Journal of SRI "Geotechnological Problems of Oil, Gas and Chemistry" of ASOIU,
Issue 2, 2025, pp. 121-129
https://doi.org/10.65294/gpogc.2026.09

Python-based modelling improves torque and drag modelling in horizontal extended reach well

V.A. Iskandarov[2], G.V. Jabbarova[1,2], Y.Y. Shmoncheva[1,2], R.R. Tashmenov [3]

[1] Scientific Research Institute "Geotechnological Problems of Oil, Gas and Chemistry", 227 Dilara Aliyeva str., AZ1010, Baku, Azerbaijan

[2]Azerbaijan State Oil and Industry University, 20 Azadlig Avenue, AZ1010, Baku, Azerbaijan

[3]M. Auezov South-Kazakhstan State University, Building «B», Faculty mechanical and petroleum engineering G. Ilayev st. 8, Shymkent, Kazakhstan

Abstract. Extended-reach drilling (ERD) wells are increasingly deployed to maximize reservoir exposure while reducing surface footprint, particularly in offshore environments. In Field X, typical ERD wells reach ~7,500 m measured depth (MD) with more than 3,000 m of horizontal departure, drilled from an offshore platform in 330 m water depth. These wells include two aggressive build-up sections—commonly 10–12°/30 m DLS—before entering long horizontal intervals drilled through alternating sandstone and shale. This complex geometry significantly elevates friction and drag, making accurate torque and drag (T&D) modelling crucial for successful casing-running operations, stuck-pipe avoidance, and overall well delivery reliability.

To improve predictive accuracy for ERD completions, a Python-based workflow was developed to automatically extract, process, and analyze continuous hook-load data recorded by the mud-logging system. The workflow processed over 33,000 hook-load datapoints, applying rolling filters and peak-detection algorithms to generate high-resolution pick-up (PU) and slack-off (SO) profiles across the entire open hole. Validation against rig-measured loads demonstrated excellent agreement, achieving MAPE of 3.6% (SO) and 3.59% (PU), RMSE of 4.2 t and 6.5 t, and R^2 values above 0.99, confirming the reliability of the automated extraction technique.

Comparison with the original WellPlan model revealed that the existing T&D simulations over-predicted drag in the horizontal and shale sections of the ERD well, particularly across intervals with tight spots and micro-tortuosity. By recalibrating the model using Python-derived depth-based friction factors—ranging between 0.10 and 0.40, depending on lithology—the updated T&D model achieved strong alignment with actual tripping behavior. This improved calibration enhances operational safety margins, reduces the risk of excessive hookload or casing resistance, and strengthens planning for cementing, centralization, and completion installation.

Overall, the results demonstrate that Python-based modelling provides a robust, scalable, and high-accuracy method for friction-factor calibration and torque-and-drag optimization in horizontal ERD wells, enabling more reliable and safer well-construction performance.

Keywords. Torque and drag, extended-reach drilling (ERD), horizontal wells, hook-load extraction, friction-factor calibration, mud-logging data, python-based workflow, casing running.

*Corresponding author. Tel.: +994 705117707
E-mail address: i.vusal99@gmail.com (V.A. Iskandarov)

Introduction. Horizontal wells are essential from a subsurface perspective as allowing them to maximize reservoir contact and greatly improve drainage efficiency. By staying within the most productive reservoirs for long intervals, horizontal wells enable higher recovery factors, better exposure to reservoir, and more uniform depletion across the reservoir [3]. This makes horizontal wells a key technology for developing tight, heterogeneous, or low-permeability formations where vertical penetration alone would not deliver sufficient productivity [5].

However, horizontal wells also introduce additional challenges during completion operations. As the wellbore turns from vertical to horizontal, friction, drag, and wellbore tortuosity increase significantly, making it harder to run casing, completions, or lower tools to depth. Cuttings transport becomes more difficult, the risk of ledges, key-seats, and differential sticking rises, and mechanical loads on equipment become less predictable. These complexities require more advanced planning, and tighter operational control to ensure successfulcompletion in horizontal environments.

This paper discusses how a Python-based application was utilized to update and then calibrate the torque and drag (T&D) model for casing running operations in horizontal extended-reach well (ERD) in X field. The field X was located offshore with 330 m water depth. The top of the reservoir was located at 3600 m TVD RT and contained sandstone with low permeability. Long open-hole completion equipped with plug and perforations was utilized in the field to shut-off some intervals for future water breakthroughs also to produce economic rates. Typical wells had a complex trajectory with vertical section followed by build-up #1, tangent section with 45^0 and build-up #2 before having long horizontal section with over 3000 m

Figure 1.

