WELL PORTFOLIO OPTIMIZATION :

Accelerating Well Intervention Candidate Selection with Automated Analytics and Machine Learning - A Case Study From Attaka Field, Pertamina Hulu Kalimantan Timur, Indonesia

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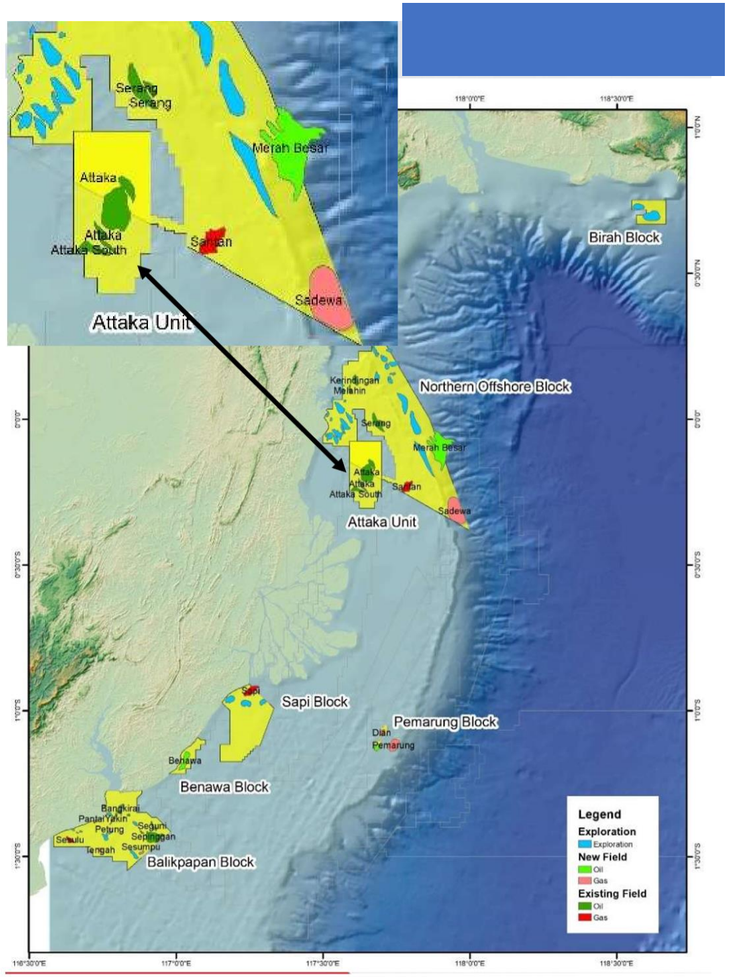
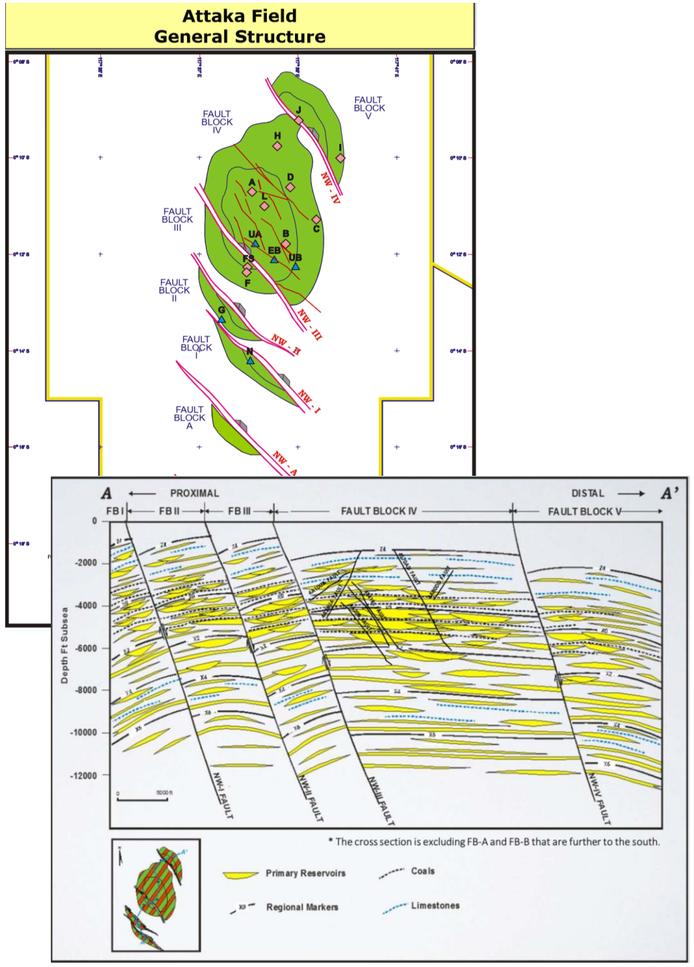
Schlumberger | Digital Forum 2022
September 20th – 21st 2022

Agenda

- Well Portfolio Optimization Introduction
- Well Portfolio Optimization Detailed Workflow
- Q&A

PHKT WELL PORTOFOLIO OPTIMIZATION (WEPON) | Field Overview





- Giant field, discovered in 1970
- Production from 1972
- Area approx. 280 km^2
- Water depth ~ 55 m
- 414 wells, 80 horizontal
- 7 main fault blocks
- Major reserves in FB IV
- Low seismic quality due to shallow gas cloud
- Multiple **markers** in one well

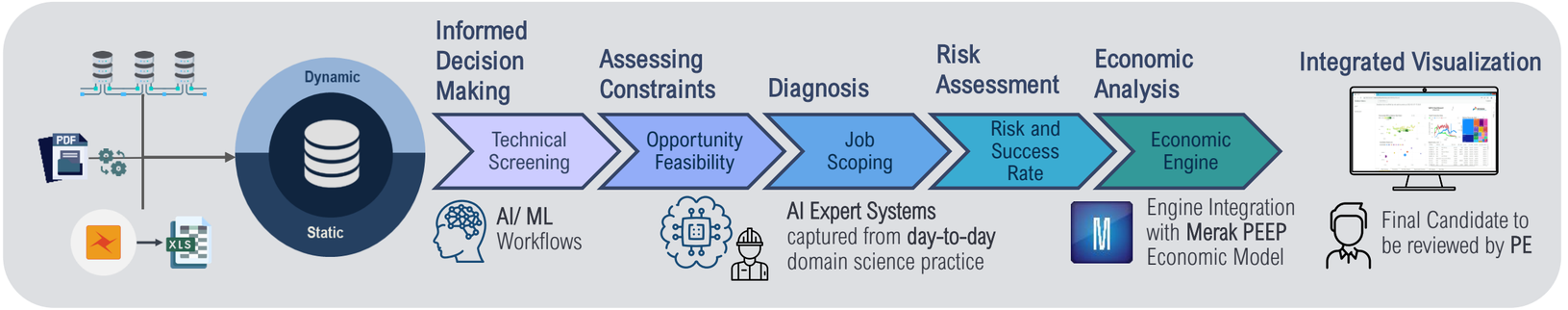
Challenges : heavily faulted and compartmentalized, diverse properties and heterogeneous formations, contrasting pressure regimes, interconnected gas expansion and water drive reservoirs, un-organized and inconsistent data/parameters and workflows to review wells in finding or defining workover/well service opportunities.

