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OPTIMIZATION AND BUSINESS IMPROVEMENT

STUDIES IN UPSTREAM OIL AND GAS INDUSTRY

SANJIB CHOWDHURY

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Optimization and Business Improvement Studies in Upstream Oil and Gas Industry · Sanjib Chowdhury

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In memory of my beloved parents and elder brothers,
whose blessings I count on and keep me moving.

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PREFACE

Oil and gas exploration and production (E&P) is a complex process involving a series of activities that are costly, risky, and technology intensive and require specialized manpower.

With a rise in the global oil demand and fast depletion of easy reserves, the search for oil is now directed to more difficult areas, such as deepwater and arctic region, and future production is expected to come from increasingly difficult reserves (deeper horizon, heavy oil, etc.). As a result, E&P activities are now even more costly, risky, and dependent on cutting-edge technology. Therefore, it is necessary to optimize resources, opportunities, and costs and improve business performance in the entire gamut of E&P activities.

Furthermore, due to inherent uncertainties involved in E&P activities, where input is deterministic but output is probabilistic, it is imperative that oil companies use their capital and resources judiciously. In this regard, various optimization and business process improvement techniques have been discussed in this book, which have the potential of saving substantial amounts of money and improve organizational efficiency.

The book is unique as it delves into the core and functional areas covering a wide range of operations and processes in the upstream oil and gas industry. The book contains 11 real-life studies conceived and developed by the author covering an extensive array of activities and processes, namely, optimization of strategies, resources, and costs; improvement in business performance and operational productivity in core activities; identification and removal of inefficiencies in core and functional areas; standardization of consumption of materials; development of uniform standards for offshore safety alarm system; simplification of business processes for enhancing organizational efficiency; and improvement in human resource productivity. The book is replete with examples of quantitative and qualitative techniques, such as linear programming, queuing theory, critical path analysis, economic analysis, best practice benchmark, and business process simplification. The quantitative techniques are based on mathematical treatise that has universal applicability and acceptability.

The book will be of immense interest to practicing managers, professionals, and employees at all levels and disciplines in oil and gas companies, especially upstream companies to improve their respective operational areas, business processes, systems, and organizational efficiency. It will also be useful to academicians; scholars; educational institutes; energy research institutes, especially dealing with oil and gas; consultants; and others, as the work is rich and replete with the application of quantitative techniques in real-life problems. The work may also be used as a practical guide by professionals to enhance organizational efficiency and performance and optimize resources. The availability of such type of book has not yet been reported in the market or in the industry. Practicing managers and professionals at all levels in oil and gas industry would find it useful to know the nuances of optimization and emulate these studies in their respective domain of work, thus immensely benefiting their organizations. All these studies have the potential of saving substantial amounts of money, besides improving organizational efficiency. One can ignore the book, if one can afford to splurge substantial amounts of money!

Review exercises have been included at the end of each chapter, which will help readers to recapitulate the key learnings and test their understanding about the subject. It will also assist the readers to focus on important areas and revisit the relevant portions to capture their essence. Review exercises are mostly related to topics discussed in the respective chapters. But a couple of questions in Chapters 2, 3, 4, and 6 are a bit more technical and specialized in nature, which are marked as “Advance.” These have not necessarily been discussed in detail in these chapters and require further studies. These are meant for subject matter experts (SMEs) and E&P professionals dealing with these jobs.

An enriching list of “References, Useful Links, and Further Reading” have also been incorporated at the end of each chapter, which will help the interested readers to learn more and go deep into the respective subjects as per their need.

The views expressed in the book are those of author’s and do not necessarily reflect the views of any organization or entity or individual.

ABOUT THE AUTHOR

Dr. Sanjib Chowdhury is working in a major oil company and has over 30 years of experience in cross-functional areas of strategic and corporate planning, optimization and business improvement, HR, and general management in upstream sector. He has held responsible positions and carried out many impressive work and studies in these areas—this book is a testimony to that. He holds B. Tech., M. Tech., and Ph. D. degrees in Industrial Engineering and Management all from the Indian Institute of Technology, Kharagpur, and published several technical papers in journals of repute. He mentored several MBA students and junior professionals and was a guest faculty to business schools.

Esteemed readers are invited for critiquing and suggestions for the improvement of this book (optimize.upstream@gmail.com). The author wishes to share more such actionable ideas for enhancing revenue, saving cost, and improving productivity, and so on, worth substantial amounts of money in the future.