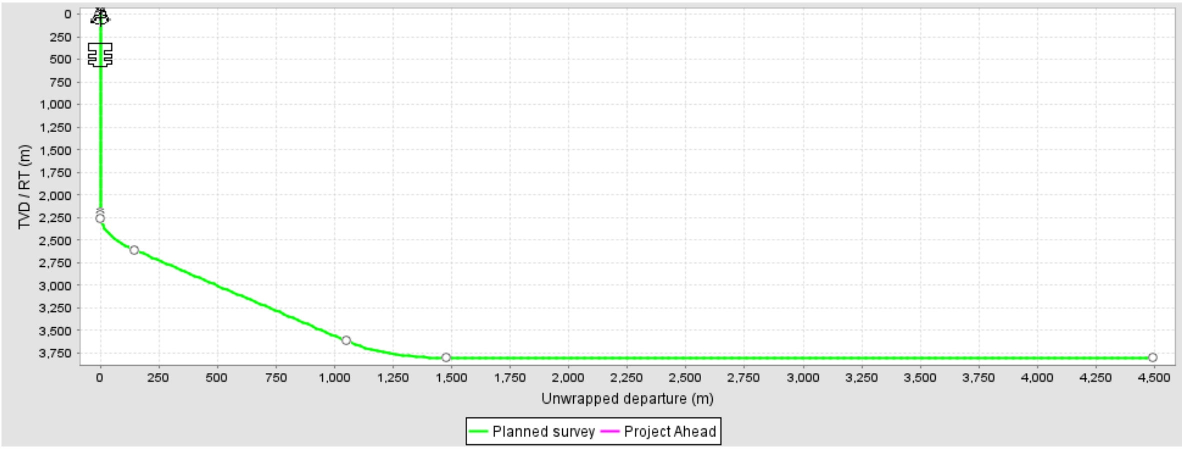


Figure 1. Typical planned well trajectory for ERD wells in Field X (TVD vs Departure).

Challenges. The well paths drilled in shale formations and horizontal section tend to have challenging well geometrics due to having significant levels of friction and drag. However, the longer the horizontal section means the more reservoir exposure, hence better and long-term production. Also, due to state regulations it is standard to build as rapidly as possible from vertical to horizontal section, in order to adhere to lease lines. As a result, advanced directional drilling tools are heavily used, creating severe dog-leg severity – sometimes even 12 deg per 30 m.

It is widely recognized that running liners or casing in hole generates higher drag and typically requires greater friction factors than running a drill string. This is largely because casing has a larger outer diameter than drill pipe, resulting in reduced annular clearance and increased bending stresses as it passes through doglegs. Although the friction factor itself does not change with weight, the substantially heavier casing string naturally produces higher drag forces. The friction factor—defined as a dimensionless coefficient—captures not only the basic contact friction between pipe and wellbore but also a range of difficult-to-measure influences that contribute to drag. These include wellbore tortuosity between survey stations, the buildup of cuttings beds, fluid-related resistance to pipe movement, and the stiffness-related resistance of the tubular as it bends through the well path. For decades, friction factors have served as a practical way to characterize overall hole conditions and to compare predicted torque and drag performance with actual hook-load measurements [6]. However, nowadays, drilling and completion engineers are using real field measurements to calibrate friction factors used in T&D models to enhance the accuracy of the models. In most of the cases, the rig measurements are limited to handful of actual pick-up (PU) and slack-off (SO) weights of the casing string. Considering to have long and horizontal wells with high degree of DLS, it is not recommended practice to rely on few measurements to calibrate the models.

