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ORIGINAL PAPER-EXPLORATION ENGINEERING

Development of well complexity calculator and its integration into standard well engineering management system/well delivery system

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Abstract

Oil and gas well drilling is the most important and complex task for oil and gas exploration. It is not necessary that design and execution complexity remain the same for two different wells even in the same field. It is possible to have a very complex well to drill after a very straightforward simple well being drilled earlier in the same field. Making correlation or comparison of any of the two or more than two oil and gas drilling wells is an ongoing debate in the petroleum industry. Generally, companies compare the oil and gas drilling wells on a single or two parameters, for example: time versus depth, directional trajectories, well cost and/or other single factors in disengagement of one another. In order to compare two different types of oil and gas drilling wells, having distinctive design, drilling and fluid program and challenges, a scientific rating system is required, which can relate various wells with one another. In this research paper, a calculator named Well Complexity Calculator has been developed to measure the complexity of the oil and gas well drilling by using different parameters. All these parameters are commonly affecting the drilling program and its execution. Secondly, a methodology is designed for integration of Well Complexity Calculator into standard Well Engineering Management System/Well Delivery System for better execution of drilling program. Fifty-one (51) oil and gas drilling well complexity parameters have been utilized to develop Well Complexity Calculator, where they are categorized into three main complexities types named Design Well Complexity, Geological Well Complexity and Project Well Complexity. Design and Geological Well Complexities combine to form Drilling Well Complexity, and then Drilling Well Complexity and Project Well Complexity combine to form Well Complexity. Median, Mode and Monte Carlo simulation techniques were chosen to develop the calculator where Median showed best suited results and was accordingly chosen for the final calculator. Sixty-six (66) actual oil and gas wells' camouflaged drilling data were used to analyze and fine tune the developed Well Complexity Calculator. Output complexities of these wells were falling in different complexity levels. Moreover, it was seen that the number of low, high and medium complexity wells was different for Design, Geological, Project, Drilling and Well Complexities which is in line with the real-world scenario.

The findings and the output Well Complexity Calculator can be very useful at any stage from initial planning to close-out of a well. Without the application of a system like Well Complexity Calculator, wells are categorized as low, medium or high complexity based on either two to three major parameters or based on qualitative assessment of team involved in the project. Here, step-by-step procedure is developed and explained by which any company involved in Drilling and Well Operations can develop their own Well Complexity Calculator and then accordingly integrate it into their Well Engineering Management System/Well Delivery System.

Keywords Well complexity calculator · Well management · Well engineering management system · Drilling complexity index (DCI) · Well complexity index (WCI)

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Abbreviations

AFE	Authorizations for expenditure
CwD	Casing while drilling
DCI	Drilling complexity index
DWOP	Drilling well on paper
ENV Protected	Environmentmental protection

ERD	Extended reach drilling
FIT	Formation integrity test
G&G	Geological and geophysical
HAZOP	Hazard and operability analysis
HP	Horse power
KPI	Key performance indicator
KPK	Khyber Pakhtunkhwa (Province of Pakistan)
LOT	Leak off test
LWD	Logging while drilling
MD	Measured depth
MDT	Modular formation dynamics tester
MPD	Managed pressure drilling
NPT	Non-productive time
PCI	Planning complexity index
RwC	Reaming while casing
SG	Specific gravity
TVD	Total vertical depth
UBD	Underbalanced drilling
VB	Visual basic
WC Calc (WCC)	Well complexity calculator
WCI	Well complexity index
WLL	Wireline logging

Introduction

Vulnerability is enormous in drilling operations and activities, particularly in Exploratory Wells or the wells with limited subsurface data. Drilling and Well Operations comprise numerous unpredictable operations and steps, which include both controllable and non-controllable elements/factors. Every one of these variables add to the complexity of the well and likewise sufficient possibilities should be worked in time and cost assessments of the drilling activities (Nzeda and Schamp 2014). In any case, the most ideal approach to correlate various wells is by ranking them while considering maximum possible parameters. Well Complexity Calculator developed here considers multiple factors to produce a single digit which is true representative of Well Complexity. Several studies have proposed methodologies and concepts that help quantify the costs and complexity of the well due to different parameters such as constraints posed by well drilling and planning factors, broadly classified by Well Complexity Index. It was proposed that many researches have been carried out to determine the well complexity and its costs; however, reservations exist when evaluating and predicting the factors which influence the performance of the well operations (Kaiser 2007). A number of conventional techniques have also been proposed in this aspect, where offset records are used to analyze the actual performance of the well in an oil field; however, these standards and records are subjective in nature and tends to be viable for short range and technical performance standards (Pessier and Fear 2013).

According to Nzeda, and Schamp (2014), the complexity of well operations, including drilling, completion, testing and stimulation of the well, is a risk-prone process that requires accurate amalgamation of scientific and technical concepts of petroleum engineering. However, these mathematical and computational concepts for precise calculations are integrated with the consideration of far more subjective and qualitative well operations which includes the physical hazards such as environmental catastrophe. This poses a continuous hazard throughout the well operations.

To safeguard the economics and safety of the well operations, a number of studies show the incorporation of various factors which need to be considered during the contingency planning of the complex wells which are difficult to be drilled and require a competitive budget strategy (Ezenwanne and Giadom 2018; Curry et al. 2013; Oag and Williams 2013; Dupriest 2013). Mason and Judzis (2013) proposed that the method to calculate the future performance of future higher step-out wells are very challenging. They considered that departure-to-TVD ratio, often attributed as ERD, explains the difficulty of drilling offshore wells. They demonstrated that the offset well data reveals the “Risks and Limits” of the drilling such difficult wells. The Saudi Arabian Oil Company also mentioned a similar issue by which they classified their ERW as per the measured depth (MD) and derived a new method for designing deep wells that reached a total depth of 17,600 ft (Muñoz et al. 2016).

According to Nzeda, and Schamp (2014), the complexity of well operations, including drilling, completion, testing and stimulation of the well, is a risk-prone process that requires accurate amalgamation of scientific and technical concepts of petroleum engineering. They developed Drilling Complexity Index (DCI) and Planning Complexity Index (PCI) and accordingly declared their combination as Well Complexity Index (WCI). They declared it as is a very useful tool which categorizes the complexity of the well. It is used as contingency indicator for the level of complexity to be faced in the well operations. DCI can be used at any interval of well delivery process. DCI is often used in planning of new wells. It is suggested by researchers that DCI is used in predicting the non-productive time (NPT) of the drilling operations, time and cost of the drilling plans, and portfolio management and found Drilling Complexity Index has found to be of major importance in predicting the hazards and risks in the overall well operations (Nzeda and Schamp 2014; Nzeda et al. 2014). Drilling Complexity Index (DCI), together with Planning Complexity Index (PCI), is classified as Well Complexity Index (WCI). DCI involves the challenges of subsurface operations, such as drilling rigs and equipment. Planning complexity index covers surface challenges, considering geopolitics of the well location, the climate and well logistics. These two factors are very important in project evaluation of well planning and operations (Nzeda et al. 2014).

Drilling a well is a very expensive venture, and several factors influence its drilling cost; the common characteristics are considered to be the rent of the drilling rig, transport and weather conditions, etc. Irrespective of the high-tech equipment, the weather downtime always incorporates considerable variation in the time required to drill a well (Jenkins and Crockford 2013). Loberg et al. (2013) considers the economic feasibility an important aspect in well planning, alongside technical considerations. Probabilistic well cost estimate was suggested that would strengthen and systemize the corresponding workflows of the drilling of the well.

It is suggested that Well Complexity Index is a very useful technique that allows the comprehensive planning and operating the drilling projects, addressing a broad range of aspects, from the well planning phase to the drilling phase. WCI significantly helps to evaluate the resources needed for the project and anticipated non-productive time (Nzeda et al. 2014). In any case, the most ideal approach to correlate various wells is by ranking them while considering maximum possible parameters. In this research paper, Well Complexity Calculator (WCC) has been developed where 51 oil and gas drilling well complexity parameters have been utilized to develop Well Complexity Calculator. The parameters selected here are more in quantity compared to work already done in this regard (Nzeda et al. 2014).

The parameters which are used to develop in previously published work are very few. Using a few parameters to define oil and gas well drilling complexities sometimes results in erroneous outcomes. In previous work, the detail of the procedure for application of the Well Complexity Index was also not available. In contrast, in this research paper, parameters are categorized into three main complexities types named Design Well Complexity, Geological Well Complexity and Project Well Complexity. Design and Geological Well Complexities combine to form Drilling Well Complexity, and then Drilling Well Complexity and Project Well Complexity combine to form Well Complexity. This categorization is different from the work already done in this regard (Nzeda et al. 2014) and allows to see the impact of design-related parameters, geological parameters and project-related parameters separately as well as in combination (Fig. 1).

Earlier work also doesn't explain the process of preparation of the calculator itself. Here, step-by-step procedure is presented following which any Company involved in Drilling & Well Operations can develop their own Well Complexity Calculator and accordingly integrate it into its Well Engineering Management System/Well Delivery System.

The later part of this paper consists of different sections. Firstly, materials and methods are presented in Sect. 2, which represent the main parameters selection and calculator development methodology. Section 3 is results and discussion and the last section, which is Sect. 4, is Summary and Conclusions.

Development of well complexity calculator: materials and method

The main major material required in this research study is to have the data of different oil and gas drilling wells, related with complexities of drilling at different levels.

Formulation of well complexity parameters and sub parameters

Based on the literature review and consultation with different industry experts, multiple parameters were formulated under each category; considering the application of Well Complexity Calculator on the single lateral Wells being drilled only in the onshore environment. Table 1 presents the parameters for each category used for the development of Well Complexity Calculator. These parameters are more in quantity compared to work already done in this regard (Nzeda et al. 2014).

Formulation of sub-parameters

All the parameters mentioned in Table 1 were further divided into the sub-parameters. Sub-parameters against each parameter are listed in detail in Appendix B.

Categorization of well complexity

Work already performed on Well Complexity Indices involves either single major category or fewer categories (Nzeda et al. 2014). Here Well Complexity was categorized into following three main categories:

1. Design well complexity
2. Geological well complexity
3. Project well complexity

   However, based on the combined effects of three main categories mentioned above, following two categories are produced:
4. Drilling well complexity (combined effect of Sr # 1 and 2)
5. Well complexity (combined effect of Sr # 1, 2 and 3)

Development of survey forms and conducting the survey

After formulating Well Complexity Parameters and Sub-Parameters, different options were considered for getting the

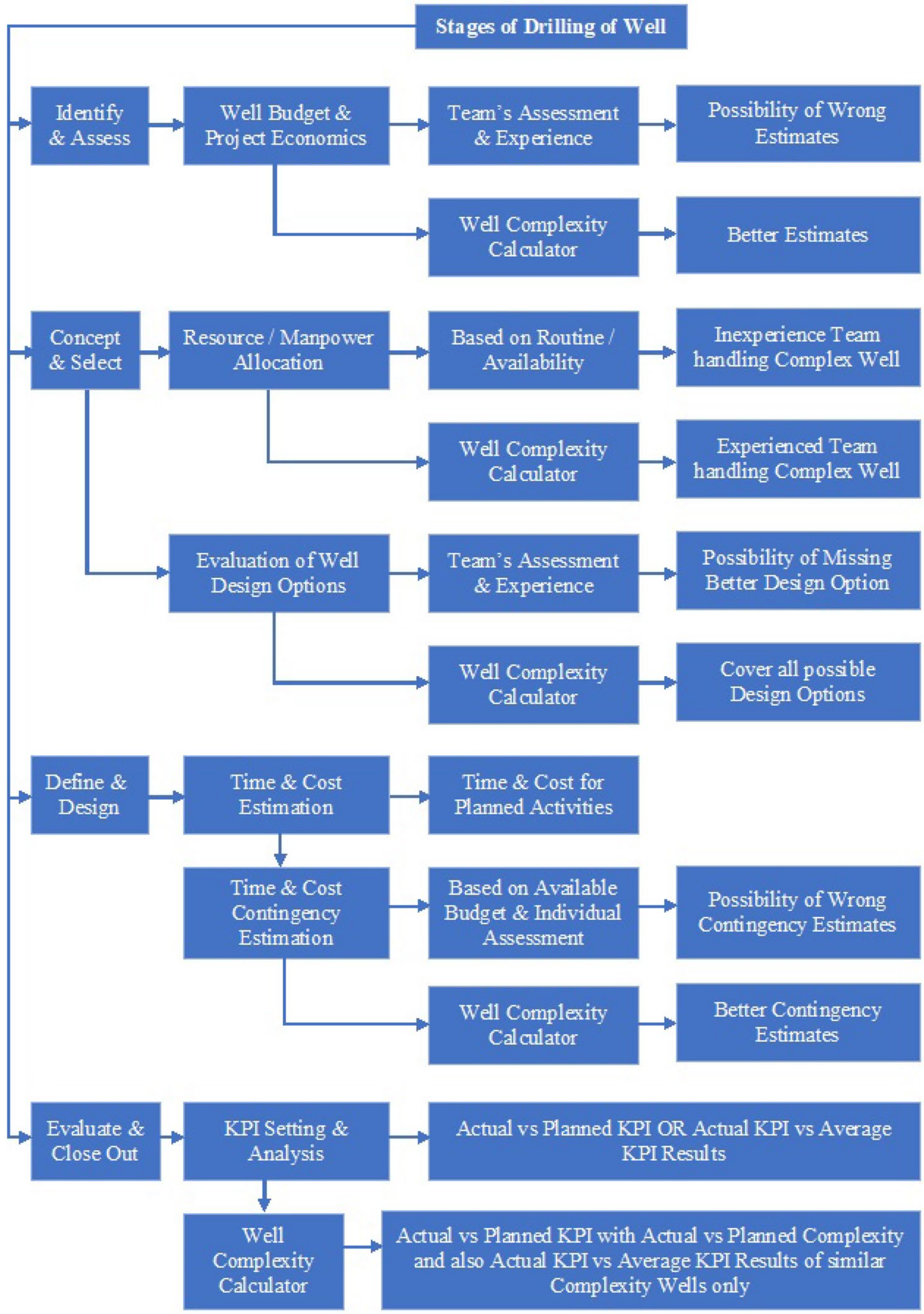

Fig. 1 Flowchart of the problem description

weightage factor against each parameter and rating against each sub-parameter. Workshop was one of the options, but it was not possible to gather all the relevant industry experts and professionals in one workshop for this purpose. Therefore, option of online survey was selected being easier and convenient to get the input from all the industry experts and professionals. Google Survey Forms were utilized for this purpose. Extract from the Google Survey being used here is presented in Appendix A.