Objective : establish a standard, consistent and more efficient process even automatic in data crunching and evaluation process in evaluating workover/wells ervice opportunity.

Well Portfolio Optimization

Accelerating production, from Automation of WI Candidate Screening Cycle with Analytics and ML

Powered by data iku



Driving **scalable** process improvements from 2-3 ~~months~~ Hours!

PERTAMINA *Use case*

$220k Cost Saving per year

89%, Well Review Time Reduced

>400x Increase in Review Scope

- **Reduce risk of dry completions**
- **Increase NPV** of your Portfolio

Decision Quality

- **Reduce >80%** of Cycle Time
- **Increase Productivity**
- **Increase and accelerate production gain** from increased scope of review

Decision Speed

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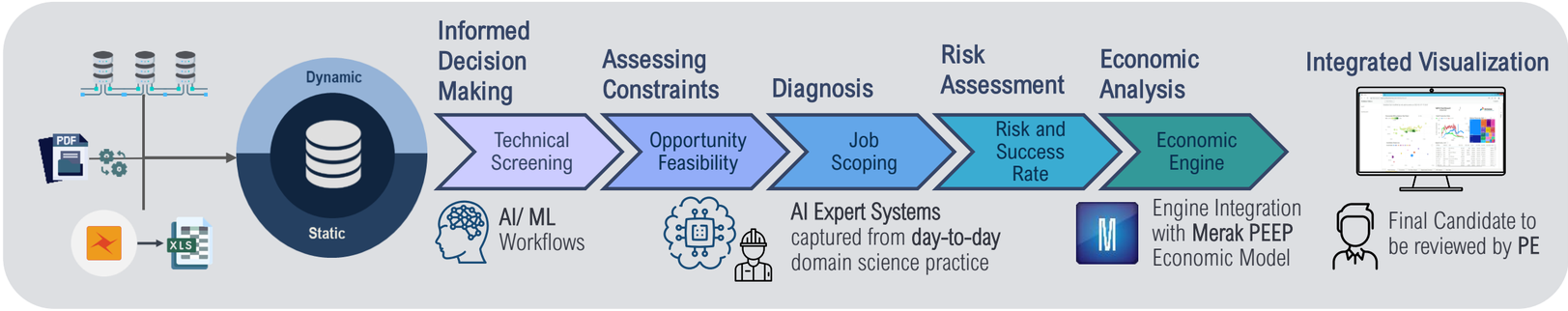


Domain Science *plus* AI/ML algorithms

AI

Analytical Hierarchy Process

- Robust ranking algorithm for already-produced candidates to gain back its hidden potential
- Incorporates data from subsurface properties, production history
- Automatic DCA Forecasting
- Heterogeneity Index
- Type Well Comparison
- Areal Trend Analysis

Behind Casing Opportunity

- Construction and deployment of ML model to predict un-opened candidates' potential
- Incorporates data from subsurface properties, well status, production history
- Powered with Dataiku to enable model reinforcement with new data

Insights & Advisory

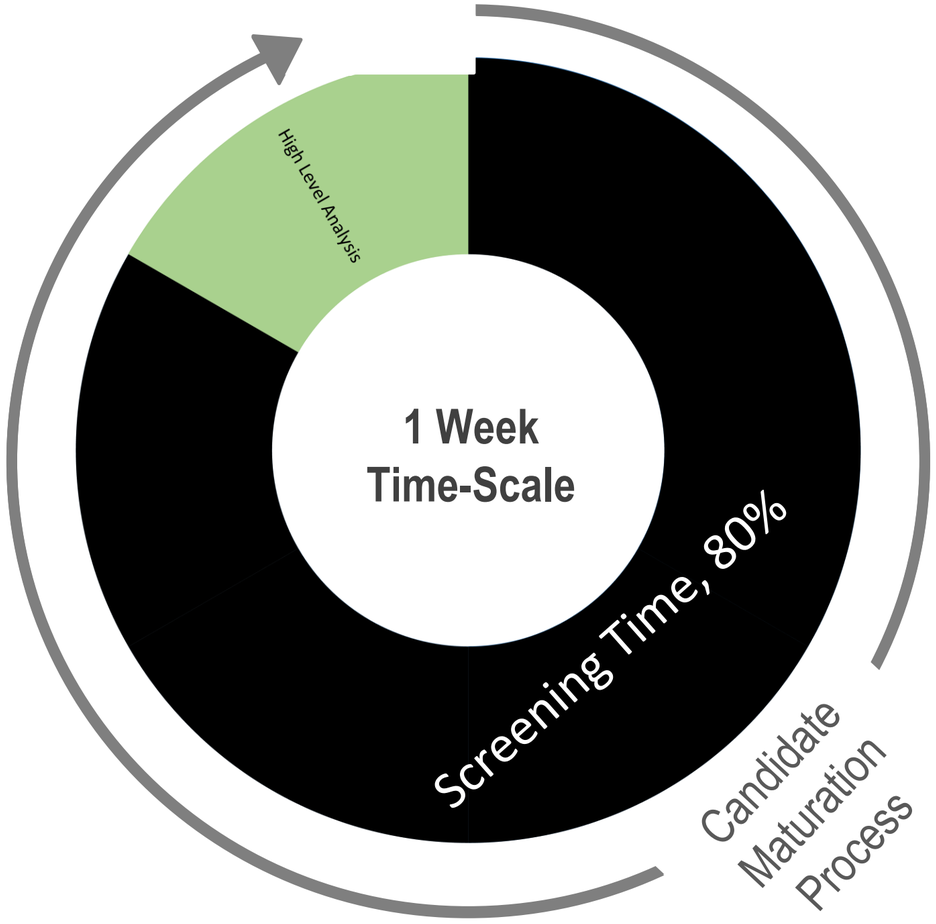
Final WO/WS candidate selection to be reviewed **by engineer**

Decision Speed

Enhancement Opportunity of Existing Well Portfolio Processes

Candidate Maturation Process

Underperforming Well Analysis – Workover/Intervention Candidate Selection



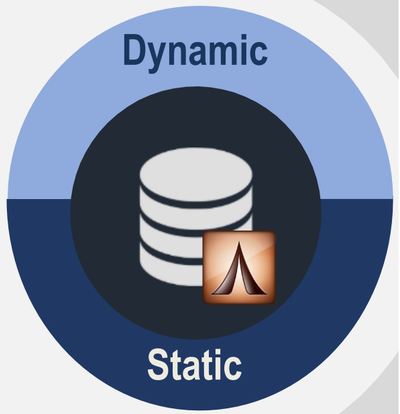
Manual Process leading to **Well Review Time** **Review Time 3 days/ well**