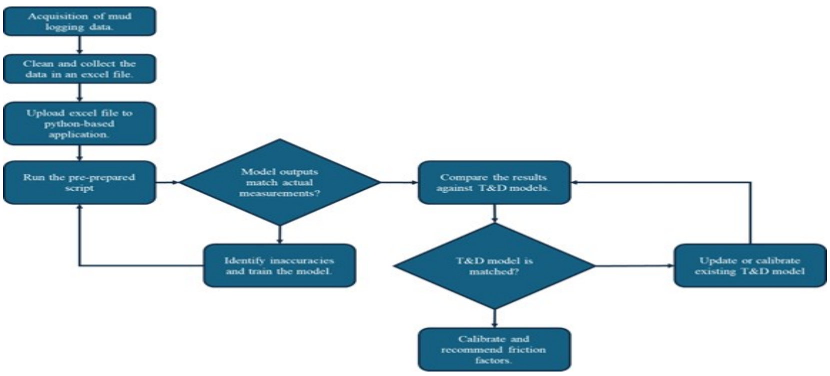
Failure to land a liner or completion string at total depth can lead to severe operational complications and significantly increase overall well costs [7]. Because of the high risk associated with these scenarios—and the elevated drag levels encountered during completion operations—it becomes essential to anticipate wellbore conditions, particularly the expected friction factor, before running the completion string. The industry's most common approach is to estimate friction factors using offset-well data from similar operations. However, the open-hole completions evaluated in this study showed considerable variability in friction factors, reducing the reliability of this traditional method. If a consistent relationship between drilling-phase and completion-phase hole conditions could be established—specifically through comparable friction factors—then drilling friction factors could be used to forecast completion friction factors with confidence. This would allow engineers to better assess safety margins in terms of hookload and slack-off behavior prior to running in hole.

In this research paper, the Python-based workflow will be applied to extract PU and SO values from actual hook load measurements from mud-logging unit, and its accuracy will be checked using field-proven statistical techniques.

A Python-based workflow. The workflow begins with acquiring continuous hook-load measurements from the mud-logging system during casing-running operations. These raw data files—often scattered across multiple Excel sheets—are cleaned, filtered, and merged to isolate only the periods relevant to casing running operations. The cleaned dataset is then uploaded into a Python-based application, where a pre-configured script automatically processes the measurements using rolling statistical filters, thresholding, and interval-based peak detection to extract pick-up (PU) and slack-off (SO) weights across the full depth interval. The results are reported and can be extracted as both chart and excel file. These model-generated PU/SO profiles are subsequently validated against actual field measurements to ensure accuracy. The validation of accuracy of the model outputs are verified using Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE) and Coefficient of Determination (R^2).

Once validated, the extracted tripping loads are compared with torque and drag (T&D) model predictions. If discrepancies appear, the workflow identifies where the model diverges and retrains or corrects the computations. The Python results are then used to calibrate friction factors on a formation-by-formation basis, ensuring that T&D models reflect lithology-driven drag variations. Finally, the updated friction factors are fed back into the T&D model to refine future simulations and improve casing-running planning and operational reliability. Detailed workflow is shown in figure 2.

Figure 2. Python based workflow for extraction of tripping loads and torque and drag model calibration.



Case study – Well X1. The workflow was first applied to Well X1 where 5 ½" x 7" production liner equipped with multiple swell packers. The casing was planned to be run to 7,500 m MD depth with long open hole section. Figure 3 shows T&D modelled tripping-in and tripping-out hook load measurements with multiple FF sensitivities and actual hook load measurements extracted from mud-logging system. The first glance at the plot reveals mis-match between T&D model outputs and actual hook load trend. Hook load trend had increasing and decreasing trend which may be explained by multiple factors. First of all, the hook load decrease across 2500 – 3500 m interval can be explained by the fact that in horizontal or deviated sections of the well, part of the string weight is no longer supported by the top drive but is instead carried by the wellbore. As this was the case, when the casing string entered the deeper deviated sections of the well, buoyancy forces from drilling fluid reduced the effective submerged weight of the string. As reported by multiple previous research, the higher the mud density, the greater the buoyant effect, which naturally lowers the hook load [2]. Additionally, as the pipe contacts the low side of the borehole—particularly in deviated or curved sections—friction between the pipe and the formation supports a portion of the axial load. This friction effectively "holds" part of the pipe, reducing what the hook sees at surface.