ACKNOWLEDGMENTS

I am grateful to almighty for bestowing me with the privilege of working at various geographical and cross-functional areas in the upstream oil and gas industry, which has enriched my professional knowledge and experience. This book relies hugely on this experience. The studies presented in this tome were conceived and developed by me. It seemed initially a daunting task, but on the whole, it was greatly educative and satisfying.

I am thankful to all those who had directly or indirectly helped me in completing these studies by providing information and data, helping me to understand different processes and perspectives, and engaging with me in professional discussions. I am especially thankful to Prof. Pradip K. Roy of Indian Institute of Technology, Kharagpur, for his encouragement, support, and advice; A. Pandey for extensive review, critiques, and suggestions; and A. Dutta and S. De for reviewing certain chapters and providing useful suggestions. All these have improved the quality of the book. I am grateful to my family for supporting me in this endeavor.

I will be immensely happy if readers find the book useful and apply the concept and learning in their work, organization, or business.

Finally, I live on blessings of my late parents and elders, which give me strength and keep me moving. I dedicate this small work in their memory.

DR. SANJIB CHOWDHURY

1

OPTIMIZATION AND BUSINESS IMPROVEMENT STUDIES IN UPSTREAM OIL AND GAS INDUSTRY: AN OVERVIEW

1.1 INTRODUCTION

1.1.1 Importance of Oil and Gas

Oil is inarguably the most important economic commodity and source of energy in today's world. It has shaped contemporary civilization and is intricately interwoven with our daily life touching every household. It fuels world economy, propels industrial growth, and impacts on nation's well-being. Oil accounts for one-third of world's energy need, while oil and gas together meet more than half of global energy demand. It will continue to dominate global energy mix in the foreseeable future. Oil is not only an economic commodity, but it has great strategic value too. The geopolitics of oil is well known, and the world has seen fierce disputes, even wars among nations for oil and gas. It influences world economy to such an extent that no country however mighty or humble can ignore it.

Life is unthinkable without oil and gas in the present-day world, which has pervaded not only our daily life but also deeply entrenched in the nation's economy encompassing all sectors including domestic, industrial, agricultural, transport, and other segments. For example, essential products, such as petrol, diesel, domestic gas, kerosene, naphtha, fuel oil, fuel gas, lubricants, wax, and so on, are derived from crude oil. It is a major component in many important products, such as fertilizers, organic chemicals, industrial chemicals, drugs, detergents, insecticides, cosmetics, and so on. It is also used in manufacturing household containers, furnitures, building materials, synthetic rubber, plastic goods, nylon clothes, CDs, DVDs, and many others. The transport sector is heavily dependent on it, and the world will come to a grinding halt without oil and gas. Ships, airplanes, trains, buses, cars, and so on, will stop plying; machineries, farm tractors, and factories will stop running; and industries using oil/gas as feedstock will close down [1].

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1.1.2 Early Use of Oil and Gas

There are many evidences and stories connected with the use of petroleum, especially oil and bitumen, in the ancient times. The "eternal fires of Baku" were the result of the ignition of oil and natural gas from seepage, the "tower of Babel" was constructed using bitumen as mortar, the basket in which baby Moses was hidden was believed to be made waterproof using bitumen, and Persians set alight the streets with sprinkling oil when Alexander the Great visited Persia. The multiple evidences suggest that in earlier days oil was used in Egypt, Persia, and Mesopotamia for heating, lighting, and paving roads. The records also suggest that North American Indians used petroleum as medicine, Mexican Indians valued bitumen as chewing gum, and Chinese were believed to be drilling wells using bamboo canes. Many famous explorers mentioned about it, for example, Sir Walter Raleigh wrote about it in his diary, Marco Polo noted that burning of mineral oil gave light and heat, and Christopher Columbus used bitumen to make his ship seaworthy [1, 2].

But it was not until A.D. 1859 that exploration for oil and gas started in earnest, when the first oil well was drilled by Edwin Drake in northwestern Pennsylvania, United States (some quarters claim it started in 1846 in Azerbaijan). Since then, a lot of advancement took place in the field of oil exploration and production (E&P), and there has been a phenomenal growth in petroleum industry, making it one of the most important sectors in the world influencing global economy and life of the people across the planet.