Aim of the survey was to rate different parameters against each other. Linear numeric rating scale from 1 to 10 was provided for recording the responses. Numeric 10 means that this parameter has the strongest impact on complexity, whereas 01 means that this particular parameter has the weakest impact on the complexity. Then sub-parameters were to be rated within each parameter separately. Most complicated/difficult sub-parameter was awarded 10, whereas most easy sub-parameter was awarded 00. Other sub-parameters within the parameter were awarded from 10

Table 1 Well complexity parameters

Sr No	Design well complexity	Geological well complexity	Project well complexity
1	well type	Formations issues	Contracts already signed
2	Rig type	Uncertainty in formation tops/thicknesses	Material available/delivered
3	Rig capability	Pore gradient evaluation method	Price volatility
4	Total measured depth	Fracture gradient evaluation method	Weather NPT expectation
5	True vertical depth	Hazardous gas presence	Natural events/disasters expectation
6	Well shape	Max bottom hole temperature	Site security condition
7	Max inclination	Max wellhead pressure	Local/political instability
8	Max dogleg	Regional difficulty factor	Site Access
9	No. of casings	Geographic factor	Ownership type
10	No. of contingent hole sections	Average drillability	Permitting
11	Smallest hole size	Coring operations	Project resources
12	Target tolerance	Wireline logging	Planning time
13	Off-set wells availability	MDT logging	Logistics/mobilization time
14	Type of mud	VSP/VSI	
15	Max mud weight	LWD	
16	Drilling margin		
17	Number of well targets		
18	UBD/MPD application		
19	Liner hanger application		
20	CwD/RwC application		
21	Under-reaming/bi-center bit application		
22	Cementing operations		
23	New technology application		

to 00 depending upon their complication/complexity/difficulty level.

Data quality check

After receiving raw data from survey, a rigorous exercise has been done for the data quality check. Aim of the data quality check was to filter the survey results which were ambiguous or were not in line with the question being asked. On certain instances, it was observed that survey participants could not understand the complexity parameters and hence entered the same rating against each of the sub-parameter. Such types of answers were removed from the survey in order to make the quality of the results better and more reliable.

Analysis of survey results

After quality check of the raw survey data, different types of analysis were performed on the data. Analysis was done mainly on following three methodologies. It is pertinent to mention that mean/average of the data produced very misleading results and hence was not adopted for the analysis.

1. Median. It is a value or quantity lying at the midpoint of a frequency distribution of observed values or quantities, such that there is an equal probability of falling above or below it.
2. Mode. It is the number which appears most often in set of numbers.
3. Monte Carlo Simulation. There are many ways in which Monte Carlo Simulation can be defined. However, it is a broad class of computational algorithms that rely on repeated random sampling, standard deviation, mean and probability to obtain numerical results. Accuracy of Monte Carlo Simulation depends on the number of iterations which are selected, however increase of iterations can increase the time required for each calculation. Here in this analysis, 5000 iterations were selected with 55% probability, which has showed reasonable consistency in the results.

Normalization and compilation of analysis results

After performing the quality check and three analysis mentioned above, obtained results were normalized. Aim of the normalization was to make the highest rated sub-parameter within each parameter equal to 10 and the lowest rated equal to 0 and accordingly rest of the sub-parameters spreading as per the ratio of actual survey results obtained. This was done to make the results in line with the original aim of the

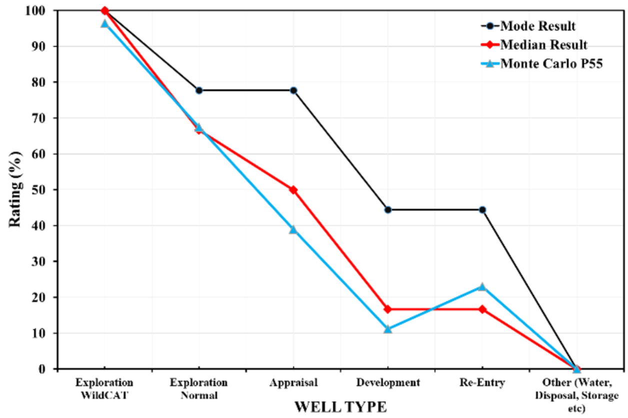

Fig. 2 Well type

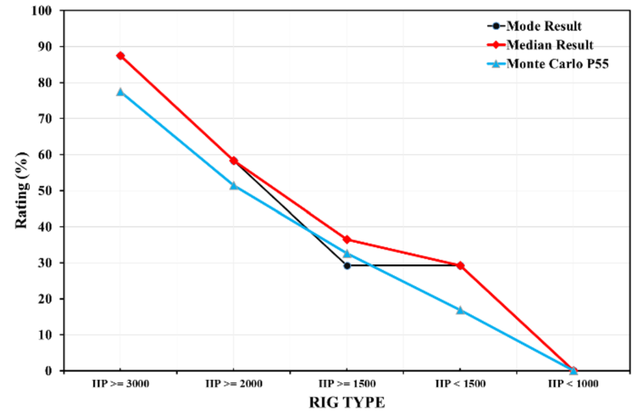

Fig. 3 Rig type

survey, which was not obtained as such due to the inputs from the survey participants. Following equation was used to normalize the survey results.

$$\text{Normalized Sub} - \text{Parameter Results} = \frac{(\text{Rating} - \text{Lowest Rating}) \times (\text{Highest Rating} - \text{Zero})}{(\text{Highest Rating} - \text{Lowest Rating})} \tag{1}$$

Thereafter, resultant ratings of each sub-parameters were multiplied with the weightage factor of each well complexity parameter to produce the end results of each well complexity sub-parameter. After applying weightage factor of parameters on the rating of each sub-parameter, resultant values made all the sub-parameters quantitatively comparable with each other although many of them are purely qualitative in nature. This normalization and compilation of survey results was performed for all the three analysis methodologies (Median, Mode and Monte Carlo Simulation).

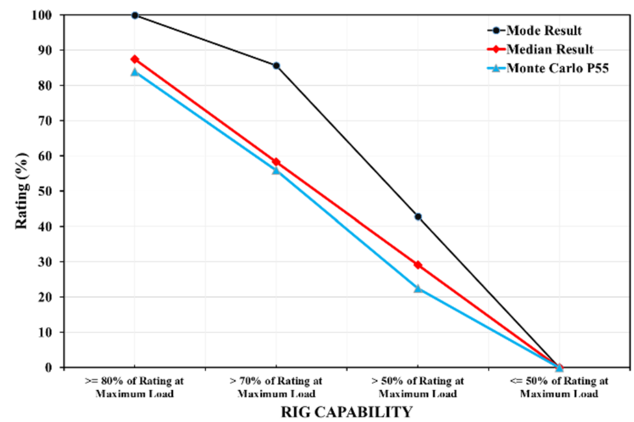

Fig. 4 Rig capability

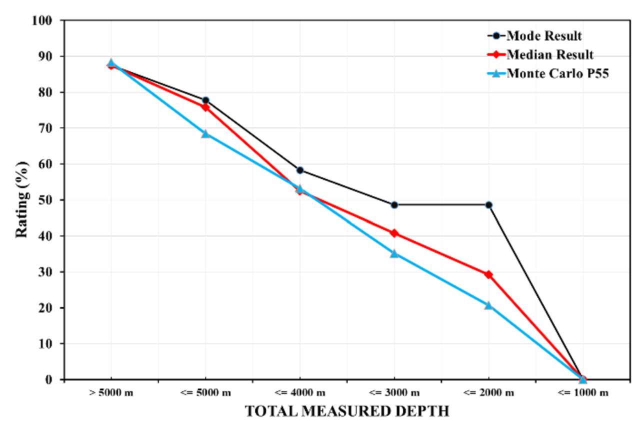

Fig. 5 Total measured depth

Results and discussion

Figures 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51 and 52 present all the three methodologies results of Well Complexity Sub-Parameters for each parameter. Out of the three methodologies, Median showed the best suited results for all the parameters without any abnormality in the trend lines/graphs, whereas Mode and Monte Carlo Simulation results show some abnormality in the trend lines on some instances which was primarily due to the type of survey input and not because of the methods itself. Anomaly in Monte Carlo result is obtained in Fig. 2, whereas anomaly in Mode result is obtained in Fig. 31. Median has not showed anomaly for any result. Accordingly, Median results were selected for onward analysis and utilization for the preparation of Well Complexity Calculator. Figures 23, 25, 29 and 33 show those parameters in which multiple sub-parameters can be selected, whereas for the rest of the parameters single sub-parameter can be selected. Resultant ratings based on Median are listed in Appendix B.

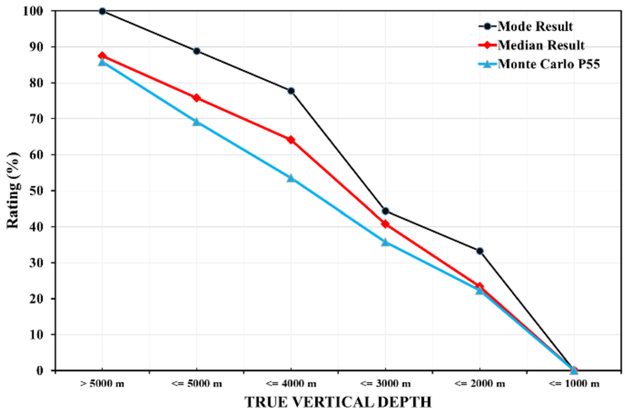

Fig. 6 True vertical depth

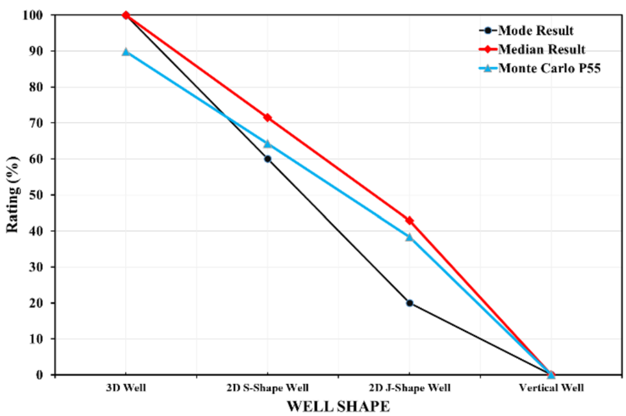

Fig. 7 Well shape

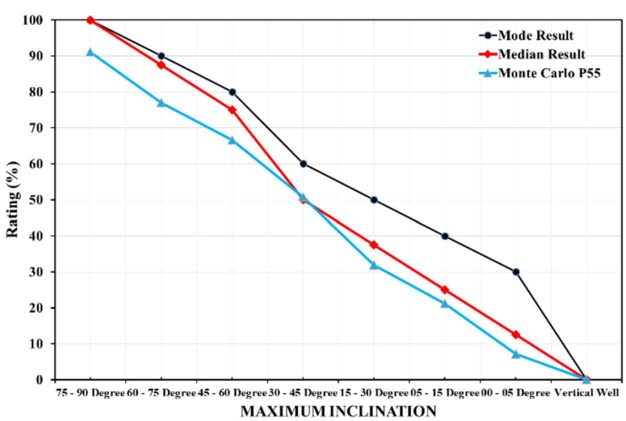

Fig. 8 Max inclination

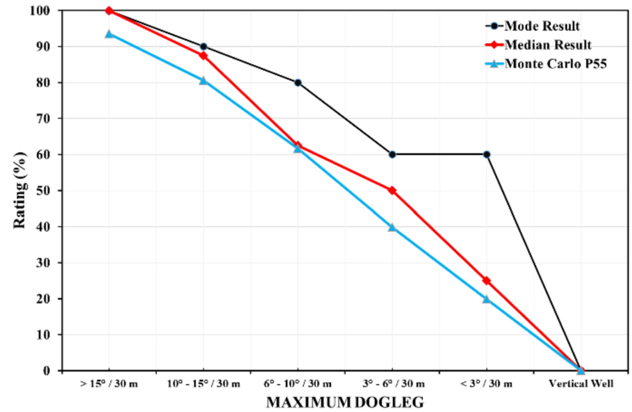

Fig. 9 Max dogleg

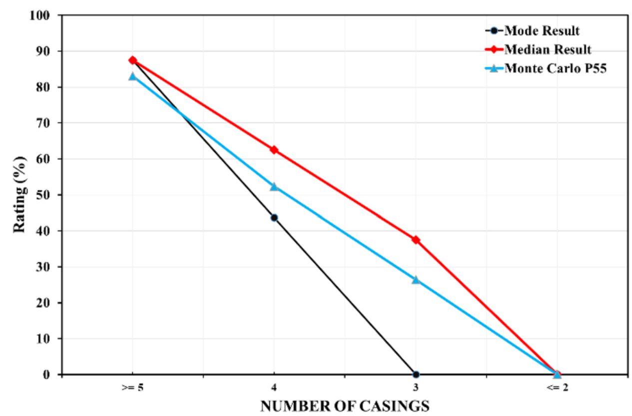

Fig. 10 No. of casings

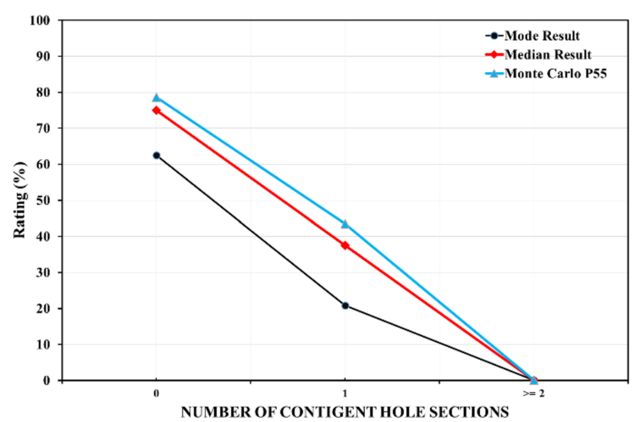

Fig. 11 No. of contingent hole sections

Creation of well complexity calculator in excel spreadsheet

Based on the results listed in Appendix-B, Well Complexity Calculator was created in Excel Spreadsheet with the simple user interface. User is required to input the well information and select sub-parameter against each parameter for the well under investigation. Screenshot of the Well Complexity Calculator is presented in Appendix C.