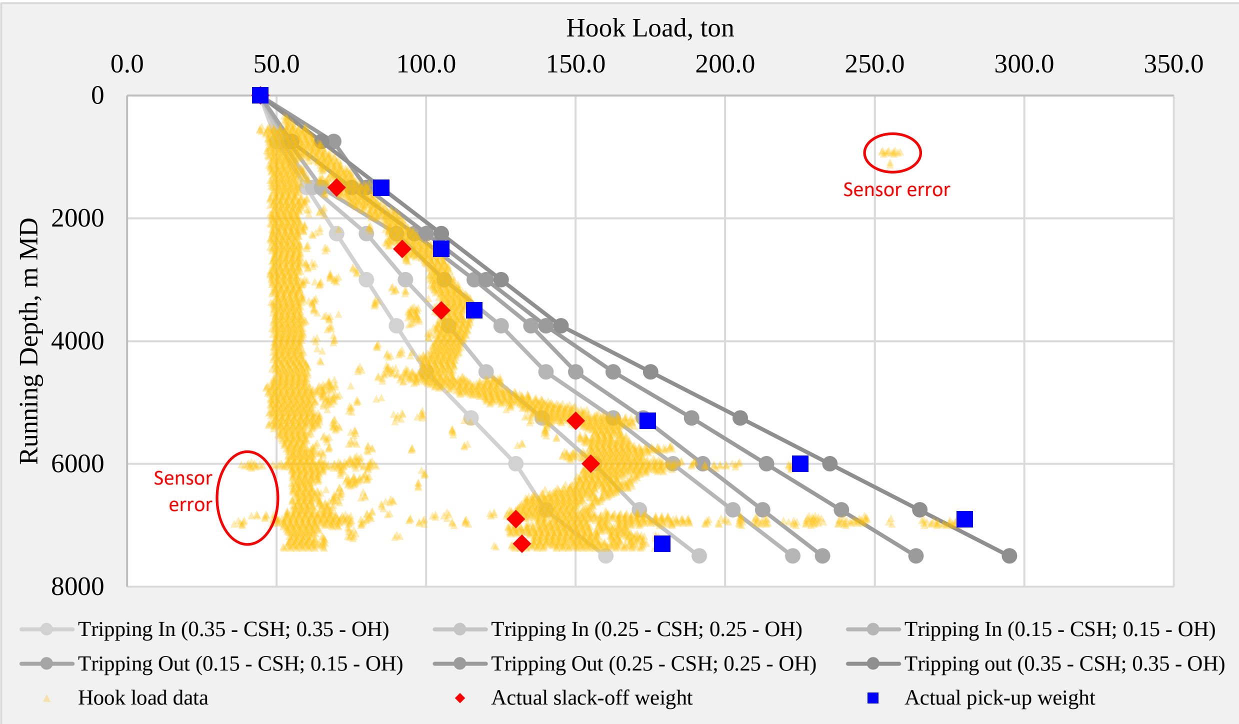


Figure 3. Actual pick-up/slack-off weights and raw hook load data compared with initial T&D model outputs.

Hook load can also drop when the running conditions temporarily reduce drag. For example, pumping while running in hole can help lift cuttings, lubricate the annulus, and decrease friction, causing the hook load to fall. Similarly, rotation of the pipe transitions static friction to lower dynamic friction, again reducing drag and lowering the measured load [9]. In some cases, localized tight spots or partial sticking paradoxically cause the hook load to drop—the formation or obstruction supports the pipe section below the restriction, so the surface equipment carries less weight [10]. All these mechanisms can lead to noticeable decreases in hook load, even while the string is being lowered.

Regarding hook load increases inside casing and across the lower part of the open-hole section, it can be related to the fact that the pipe experiences upward frictional forces that oppose its downward movement. In deviated and horizontal well sections, the pipe naturally lies along the low side of the borehole, creating continuous contact between the tubular and the formation. This contact generates drag, which acts upward against the direction of pipe travel. To continue lowering the string, the top drive and draw works must apply additional downward force, and this extra force registers as a higher hook load at surface [11]. The more complex the wellbore—featuring doglegs, key seats, micro-tortuosity, or ledges—the greater the contact and resulting friction, leading to a progressively higher hook load as depth increases [4].

Another major contributor to increasing hook load is the presence of cutting beds and local wellbore restrictions, especially in highly deviated intervals [1]. When the pipe moves over accumulated cuttings or tight spots, it must "climb" these obstructions, which creates additional upward resistance. Similarly, insufficient hole cleaning, high mud weight, surge pressure while running too fast, or stopping rotation (increasing static friction) all magnify drag forces. These effects combine to reduce the amount of the string's weight transferred naturally to the hook—forcing the rig to apply more set-down force—thereby causing the hook load to rise even though the pipe is being lowered.