1.2 E&P ACTIVITIES AND PROCESSES

Hydrocarbon E&P is a complex process beginning with prognostication and involving a series of activities, namely, geological survey, magnetic survey, gravitational survey, seismic survey, laboratory studies, geochemical study, and exploratory drilling encompassing coring, casing, cementing, mud engineering, and drill stem test (DST) followed by well testing. Based on the well testing results, the well is declared as "dry" or "hydrocarbon bearing." If no oil and gas are found, the well is abandoned. In case of discovery, another set of activities follow, namely, drilling of appraisal well, delineating of field, and assessing commercial viability of reserves. Based on these, the decision of the development of the field is taken; however, the scale of development is dependent on the potential of the field. Accordingly, field development plans are made and development wells are drilled; production installations and surface facilities (group gathering station (GGS), gas collection station (GCS), central tank farm (CTF), effluent treatment plant (ETP), etc.) are created before commencing production. All these activities are highly capital-intensive, and the gestation period for the realization of investment is quite long.

1.2.1 High-Risk and High-Cost Activity

The upstream oil and gas industry is unique. In conventional industry, inputs and outputs are deterministic, that is, with a given input (investment), one is assured of the planned output (product or services). But in the upstream oil and gas industry, the input is deterministic, but the output (outcome of exploration activity) is stochastic. With the planned investment, one is not sure about its realization—it's more like a gamble associated with uncertainty and high risk. More often than not, investment in exploration may not yield fruitful result or any return. Even if oil and gas are discovered, its commercial viability is to be assessed before the next course of action is decided. It takes a long time to develop the field before production begins. All these make E&P activities high-risk and high-cost operations.

1.2.2 High Technology Activity

Oil and gas E&P activities are technology-intensive and require expertise of diverse fields. E&P activities are essentially the application of various streams of science and engineering, such as science (geology, geophysics, geochemistry, palynology, mathematics, and statistics); engineering (petroleum, chemical, reservoir, mechanical, electrical, civil, marine and ocean, electronics, instrumentation, telecommunication, and computer science); and many others.

With depletion of easy reserves, E&P activities are becoming highly technology-intensive, as the search for oil and gas is directed to geographically and geologically difficult locations, such as deepwater exploration, arctic region, snowbound hostile terrains, mountains, deep oceans, high-pressure and high-temperature horizon, and other challenging areas. Moreover, with a phenomenal rise in global demand for oil and gas, future oil/gas production will mostly come from more difficult reservoirs, such as deeper horizon, low API gravity, and high sulfur content. Furthermore, the production of oil from aging field using conventional technology is a challenging task. The conventional technology too needs continuous improvement to sustain oil production from matured fields. *All these necessitate continuous development and induction of state-of-the-art technology, which are costly and require experts to use it and make the best out of it*. E&P activities are associated with high technology that requires multidisciplinary approach and expertise to operate "state-of-the-art technology" and cope with increasing demand and difficulties in oil and gas E&P.

1.3 NEED FOR OPTIMIZATION IN UPSTREAM INDUSTRY

We have seen in the earlier paragraph that oil and gas E&P activities are becoming increasingly costly, risky, and technology-intensive as operations are moving from easy to difficult and challenging frontiers. In order to mitigate risks and share the cost of operations, even the major and super major oil companies are forming joint ventures and consortium for venturing in new frontiers. In view of inherent risks and uncertainty associated with the upstream business where inputs are deterministic but output is probabilistic, it is important that oil companies use their capital and resources judiciously. It is necessary to optimize strategies, resources, and cost and improve business performance in all spheres of E&P activity. These are the need for survival and sustaining business. The rule of the game is "money saved is money earned." All these require innovative ideas, change in mind-set, fresh outlook, and approaches to business.

1.3.1 Optimization Techniques

Optimization is an oft-repeated word used by all, whose meaning perhaps is not as clear as it seems to most of the people. It's a catchy word! People use it liberally, as it sounds impressive without knowing its nuances or relevance to the context. Most people consider it as a synonym of maximization/minimization, and the differences are indistinct even to professionals and management people.

Optimization in its simplest form means the best available value or most favorable result *under a given set of conditions or constraints. It is usually the* maximization or minimization *of objective function subject to a set of constraints*. Optimization is basically a mathematical technique, which is widely used in engineering, management science, economics, science, mathematics, and many other fields. Literature is replete with definition of optimization with varying degree of simplicity or complexity.