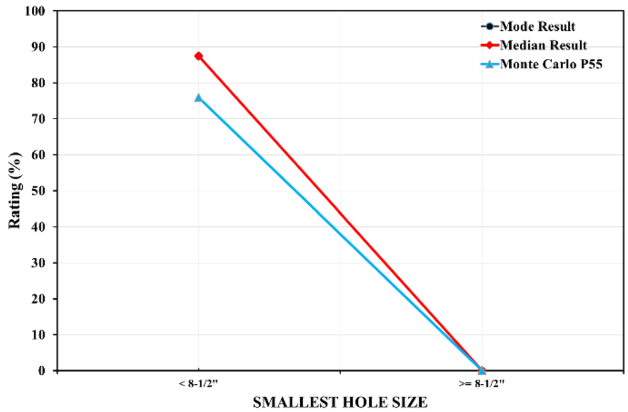

Fig. 12 Smallest hole size

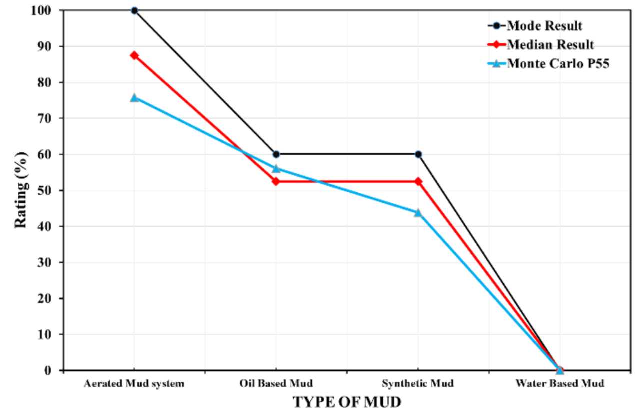

Fig. 15 Type of mud

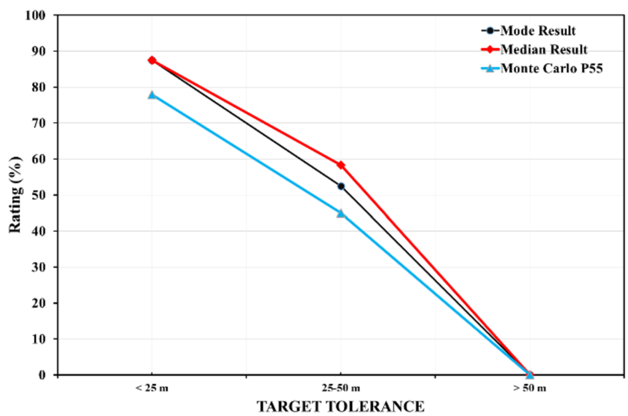

Fig. 13 Target tolerance

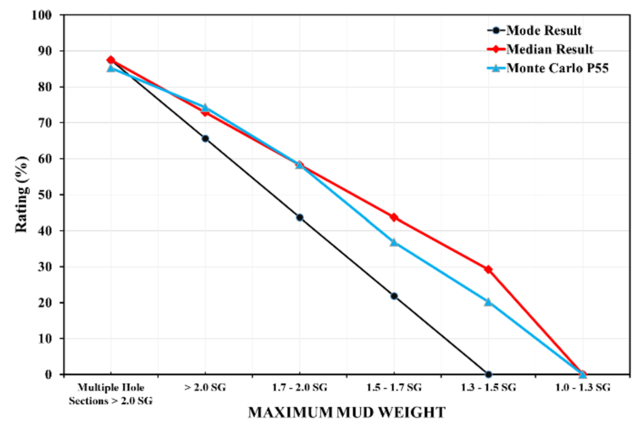

Fig. 16 Max mud weight

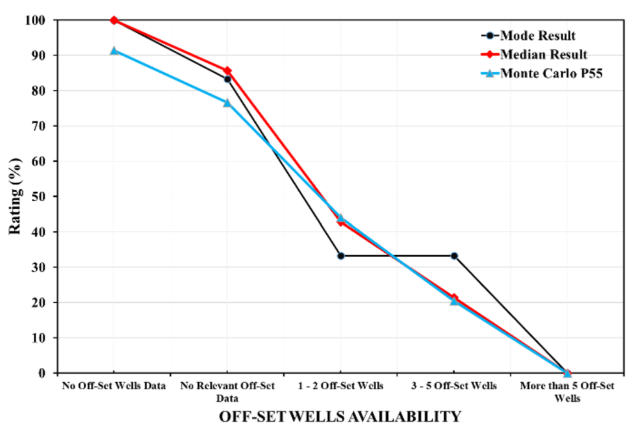

Fig. 14 Off-set wells availability

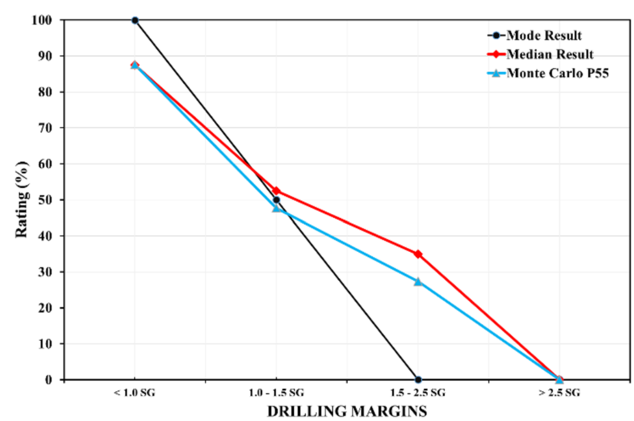

Fig. 17 Drilling margin

All the parameters are created with the drop-down option to select one of the available sub-parameters, whereas Parameters # 22, 24, 28 and 32 are with multiple selections of sub-parameters. However, each of the available sub-parameter cannot be selected in this case as well, for example in Parameter # 24, out of "Single Loss Zone" and "Multiple Loss Zone" one sub-parameter can be selected and likewise out of "Single Gain/Influx Zone" and "Multiple Gain/Influx Zones" one sub-parameter can be selected to avoid erroneous results. Hence, calculator is macro-enabled,

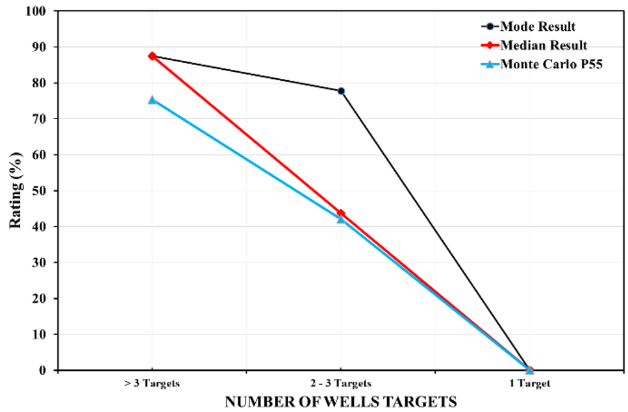

Fig. 18 No. of well targets

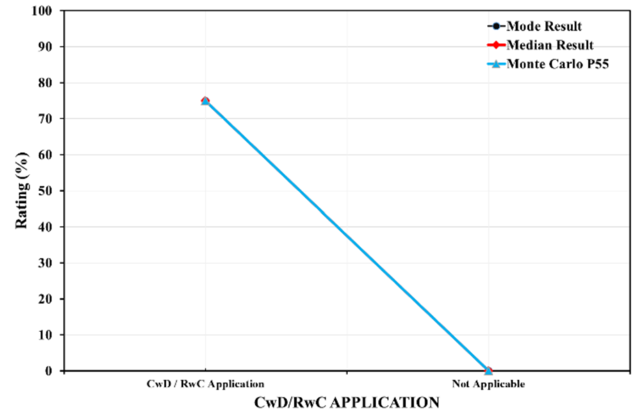

Fig. 21 CwD/RwC application

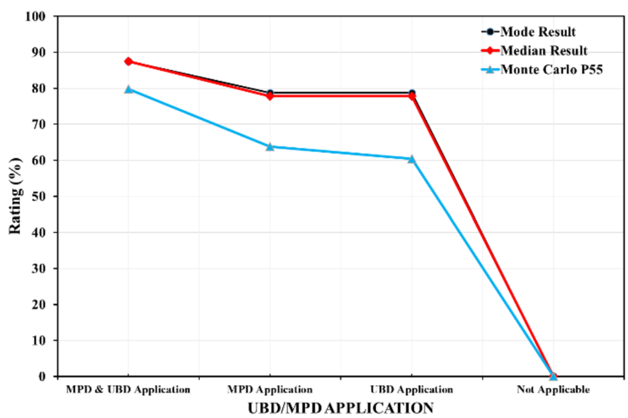

Fig. 19 UBD/MPD application

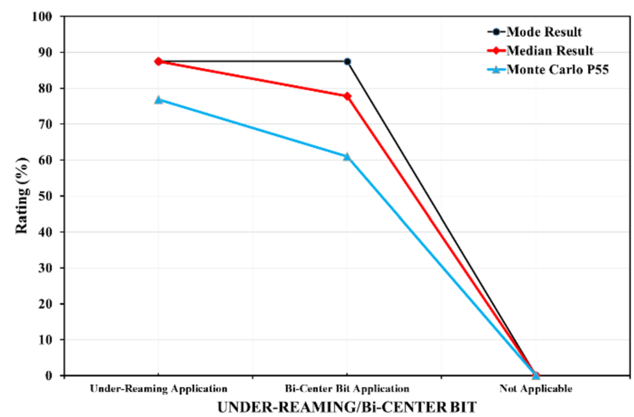

Fig. 22 Under-reaming/bi-center bit

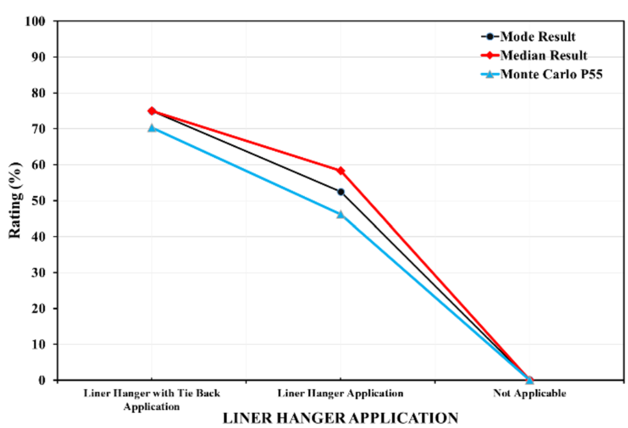

Fig. 20 Liner hanger application

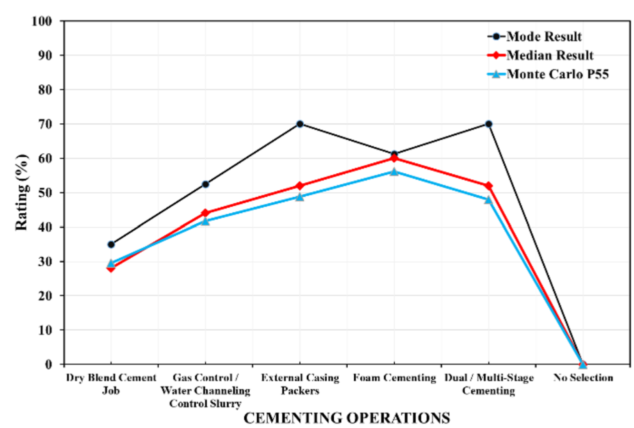

Fig. 23 Cementing operations

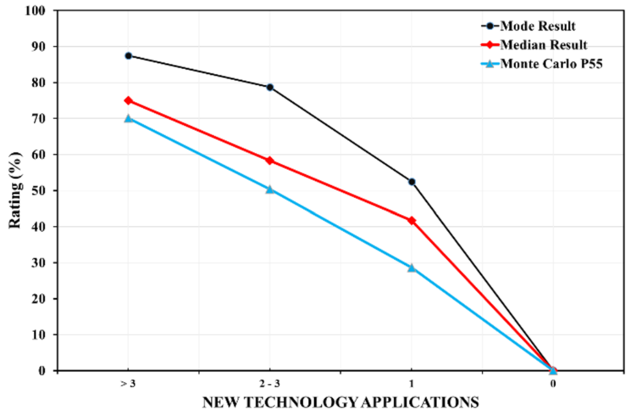

Fig. 24 New technology application

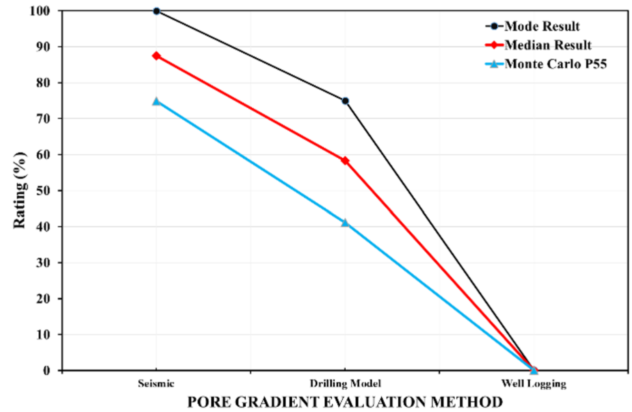

Fig. 27 Pore Grad. evaluation method

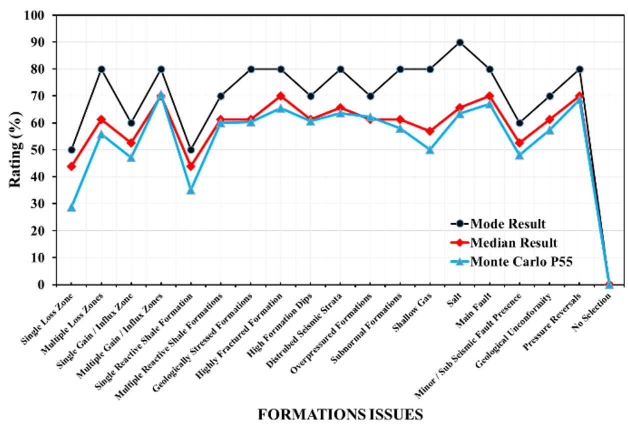

Fig. 25 Formations issues

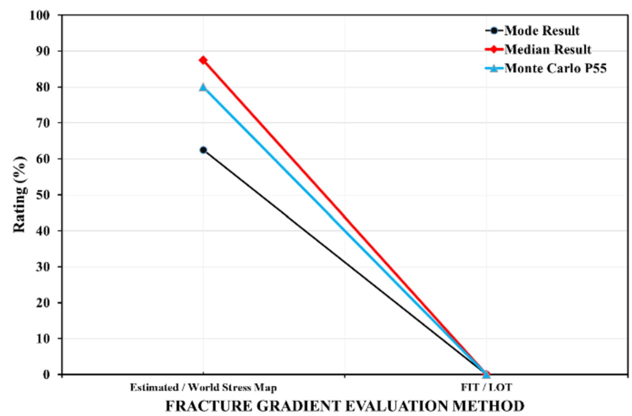

Fig. 28 Frac. Grad. evaluation method

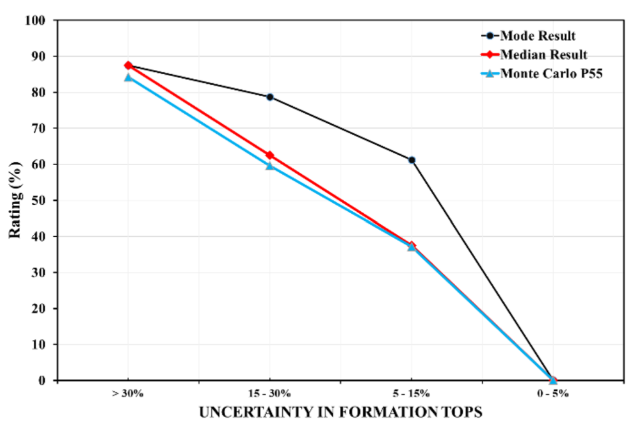

Fig. 26 Uncertainty in formation tops

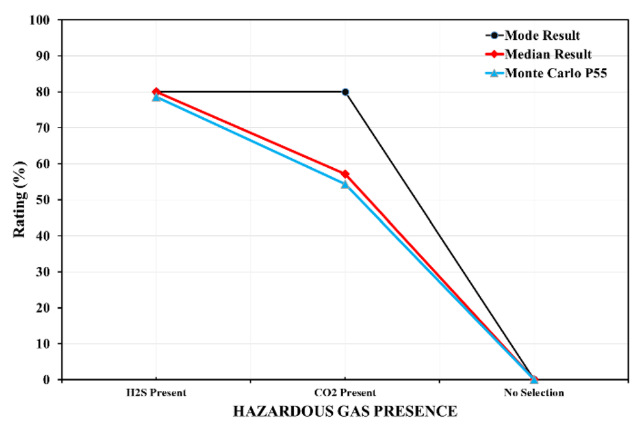

Fig. 29 Hazardous gas presence

and VB codes are included in it in order to apply these logics which restrict user to select one of these two sub-parameters while allowing the selection of other sub-parameters.