Using the Python-based application described in the previous chapter, tripping-in and tripping-out weights were extracted for the liner running operation (figure 4). The application analyzed more than 33,000 data points recorded during the operations (hook load data) and generated 2 output files; the plot showing in figure 4 and EXCEL file containing raw data, plot and normalized tripping weights for the entire well length. These outputs were generated in a couple seconds. The validation to check the accuracy was performed using rig-based hook-load measurements for SO and PU weights. MAPE, RMSE and coefficient of determination (R^2) were then applied to quantify the accuracy of the Python-based model outputs. Table 1 below highlights key metrics to understand the accuracy of Python based model against actual field measurements. The maximum error was determined to be at roughly 4% using MAPE method, proving accuracy of the outputs.

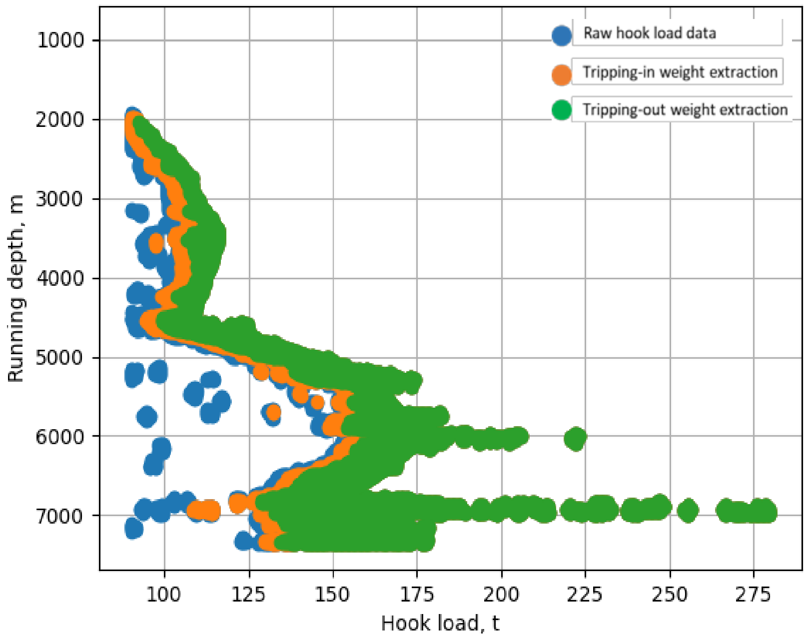


Figure 4. Tripping in and tripping out weights extracted by Python-based application.

Table 1. Summary Validation Metrics.

Series	MAPE (%)	RMSE (t)	R^2
Slack-off	4.00%	4.2	0.990
Pick-up	3.59%	6.5	0.992

Furthermore, RMSE methodology showed the maximum absolute deviation at 6.5 metric tons for PU and 4.2 metric tons for SO, with 4% and 3.6% of MAPE metrics. Therefore, referring to this result, it can be concluded that the model identified and generated PU and SO weights accurately.

After validating the outputs of the Python based workflow, the modeled torque and drag (T&D) results—generated using multiple friction-factor sensitivities—were compared against actual tripping weights to evaluate the model's predictive accuracy. This comparison showed that the existing T&D model could not reliably estimate drag in the open-hole section; in almost entire open hole, it over-predicted drag, demonstrating the need for recalibration to avoid significant mismatches between modeled and real well behavior. The post-drilling friction-factor analysis clearly highlighted discrepancies between predicted and observed tripping loads, underlining the importance of updating the WellPlan T&D model for subsequent wells.

Updating the T&D model was critical because inaccurate predictions increase the risk of excessive loads, equipment overstress, stuck pipe, and tool failures, while also compromising cementing design and zonal isolation. Mis-matched models weaken real-time decisions and heighten safety risks, especially on offshore platforms where operational margins are tighter.

Given these findings, the decision was made to update and recalibrate the existing WellPlan torque and drag model to better match actual well dynamics. A new model was generated with expanded friction-factor sensitivities for both tripping-in and tripping-out operations, using FF values ranging from 0.15 to 0.35. As illustrated in figure 5, the updated T&D outputs show strong alignment with measured hook loads, confirming that the recalibrated model provides a more accurate representation of downhole behavior and supports more reliable well planning and execution. Following this, depth-based friction-factor (FF) values were then generated, establishing the foundation for future FF calibration.

