EXPLORATION WELLS

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Petroleum Engineering

School of Chemical and Energy Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JAN 2023

ACKNOWLEDGEMENT

It is by no means, an easy feat to prepare a Master's thesis after being out of the Oil and Gas industry for almost seven years. Nevertheless, I am grateful that I have been blessed with the wonderful acquittance of my Supervisor, Ts. Dr. Mohd Akhmal bin Muhamad Sidek, who understood my challenges and provided valuable mentorship throughout the thesis journey. Without his guidance and his resource, this thesis could not have been materialised.

I also wish to express my sincere gratitude to Dr. Muraliraj Jagantheran, Chief Operating Officer of MBizM Sdn Bhd and a senior Lean Six Sigma practitioner with whom I have consulted regarding queries on the Lean Six Sigma body of knowledge. My sincere appreciation also extends to all my colleagues and family members who have helped me unconditionally.

ABSTRACT

Drilling Non-Productive Time (NPT) is loss time incurred when drilling activity has to be stopped or rate of penetration is very low during a drilling operation. Drilling NPT results in drilling cost overruns and delay in drilling schedule. Presently, there are several methods which are being deployed to mitigate drilling NPT and these methods would fall into either the anticipative or targeted category. Anticipative category focuses on development of model, database, and risk management framework to enhance information sharing and decision-making among drilling operation stakeholder while the targeted category revolves around deployment of surgical solutions which focus on one or a handful of drilling NPT categories such as wellbore instability, equipment failure etc. Both categories generally lack Drilling NPT severity assessment, validation of Root Causes and derivation of Root Cause Analysis-centric solutions, resulting in knee-jerk reactions to Drilling NPT mitigation. This study, therefore, aims to develop a Drilling NPT reduction framework using Lean Six Sigma (a process improvement methodology) based on retrospective drilling data from Buntal Exploration Wells. Lean Six Sigma advocates data-driven analytics and decision-making in solving operational problems. The drilling NPT reduction framework will follow the DMAIC (Define, Measure, Analyse, Improve and Control) stage-gate model of Lean Six Sigma. In the case of Buntal Exploration Wells, it is observed that the drilling process is not capable from operational and financial standpoints in meeting the Drilling Plan requirements (as illustrated by Process Capability Indexes which are lower than 1.0). In view of retrospective nature of the available drilling data, root causes are validated graphically and qualitatively with equipment failure appearing as the leading contributor of Drilling NPT. Potential solutions are then ideated based on the validated root causes or Vital Few Factors. It is expected that the Drilling NPT reduction framework will pave way for future research through capitalization on quantitative data and continuous feedback from the drilling fraternity.

ABSTRAK

Masa Tidak Produktif Penggerudian (MTPP) merupakan kehilangan masa yang terpaksa ditanggung apabila aktiviti penggerudian telaga terpaksa dihentikan ataupun apabila kadar penembusan mencapai tahap yang sangat rendah semasa operasi penggerudian. MTPP menyebabkan lebihan kos penggerudian serta kelewatan jadual penggerudian. Pada masa ini, terdapat beberapa kaedah untuk mengurangkan MTPP. Kaedah-kaedah yang sedia ada boleh digolongkan dalam dua kategori, iaitu kategori penyelesaian berteraskan jangkaan ataupun kategori penyelesaian berteraskan sasaran. Kategori penyelesaian berteraskan jangkaan memberikan tumpuan pada pembangunan model, pangkalan data dan rangka kerja pengurusan risiko untuk meningkatkan perkongsian maklumat sebelum keputusan dibuat dalam kalangan pihak berkepentingan operasi penggerudian. Kategori penyelesaian yang berteraskan sasaran merujuk pada penggunaan penyelesaian spesifik yang memfokuskan pada satu atau segelintir kategori MTPP seperti ketidakstabilan lubang telaga, kegagalan peralatan dan lain-lain. Kedua-dua kategori ini secara amnya tidak mempunyai penilaian keterukan MTPP pengesahan punca-punca akar umbi dan terbitan penyelesaian berpusatkan analisa punca akar umbi sehingga mengakibatkan tindak balas sekelip lutut dalam pengurangan MTPP.Oleh itu, kajian ini bertujuan untuk membangunkan rangka kerja pengurangan NPT Penggerudian menggunakan Lean Six Sigma (metodologi penambahbaikan proses) berdasarkan data penggerudian retrospektif dari Telaga Eksplorasi Buntal. Lean Six Sigma menyokong analisa berlandaskan data dalam penyelesaian masalah organisasi. Rangka kerja pengurangan MTPP akan mengikuti model gerbang DMAIC. Dalam kes Telaga Eksplorasi Buntal, didapati bahawa proses penggerudian sebenarnya tidak berkebolehan dari sudut operasi dan kewangan dalam memenuhi keperluan Pelan Penggerudian (seperti yang digambarkan oleh Indeks Keupayaan Proses yang rendah daripada nilai 1.0). Memandangkan unser retrospektif data penggerudian, punca-punca MTPP disahkan secara grafik dan kualitatif dengan kegagalan peralatan sebagai penyumbang utama MTPP. Rangka kerja pengurangan MTPP dijangka akan memberi laluan kepada penyelidikan masa depan melalui penggunaan data kuantitatif dan maklum balas daripada fraterniti penggerudian.