The genesis of "optimization technique" traces back to the work of Fermat and Lagrange for identifying optima with calculus-based formula. Newton and Gauss used iterative methods for moving toward an optimum solution. In modern days, George B. Dantzig developed an optimization technique called "linear programming" based on simplex algorithm. It was developed during World War II for scheduling warfare logistics and related problems for US military. Much of the work of G. B. Dantzig was based on the theory introduced by Leonid Kantorovich in 1939, but Dantzig made substantial improvement on it making it more powerful and versatile [3]. Based on the types of objective function and set of constraints, the optimization models/techniques are classified as linear programming, integer programming, geometric programming, goal programming, quadratic programming, nonlinear programming, fractional programming, dynamic programming, and so on. These are essentially the extension of either linear programming or particular case(s) of nonlinear programming.

Various optimization and business improvement techniques have been used in this book, such as benchmarking, technical and qualitative analysis to optimize productivity of drilling operation (Chapter 2); diagnostic approach and root cause analysis to optimize controllable rig time loss (Chapter 3); technical, qualitative, and economic analysis to optimize geology and geophysics (G&G) strategy for deepwater oil and gas exploration (Chapter 4); queuing theory to determine optimum number of offshore supply vessel (OSV) fleet size (Chapter 5); technical and statistical analysis for standardizing consumption of consumables in oil/gas wells and rigs (Chapter 6); critical path analysis using Program Evaluation and Review Technique/Critical Path Method (PERT/CPM) to optimize rig move/mobilization time and activity scheduling (Chapter 7); development of uniform standards for emergency alarm systems and indicators at offshore installations based on recognized international codes (Chapter 8); qualitative and quantitative analysis to optimize supply chain management (SCM) system (Chapter 9); best practice benchmark, work study, qualitative and quantitative analysis for manpower optimization, and strategic workforce planning (Chapter 10); enhancement of organizational efficiency through business process simplification (Chapter 11); and linear programming to optimize base oil price (Chapter 12).

1.4 IMPORTANCE OF CREATIVITY AND DATA USABILITY FOR BUSINESS PERFORMANCE IMPROVEMENT

E&P companies usually maintain a plethora of operational data and use these in good measure for preparation of reports, monitoring of activities, review, and decision making. Apart from these, the huge caches of data mostly remain in archive with limited usability, but this can turn to a treasure trove, if dealt with innovatively. What's needed are creative ideas, fresh outlook, and analytical abilities, which are often stifled in this fast-paced business world. Although there is no dearth of talent but work pressure, tight schedule for delivery, annual commitment, and so on, don't leave much room for creativity to flourish. A good idea or groundbreaking study need not necessarily be complex; in fact, most of them spring from simple ideas. A good idea or powerful study is easy to understand and easy to implement and brings in desired improvement. The characteristics of a good idea or innovative study are that it looks simple and is easily understood by most of the people, yet no one conceived or figured it out until it was presented. Like no one bothered till Sir Isaac Newton explained—"why apple falls on the ground." That's the hallmark of creativity!

1.5 OVERVIEW OF THE BOOK

As the title suggests, this book deals with optimization and business improvement studies in the backdrop of upstream oil and gas industry, but some of these studies, approaches, and techniques are also applicable to other industries. The book contains studies on optimization of strategies, resources, and cost; improvement in business performance and operational productivity; identification and removal of inefficiencies; standardization of consumption of materials; standardization of important safety measures; business process simplification, manpower optimization, improvement in human resource productivity, and so on. Various business processes, systems, and operational areas in E&P business were studied, inefficiencies were identified, and measures for improvement were suggested. The purpose of the book is not to delve deep into the operational technicalities but to emphasize on the approach for optimization and improve operational and functional performance using quantitative and qualitative tools. Therefore, technical discussions related to operational and functional areas have been kept at necessary level.

The book is divided into 12 chapters; besides the introductory chapter, it contains 11 real-life optimization and business improvement studies that are worth mentioning and emulating. Chapter 1 is the introductory part that explains the purpose and structure of the book. It portrays the overview and chapterwise contents of this volume covering a wide spectrum of activities from E&P operations to business process improvement and the like.

In order to contain the spiraling cost of drilling, especially at offshore, the E&P companies and drilling operators are continuously trying to improve the productivity of drilling operation, which is a necessity for survival in these days. Chapter 2 deals with optimization of productivity of drilling and dispels few long-held beliefs in the organization about poor performance of own rigs compared to the hired rigs. The study diagnoses areas of concern, identifies major factors affecting drilling performance, and categorizes these as *human factors*, *organizational factors*, and *technical factors*. All these factors and subfactors were analyzed, and remedial measures were suggested for optimizing the productivity of drilling operations with the potential of saving around USD 60.5 million per year for offshore Asset under study.