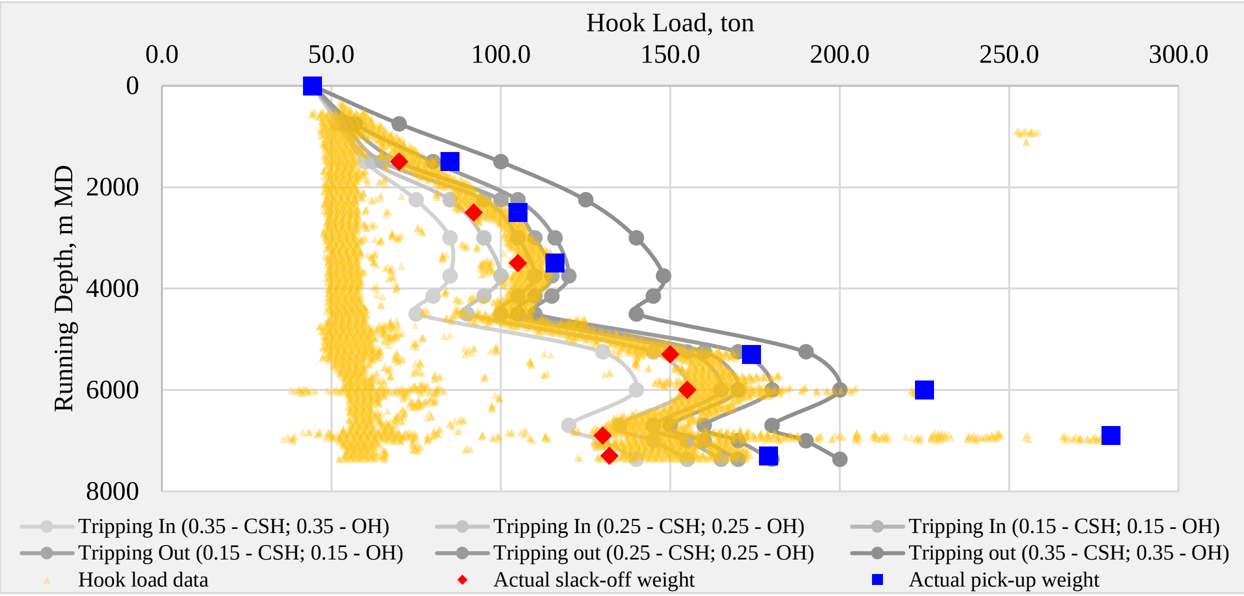


Figure 5. Actual pick-up/slack-off weights and raw hook load data compared with updated and calibrated T&D model outputs.

As shown in [8], the FF profiles for both tripping-in and tripping-out illustrate the varying friction mechanisms along the wellbore. In the lower portion of the open hole—where the trajectory transitions to horizontal and intersects shale intervals—drag increases significantly, and multiple tight spots were observed. Alignment of high FF values or drag with shale intervals where tight spots occurred, the FF values can be related to interpreted lithologies per interval along the open hole section. Alignment of high FF values with shale intervals where tight spots occurred suggests lithology-driven drag variations (see figure 7; [8]).