Limitation in **Well Review Frequency** **6 wells/ month**

Less Comprehensive and Data-driven approach to increase accuracy in gain prediction

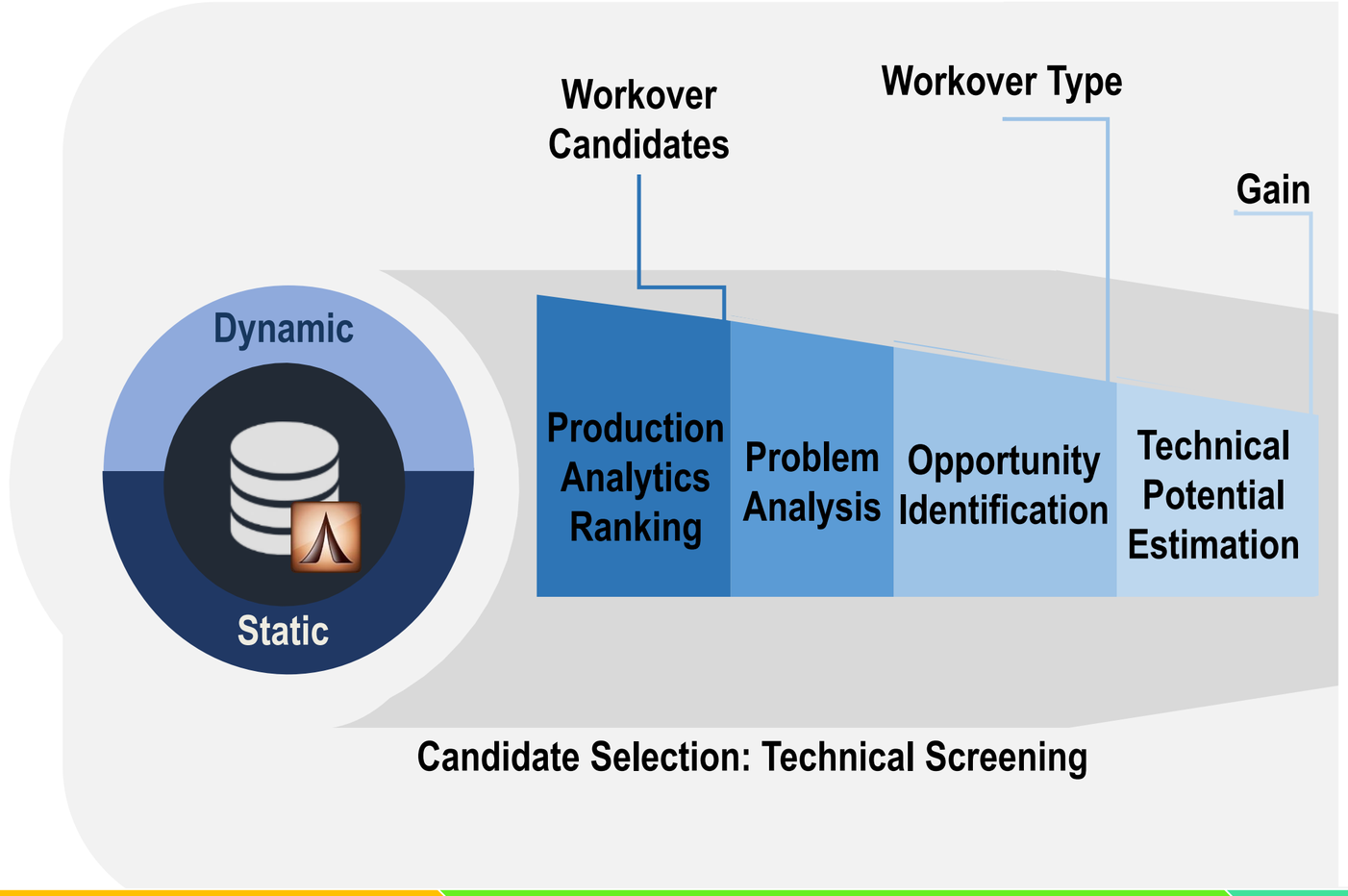
Solution Approach

Solution Approach | Process Flow



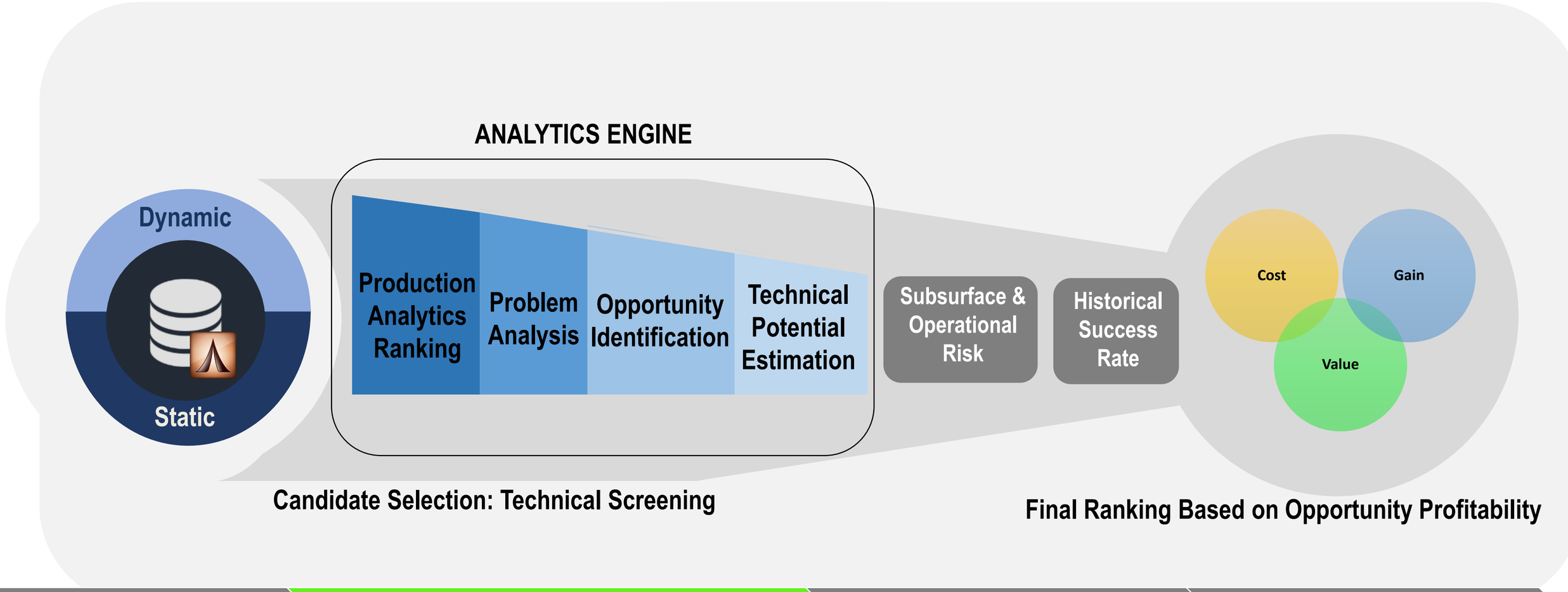
Knowledge Base → Technical Analysis → Chance of Success → Economic Analysis