Drilling is a capital-intensive activity consuming a lion's share of the capital budget of an E&P company. Therefore, it is desirable to minimize nonproductive drilling time and improve rig time availability. Chapter 3 discusses optimization of controllable rig time loss using diagnostic approach. The study identifies causes of rig time loss, quantifies, and groups these under five categories, namely, waiting on material, waiting on decision, waiting on logging tool, equipment repair downtime, and other shutdown. The study reveals that controllable rig time loss accounts for 14.2% of available rig-days costing around USD 60.5 million per year in the Asset under study. Remedial measures to minimize these losses have been suggested, which would entail a saving of around USD 34.5 million per year in the Asset under study.

Deepwater exploration holds promising prospects for the future, as easy oil and gas reserves are depleting fast in this oil-hungry world. But deepwater exploration is costly, risky, and technologically challenging, which necessitates extreme economic prudence and strict monitoring of E&P operations. Ironically, some G&G activities escape attention because of inherent subjectivity and uncertainties involved in these operations. Chapter 4 aims to optimize G&G strategies for exploring oil and gas in deepwater and analyze some G&G decisions and their effect on well economics through the following: (i) optimization of G&G evaluation time in deepwater wells, (ii) techno-economic assessment of acquiring logging while drilling (LWD) in own deepwater rig, (iii) improvement of accuracy of geological predictions, (iv) effect on downhole complications due to variation in formation pressure (between actual and predicted pressure in a well), (v) containment of slippage in deepwater well completion, and (vi) influence of people's factors on the success and performance of deepwater exploration. The study provides valuable insights and offers suggestion in these areas, which would help in optimizing G&G strategy in deepwater exploration with the potential of saving around USD 50 million in less than a year.

OSV is the lifeline of offshore E&P operations. Waiting cost of offshore installations is extremely high, and it is undesirable that installations wait for materials that are supplied by OSVs. Therefore, adequate number of OSVs is required for uninterrupted operation, but OSVs are also costly items. It is necessary to trade-off between waiting time of installations and that of OSVs. Chapter 5 develops a queuing model to optimize OSV fleet size with the objective of minimizing waiting time of installations, which in turn would lead to optimizing waiting cost of installations and the total system cost. The study also determines various operating characteristics of the queuing model, which would help in decision making under dynamic conditions.

Chapter 6 deals with standardizing consumption of high-speed diesel (HSD), cement, and chemicals in oil/gas wells and rigs to prevent stockout situation, avoid excess inventory, monitor consumption, check wastages and aberrations, and help drawing future procurement plan. HSD consumption depends on various technical, geological, and physical factors. **Average HSD consumption** per meter drilling for similar category and capacity of rigs operating in similar geological formation and depth with similar rate of penetration was grouped for standardization. Accordingly, unit fuel consumption for different types and capacities of rigs in different regions/Assets/Basins were computed and standardized both at onshore and offshore. Suggestions have been offered for the improvement of HSD consumptions in drilling rigs, which can save up to USD 62.8 million per year. **Consumption of cement** depends on various technical and geological factors like casing policy, hole size and depth, cement rise, number of objects to be tested, activity and mud loss, downhole complications, and so on. Consumption of cement was standardized for different casing policy wells in different fields/regions taking into consideration the aforementioned factors. **Consumption of chemicals** in an oil/gas well depends on various technical and geological factors, such as well depth, formation pressure, lithology, and borehole instability, to mention a few. The unit consumption (kg/m) of chemicals in oil/gas wells varies widely with high standard deviation, not only in different fields but even within the same field. Therefore, consumption range and upper limit of consumption of chemicals have been determined for various groups of wells.

Rig move/mobilization is considered as unproductive rig time, which needs to be minimized to ensure more time for drilling and completion. Network analysis using PERT/CPM technique has been used in Chapter 7 to optimize rig move time and develop optimal activity schedule. The study identifies critical path and critical activities and focuses on timely completion of critical tasks to avoid delay in rig move/mobilization. The study suggests a set of recommendations for optimizing rig move time and activity schedule, which has the potential of saving 500 rig-days amounting to USD 30 million per year in the E&P company under study.

Chapter 8 focuses on developing uniform standards for emergency alarm systems and code of signals for offshore installations of an E&P company, which are found to vary widely. This creates confusion and possesses safety threat to offshore-bound personnel, especially those who frequent different installations. The study classifies different emergency situations, and provides useful guidance for developing code of signals for emergency alarm system and indicators based on recognized international codes. It suggests uniform adoption of standards across various offshore installations of the organization.