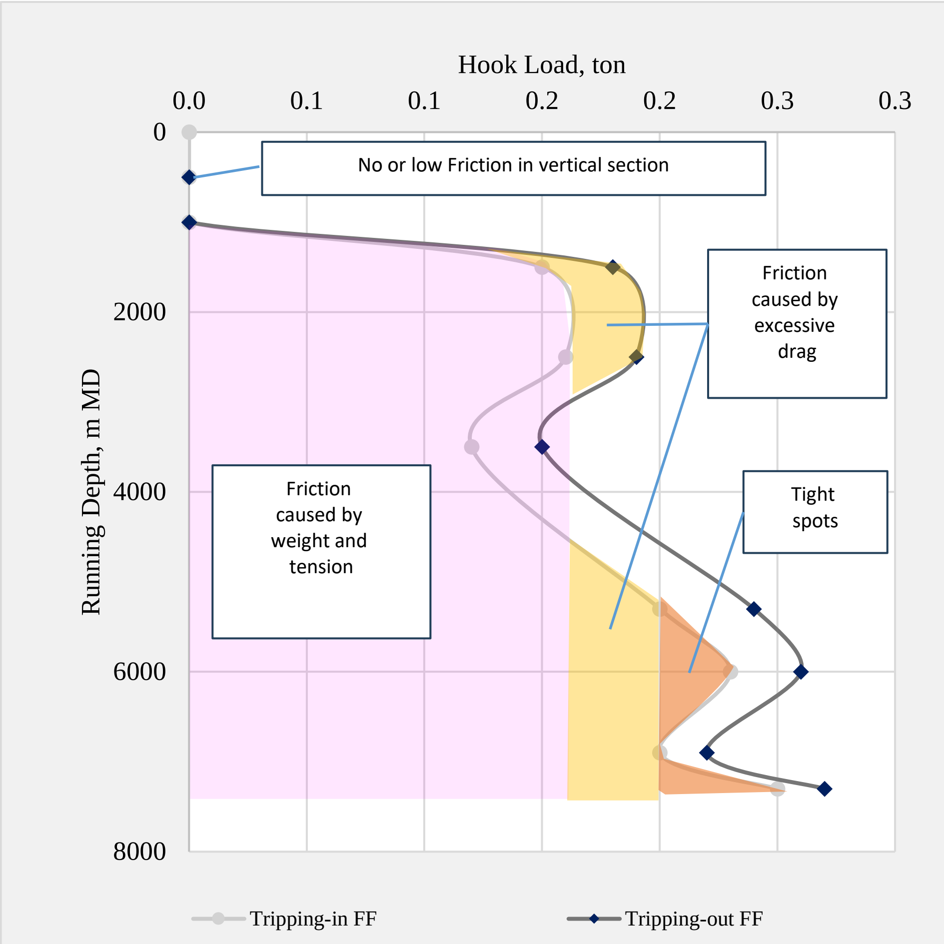


Figure 6. Sensitivity analysis of Friction Factors vs measured depth.

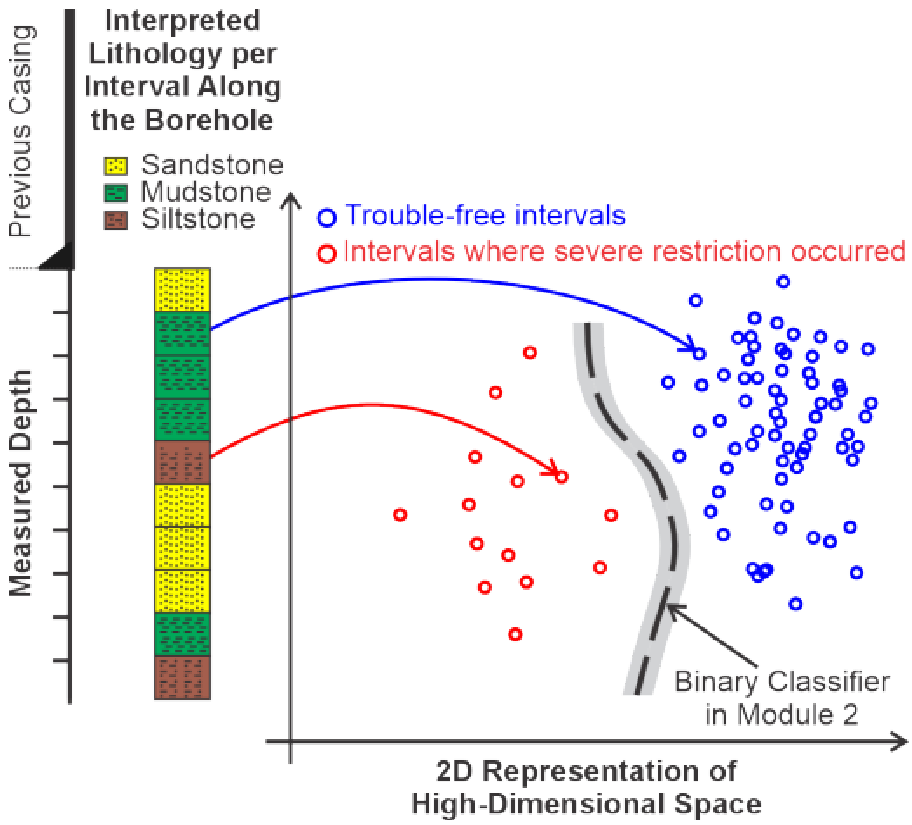


Figure 7. Illustration of hook load measurements depending on various lithologies [8].

