

REVIEW

## Analyzing average rig time and ease of drilling in Indian sedimentary basins: an informative tool for exploration decision-making

Surajit Gorain and Pralay Sen

Directorate General of Hydrocarbons, Ministry of Petroleum and Natural Gas, Uttar Pradesh, India

### ABSTRACT

Hydrocarbon exploration entails complex and costly endeavors, with drilling activities accounting for the highest expenses. To facilitate informed decision-making for geoscientists and investors, this study presents a template highlighting the average rig days and drilling ease in Indian sedimentary basins. Leveraging data from over 19,000 wells across these basins, a comprehensive analysis was conducted. While the physics and chemistry of drilling are well understood, uncertainties arise from local geological conditions, well specifications, contractor expertise, timely rig availability, market factors, and local regulations. By filtering out extreme rig times affected by these factors, average rig time (ART) and average total depth (ATD) were calculated for each basin using a simple averaging approach. ART was visualized as a basin-wise bubble map, providing an overview of the drilling duration required to reach total depth. This aids in estimating drilling costs for future wells in relatively unexplored areas. Additionally, a contour map incorporating basin-wise ATD was generated, offering insights into structural variations and basement configurations. Combining ART and ATD, a single factor known as the ease of drilling (EOD) was calculated and presented as a bubble map across Indian sedimentary basins. This map serves as a valuable tool for investors, providing information on the optimal depth and duration of drilling in each basin and aiding decision-making processes for exploration projects.

### KEYWORDS

Average days; Data analysis; Bubble map; Easiness of drilling; Average total depth

### ARTICLE HISTORY

Received 19 June 2023;  
Revised 26 August 2023;  
Accepted 4 September 2023

### Introduction

In the past few decades, significant research has been conducted to understand the factors influencing the Rate of Penetration (ROP) in drilling operations. Initially, empirical models were developed to optimize drilling parameters, establishing empirical expressions for bit life and ROP using Weight on Bit (WOB), depth, and revolutions per minute (RPM). Researchers like Maurer introduced models to predict ROP [1], while Eckel demonstrated the impact of overbalanced pressure on drillability [2]. Bourgoyne and Young developed a highly influential empirical model for ROP optimization [3], which was later refined by Warren and Al-Betairi et al. [4,5]. Maidla and Ohara contributed by developing optimization software for roller-cone bits, effectively reducing drilling costs [6]. Motahhari et al. developed a Polycrystalline Diamond Compact (PDC) model incorporating confined compressive strength (CCS), RPM, WOB, and bit size [7]. However, these physics-based models rely on empirical coefficients and are limited by lithology dependence and calibration variability.

Researchers have also explored alternative approaches, such as metaheuristic techniques like the rain optimization algorithm (ROA), as well as artificial intelligence (AI) and hybrid models, for accurate ROP prediction. Despite these advances, there is currently no available document or template in India that can accurately envisage the Average Rig Time

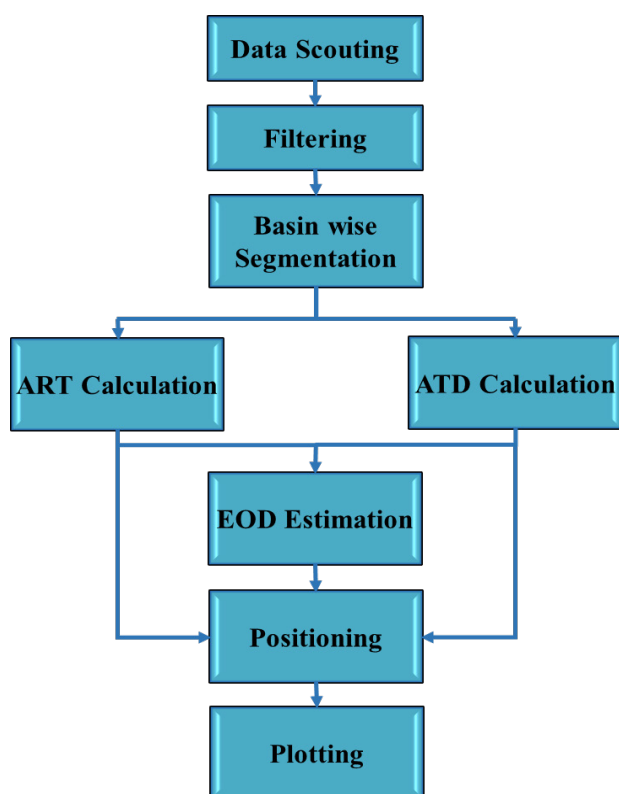
(ART) or EOD specifically for the Indian sedimentary basins, even though a large number of wells have been drilled in the country. The absence of a public platform providing access to past drilled data hampers the ability of potential investors to predict rig days accurately before actual drilling operations. As a result, operators often estimate rig days either excessively or inadequately, leading to adverse effects on project economics.