Chapter 9 deals with optimization of SCM system and highlights importance of SCM system for smooth functioning of E&P operations. It identifies opportunities for improvement by assessing maturity of key supply chain functions and benchmarking these with comparable industry standard. The study aims to improve procurement cycle time by streamlining material planning, tendering, and order execution processes along with other measures. It also suggests improvement in inventory management and warehouse functions. Furthermore, the study emphasizes the need for SCM support services, namely, demand forecasting, strategic procurement, and vendor relationship management, which are currently unorganized or nonexistent in the organization under study. The recommendations made in this study can improve SCM system in the organization and have the potential of saving USD 244 million per annum.

Chapter 10 discusses manpower optimization and strategic workforce planning of an E&P company emphasizing on multiskilling, multidisciplinary approach to improve employee utilization and productivity and enrich the quality of human resources. It rationalizes the large pool of disciplines/subdisciplines and impresses on modification of the organization’s manning norms aligning with the best practice benchmark. It studies the current manpower planning process in the organization, finds out shortcomings that are not conducive to good practices, and suggests measures to overcome these. A real-life case study has been presented illustrating the process of manpower optimization that includes demand forecasting, supply (availability) prediction, and balancing demand–supply gap. The study reveals that there is enormous scope for savings on account of manpower optimization in the organization, approximately USD 290 million.

Chapter 11 illustrates some real-life examples of business process simplification, which is a powerful tool to improve system efficiency, especially in large enterprises where processes are deeply embedded in organizational structure and culture and seem inseparable. The study highlights the efficacy of business process simplification in improving customer satisfaction and service quality, reduction of processing time, elimination of nonvalue adding tasks, and duplication of efforts, freeing up scarce resources and creating awareness in an enterprise.

Oil pricing is a complex and sensitive issue, which is not dependent on economic criteria alone—a set of environmental factors like social, political, technical, and geopolitical issues strongly influence it. Chapter 12 develops a quantitative model to optimize base oil price for a country using linear programming, taking into account the cost and share of domestic oil production and that of oil import and other factors. It aims to maximize profitability and drive oil production by reinvesting into E&P activities. It is an illustrative model that develops a framework to study the effect of various parameters on base oil price and aid decision making under dynamic circumstances.

All these are real-life examples of optimization and business improvement studies, which are based on simple concept, notwithstanding inherent uncertainties involved in E&P business. A wide range of topics are covered in the book containing powerful drivers to capitalize opportunity cost and shore up business performance. These studies are easy to emulate and have the potential of saving billions of dollars, besides improving organizational efficiency.

REVIEW EXERCISES

1.1 Describe the importance of oil and gas in today's world.

1.2 What are the sequence and process of E&P activities?

1.3 Is there any need for optimization in upstream industry? Explain.

1.4 Define optimization. Is it different from maximization/minimization? Explain.

1.5 What are the various optimization techniques you are aware of? Mention their applicability.

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2

OPTIMIZING PRODUCTIVITY OF DRILLING OPERATIONS

2.1 INTRODUCTION

Drilling is an expensive and technology-intensive activity, which consumes a major part of an E&P company's budget, especially in offshore Assets and Basins. The cost of drilling is increasing over the years throughout the world, which is confirmed by various reports and studies conducted by well-known groups, agencies, authorities, and organizations like Joint Association Survey [1], US Energy Information Administration (EIA) [2], E&P companies, and so on. This is expected due to the fact that easy and shallow reserves are depleting fast, and the search for and production of oil and gas are directed to greater depth and in difficult areas (e.g., production from matured fields using secondary and tertiary recovery methods, exploring in ultradeep water, producing from deep reservoir, targeting small and marginal oil pools from the same well). This requires acquisition and use of advanced technology, which adds to the cost. In addition, the cost of drilling increases exponentially with depth, which is also confirmed by various E&P companies and studies carried out by different groups and experts [3, 4].

Furthermore, E&P activities have increased over the years with the rise in demand for oil. All these have resulted in higher demand for rigs. But the manufacturing and supply of rigs have not kept pace with the soaring demand. As a result, there is shortage of drilling rigs all over the world, thus pushing up rig hiring cost. All these contributed to an increase in drilling cost over the years. E&P companies and drilling contractors are striving hard to contain the rising drilling cost through various means under their control like efficient use of available resources and economic prudence. They are always on the lookout to find ways to minimize drilling cost and improve drilling productivity.