Conclusion. This study demonstrates that a Python-based workflow can significantly enhance the accuracy and reliability of torque and drag (T&D) modeling for complex horizontal well completions through friction factor calibration. By extracting hook-load measurements continuous through entire well length directly from mud-logging data and validating them through robust statistical methods—MAPE, RMSE, and R^2—the workflow provides a far more representative picture of actual downhole behavior than traditional reliance on limited rig measurements or offset-well friction-factor assumptions. Application to Well X1 clearly showed that the original T&D model consistently over-predicted drag in the open-hole section, particularly across high-DLS intervals and shale units, highlighting the need for recalibration to prevent operational misinterpretation of loads.

Through depth-based friction-factor calibration and comparison against field-measured pick-up and slack-off trends, the updated T&D model achieved strong alignment with real well dynamics, reducing prediction uncertainty and improving operational decision-making. This improvement is critical for safe casing-running operations, optimized tripping strategies, and accurate planning for cementing, zonal isolation, and long-term well integrity. By integrating continuous field data, automated load extraction, and multi-sensitivity FF modeling, the Python-based approach offers a scalable, efficient, and field-deployable solution that strengthens well delivery performance and reduces risk—particularly for long horizontal wells drilled from offshore platforms where operational margins are narrow and consequences of model inaccuracy are high.

Conflict of interest.

The authors declare that they have no conflict of interest in relation to this research.

References

1. Baldino, S., & Ozbayoglu, E. (2025). Quantifying the impact of cuttings and fluid properties on friction coefficient in torque & drag analysis. Paper presented at the *SPE/IADC International Drilling Conference and Exhibition*, Stavanger, Norway (Paper No. SPE/IADC-223671-MS). https://doi.org/10.2118/223671-MS.

2. Cayeux, E., Skadsem, H. J., & Kluge, R. (2015). Accuracy and correction of hook load measurements during drilling operations. Paper presented at the *SPE/IADC Drilling Conference and Exhibition*, London, United Kingdom (Paper No. SPE/IADC-173035-MS). https://doi.org/10.2118/173035-MS.

3. Economides, M. J., Hill, A. D., Ehlig-Economides, C., & Zhu, D. (2012). *Petroleum production systems* (2nd ed.). Pearson.

4. Gaynor, T., Hamer, D., Chen, D. C.-K., & Stuart, D. (2002). Quantifying tortuosities by friction factors in torque and drag model. Paper presented at the *SPE Annual Technical Conference and Exhibition*, San Antonio, TX, USA (Paper No. SPE-77617-MS). https://doi.org/10.2118/77617-MS.

5. Joshi, S. D. (1991). *Horizontal well technology*. PennWell Publishing Company.

6. Maidla, E. E., & Wojtanowicz, A. K. (1988). Prediction of casing running loads in directional wells. Paper presented at the *Offshore Technology Conference*, Houston, TX, USA (Paper No. OTC-5791-MS). https://doi.org/10.4043/5791-MS.

7. Mason, C.J., Lopez, J., Meling, S., Munger, R., & Fraser, B. (2003). Casing running challenges for extended-reach wells. Paper presented at the *SPE Annual Technical Conference and Exhibition*, Denver, CO, USA (Paper No. SPE-84447-MS). https://doi.org/10.2118/84447-MS.

8. Montes, A.C., Ashok, P., van Oort, E., Les, B., Mullendore, M., & Limaye, S. (2025). Casing run failure avoidance through automated assessment of borehole quality. *SPE Journal, 30*(11), 6715–6738. https://doi.org/10.2118/223706-PA.

9. Shi, X.-L., Huang, W.-J., & Gao, D.-L. (2021). Mechanical behavior of drillstring with drag reduction oscillators and its effects on sliding drilling limits. *Petroleum Science, 18*(6), 1689–1697. https://doi.org/10.1016/j.petsci.2021.09.007.

10. Wang, P., Cao, J., Zhang, H., Yue, W., Ni, H., & Zhang, R. (2024). Axial load peristaltic transfer mechanism of the drillstring to improve penetration rate. *SPE Journal, 29*(7), 3472–3487. https://doi.org/10.2118/219737-PA.

Wu, A., Hareland, G., & Fazaelizadeh, M. (2011). Torque & drag analysis using finite element method. *Modern Applied Science, 5*(6), 13–27. https://doi.org/10.5539/mas.v5n6p13.