Based on the sub-parameters selected by user, scores are picked which are accumulated and accordingly Well Complexities were calculated on the Scale of 10 through Eqs. 2–6.

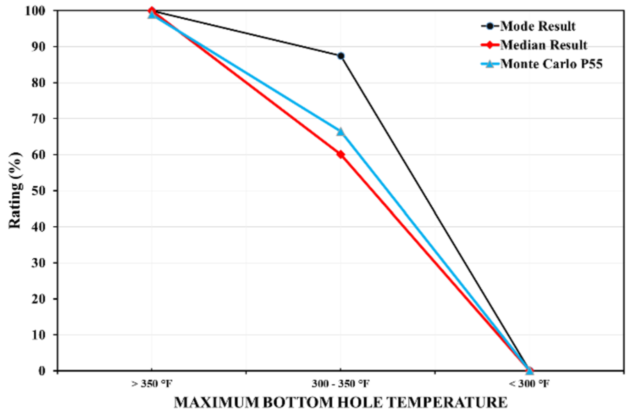

Fig. 30 Max bottom hole temperature

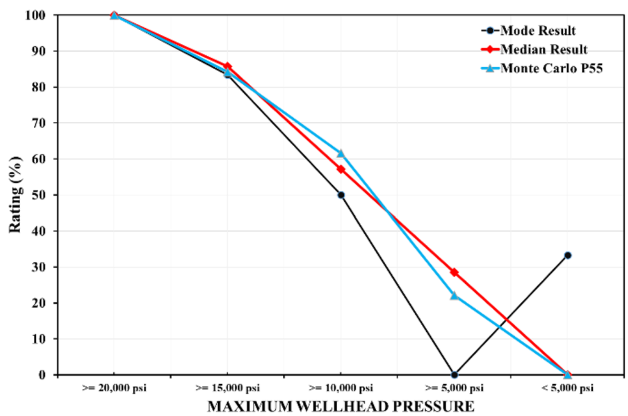

Fig. 31 Max. wellhead pressure

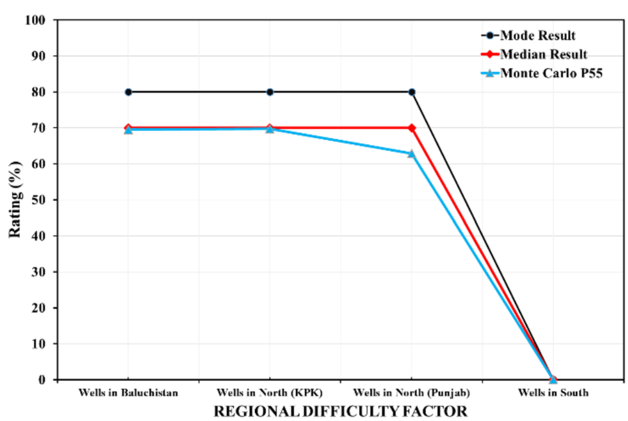

Fig. 32 Regional difficulty factor

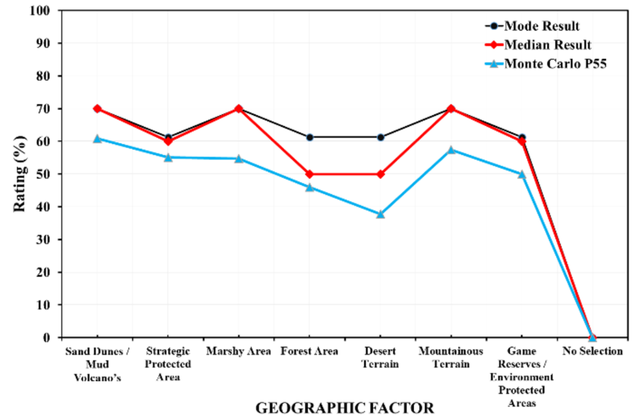

Fig. 33 Geographic factor

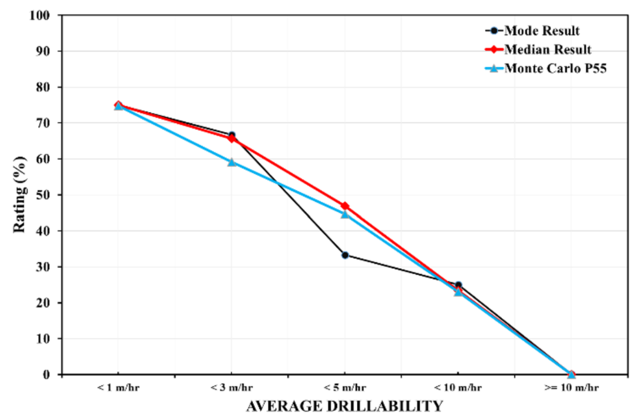

Fig. 34 Average drillability

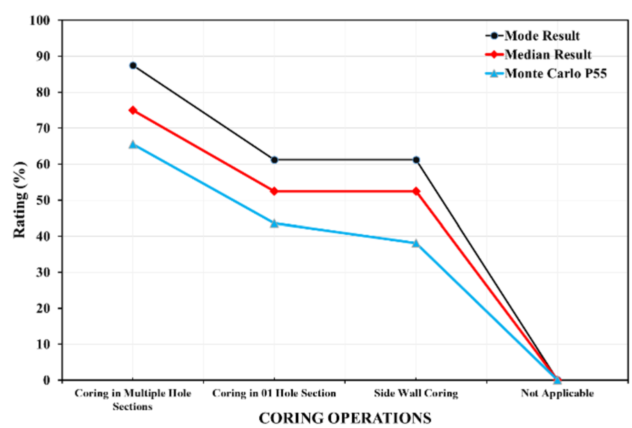

Fig. 35 Coring operations

$$\text{Design Well Complexity} = \frac{10 \times \text{Sum of Scores for Selected Sub Parameters for Parameters 1 to 23}}{\text{Sum of Maximum Scores for Parameters 1 to 23}} \quad (2)$$

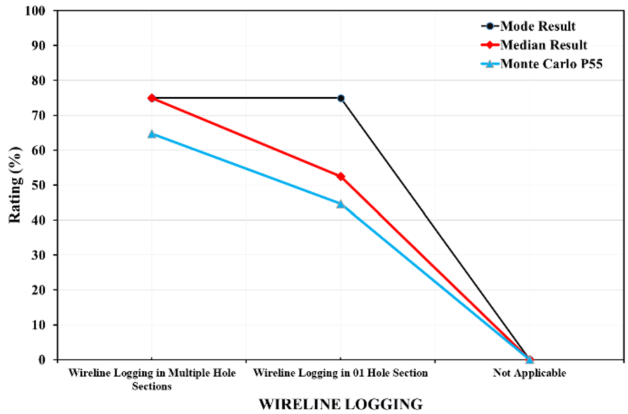

Fig. 36 Wireline logging

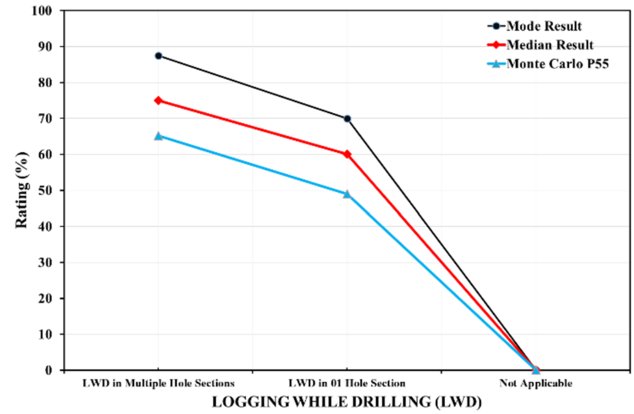

Fig. 39 LWD

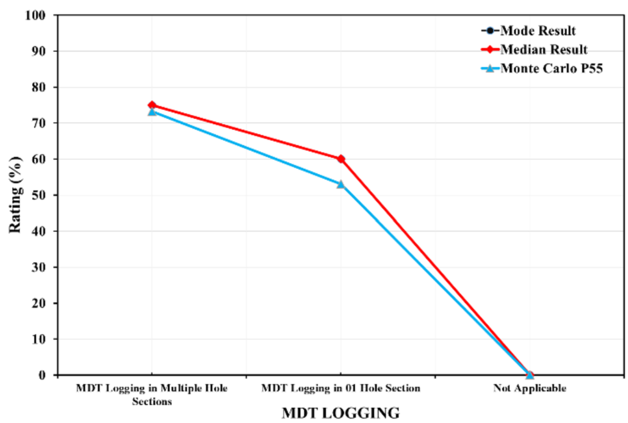

Fig. 37 MDT logging

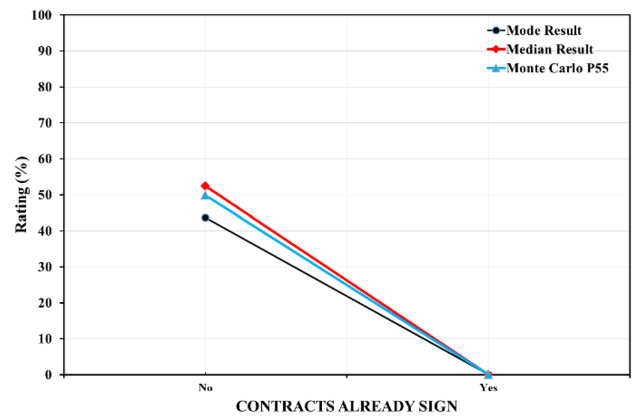

Fig. 40 Contracts already signed

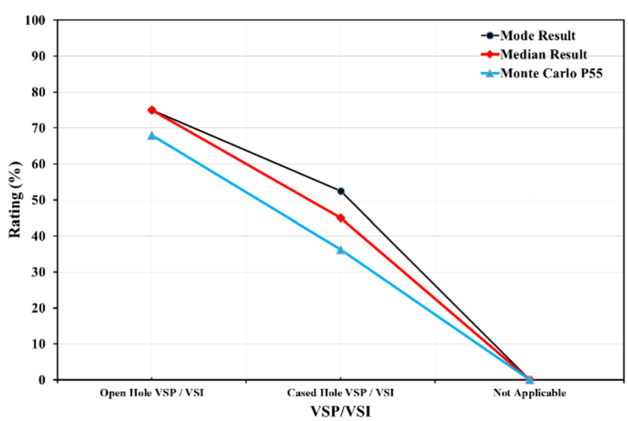

Fig. 38 VSP/VSI

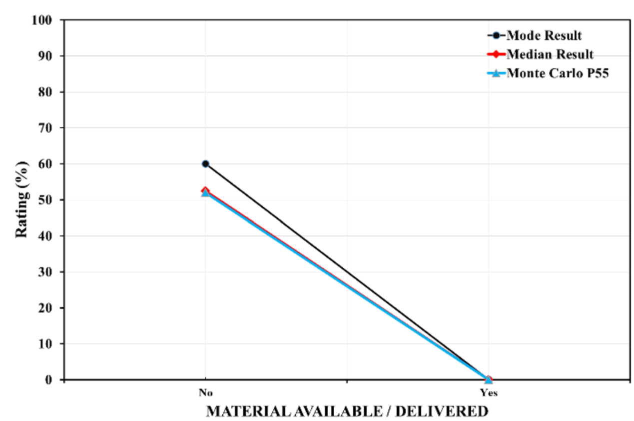

Fig. 41 Material available/delivered

$$\text{Geological Well Complexity} = \frac{10 \times \text{Sum of Scores for Selected Sub Parameters for Parameters } 24 \text{ to } 38}{\text{Sum of Maximum Scores for Parameters } 24 \text{ to } 38} \quad (3)$$