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CHAPTER 1

INTRODUCTION

1.1 Background

Drilling, in the context of petroleum engineering, refers to the practice of boring a hole into the Earth's subsurface to access a potential hydrocarbon reservoir. Drilling engineering, the practical application governing drilling in the petroleum industry, encompasses the design organization and construction aspects of exploration and development wells. Drilling plays an important role in the first three phases of the oil and gas wells life cycle. Firstly, during Exploration phase, exploration wells are drilled to determine the presence of hydrocarbon and collect geological data for formation evaluation. Secondly, during the Appraisal phase, appraisal wells are drilled to consolidate further information depending on the analysis of data from exploration wells. Finally, during the Development phase and contingent upon the approval Field Development Plan (FDP), development wells are drilled and equipped with well completion equipment and production infrastructure.

Oil and gas companies normally do not drill the well themselves as they do not own the drilling equipment or maintain drilling rig staffs. Instead, drilling works are usually contracted to drilling contractors who upkeep relevant drilling equipment and drilling rig staff. It is worth noting that drillers do not contribute to revenue which is linked directly to petroleum production. As such, the expectations of oil and gas companies while contracting a drilling work is for the drilling contractor to complete the required drilling works as per the designated drilling programme safely with no compromise on quality within the stipulated time and cost.

Drilling operation has its own challenges which if not mitigated properly, could result in drilling problems which can pose Health, Safety and Environment (HSE) concerns, damage equipment or result in non-productive time (NPT). Drilling NPT is defined as time elapsed during which drilling operation is ceased or when the drilling penetration rate becomes exceptionally low (Krygier, Solarin and Orozova-Bekkevold, 2020). Drilling NPT events can be clustered into two major groups: geological or subsurface related and non-geological (Emhanna, 2018). Drilling NPT can be segmented into several categories under the two major groups, which are geological or subsurface related and non-geological.

The following categories reside under the geological or subsurface related drilling NPT:

(a) Bottom hole problems associated with the subsurface environment e.g., lost circulation, wellbore instability etc.

(b) Fishing

The following categories reside under the non-geological related drilling NPT:

(a) Equipment failure (both surface & subsea)

(b) Rig repair

(c) Waiting e.g., on water, service company, order etc.

(d) Weather

(e) Accident or incident

Drilling NPT has significant financial repercussions in any drilling operations. As drilling operation gets stalled or progresses tremendously slow during drilling NPT, overall drilling time expands, leading to cost overruns which can be transferred by drilling contractors to oil and gas companies. Generally, it is found that drilling NPT results in additional cost increment of 10% to 15% of the total drilling costs with some literatures citing increment up to 30% (Rangel et al., 2020).As far as the Malaysian drilling industry is concerned, the industry recorded an average of 14% NPT which amounts to USD 550 million (Ahmad et al., 2016). Therefore, reducing drilling NPT is crucial for oil and gas companies operating in low oil price environment.

Drilling industry has been deploying several methods in reducing Drilling NPT. Some of these methods can be quite general and mirrors knee jerk response to some drilling NPT categories such as improving maintenance management of rig and increasing drilling rig crew competency (Lloyd's, 2016). There are also some methods which target a particular drilling NPT category. For example, the use of real-time remote pressure management system to reduce drilling NPT in drilling operations is advocated where bottom hole problem e.g., lost circulation and wellbore stabilities are major drilling NPT contributors (Sadlier et al., 2011). The real-time remote pressure management system relies on feeding live drilling and logging data into a geomechanical model which analyses the data and prompts the duty engineer on a potential bottom hole problem so that pre-emptive actions can be taken immediately. A toned down approach without the involvement of real-time data input is the development of a mechanical earth model which will be subjected to tests and simulations under various drilling scenarios before the development of Drilling Plan (Moazzeni et al., 2010). Another method which is gaining prominence is the use of predictive analytics technology which utilizes Machine Learning in the form of Case-Base Reasoning (CBR) to scour through existing drilling data repository and provide the drilling engineer with recommendation for remedial actions in the face of a potential problem which can lead to drilling NPT (Wade, 2014).