Solution Approach | Process Flow



Knowledge Base | Technical Analysis | Chance of Success | Economic Analysis

Solution Approach | WPO Knowledge Base



Knowledge Base | Technical Analysis | Chance of Success | Economic Analysis

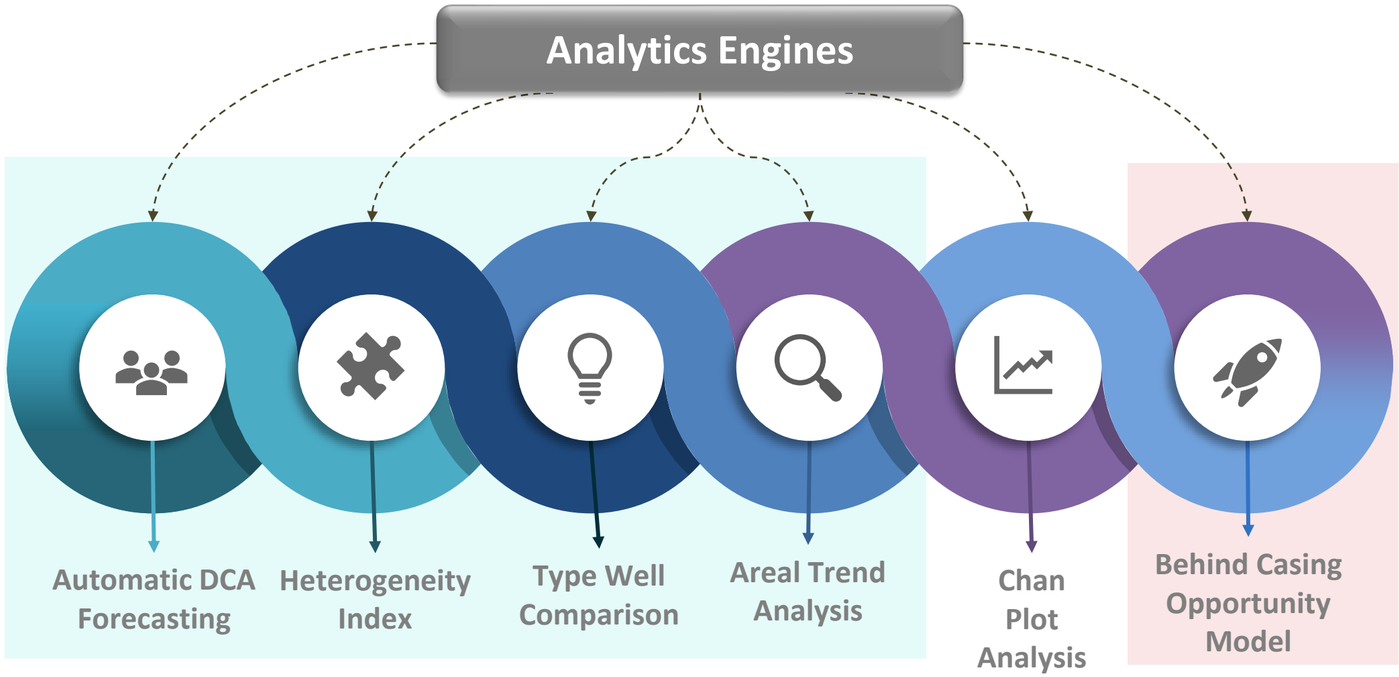
Technical Analysis | Technical Screening

To screen candidates based on their performance and potential. A bottom-up approach is taken to do this, i.e. the completions are diagnosed, and then the results are aggregated upwards following the hierarchy (well – string).

It consists two steps, classified from whether a completion has produced/ perforated in the past or not.

1. **Analytical Hierarchy Process (AHP):** Rank the perforated/ produced completions based on a set of production and petrophysical KPIs using a Multi-Criteria-Decision-Making-Process (MCDMP) called AHP. The higher the rank of a well, the better the candidate it is from a technical perspective.

2. **Behind Casing Opportunity (BCO):** A machine learning model trained from the perforated/ produced completions' production data, petrophysical properties, and subsurface coordinates to predict un-opened completions' oil rate.