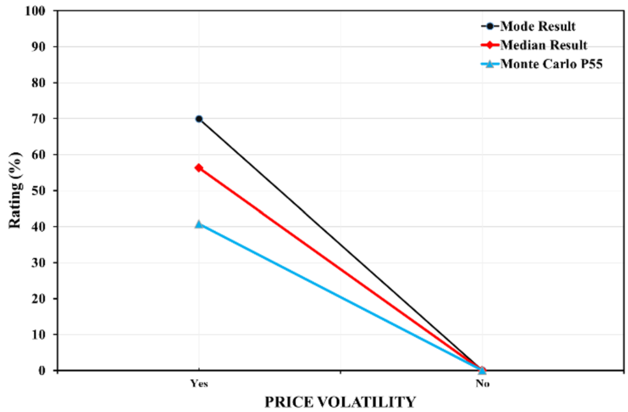

Fig. 42 Price volatility

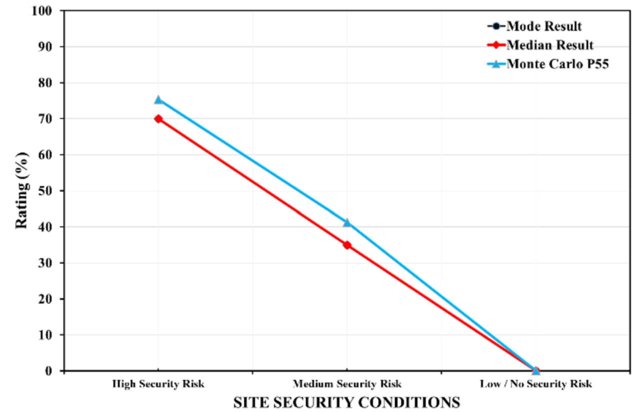

Fig. 45 Site security condition

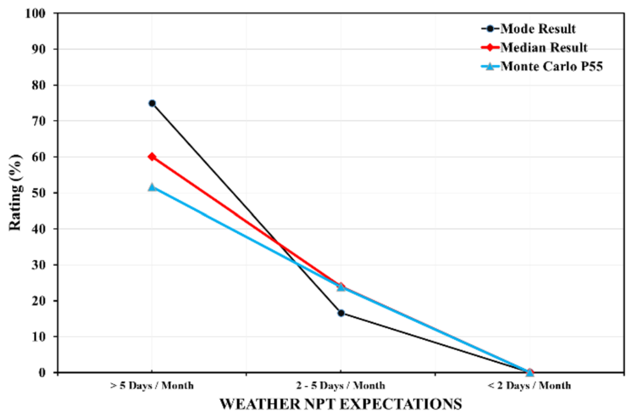

Fig. 43 Weather NPT expectation

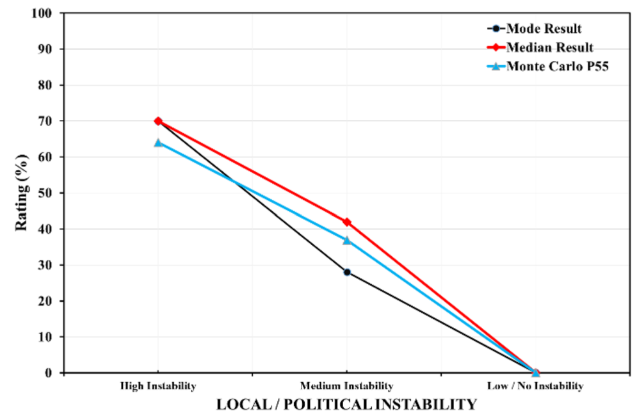

Fig. 46 Local/political instability

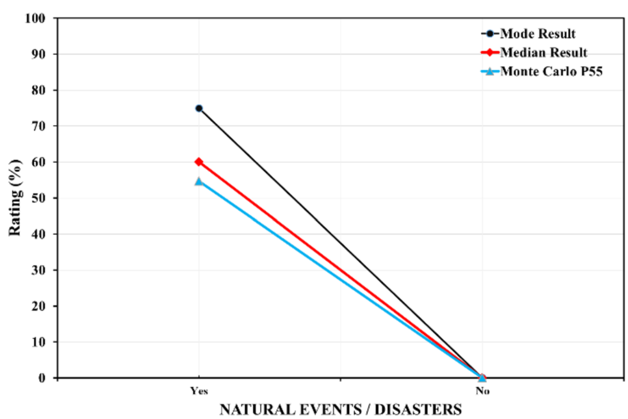

Fig. 44 Natural events/disasters

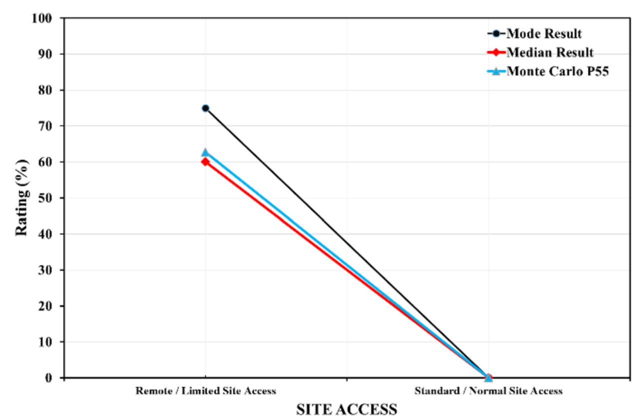

Fig. 47 Site access

$$\text{Project Well Complexity} = \frac{10 \times \text{ Sum of Scores for Selected Sub Parameters for Parameters } 39 \text{ to } 51}{\text{Sum of Maximum Scores for Parameters } 39 \text{ to } 51} \tag{4}$$

$$\text{Drilling Well Complexity} = \frac{10 \times \text{ Sum of Scores for Selected Sub Parameters for Parameters 1 to 38}}{\text{Sum of Maximum Scores for Parameters 1 to 38}} \quad (5)$$

$$\text{Well Complexity} = \frac{10 \times \text{Sum of Scores for Selected Sub Parameters for Parameters 1 to 51}}{\text{Sum of Maximum Scores for Parameters 1 to 51}} \quad (6)$$

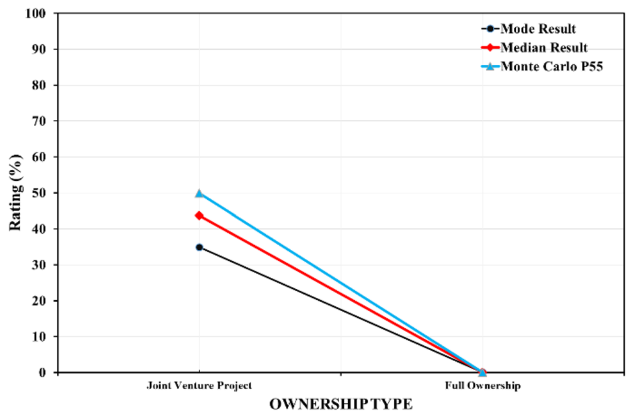

Fig. 48 Ownership type

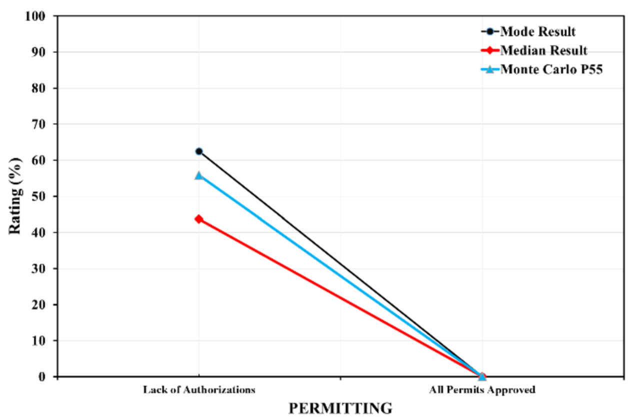

Fig. 49 Permitting

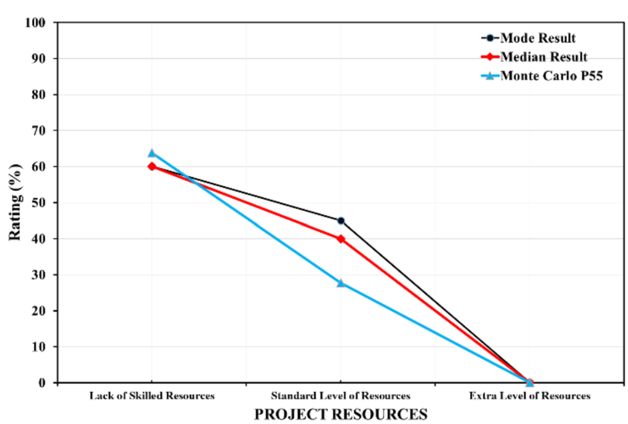

Fig. 50 Project resources

Actual wells data and adjustment of well complexity equations

One of the most critical step was to verify the results of the Well Complexity Calculator. In this regard, 66 actual wells' camouflaged data were utilized having different specifications and being drilled in different areas of Pakistan. Data used in Well Complexity Calculator are of public nature without any confidentiality. For each well, respective sub-parameters were chosen to obtain the outcomes of all the five Well Complexities.

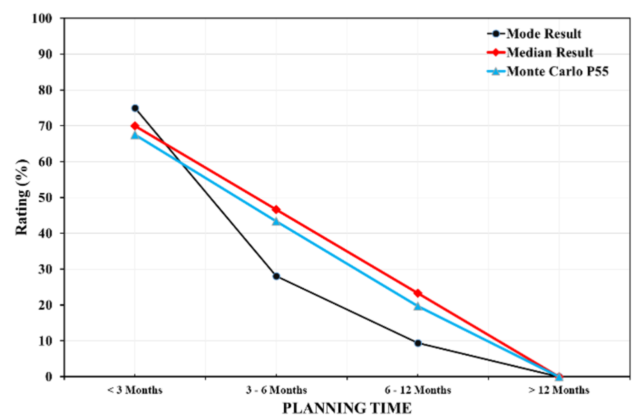

Fig. 51 Planning time

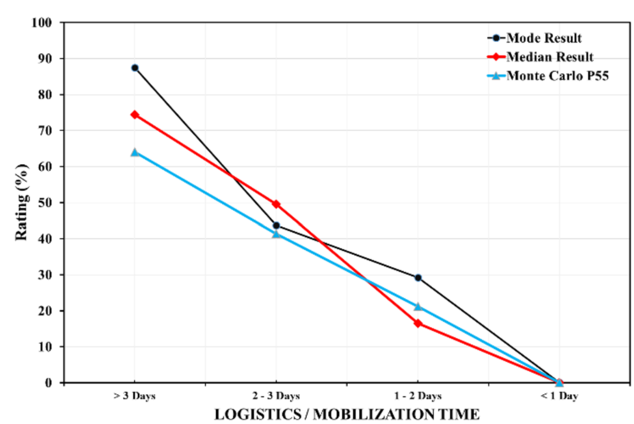

Fig. 52 Logistics/mobilization time

After calculating Well Complexities of all the wells, it was observed that Eqs. 2–6 need adjustment with some factor since denominator in these equations was leading to comparatively lower values for all the five Well Complexities. Hence, sensitivity was run and it was concluded that factor of 0.75 in denominator gave the resultant Well Complexities similar to prima-facie complexities of these Wells. This factor doesn't change the complexity metric scale and is introduced to align the calculated Well Complexities with the perceived complexities of the well (Nzeda et al. 2014). This factor would vary depending on the type of wells in hand. Accordingly, based on the actual wells data presented here, Well Complexity Calculator equations were adjusted and are presented from Eqs. 7–11.

$$\text{Design Well Complexity} = \frac{10 \times \text{Sum of Scores for Selected Sub Parameters for Parameters 1 to 23}}{0.75 \times \text{Sum of Maximum Scores for Parameters 1 to 23}} \tag{7}$$

$$\text{Geological Well Complexity} = \frac{10 \times \text{Sum of Scores for Selected Sub Parameters for Parameters 24 to 38}}{0.75 \times \text{Sum of Maximum Scores for Parameters 24 to 38}} \tag{8}$$

Table 2 Well complexities for actual wells

	Design complexity	Geological complexity	Project complexity	Drilling complexity	Well complexity
No. of wells	66	66	66	66	66
No. of low complexity	07	19	0	13	8
No. of Med. complexity	40	33	53	37	42
No. high complexity	19	14	13	16	16
Maximum complexity	9.3	9.0	8.3	8.6	8.4
Minimum complexity	1.5	2.0	3.6	2.0	2.3
Average complexity	5.4	4.8	5.3	5.1	5.1