Apart from direct and technology-driven solutions, risk-based analysis and integrated solutions approach is also being considered in the drilling industry. This approach involves identifying drilling operations risks and their consequences before recommending solutions (Barakat, Abu El Ela and Khalaf, 2021). In case study where the approach is deployed in Gulf of Mexico, a 57% reduction in overall drilling time is observed, which also translates into lower drilling NPT occurrence (Rangel et al., 2020).

The difference between methods to reduce drilling NPT demonstrate a growing tendency to either resort to direct solutions based on identified drilling NPT categories or model-based decision-making and risk-based integrated solutions approach. A wholesome framework to reduce drilling NPT is required and this is where the deployment of Lean Six Sigma can be advantageous. Lean Six Sigma is a process improvement methodology which capitalizes on the synergy between two essential concepts: Lean and Six Sigma. Lean has its humble beginning from Toyota where it began as Toyota Production Systems (Brenig-Jones, 2017) . Six Sigma is the brainchild of Bill Smith, a Motorola engineer who famously highlighted the correlation between the number of reworks experienced by a product and the customer complaints the product accumulated in the after sales segment. As each problem can be traced to a particular process in which it resides, Lean Six Sigma has been used by many Fortune 500 Companies, notably General Electric (GE) as data-driven decision-making framework for problem solving.

Lean focuses on waste elimination; wastes are non-value adding tasks or activities which drain resources without converting them into useful or customer-desired outputs. When wastes are identified and eliminated from a process, the process becomes faster. Lean therefore, advocates speed in a process. Six Sigma on the other hand, focuses on reducing variation; variations are inherent differences or non-uniformness in output due to a myriad of factors affecting a process. When variations are measured and reduced, the process can function by producing products or services at consistent quality. A process is said to be operating at Six Sigma level if in any one million opportunities, the process only records 3.4 non-conformances, which corresponds to 99.99967% of good conformance (Buell and Turnipseed, 2004) .

When a process becomes faster and can produce products or services at consistent quality, this leads to standardization and fulfilment of customer requirements. Lean Six Sigma is one of the several process improvement methodologies in the quality management industry which has been widely used in manufacturing and services industries. Apart from Lean Six Sigma, Agile and Design Thinking are two other methodologies presently gaining momentum in an increasingly digitalized operating environment. Agile revolves around running quick iterations of tasks in several sprints to achieve customer desired output incrementally. Agile is becoming staple in software development industry which usually involves cross-functional team members with tight schedules. Design Thinking on the other hand, is an innovative problem-solving process which seeks to understand a problem, explore a wide range of possible solutions, iterate the solutions through prototyping and testing before deploying the refined solution to customers (Linke, 2017). Nevertheless, Lean Six Sigma has its unique value proposition as it seeks to dissect a problem structurally via Root Cause Analysis and facilitate decision-making based on data-driven analytics.

1.2 Problem Statement

Present common solutions or recommendation to mitigate drilling NPT issues primarily revolve around the following two approaches:

(a) Anticipative: Development of model, database, and risk management framework to enhance information sharing and decision-making among drilling operation stakeholders

(b) Targeted: Surgical solutions which focus on one or a handful of drilling NPT categories such as wellbore instability, equipment failure etc.

Both approaches generally lack Drilling NPT severity assessment, validation of root causes and derivation of Root Cause Analysis-centric solutions. While the drilling NPT categories and potential factors leading to drilling NPT are well-documented in many academic papers, the potential factors however, were not drilled down and analysed to reveal vital few factors which significantly affects drilling NPT. In a Drilling Contractor article, the need to conduct Root Cause Analysis for drilling NPT reduction instead of mitigating symptomatic problem or jumping straight to solutions is highlighted (Hsieh, 2010). The same article also cited an internal study by Chevron on one its drilling contractor which revealed that 94% of all NPT incidents did not have Root Cause Analysis performed over a period of two years. Failure to identify potential root causes, distil them into vital few factors and develop solutions based on these factors leads to recurring drilling NPT issues which may vary depending on changes encountered in the drilling operation. Even worse, a solution which works for one instance may not work well for another.