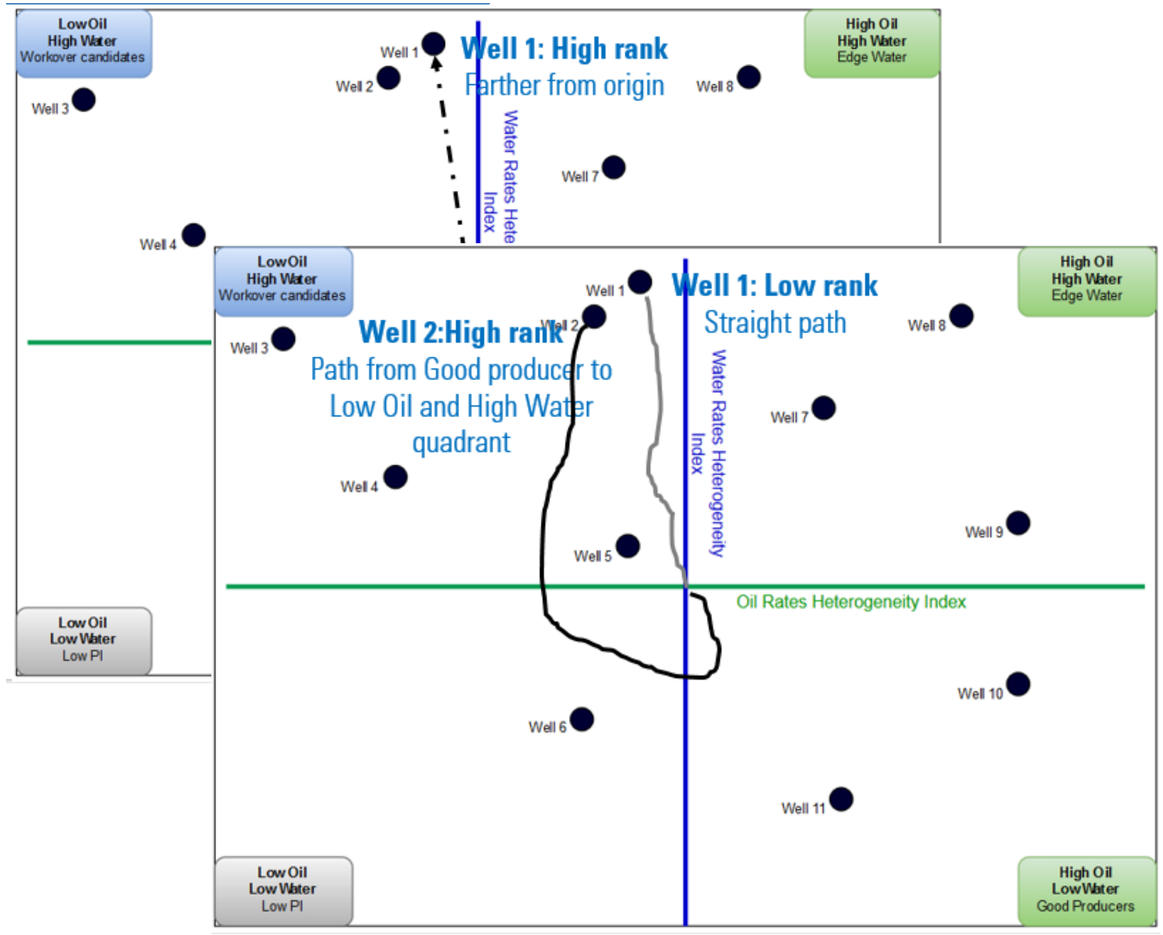


Knowledge Base | Technical Analysis | Chance of Success | Economic Analysis

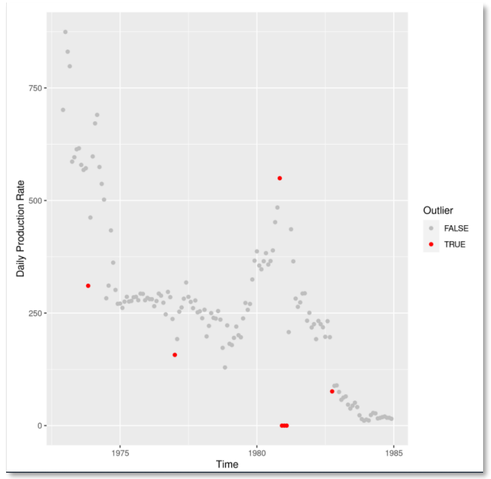
Technical Analysis | Technical Screening – AHP - Heterogeneity Index Scoring

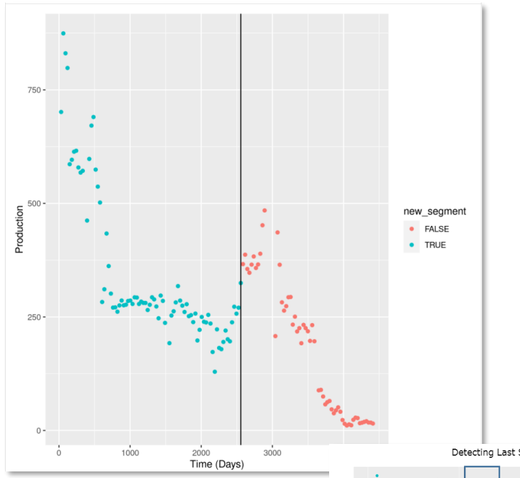
Provide a **scoring methodology** based on the characteristics of HI traces over time

- Inputs
  - **Last HI Plot Quadrant**
  - **Location & distance from origin:** The further the point & more undesirable quadrant, the higher the score
  - **Historical directional movement:** Incorporates the HI path of a completion
  - **Time-dependent outlyingness of a well:** Score incorporate the time when the completion is active
- Methodology
  - Outlyingness quantification using
    - Local Outlier Factor algorithm
    - Exponential weighted moving average of directional movement
    - Weighted score of all inputs

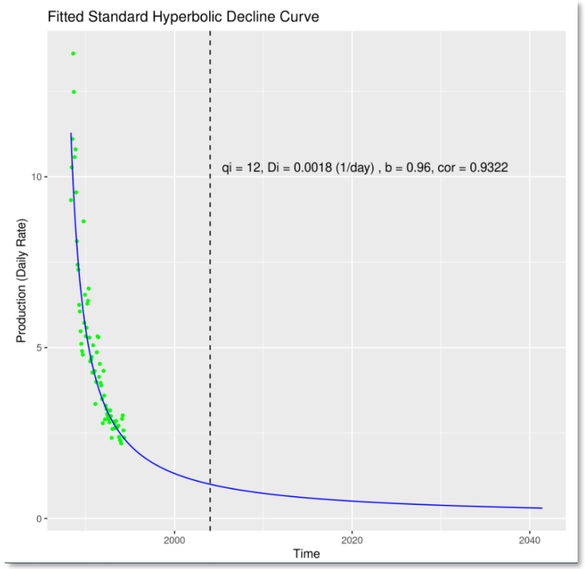


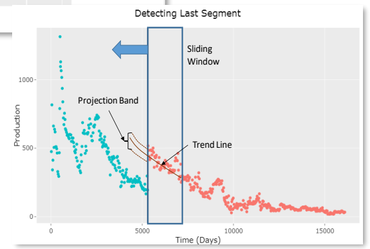
Technical Analysis | Technical Screening – AHP – Automatic DCA Forecasting





$$z_i = \frac{q_i - \mu_q}{\sigma_q}$$





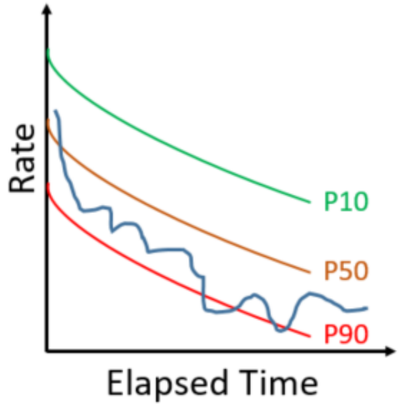
Fully automate the decline curve analysis procedure, using Arps' decline curve principle

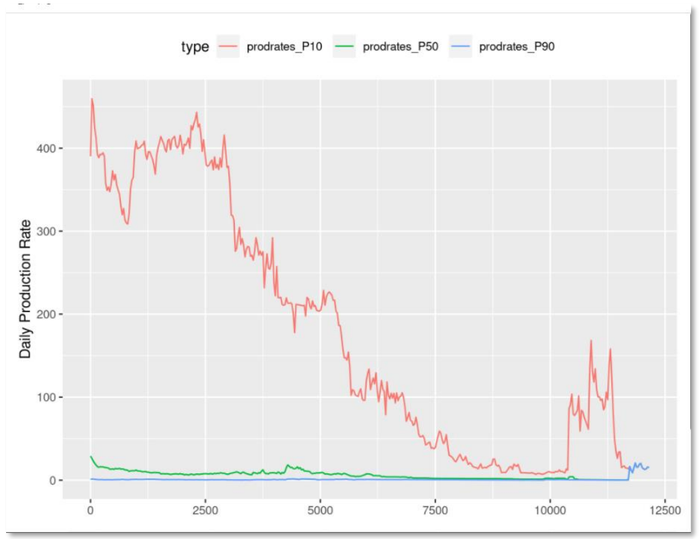
- Outlier detection and removal
- Identify segmentation from the data pattern
- Regression model fitting: b & Di
- Production Forecast
  - Neighbor DCA parameters retrieval for completions with insufficient production data