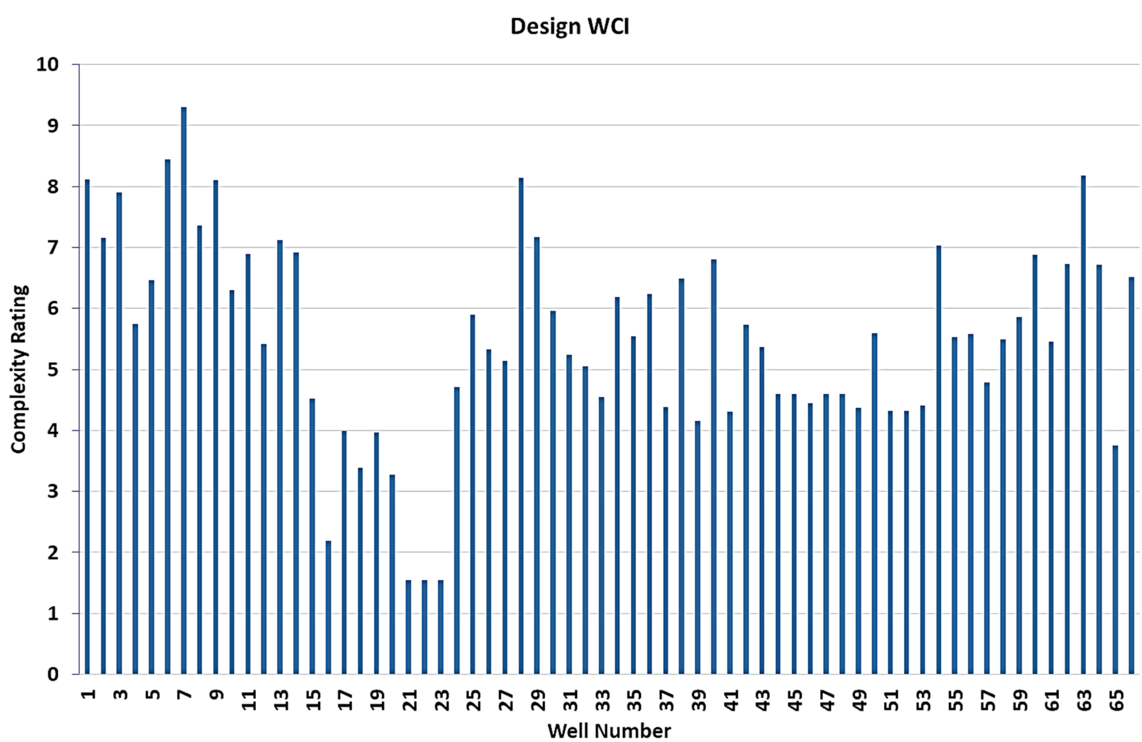

Fig. 53 Design well complexity for actual wells

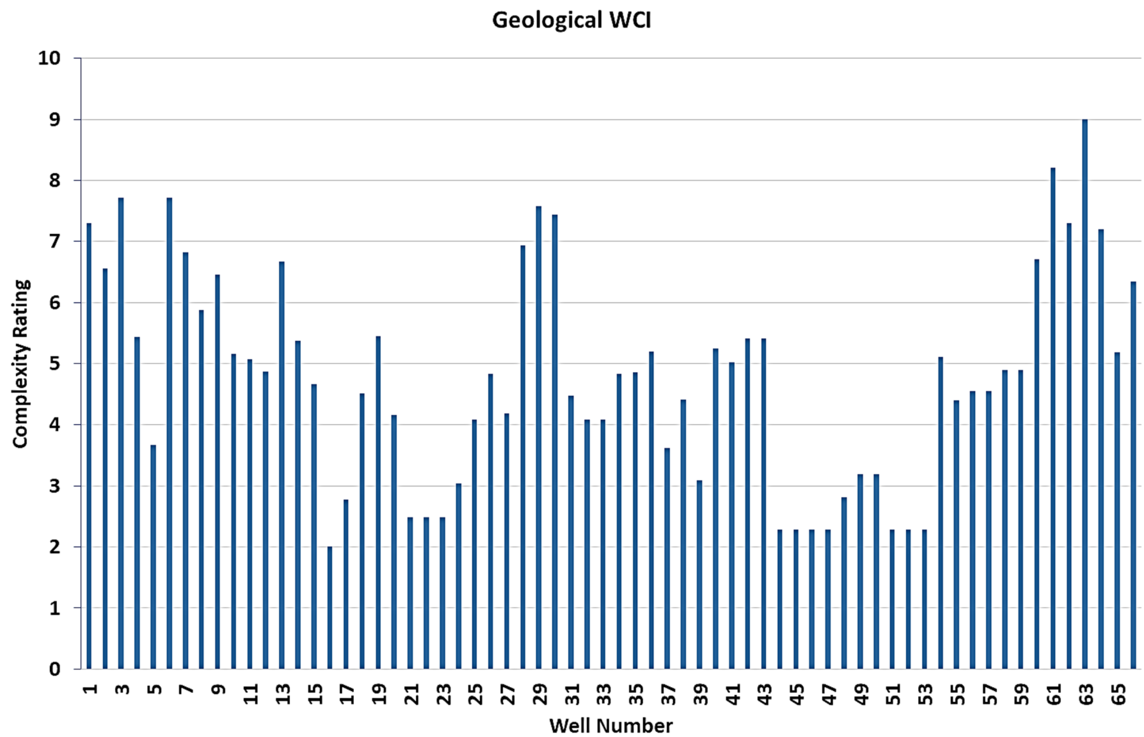

Fig. 54 Geological well complexity for actual wells

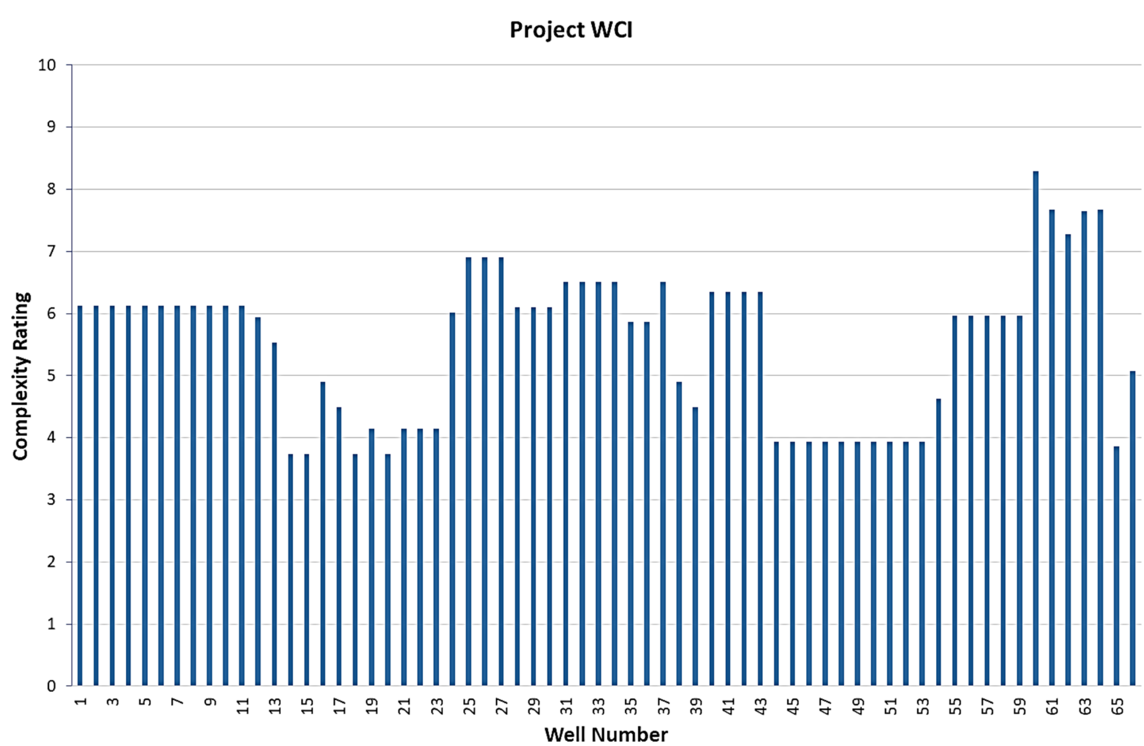

Fig. 55 Project well complexity for actual wells

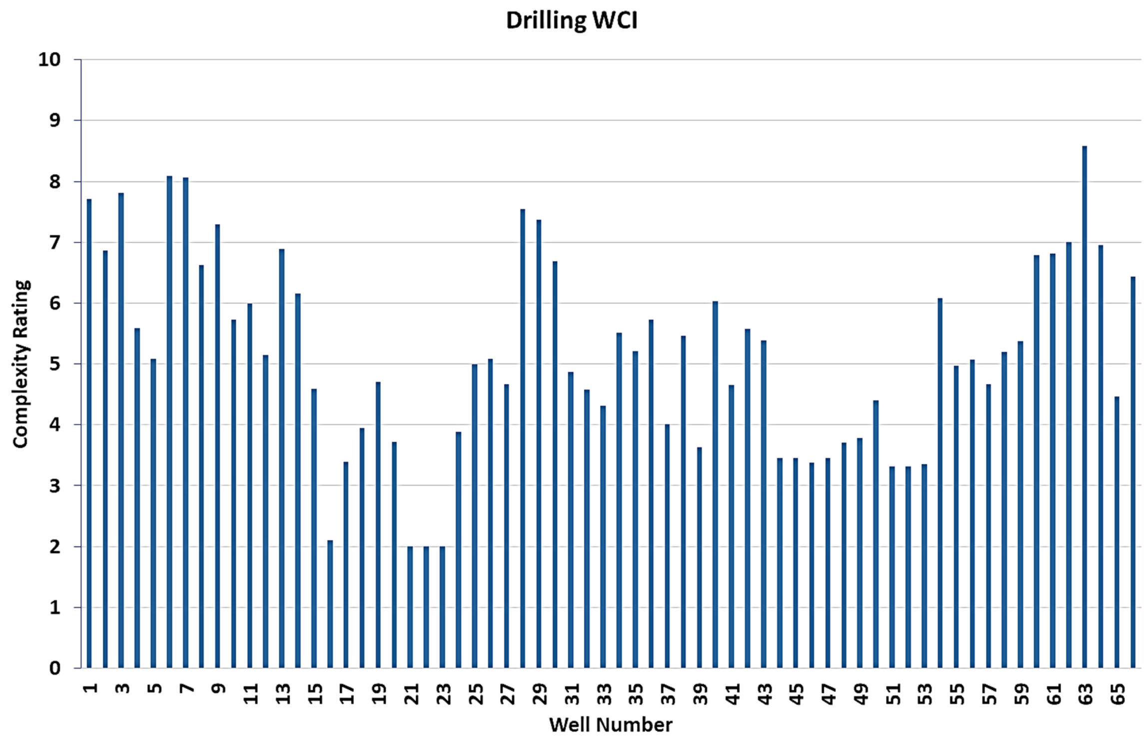

Fig. 56 Drilling well complexity for actual wells

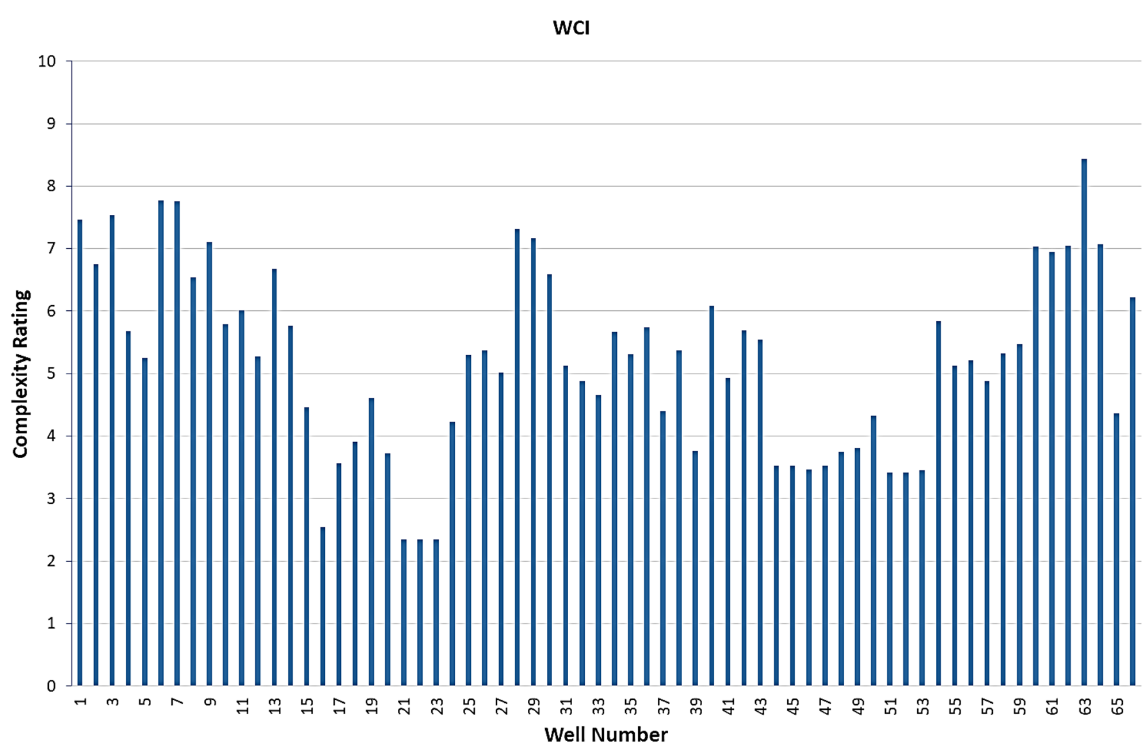

Fig. 57 Well complexity for actual wells

$$\text{Project Well Complexity} = \frac{10\times\ \text{Sum of Scores for Selected Sub Parameters for Parameters}\ \ 39\ \text{to}\ \ 51}{0.75\ \times\ \text{Sum of Maximum Scores for Parameters}\ \ 39\ \ \text{to}\ \ 51} \tag{9}$$

$$\text{Drilling Well Complexity} = \frac{10\times\ \text{Sum of Scores for Selected Sub Parameters for Parameters}\ \ 1\ \text{to}\ \ 38}{0.75\times\ \text{Sum of Maximum Scores for Parameters}\ \ 1\ \ \text{to}\ 38} \tag{10}$$

$$\text{Well Complexity} = \frac{10\times\ \text{Sum of Scores for Selected Sub Parameters for Parameters}\ \ 1\ \text{to}\ \ 51}{0.75\times\ \text{Sum of Maximum Scores for Parameters}\ \ 1\ \ \text{to}\ \ 51} \tag{11}$$

Divisions of well complexities

Based on the Well Complexities calculated for actual Wells, following three division are concluded. However, these divisions can be adjusted as per the Company's own assessment/requirement.

1. Low complexity wells for complexity values 0.00–3.49

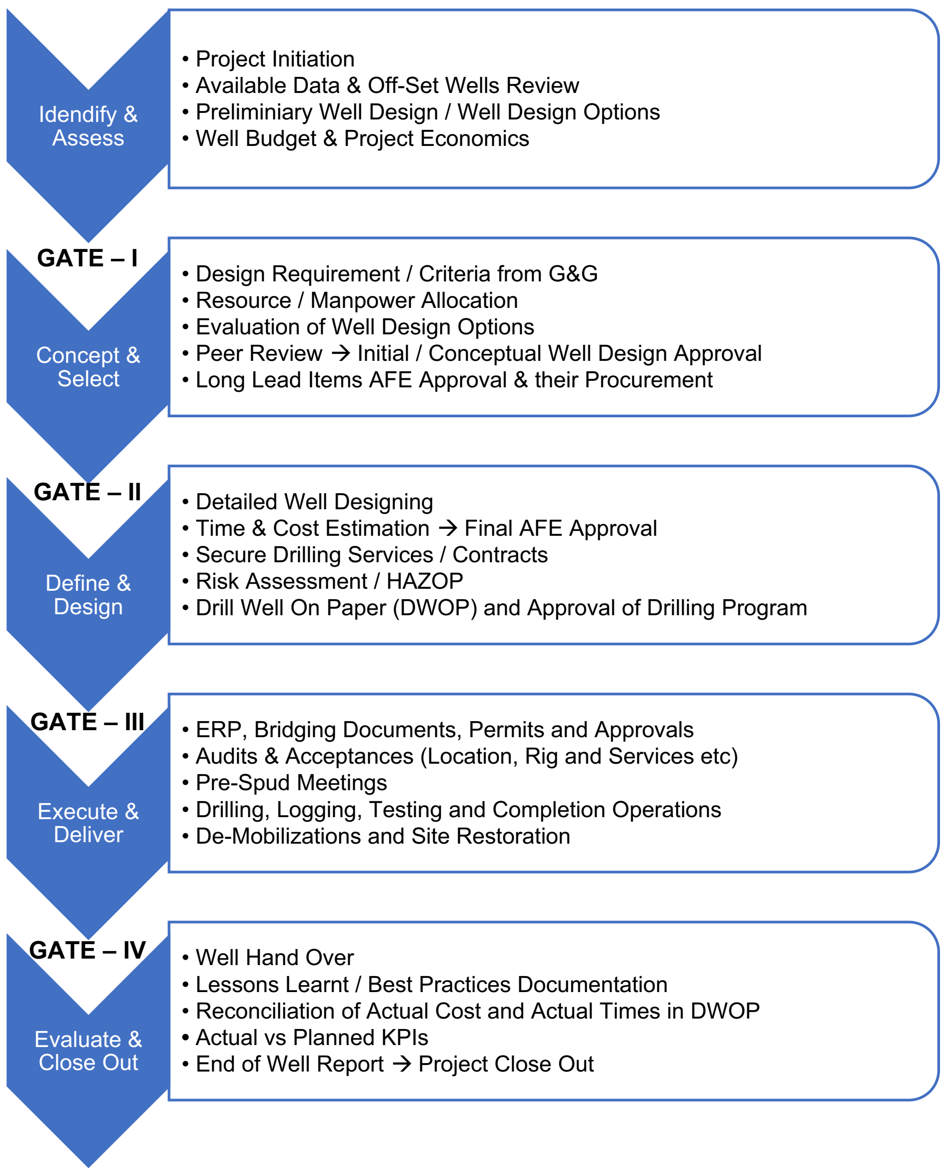

Fig. 58 Standard well engineering management system/well delivery system

2. Medium complexity wells for complexity values 3.50–6.49
3. High complexity well for complexity values 6.50–10.0

Results of Well Complexities are summarized in Table 2 and are presented in Figs. 53, 54, 55, 56 and 57 which show that wells selected for the analysis and verification of Well Complexity Calculator are having different complexities.

Integration of well complexity calculator in standard well engineering management system/well delivery system

Review of standard well engineering management system/well delivery system.