India possesses a substantial Exploration and Production (E&P) database at the National Data Repository (NDR), which can be effectively utilized to envisage such factors. This study aims to create a template that visualizes the average rig days and ROP in the Indian sedimentary basins, enabling investors to make informed decisions before committing to drilling activities during hydrocarbon exploration.

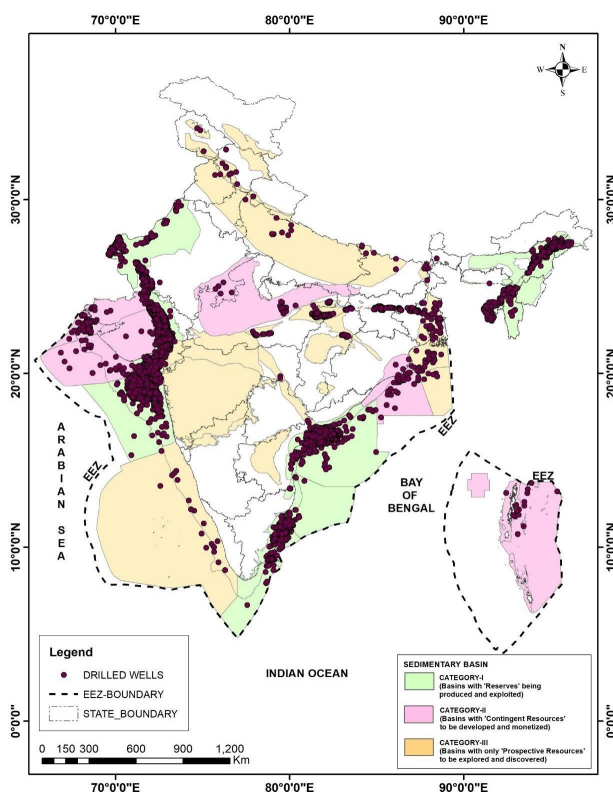
### Methodology

The methodology employed in this study follows a specific workflow shown in Figure 1. It begins with data scouting, utilizing the National Data Repository (NDR) master data storage (MDS), which contains a comprehensive dataset of over 195000 wells of various types, including exploratory, appraisal, development, core, and wildcat wells until March 2022. Figure 2 shows the location of the wells which are considered for analysis.

\*Correspondence: Surajit Gorain, Directorate General of Hydrocarbons, Ministry of Petroleum and Natural Gas, Uttar Pradesh, India, e-mail: [dr.surajitgorain@gmail.com](mailto:dr.surajitgorain@gmail.com)

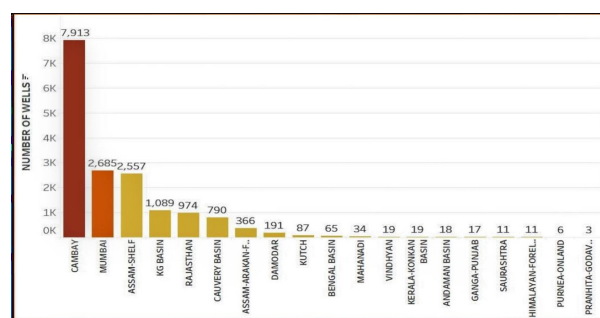


**Figure 1.** Methodology adopted for this study, highlighting the approach and techniques employed in the analysis.



**Figure 2.** Geographical distribution of wells considered for analysis, providing a visual representation of the spatial distribution of wells within the Indian Sedimentary Basin.

In the second step, exceptional wells characterized by extremely low or high rig times, attributed to factors such as local geologic conditions, special well specifications, contractor issues, timely availability of drilling rigs and equipment, market-related factors, and local administrations, are filtered out and not included in the analysis. Approximately 3000 wells are filtered out through this process. After filtering out the exceptional wells, the wells are segmented basin-wise. Frequency plots are generated to visualize the distribution of wells across different basins (Figure 3). The plots indicate that a majority of wells are drilled in the Cambay, Mumbai offshore, and Assam Basins.



**Figure 3.** Frequency distribution of wells across different basins, presenting a graphical representation of the distribution of wells among various basins, offering insights into their relative abundance.