The terms "drilling efficiency" and "drilling productivity" are used interchangeably in E&P industry, although there are subtle differences. Efficiency is a metrics of output for

Optimization and Business Improvement Studies in Upstream Oil and Gas Industry, First Edition.
Sanjib Chowdhury.

a given set of inputs; it highlights how best the resources are used for a specific output. Productivity, in simple terms, is the rate of output with respect to inputs conforming to standards or quality. Drilling efficiency is generally measured in terms of footage drilled per day or per rig, resources added per well or per rig, wells drilled per rig, drilling cost per foot, energy consumption, drilling speed, and so on. The term “drilling productivity” has wide connotations and is interwoven with various intricate issues, such as operational productivity, geologic conditions and reservoir properties, drilling parameters, achieving target objectives, economic and financial factors, and so on. Different groups usually focus on different aspects mentioned previously depending on their expertise, interest, capability, and objectives. A concerted effort is required to assimilate related information and knowledge for cost optimization and improving the productivity of drilling.

It may be noted that a common benchmark for “drilling productivity” would be unrealistic due to wide variability and large number of factors affecting drilling performance. Therefore, it would be appropriate to benchmark drilling performance under similar geologic conditions and depths; otherwise, it would be an inappropriate comparison. *This study deals with the improvement of “drilling productivity” taking into account many of the aforementioned factors. It benchmarks drilling performance of own drilling rigs against the contract rigs operating in the same area under similar geological conditions. The factors affecting low performance were identified and analyzed, and measures for improvement were suggested.*

Before we proceed further, a brief note on drilling operation and cost is explained in the next paragraph, which may be useful to the esteemed readers.

2.2 A BRIEF NOTE ON DRILLING OPERATION AND COST

Drilling technology has evolved over the years—drilling in earlier days was percussive type, that is, raising and dropping cable tool with a pulley system. But, major changes took place with the introduction of rotary drilling in 1930s, which paved the way to drill more efficiently to a greater depth and at a faster rate. Drilling rig is a common landmark of upstream oil and gas industry, which is easily recognized by the huge and tall steel structure called “derrick” anchored to the ground. Drilling rig consists of a number of components and equipment, such as derrick, high-powered engines, mud pump, mud circulation system, draw works, blowout preventer, water tanks, fuel tanks, and so on (Fig. 2.1). The traveling block is suspended from the crown block—a large pulley at the top of the derrick. The swivel attached by a large hook to the traveling block can rotate freely, and the Kelly is fitted onto this. A rotatory table at the center of the derrick floor holds the Kelly (which has a square or hexagonal cross-section) and can be rotated at a desired speed by the engine. To begin drilling operation, the Kelly is hauled up the derrick, and its bottom is fitted with a drill bit and lowered through the rotary table until the bit rests on the earth. With the start of engine, the rotary table rotates the Kelly and drill bit, which is pressed hard against the earth by the weight of the drill string, thus cutting and penetrating the rock at the bottom [5].

Drilling fluid, popularly known as mud, is a specially designed slurry of chemicals, salt, and water, which is run through the drill pipe to the bottom of the hole. It comes out from the nozzle of the drill bit and makes way to the surface through annulus of the drill pipe and borehole wall/casing. It serves several important functions, such as flushing out of rock cuttings, cooling and lubricating the drill bit, balancing formation pressure, and so on.