Well Engineering Management System/Well Delivery System of any company is a structured and a step-by-step approach for planning, execution and close-out of any drilling project (Nzeda and Schamp 2014). An actively maintained Well Engineering Management System/Well Delivery

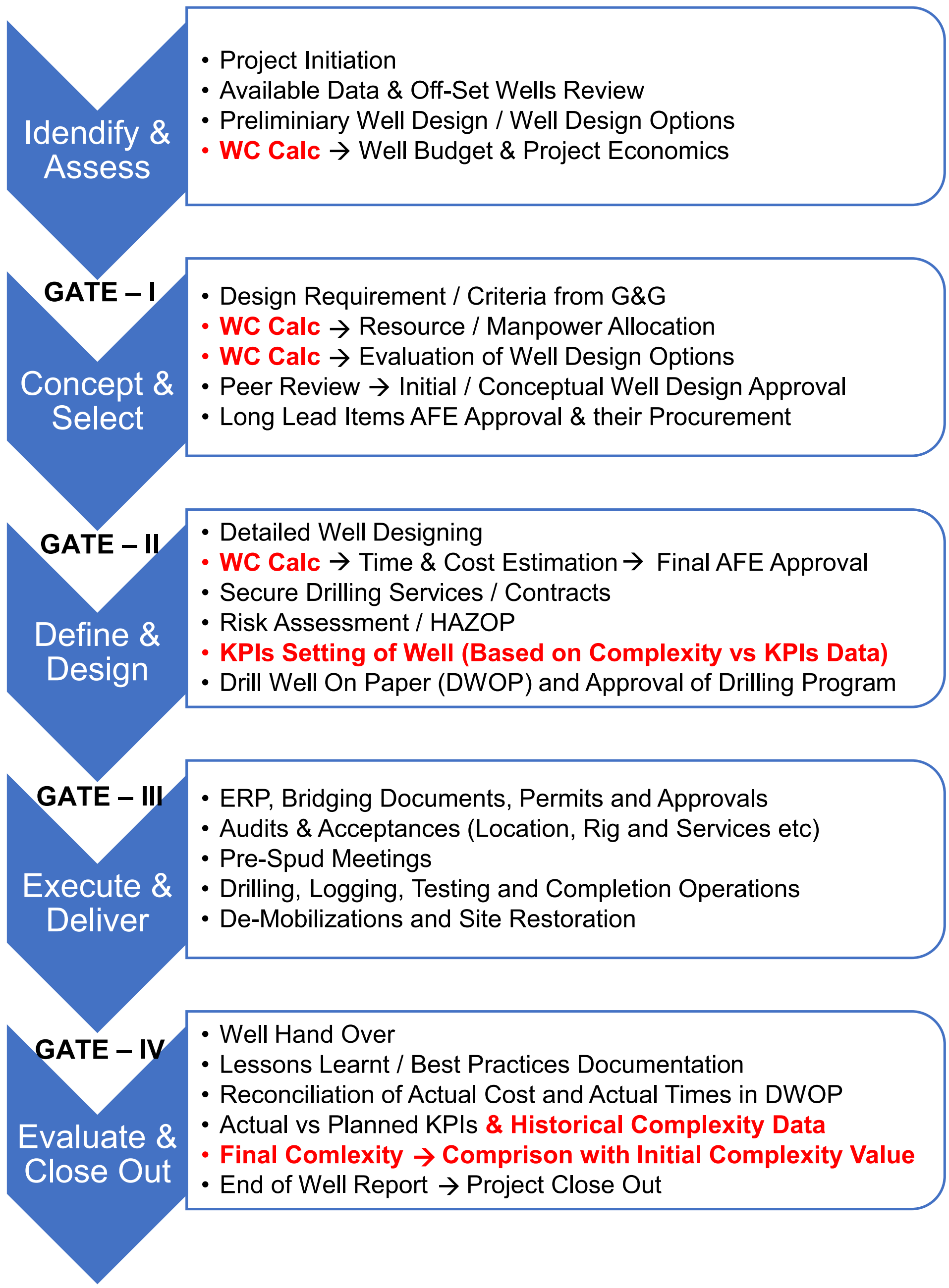

Fig. 59 Well complexity calculator integrated into standard well engineering management system/well delivery system

System provides the means to capture lessons learned and to retain knowledge for future reference (De Wardt 2010) (Fig. 58).

Without proper Well Engineering Management System/Well Delivery System, well planning, execution and close-out would always go through different approach each time the well is planned, executed and closed out. Different companies use Well Engineering Management System/Well Delivery System adjusted as per their business methodologies. However, basic concept and structure remains the same which aim toward following the same pattern each time the work is done and to include more steps as the approach becomes maturey.

Basic stages/phases in any Well Engineering Management System/Well Delivery System are as under:

1. Identify & Assess
2. Concept & Select
3. Define & Design
4. Execute & Deliver
5. Evaluate & Close-Out

Moreover, Well Engineering Management System/Well Delivery System also normally has the gate system or stage gate system in which associated gate keepers approve the things and gate is considered approved upon achievement of certain deliverables and documentations (Al-Salem et al. 2018).

Gate system verifies that no steps/stages/phases in Well Engineering Management System/Well Delivery System are skipped before moving ahead and all required documentation is secured and archived. Normally gates are simply named numerically as under:

1. Gate—I
2. Gate—II
3. Gate—III
4. Gate—IV

Standard Well Engineering Management System/Well Delivery System is presented in Error! Reference source not found., in which different steps from project initiation to project close-out are covered. It is also shown that how these steps are distributed among different stages/phases and being controlled by different gates.

Work already done in this regard considered Well Complexity Index mainly a planning tool (Blaise et al. 2014). However, its usage during the Evaluate & Close-Out phase is also very important. As presented in Fig. 59, Well Complexity Calculator can be integrated into a Standard Well Engineering Management System/Well Delivery System at following phases/stages:

1. Identify & Assess
2. Concept & Select
3. Define & Design
4. Evaluate & Close-Out

Integration of well complexity calculator in identify & assess phase/stage

Well Complexity Calculator can be integrated at Identify & Assess phase/stage to get its benefit at the early stage of the project. In this phase/stage, upon carrying out preliminary well design based on available data and off-set wells review, well budget & project economics are prepared. Here, Well Complexity Calculator can be a useful tool to estimate the Time & Cost of a well by comparing its calculated Well Complexity value with company's historical Well Complexity data. Historical data of Well Complexity vs Dry Hole Drilling Days can be used to estimate the time/refine the time estimates, whereas historical data of Well Complexity vs Dry Hole Drilling Cost can be used to estimate the cost/refine the cost estimates at this level.

Integration of well complexity calculator in concept & select phase/stage

Concept & Select phase starts with the receiving of well design requirements and criteria from G & G team, based on which well designing is done, whereas normally project specific organogram is prepared based on overall workload distribution, instead of criticality or complexity of the project itself.

In Concept & Select phase, Well Complexity Calculator can be used as the basis of resources/manpower allocation for the project according to its complexity level. Based on the Well Complexity value, project team of relevant experience and expertise can be formulated for a well in hand. Furthermore, during preparation and evaluation of different well design options, Well Complexity value for each well design can be calculated and be one of the key factors in making the selection of well design. Therefore, during the peer review meeting, Well Complexity value for each well design option can be presented along with pros and cons of different well design options in order to have a quantitative perspective of each well design along with conventional approach of qualitative selection.

Integration of well complexity calculator in define & design phase/stage

In Define & Design phase/stage, detailed well designing is performed, followed by more refined Time & Cost estimation which is then used in preparation and approval of Well AFE.

Fig. 60 Extract from google survey

Basic Questionnaire

1. **Q # 1: Please Enter Your Name? ***

2. **Q # 2: Please Enter Your Designation ***

3. **Q # 3: Please Enter Your Company Name ***

4. **Q # 4: Please Enter Your Number of Years of Experience in Oil & Gas Industry ***

Section 1

Ratings for Sub-Categories (Relative Complexity)

5. **01: Complexity Rating for Well Type ***
Mark only one oval per row.

	0	1	2	3	4	5	6	7	8	9	10
Exploration WildCAT											
Exploration Normal											
Appraisal											
Development											
Re-Entry											
Other (Water, Disposal, Storage etc)											

6. **02: Complexity Rating for Rig Type ***
Mark only one oval per row.

	0	1	2	3	4	5	6	7	8	9	10
HP >= 3000											
HP >= 2000											
HP >= 1500											
HP < 1500											
HP < 1000											

https://docs.google.com/forms/d/1sC0tdav7DwWOg-CcOByw0Yat_vEXOwnXILhH5Afj5sU/edit

Well Complexity Calculator can be used for more refined time calculation. Normally, time estimation of any well depends on the available information from off-set wells for similar activities in which time for additional planned activities is added on same basis/assumptions. Using Well Complexity Calculator, a more structured approach can be adopted for calculation of time contingency and expected non-productive time by comparing Well Complexity value of a well in hand to the historical data of wells having similar complexity values. Thereafter, expected drilling time estimated using Well Complexity can be directly used to calculate the Well AFE. Moreover, comparison of AFE can be made with the historical data of Well Complexity vs Dry Hole Drilling Cost for further refinement.

In Define & Design phase/stage, the next important utilization of Well Complexity Calculator is to set Key Performance Indicator (KPI) Targets of the well in hand. If there is no Well Complexity Calculator in use, usually this step is

Table 3 Sub-parameters resultant ratings

Sr No.	Well complexity Parameters	Median of parameters weightage	Quality checked median of parameters weightage (10 × median ÷ max of all parameters weightage)	Well complexity sub-parameters	Quality checked median of sub-parameters rating	Quality checked rating × quality checked weightage	Normalized sub-parameter results (by Eq. 1)
1	Well type	8	10	Exploration WildCAT	10	100	100.00
				Exploration normal	8	80	66.67
				Appraisal	7	70	50.00
				Development	5	50	16.67
				Re-entry	5	50	16.67
				Others	4	40	0.00
2	Rig type	7	8.75	HP ≥ 3000	10	87.5	87.50
				HP ≥ 2000	8	70	58.33
				HP ≥ 1500	6.5	56.875	36.46
				HP < 1500	6	52.5	29.17
				HP < 1000	4	35	0.00
3	Rig capability	7	8.75	≥80% of rating at max load	10	87.5	87.50
				> 70% of rating at max load	8	70	58.33
				> 50% of rating at max load	6	52.5	29.17
				≤50% of rating at max load	4	35	0.00
4	Total measured depth	7	8.75	> 5000 m	10	87.5	87.50
				≤5000 m	9	78.75	75.83
				≤4000 m	7	61.25	52.50
				≤3000 m	6	52.5	40.83
				≤2000 m	5	43.75	29.17
				≤1000 m	2.5	21.875	0.00
5	True vertical depth	7	8.75	> 5000 m	10	87.5	87.50
				≤5000 m	9	78.75	75.83
				≤4000 m	8	70	64.17
				≤3000 m	6	52.5	40.83
				≤2000 m	4.5	39.375	23.33
				≤1000 m	2.5	21.875	0.00
6	Well shape	8	10	3D well	10	100	100.00
				2D S-shape well	8	80	71.43
				2D J-shape well	6	60	42.86
				Vertical well	3	30	0.00
7	Max inclination	8	10	75°–90°	10	100	100.00
				60°–75°	9	90	87.50
				45°–60°	8	80	75.00
				30°–45°	6	60	50.00
				15–30°	5	50	37.50
				05°–15°	4	40	25.00
				00–05°	3	30	12.50
				Vertical well	2	20	0.00

skipped in a Standard Well Engineering Management System/Well Delivery System and Panned Dry Hole Drilling Days and Dry Hole Drilling Cost is considered to be the only KPI Target of the Well.

Integration of well complexity calculator in evaluate & close-out phase/stage

In Evaluate & Close-Out phase/stage, comparison is done between planned and actual KPIs. In addition to this, lesson learnt and best practices are tracked and documented for future reference along with reconciliation of actual Cost and Time.

Proper use of Well Complexity Calculator during Evaluate & Close-Out phase is important not only to compare the broader range of planned KPIs set for the well during Define & Design phase with the actual KPIs results but also to compare the actual KPIs results with historical data of Well Complexity values vs different well KPIs. In addition to this, Final Well Complexity values must be made part of historical database of Well Complexity in order to use it for future reference.

Summary and conclusion

Without the application of a system like Well Complexity Calculator, wells during planning phase are categorized as low, medium or high complexity based on either two to three major parameters or based on qualitative assessment of team involved in the project.

Furthermore, wells during the close-out phase are categorized as low, medium or high complexity based on the actual downtime/problems encountered during execution instead of actual Well complexity. Through the application of Well Complexity Calculator, Well Complexity can be computed considering multiple parameters. The main conclusive outcomes of this study are:

- Well Complexity Calculator (WCC) developed here considers 51 different parameters.
- Parameters are categorized into three main complexities types named Design Well Complexity, Geological Well Complexity and Project Well Complexity. Design and Geological Well Complexities combine to form Drilling Well Complexity, and then Drilling Well Complexity and Project Well Complexity combine to form Well Complexity.
- This categorization allows to see the impact of design-related parameters, geological parameters and project-related parameters separately as well as in combination.
- All the qualitative/quantitative parameters are converted into five different types of Well Complexities, where each complexity is a single digit on the scale of 10.
- Well Complexity Calculator developed in this study is validated through the actual wells' camouflaged data. Well Complexity Calculator can be used at any stage from initial planning to close out stage of a Well.
- Well Complexity Calculator will give the practical benefit when it is integrated into Well Engineering Management System/Well Delivery System of an organization and made part of the approval processes. It is recommended to integrate Well Complexity Calculator into Well Engineering Management System/Well Delivery System or; in case of its absence; into a normal well planning process of any organization and accordingly evaluate its results against different Well KPIs.
- If results are reasonable with respect to that organization, it can be made permanent part of the system.
- In case of unsatisfactory results, Well Complexity Calculator can be further analyzed on the similar methods and methodologies carried out here for its refinement and adjustment with respect to that organization's data and experience.
- This research paper presents step-by-step procedure following which any Company involved in Drilling & Well Operations can develop their own Well Complexity Calculator and accordingly integrate it into its Well Engineering Management System/Well Delivery System.

The research outcomes from this study also show some limitations, which are:

- The limitation of this study is kind of input that it received from the experts carrying out the initial assessment of the parameters and sub-parameters.
- This limitation can be eradicated by careful quality check of the input data which has been done here in this research paper.
- After rigorous exercise of data quality check, subsequent steps were carried out in order to prepare the Well Complexity Calculator.
- Another limitation is the kind of well which was available for the verification of the calculator are single lateral wells being drilled in onshore environment. The calculator developed here is applicable for single lateral wells being drilled in the onshore environment.
- However, steps explained in this research papers will remain same for preparation of Well Complexity Calculator with the inclusion of number of laterals and drilling environment as two more parameters; and accordingly this limitation can be eliminated as well.