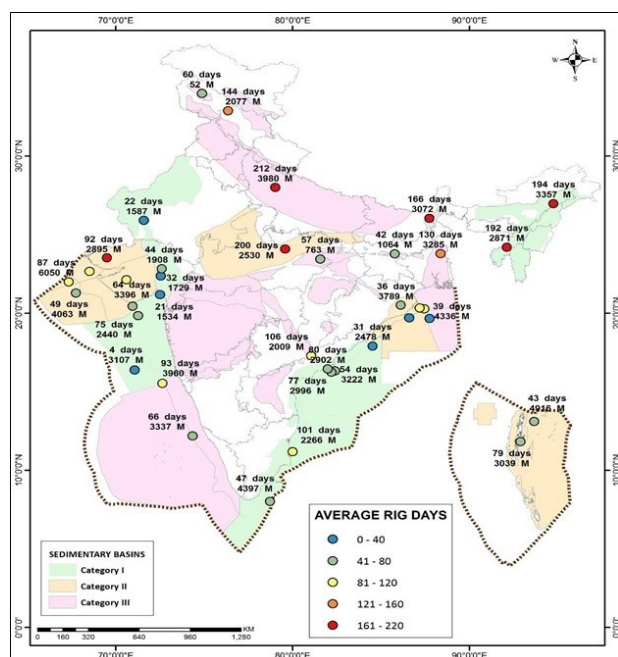
The rig time and target depth of each well are noted using the information available in Well Completion Report (WCR). The ART and ATD for each basin are calculated using a simple averaging principle. In the context of rig operations, one must consider that the duration of these operations is influenced by a combination of geological and non-geological factors. To illustrate the variations in rig days associated with geological aspects, two contributing factors, ART and ATD, are combined. This introduces the concept of EOD, which is essentially a normalized ART, representing the ratio of ATD to ART.

The critical aspect of this workflow is the positioning of representative locations. As multiple wells have been drilled in each basin, and the wells are distributed throughout the basin, it is decided to represent each basin by the position of a well whose drilling completion time is closest to the average drilling completion time of that basin. In this way, all the data points are represented by a single location, simplifying the visualization and analysis process.

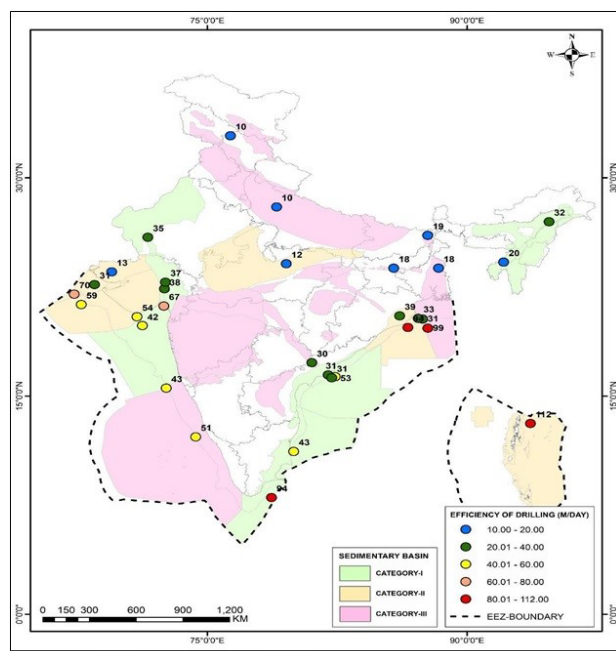
## Results and Discussions

After the data analysis, several visual representations are created. Figure 4 represents the bubble plot of average rig days and average target depth in Indian basins. Figure 5 depicts a bubble plot of the average easiness of drilling in Indian basins. Additionally, a contour map based on ATD data points is prepared and shown in Figure 6.

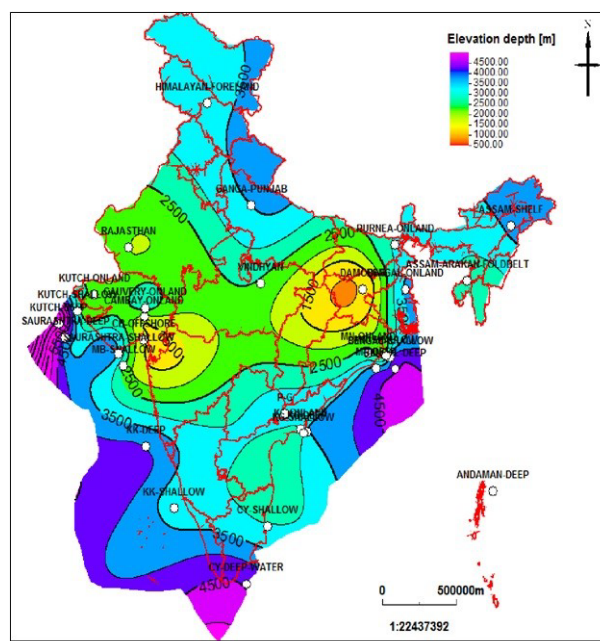
The bubble plot of average rig days and target depth reveals (Figure 4) that the ART for all Indian basins is around 90 days. Basins with higher ART values are marked with red bubbles, while those with lower values are marked with blue bubbles. This map provides a comprehensive understanding of