Technical Analysis | Technical Screening – AHP

Type Well Comparison

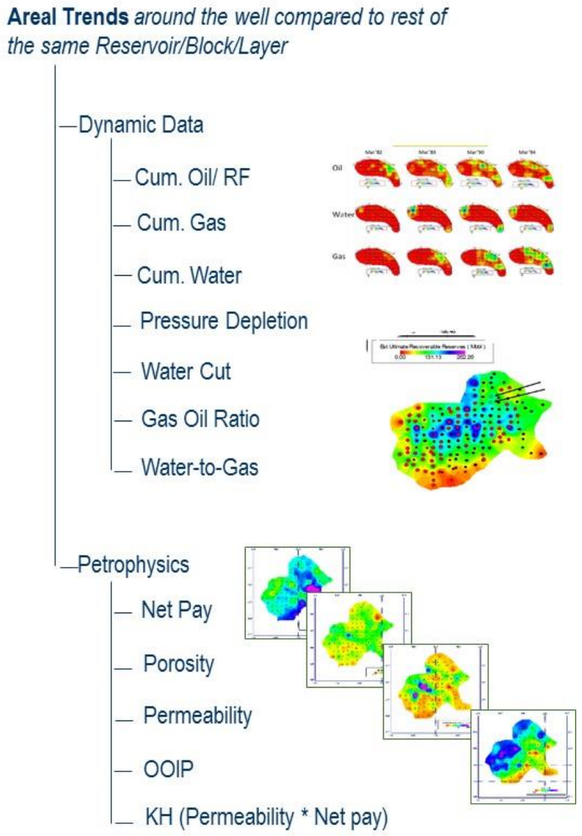
- How does a well compare with the rest of the group over time?
- Methodology
  - Compute distance of individual well rate curve to group P50 curve
  - Compare overall and recent historical trends of individual well rate curve with group P50 curve



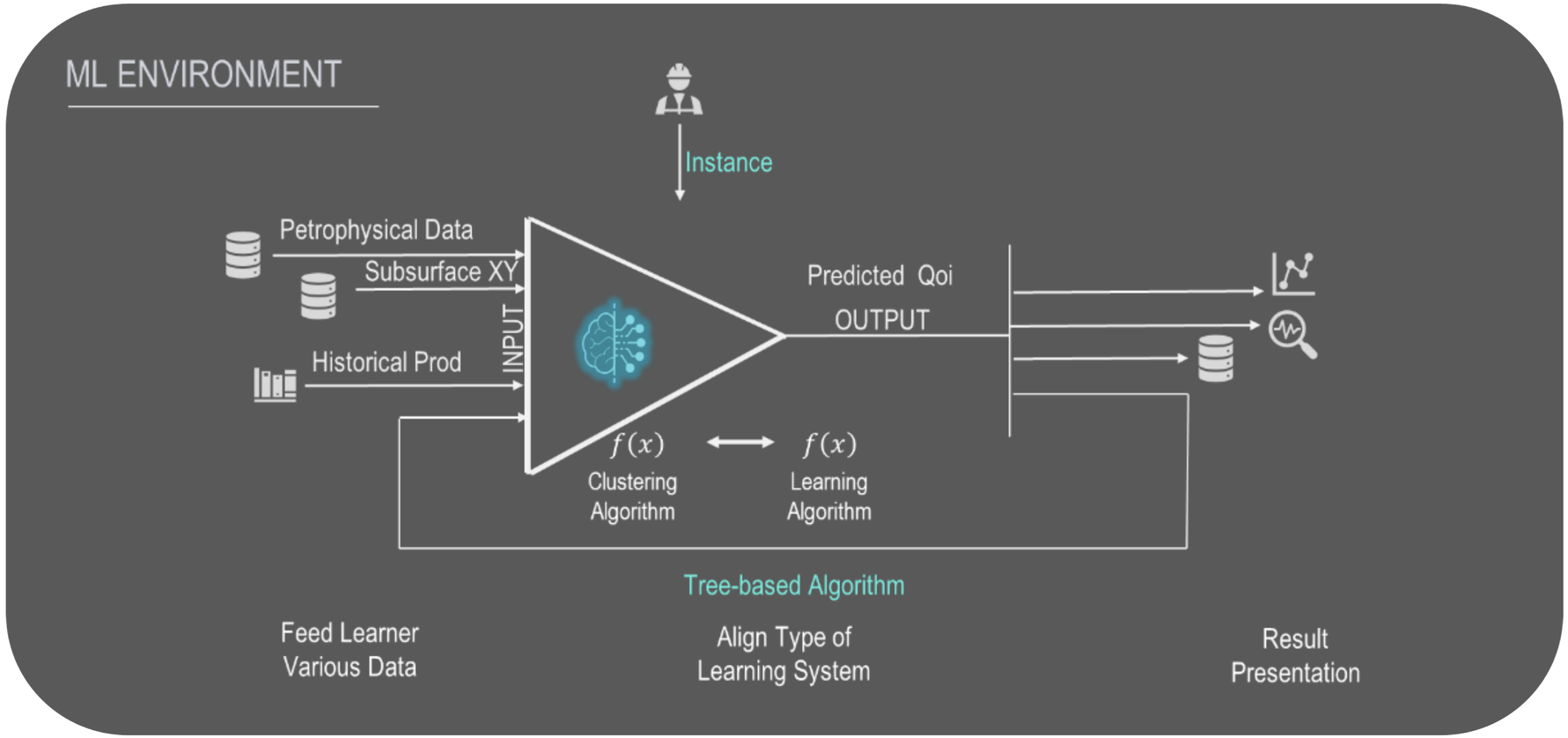


Areal Trend Analysis

Moving domain analysis where “Water-Cut-for-Oil” and “Water-to-Gas” ratio are benchmarked against the neighbouring wells to evaluate its relative performance



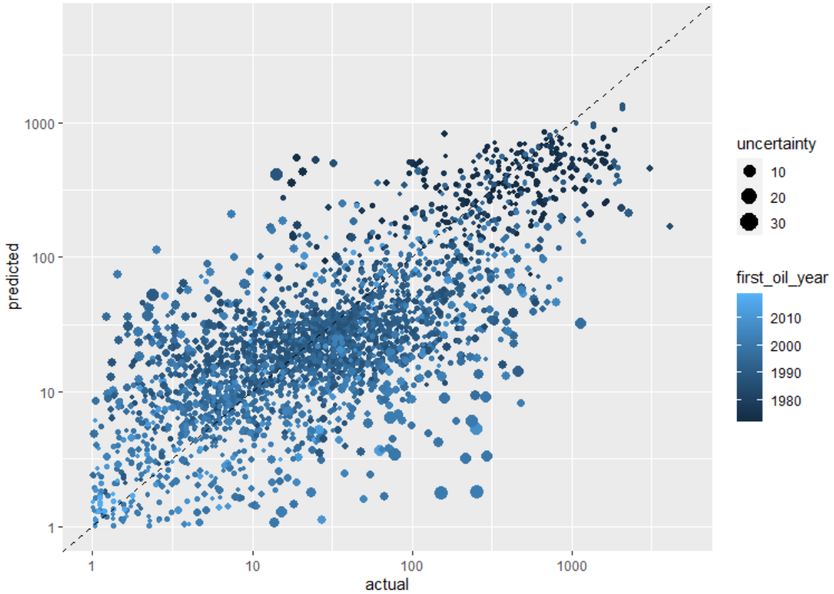
Technical Analysis | Technical Screening – BCO