Table 3 (continued)

Sr No.	Well complexity Parameters	Median of parameters weightage	Quality checked median of parameters weightage (10 × median ÷ max of all parameters weightage)	Well complexity sub-parameters	Quality checked median of sub-parameters rating	Quality checked rating × quality checked weightage	Normalized sub-parameter results (by Eq. 1)
8	Max dogleg	8	10	> 15°/30 m	10	100	100.00
				10°–15°/30 m	9	90	87.50
				6°–10°/30 m	7	70	62.50
				3°–6°/30 m	6	60	50.00
				< 3°/30 m	4	40	25.00
				Vertical well	2	20	0.00
9	Number of casings	7	8.75	≥5	10	87.5	87.50
				4	8	70	62.50
				3	6	52.5	37.50
				≤2	3	26.25	0.00
10	Number of contingent hole sections	6	7.5	0	10	75	75.00
				1	7	52.5	37.50
				≥2	4	30	0.00
11	Smallest hole size	7	8.75	< 8–1/2″	10	87.5	87.50
				≥8–1/2″	5.5	48.125	0.00
12	Target tolerance	7	8.75	< 25 m	10	87.5	87.50
				25–50 m	8	70	58.33
				> 50 m	4	35	0.00
13	Off-Set wells availability	8	10	No off-set wells data	10	100	100.00
				No relevant off-set data	9	90	85.71
				1–2 off-set wells	6	60	42.86
				3–5 off-set wells	4.5	45	21.43
				More than 5 off-set wells	3	30	0.00
14	Type of mud	7	8.75	Aerated mud system	10	87.5	87.50
				Oil based mud	8	70	52.50
				Synthetic mud	8	70	52.50
				Water based mud	5	43.75	0.00
15	Max mud weight	7	8.75	Multiple hole sections > 2.0 SG	10	87.5	87.50
				> 2.0 SG	9	78.75	72.92
				1.7–2.0 SG	8	70	58.33
				1.5–1.7 SG	7	61.25	43.75
				1.3–1.5 SG	6	52.5	29.17
				1.0–1.3 SG	4	35	0.00
16	Drilling margin	7	8.75	< 1.0 SG	10	87.5	87.50
				1.0–1.5 SG	8	70	52.50
				1.5–2.5 SG	7	61.25	35.00
				> 2.5 SG	5	43.75	0.00

Table 3 (continued)

Sr No.	Well complexity Parameters	Median of parameters weightage	Quality checked median of parameters weightage (10 × median ÷ max of all parameters weightage)	Well complexity sub-parameters	Quality checked median of sub-parameters rating	Quality checked rating × quality checked weightage	Normalized sub-parameter results (by Eq. 1)
17	Number of well targets	7	8.75	> 3 targets	10	87.5	87.50
				2–3 targets	7	61.25	43.75
				1 target	4	35	0.00
18	UBD/MPD application	7	8.75	MPD & UBD application	10	87.5	87.50
				MPD application	9	78.75	77.78
				UBD application	9	78.75	77.78
				Not applicable	1	8.75	0.00
19	Liner hanger application	6	7.5	Liner hanger with tie back	10	75	75.00
				Liner hanger application	8	60	58.33
				Not applicable	1	7.5	0.00
20	CwD/RwC application	6	7.5	CwD/RwC application	10	75	75.00
				Not applicable	1	7.5	0.00
21	Under-reaming/bi-center bit application	7	8.75	Under-reaming application	10	87.5	87.50
				Bi-center bit application	9	78.75	77.78
				Not applicable	1	8.75	0.00
22	Cementing operations	6	7.5	Dry blend cement job	4	30	28.00
				Gas/water channeling control slurry	6	45	44.00
				External casing packers	7	52.5	52.00
				Foam cementing	8	60	60.00
				Dual/multi-stage cementing	7	52.5	52.00
				No selection	0.5	3.75	0.00
23	New technology application	6	7.5	> 3	10	75	75.00
				2–3	8	60	58.33
				1	6	45	41.67
				0	1	7.5	0.00

Table 3 (continued)

Sr No.	Well complexity Parameters	Median of parameters weightage	Quality checked median of parameters weightage (10 × median ÷ max of all parameters weightage)	Well complexity sub-parameters	Quality checked median of sub-parameters rating	Quality checked rating × quality checked weightage	Normalized sub-parameter results (by Eq. 1)
24	Formations issues	7	8.75	Single loss zone	5	43.75	43.75
				Multiple loss zones	7	61.25	61.25
				Single gain/influx zone	6	52.5	52.50
				Multiple gain/influx zones	8	70	70.00
				Single reactive shale formation	5	43.75	43.75
				Multiple reactive shale formations	7	61.25	61.25
				Geologically stressed formations	7	61.25	61.25
				Highly fractured formation	8	70	70.00
				High formation dips	7	61.25	61.25
				Disturbed seismic strata	7.5	65.625	65.63
				Shallow gas	6.5	56.875	56.88
				Salt	7.5	65.625	65.63
				Main fault	8	70	70.00
				Minor/sub seismic fault presence	6	52.5	52.50
				Geological unconformity	7	61.25	61.25
				Pressure reversals	8	70	70.00
				No selection	0	0	0.00
25	Uncertainity in formation tops/thicknesses	7	8.75	> 30%	10	87.5	87.50
				15–30%	8	70	62.50
				5–15%	6	52.5	37.50
				0–5%	3	26.25	0.00
26	Pore gradient evaluation method	7	8.75	Seismic	10	87.5	87.50
				Drilling model	8	70	58.33
				Well logging	4	35	0.00
27	Fracture gradient evaluation method	7	8.75	Estimated/world stress map	10	87.5	87.50
				FIT/LOT	5	43.75	0.00

Table 3 (continued)

Sr No.	Well complexity Parameters	Median of parameters weightage	Quality checked median of parameters weightage (10 × median ÷ max of all parameters weightage)	Well complexity sub-parameters	Quality checked median of sub-parameters rating	Quality checked rating × quality checked weightage	Normalized sub-parameter results (by Eq. 1)
28	Hazardous gas presence	8	10	H_2S present	8	80	80.00
				CO_2 present	6	60	57.14
				No selection	1	10	0.00
29	Max bottom hole temperature	8	10	> 350 °F	10	100	100.00
				300–350 °F	8	80	60.00
				< 300 °F	5	50	0.00
30	Max wellhead pressure	8	10	≥ 20,000 psi	10	100	100.00
				≥ 15,000 psi	9	90	85.71
				≥ 10,000 psi	7	70	57.14
				≥ 5000 psi	5	50	28.57
				< 5000 psi	3	30	0.00
31	Regional difficulty factor	7	8.75	Wells in Baluchistan	8	70	70.00
				Wells in North (KPK)	8	70	70.00
				Wells in North (Punjab)	8	70	70.00
				Wells in South	5	43.75	0.00
32	Geographic factor	7	8.75	Sand dunes/mud volcano's	8	70	70.00
				Strategic protected area	7	61.25	60.00
				Marshy area	8	70	70.00
				Forest area	6	52.5	50.00
				Desert terrain	6	52.5	50.00
				Mountainous terrain	8	70	70.00
				Game reserves/ Env. protected	7	61.25	60.00
				No selection	1	8.75	0.00
33	Average drillability	6	7.5	< 1 m/hr	10	75	75.00
				< 3 m/hr	9	67.5	65.63
				< 5 m/hr	7	52.5	46.88
				< 10 m/hr	4.5	33.75	23.44
				≥ 10 m/hr	2	15	0.00
34	Coring operations	6	7.5	Coring in multiple hole sections	10	75	75.00
				Coring in 01 hole section	7	52.5	52.50
				Side wall coring	7	52.5	52.50
				Not applicable	0	0	0.00
35	Wireline logging	6	7.5	WLL in multiple hole sections	10	75	75.00
				WLL in 01 hole section	7	52.5	52.50
				Not applicable	0	0	0.00

Table 3 (continued)

Sr No.	Well complexity Parameters	Median of parameters weightage	Quality checked median of parameters weightage (10 × median ÷ max of all parameters weightage)	Well complexity sub-parameters	Quality checked median of sub-parameters rating	Quality checked rating × quality checked weightage	Normalized sub-parameter results (by Eq. 1)
36	MDT logging	6	7.5	MDT in multiple hole sections	10	75	75.00
				MDT in 01 hole section	8	60	60.00
				Not applicable	0	0	0.00
37	VSP/VSI	6	7.5	Open hole VSP/VSI	10	75	75.00
				Cased hole VSP/VSI	6	45	45.00
				Not applicable	0	0	0.00
38	LWD	6	7.5	LWD in multiple hole sections	10	75	75.00
				LWD in 01 Hole section	8	60	60.00
				Not applicable	0	0	0.00
39	Contracts already signed	6	7.5	No	7	52.5	52.50
				Yes	2	15	0.00
40	Material available/delivered	6	7.5	No	7	52.5	52.50
				Yes	2	15	0.00
41	Price volatility	6	7.5	Yes	7.5	56.25	56.25
				No	2.5	18.75	0.00
42	Weather NPT expectation	6	7.5	> 5 Days/Month	8	60	60.00
				2–5 Days/Month	5	37.5	24.00
				< 2 Days/Month	3	22.5	0.00
43	Natural events/disasters	6	7.5	Yes	8	60	60.00
				No	2	15	0.00
44	Site security condition	7	8.75	High security risk	8	70	70.00
				Medium security risk	6	52.5	35.00
				Low/no security risk	4	35	0.00
45	Local/political instability	7	8.75	High instability	8	70	70.00
				Medium Instability	6	52.5	42.00
				Low/no instability	3	26.25	0.00
46	Site access	6	7.5	Remote/limited site access	8	60	60.00
				Standard/normal site access	3	22.5	0.00
47	Ownership type	5	6.25	Joint venture project	7	43.75	43.75
				Full ownership	4	25	0.00
48	Permitting	5	6.25	Lack of authorizations	7	43.75	43.75
				All permits approved	3	18.75	0.00

Table 3 (continued)

Sr No.	Well complexity Parameters	Median of parameters weightage	Quality checked median of parameters weightage (10 × median ÷ max of all parameters weightage)	Well complexity sub-parameters	Quality checked median of sub-parameters rating	Quality checked rating × quality checked weightage	Normalized sub-parameter results (by Eq. 1)
49	Project resources	6	7.5	Lack of skilled resources	8	60	60.00
				Standard level of resources	6	45	40.00
				Extra level of resources	2	15	0.00
50	Planning time	7	8.75	< 3 Months	8	70	70.00
				3–6 Months	6	52.5	46.67
				6–12 Months	4	35	23.33
				> 12 Months	2	17.5	0.00
51	Logistics/mobilization time	7	8.75	> 3 Days	8.5	74.375	74.38
				2–3 Days	7	61.25	49.58
				1–2 Days	5	43.75	16.53
				< 1 Day	4	35	0.00

Fig. 61 Well complexity calculator screenshot

INPUT	
Well Name	
Field / Block Name	
Company Name	
WEMS Gate Level	
Well TD (m)	
Dry Hole Drilling Days	
NPT Hours	
Dry Hole Drilling Cost	

Categories			Sr#	Complexity Parameters	Sub-Categories Selection
Well Complexity	Drilling Well Complexity	Design Well Complexity	1	Well Type	Exploration WildCAT
			2	Rig Type	HP >= 3000
			3	Rig Capability	>= 80% of Rating at Maximum Load
			4	Total Measured Depth (MD)	<= 5000 m
			5	True Vertical Depth (TVD)	<= 5000 m
			6	Well Shape	3D Well
			7	Max Inclination	Vertical Well
			8	Max Dogleg	Vertical Well
			9	Number of Casings	>= 5
			10	Number of Contingent Hole Sections	1
			11	Smallest Hole Size	< 8-1/2"
			12	Target Tolerance	25-50 m
			13	Off-Set Wells Availability	No Off-Set Wells Data
			14	Type of Mud	Water Based Mud
			15	Max MW	Multiple Hole Sections > 2.0 SG
			16	Drilling Margin (Difference b/w Max PP & Min FP)	< 1.0 SG
			17	Number of Well Targets	> 3 Targets
			18	UBD / MPD Application	MPD Application
			19	Liner Hanger Application	Not Applicable
			20	CwD / RwC Application	CwD / RwC Application
			21	Under-Reaming / Bi-Center Bit Application	Under-Reaming Application
			22	Cementing Operations	☑ Dry Blend Cement Job
					☐ Gas Control / Water Channeling Control Slurry
					☐ External Casing Packers
					☐ Foam Cementing
					☑ Dual / Multi-Stage Cementing
					☐ No Selection
			23	New Technology Application	2 - 3
		Geological Well Complexity	24	Formations Issues	☐ Single Loss Zone
					☑ Multiple Loss Zones
					☑ Single Gain / Influx Zone
					☐ Multiple Gain / Influx Zones
					☑ Single Reactive Shale Formation
					☐ Multiple Reactive Shale Formations
					☐ Geologically Stressed Formations
					☑ Highly Fractured Formation
					☐ High Formation Dips
					☐ Disturbed Seismic Strata
					☐ Shallow Gas
					☑ Salt Formation
					☐ Main Fault
					☐ Minor / Sub Seismic Fault Presence
					☐ Geological Unconformity
					☐ Pressure Reversals
					☐ No Selection
			25	Uncertainity in Formation Tops / Thicknesses	0 - 5%
			26	Pore Gradient Evaluation Method	Seismic
			27	Fracture Gradient Evaluation Method	Estimated / World Stress Map
			28	Hazardous Gas Presence	☐ H2S Present
					☐ CO2 Present
					☑ No Selection
			29	Max Bottom Hole Temperature	< 300 °F
			30	Max Wellhead Pressure	< 5,000 psi
			31	Regional Difficulty Factor	Wells in North (KPK)
			32	Geographic Factor	☐ Sand Dunes / Mud Volcano's
					☐ Strategic Protected Area
					☐ Marshy Area
					☐ Forest Area
					☐ Desert Terrain
					☐ Mountainous Terrain
					☐ Game Reserves / Environment Protected Areas
					☑ No Selection
			33	Average Drillability	>= 10 m/hr
			34	Coring Operations	Side Wall Coring
			35	Wireline Logging	Wireline Logging in Multiple Hole Sections
			36	MDT Logging	MDT Logging in Multiple Hole Sections
			37	VSP / VSI	Cased Hole VSP / VSI
			38	LWD	Not Applicable
	Project Well Complexity		39	Contracts Already Signed	Yes
			40	Material Available / Delivered	No
			41	Price Volatility	No
			42	Weather NPT Expectation	< 2 Days / Month
			43	Natural Events / Disastors Expectation	No
			44	Site Security Condition	High Security Risk
			45	Local / Political Instability	Medium Instability
			46	Site Access	Remote / Limited Site Access
			47	Owenership Type	Joint Venture Project
			48	Permitting	All Permits Approved
			49	Project resources	Lack of Skilled Resources
			50	Planning Time	3 - 6 Months
			51	Logistics / Mobilization Time	1 - 2 Days

OUTPUT	
Design Well Complexity	9.95
Geological Well Complexity	5.18
Drilling Well Complexity	7.59
Project Well Complexity	6.75
Well Complexity	7.45

Appendix A: Extract from google survey

Figure 60 presents the extract from the Google Survey being used for the Development of Well Complexity Calculator.

Appendix B: Sub-parameters resultant ratings

Table 3 presents the resultant ratings of all the Sub-Parameters based on Median, which are used for onward analysis and preparation of Well Complexity Calculator.

Appendix C: Well complexity calculator screenshot

Figure 61 presents the screenshot of well complexity calculator.

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Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. On behalf of all the co-authors, I, Dr. Javed Haneef, states that there is no conflict of interest.

Ethical approval On behalf of all the co-authors, I, Dr. Javed Haneef, states that all accepted principles of ethical and professional conduct have been followed while doing this research. There is no financial obligation and potential conflicts of interest (financial or non-financial).

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