**Figure 4.** Bubble plot depicting the average rig days and average target depth in Indian basins, visually illustrating the relationship between the average duration of drilling operations (rig days) and the average depth of the targeted reservoirs within Indian basins.



**Figure 5.** Bubble plot illustrating the average easiness of drilling in Indian basins, presenting a graphical representation of the average ease or difficulty of drilling operations within Indian basins, using bubbles to depict different levels of drilling ease.



**Figure 6.** Contour map showcasing the average target depth within Indian basins, utilizing contour lines to represent the average depth of the targeted reservoirs, providing a visual overview of the depth patterns across the Indian basins.

the drilling time required on a basin-wise basis, aiding in the estimation of drilling costs for future wells in relatively new areas.

The bubble plot of the average easiness of drilling in Indian basins (Figure 5) demonstrates that basins like Assam-Arakan fold belt, Assam-shelf, Ganga Punjab, Pranhita Godavari, Purnea on land, Himalayan foreland, Kutch on land, Vindhyan, Saurashtra on land, and South Rewa basins have below-average EOD. On the other hand, Cambay on land, Bengal, Mahanadi, Cauvery, and Andaman deep-water basins have above-average EOD.

The contour map of average target depth within Indian basins provides insight into the structural variation or basement configuration of the basin (Figure 6). For example, the ATD ranges around 2000-2500m in basins such as Cambay, Kutch-Saurashtra, Decan syncline, Vindhya, Satpura, Narmada, South Rewa, and Ganga Basin. In offshore part of Krishna Godavari (KG), Cauvery (CY), Mahanadi (MN), Kerala-Konkan (KK), Mumbai (MB), and Kutch- Saurashtra (KS), the ATD is around 3500-4500m. Meanwhile, in the northeastern part of India (Assam, Arunachal, and Tripura), the ATD is around 3000m.

A thorough and extensive study was conducted to identify the key factors that contribute to the challenges and complexities encountered during drilling operations across various basins. The findings of this study were compiled into a comprehensive table, aiming to provide investors with essential information and insights prior to making any drilling commitments. Table 1 presents a detailed overview of the basin-wise challenges and complexities identified in the study, serving as a valuable resource for investors to make

**Table 1.** Overview of basin-wise challenges and complexities identified in the study, serving as a valuable resource for investors to make well-informed decisions.