- BCO is the WPO term used to zones that haven't been produce yet from a well.
- BCO workflow predicts oil production gain with ML model trained from already-produced completions with these 3 main inputs to generate >50 features:
  - Petrophysical Data
  - Subsurface XY
  - Produced completion historical Production Data

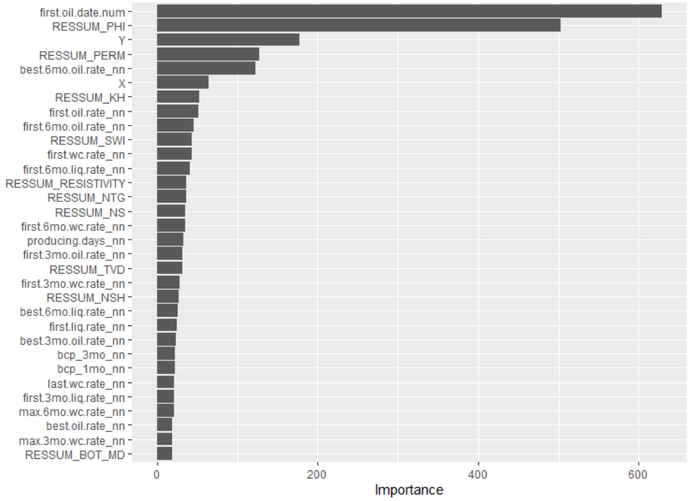
Technical Analysis | Technical Screening – BCO

- **Input Datasets:**
  - Production History (generated tens of variables from time-series statistics. Use as is for training data, and neighboring aggregated value for BCO candidate prediction)
  - Petrophysics (Swi, KH, etc.)
  - Subsurface coordinates (X,Y)
- **Target:** $\log(first.3mo.oil.rate)$
- **Features:** Top 32 variables of from feature importance
- **Selected Model:** Random Forest
- **Performance:**
  - **N** = 3338
  - **Out-of-bag R^2** = 0.77
  - **Out-of-bag RMSE** = 0.508 (log scale)



Test (OOB) Actual vs Prediction Plot

Feature Importance chart, top 32 variables represent 90.5% of total scores



Technical Analysis | Technical Screening – BCO - Result

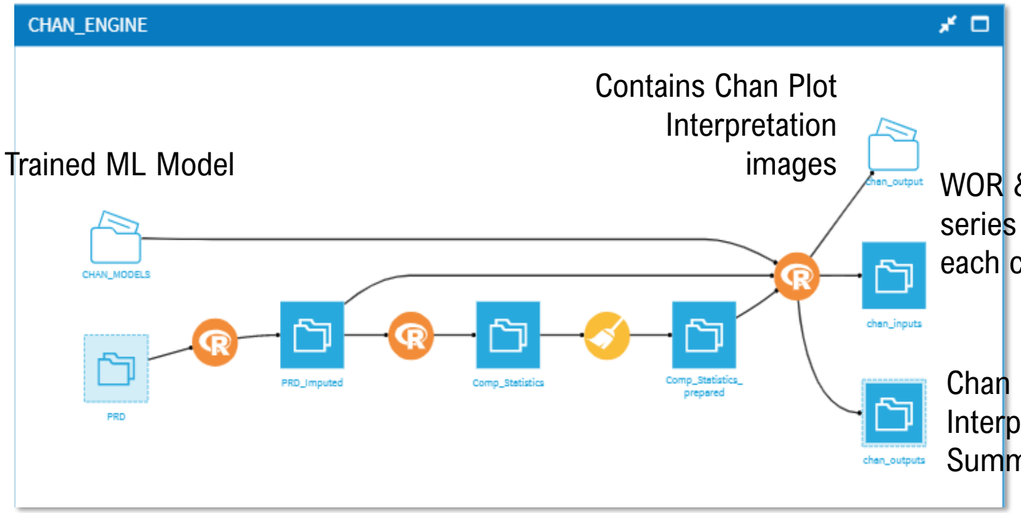
- The raw results of BCO predictions in Dashboard – ***Pre-filter Analysis***

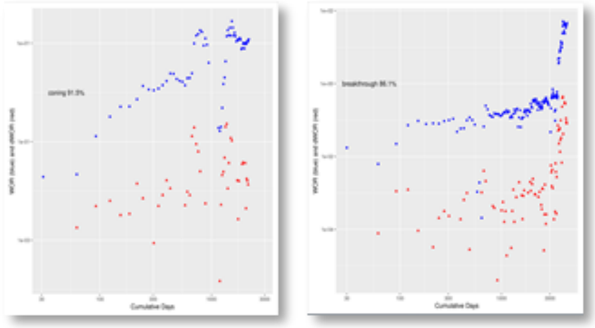
In BCO specialized dashboard, aside from the BCO result, information about the DCA parameters retrieval can be shown, and the top features values are also shown to the users

The greener the color, the less uncertainty it has. The bigger the radius, the higher the oil rate. The plot is done on marker basis

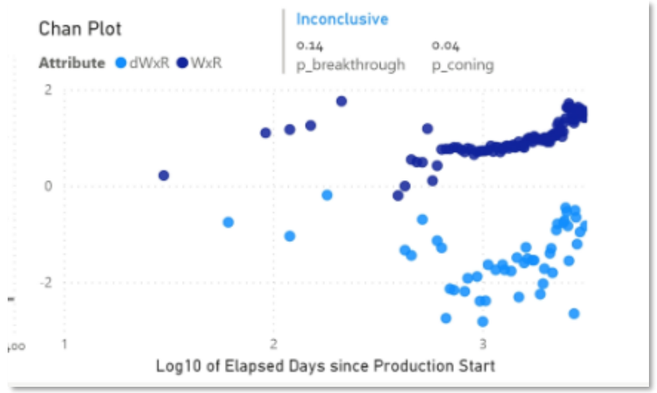
Technical Analysis | Job Scoping – Example: Chan Plot ML

- **Classify Chan plot signatures** into one of these major patterns with trained **Machine Learning Model**
  - Near-wellbore breakthrough
  - Water coning
- Inputs
  - Water-to-oil ratio time series for oil wells
  - Water-to-gas ratio time series for gas wells
  - Water cut time series
- Methodology
  - Feature engineering using non-parametric change-point and slope estimation algorithm
  - Logistic regression models for pattern classification