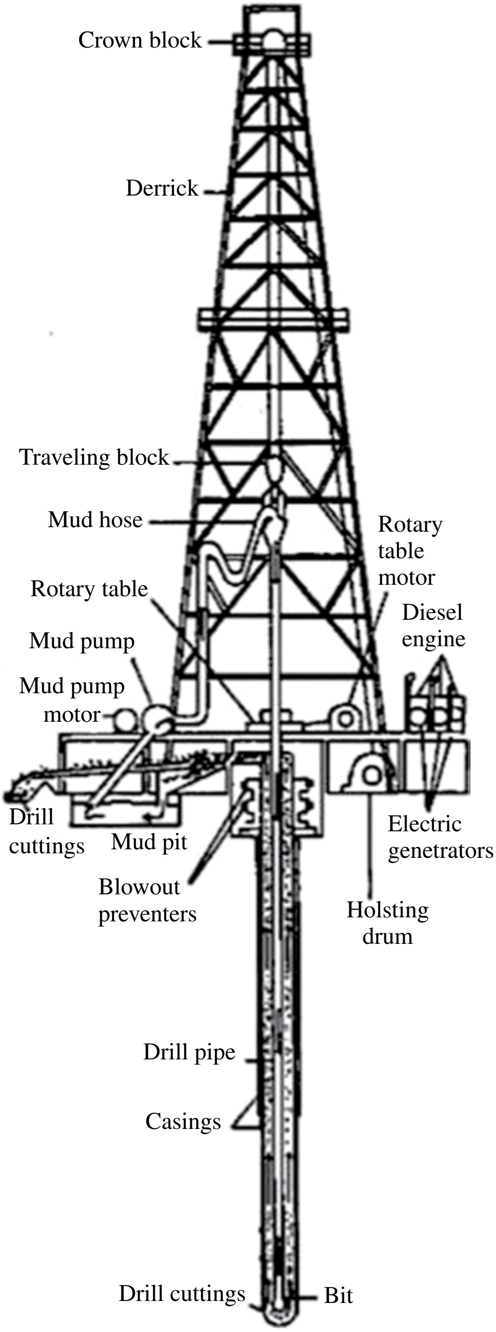

FIGURE 2.1 On-land drilling rig. Source: NISCAIR, India.

As the well gets deeper, additional drill pipe is connected with the drill string under the Kelly or top drive at the surface, which is known as "making a connection" or tripping. After drilling a certain depth, the casing pipes are lowered and cemented to prevent collapse of the sidewall and retain structural integrity of the well, which are known as casing and cementing. The wellbore is telescopic in nature whose ultimate productive size depends on the number of casing string. While drilling a well, several operations, namely, well logging, coring, production testing, and so on, are carried out to evaluate the formation properties. All these important functions, namely, mud circulation and drilling fluids, casing and cementing, and formation evaluation—logging, coring, production testing, and so on, are further elaborated in Chapters 4 and 6.

Till 1970s, oil and gas wells were mostly vertical; the development of directional drilling took place in 1970s, which culminated in the development of horizontal drilling. Nowadays, horizontal drilling is a common practice, which has many advantages over vertical wells and is especially useful: (i) for drilling multiple wells from single location (e.g., central offshore platform) targeting different reservoir zones, (ii) horizontal wells have greater surface area with production zone (i.e., maximum reservoir contact) in thin reservoir than vertical wells resulting in higher flow rates which in turn make it economic, and (iii) inaccessible location, for example, densely populated area, environmentally sensitive area, drilling offshore location from onshore, and so on. The advent of top drive system (TDS) replacing the Kelly drive system vastly improved horizontal well capability due to its inherent advantages of reaming up and down and reducing connection time.

Since then, there has been remarkable advancement in drilling technology; sophisticated tools and equipment like measurement-while-drilling (MWD), logging-while-drilling (LWD), and so on, provide real-time information about subsurface properties and drilling parameters. All these help drilling engineers and G&G professionals to take quick decision and follow safe course of action to avoid downhole complications and improve drilling efficiency. Multilateral drilling technology that enables drilling multiple horizontal wells from the same well vastly improved cost and resource optimization.

Based on areas of operation, drilling activity is called on-land drilling and offshore drilling. The drilling process and equipment are mostly same for both on-land and offshore drilling, except the types of rigs used. The difference between on-land and offshore rig is mainly the way rig is supported. The design and engineering of rig support for offshore is far more complex and different from that of on-land rigs. Due to marine environment and remoteness from the shore and base, offshore rigs require additional support, such as diver support, logistics (marine and aviation) support, meteorology station, and so on.

Depending on water depth, offshore rigs are either floating type (e.g., drill ship and semisubmersible), moored or unmoored type (dynamic position rig), or fixed to the seabed (e.g., jack-up). Offshore drilling rigs are mainly of three types—Jack-up (suitable for drilling up to 500 ft water depth); platform type, semisubmersible (capable of drilling at 1,650–9,900 ft water depth); drill ships (capable of drilling at 1,650–12,000 ft water depth). Semisubmersible rig and drill ships may be anchored or dynamic-positioned. The capability of anchored rig is limited to water depth 5,000 ft, whereas dynamic-positioned drill ship is capable of drilling up to water depth 12,000 ft.

The hiring charges of drilling rig is a major component of well cost. It accounts for nearly **30% of well cost and half of rig operating cost at offshore** (refer to Section 2.4g, Figs. 2.10 and 2.11). The current (2015) rig hiring charges of offshore drill ship capable of drilling above 4000 ft water depth is approximately USD 500,000 per day, and those less than 4000 ft water depth is approximately USD 250,000 per day. Similarly, hiring cost of semisubmersible rig capable of drilling above 4000 ft water depth is approximately