| Basin Name                     | Av<br>EOD<br>(m/d) | Common Challenges                                                                                                                                                                                                                                                     |
|--------------------------------|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Onshore basins</b>          |                    |                                                                                                                                                                                                                                                                       |
| Assam-Arakan-<br>Fold belt     | 43                 | Lithology is very sticky (Pleistocene)<br>Shell swelling (Miocene) causes major horizontal drifting.                                                                                                                                                                  |
| Ganga Punjab<br>Basin          | 13                 | Severe Mud loss problem                                                                                                                                                                                                                                               |
| Kutch on land                  | 21                 | Shell Swelling<br>Major horizontal fracture due to dolerite fracture zone                                                                                                                                                                                             |
| Bengal on land                 | 31                 | Surface Seepage<br>Dynamic mud loss is very frequent within 1000 m of drilling (Pliocene)                                                                                                                                                                             |
| Purina On Land                 | 26                 | Severe surface seepage problem up to a depth of 450 m (Pleistocene)<br>Reverse Drill breakup problem                                                                                                                                                                  |
| Himalayan-<br>Foreland         | 12                 | Frequent cementation job failures<br>Abrupt increase of geothermal gradient                                                                                                                                                                                           |
| Vindhyan Basin                 | 20                 | Extremely hard formation (Sivalik Formation) within 250-700 m                                                                                                                                                                                                         |
| <b>Shallow offshore basins</b> |                    |                                                                                                                                                                                                                                                                       |
| Bengal shallow<br>water        | 68                 | Frequent mud loss within 500-700 m (Pliocene to late Miocene) Heavy gas<br>breakout problem within 2800-3000 m (Late Miocene)<br>Very high-pressure water inflow within a depth interval of 3200-3500 m<br>(Late Miocene)                                             |
| KG shallow water               | 90                 | The presence of high-pressure aquifer causes frequent hole collapse and pitgain within<br>intervals 700-1200 m (Pleistocene to Pliocene)<br>Mud loss and sudden increase of gas bubbles, and kicks are very common within depth<br>intervals of 2400-2900 m (Miocene) |
| Kutch shallow<br>water         | 31                 | Frequent Hole collapse incidents, tight pull observed several times within interval 2200<br>-2800m (cretaceous to Jurassic)<br>Flowline choking due to gumbo clay observed within 300-500 m (Pleistocene)                                                             |
| Mahanadi Shallow<br>water      | 38                 | Serve loss circulation observed within the interval 1900-2400 m (Early Miocene)                                                                                                                                                                                       |
| <b>Deep offshore basins</b>    |                    |                                                                                                                                                                                                                                                                       |
| Kerala-Konkan-<br>deep-water   | 48                 | EOD is less entirely due to Technical issues like Fishing, Tool stuck etc.                                                                                                                                                                                            |
| KG deep water                  | 72                 | Mud loss was reported for several wells within a depth interval of 1750-2200 m<br>(Pliocene to Recent)                                                                                                                                                                |
| Kutch deep water               | 70                 | Tight Pull observed within intervals 2500-2800 m (Cretaceous) and 5100-5350 m<br>(Jurassic)                                                                                                                                                                           |
| Saurashtra-deep-<br>water      | 59                 | Sudden inflow of pressurized water within intervals 4800-5100 m (Early Eocene)<br>Very tight pull observed within interval 2300-2600 m (Middle Eocene)                                                                                                                |

well-informed decisions. It provides a comprehensive analysis of the specific challenges and complexities encountered in each basin, offering insights and guidance for investors evaluating investment opportunities in the oil and gas sector.

### Conclusions

The bubble plots depicting the average rig time (ART), average total depth (ATD), and average easiness of drilling (EOD) reveal interesting insights about different basins. In the Bengal and Mahanadi Basins, the average EOD is high (>80m/d),

while the ART is low, despite the relatively high ATD (>4000m). This suggests that drilling operations in these basins are efficient and productive. In contrast, the Cambay Basin exhibits a low ART due to the focus on relatively shallow exploration, whereas the northeastern area experiences lower drilling efficiency, resulting in a higher ART. The western offshore areas demonstrate smooth drilling operations with favorable EOD.

Overall, these templates provide a valuable understanding of the average rig days and drilling efficiency on a basin-by-basin basis. They serve as reliable benchmarks for cost estimation during drilling and guide future exploration strategies. By utilizing this information, potential investors can make informed decisions regarding the time and financial commitments required for drilling activities. This knowledge proves especially useful during the bidding process for exploration acreage under the Open Acreage Licensing Policy (OALP) and for assessing project feasibility. Thus, this study significantly assists potential investors by providing essential references for time and cost estimations, enabling them to make informed decisions when venturing into drilling commitments and subsequent projects.

### Disclosure statement

No potential conflict of interest was reported by the authors.

### References

1. Maurer WC. The 'Perfect-Cleaning' Theory of Rotary Drilling. *J Pet Technol.* 1962;14(11):1270-1274.
2. Eckel JR. Microbit Studies of the Effect of Fluid Properties and Hydraulics on Drilling Rate. *J Pet Technol.* 1967;19(4):541-546.
3. Bourgoyne Jr AT, Young Jr FS. A Multiple Regression Approach to Optimal Drilling and Abnormal Pressure Detection. *Soc Pet Eng J.* 1974;14(4):371-384.
4. Warren TM. Penetration-rate performance of roller-cone bits. *SPE Drill Eng.* 1987;2(1):9-18.
5. Al-Betairi EA, Moussa MM, Al-Otaibi S. Multiple Regression Approach to Optimize Drilling Operations in the Arabian Gulf Area. *SPE Drill Eng.* 1988;3(1):83-88.
6. Maidla EE, Ohara S. Field Verification of Drilling Models and Computerized Selection of Drill Bit, WOB, and Drillstring Rotation. *SPE Drill Eng.* 1991;6(3):189-195.
7. Motahhari HR, Hareland G, James JA. Improved Drilling Efficiency Technique Using Integrated PDM and PDC Bit Parameters. *J Can Pet Technol.* 2010;49(10):45-52.