As such, apart from operational and financial needs to reduce drilling NPT in a low oil price environment, the need to assess drilling NPT situation, along with the validation of root causes and subsequent derivation of Root Cause Analysis-centric solutions based on data analytics is of paramount importance. This is where Lean Six Sigma can be utilized to perform structured data analysis in reducing drilling NPT.

1.3 Hypotheses

Several hypotheses have been established on the Drilling NPT reduction via Lean Six Sigma process improvement methodology. Data collection and analytics which will done in the later course of the project will be used to determine if the hypotheses are valid (Mukamal, 2006). Below is the list of all the hypotheses which will be investigated further:

(a) The severity of Drilling NPT situation from both operational and financial standpoints can be assessed quantitatively.

(b) Potential root causes for Drilling NPT can be validated using graphical and qualitative data analysis.

(c) Potential solutions for Drilling NPT can be generated based on validated root causes or Vital Few Factors.

1.4 Objectives

The objectives of the projects are listed below:

(a) To evaluate the severity of Drilling NPT situation from operational and financial standpoints quantitatively.

(b) To validate potential root causes of Drilling NPT using graphical and qualitative data analysis.

(c) To generate potential solutions for Drilling NPT based on validated root causes (Vital Few Factors).

1.5 Research Scope

The following project scopes listed below encompass the drilling NPT reduction framework using Lean Six Sigma methodology:

(a) Selecting the candidate (Buntal Exploration Wells) based on drilled depth (Operational) and Approved Financial Expenditure (AFE) overspend (Financial).

(b) Evaluating the severity of Drilling NPT quantitatively using Process Capability Index for both Operational and Financial standpoints.

(c) Distinguishing every primary daily drilling activity using Value Analysis.

(d) Identifying potential root causes which can be attributed to Drilling NPT via Root Cause Analysis.

(e) Validating potential root causes using graphical and qualitative data analysis.

(f) Proposing potential solutions for minimizing Drilling NPT based on Vital Few Factors.

1.6 Significance of Study

Firstly, the Drilling NPT reduction framework using Lean Six Sigma methodology will enable the use of analytical tools in evaluating the severity of Drilling NPT issues, validating potential root causes and generating solutions which are based on Vital Few Factors. As such, it can be used as a guiding framework for future Drilling NPT reduction initiatives. The framework can complement the existing anticipative or targeted approach of mitigating Drilling NPT through the use of process capability assessment, Root Cause Analysis, validation of potential root causes and derivation of root cause-centric solutions.

Secondly, the study is expected to aid in the promotion and advocacy of Lean Six Sigma in the Oil and Gas industry. Although Lean Six Sigma has been widespread across various industries, its adoption in the oil and gas industry has been somewhat marginal. This is partly due to the top-to-bottom management approach required in a typical Lean Six Sigma deployment, coupled with the vast intricacies of supply chain logistics and contractors. For these very reasons, Lean is more widely known in the oil and gas industry than its peer, Six Sigma or its synergic version, Lean Six Sigma. Many Lean management practices advocate bottom-to-up approach and require less data analytics than Lean Six Sigma. Often, lack of data availability and integrity for detailed analysis may hamper process improvement projects based on Lean Six Sigma. However, in a dynamic environment such as the oil and gas industry, Lean alone will not be enough. Having a faster drilling process does not matter if there is no consistency in service quality. As such, the need to study the problem at hand thoroughly and understand all the relevant factors contributing to a problem requires a structured statistical approach. As a research-based methodology in problem solving

through process improvement project, this is where Lean Six Sigma will come in useful.

Thirdly, this study seeks to address conceptual fallacies observed in several Lean Six Sigma literatures from the oil and gas industry. These conceptual fallacies have undermined the effectiveness of Lean Six Sigma tools used. For example, the incorrect use of Pareto Chart (graphical illustration of 80:20 rule) is observed in the following papers:

(a) Application of Lean Six Sigma Results in Improved Acid Stimulation Oil Gains in Duri Heavy Oil Field (Fahruri, Artyasa and Sadono, 2007)

(b) Reducing NPT of Rigs Operation through Competency Improvement: A Lean Manufacturing Approach' (Basbar, Al Kharusi and Al Kindi, 2016)

(c) Continuous Improvement of Drilling Ultra-Shallow Horizontal Well through Lean Six Sigma methodology (Wahyudi and Yudoko, 2019)

Therefore, the development of Drilling NPT reduction framework via Lean Six Sigma methodology is not only valuable from the operational and financial perspectives, but also generates value-adding insights to the global research community about Lean Six Sigma application. It is expected that this project and its ensuing publication will become flagship literature for Lean Six Sigma deployment in the oil and gas industry.

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