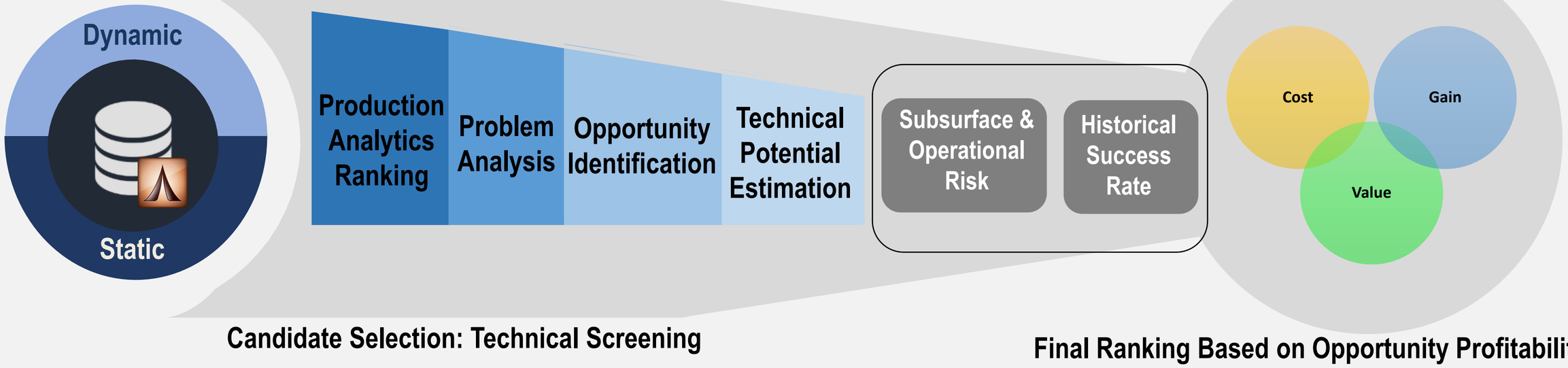
Chan Plot in **chan_output** Folder



Chan Plot in WPO Dashboard

Technical Analysis | Job Scoping – Example: Chan Plot ML

Solution Approach | Chance of Success



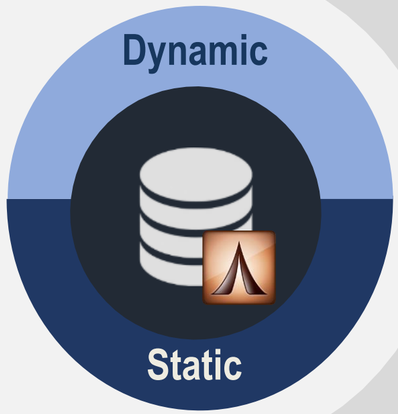
Candidate Selection: Technical Screening

Final Ranking Based on Opportunity Profitability

Knowledge Base | Technical Analysis | Chance of Success | Economic Analysis

Solution Approach | Economic Analysis

$$EV = NPV * (1 - Risk\ Factor) * Historical\ Success$$



Production Analytics Ranking

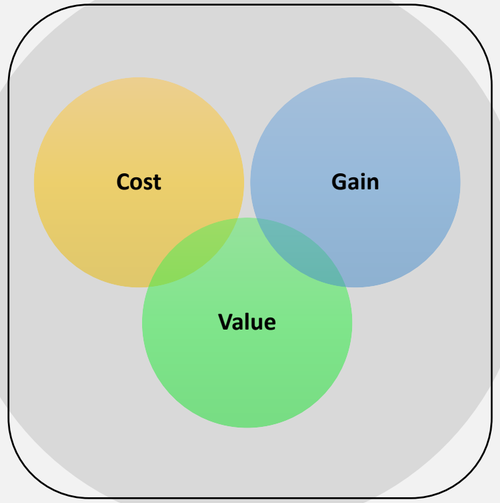
Problem Analysis

Opportunity Identification

Technical Potential Estimation

Subsurface & Operational Risk

Historical Success Rate



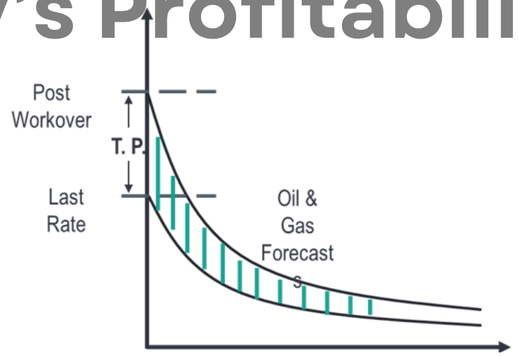
Candidate Selection: Technical Screening

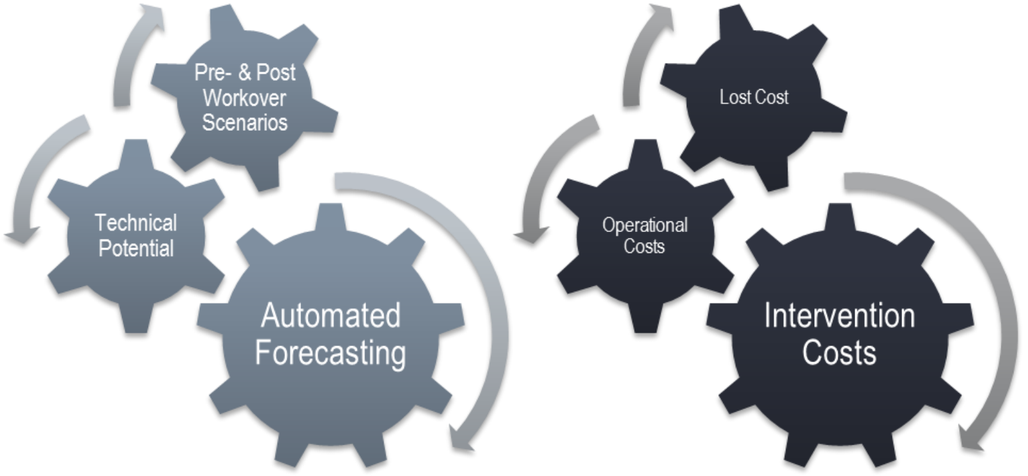
Final Ranking Based on Opportunity Profitability

Knowledge Base | Technical Analysis | Chance of Success | Economic Analysis

Economic Analysis | Opportunity's Profitability

1. Cost Vs Gain Analysis
2. Incremental NPV, while accounting for:
   - Inflation
   - Oil & Gas Price Model (ICP)
   - Production Sharing Contract (PSC) Model
   - Discount Factor
   - CAPEX, OPEX
   - Opportunity Gain
   - Taxation
3. Estimated Opportunity Value (EV)
   - NPV
   - Risk Factor
   - Historical Success





Total Opportunity Gain (bbl)

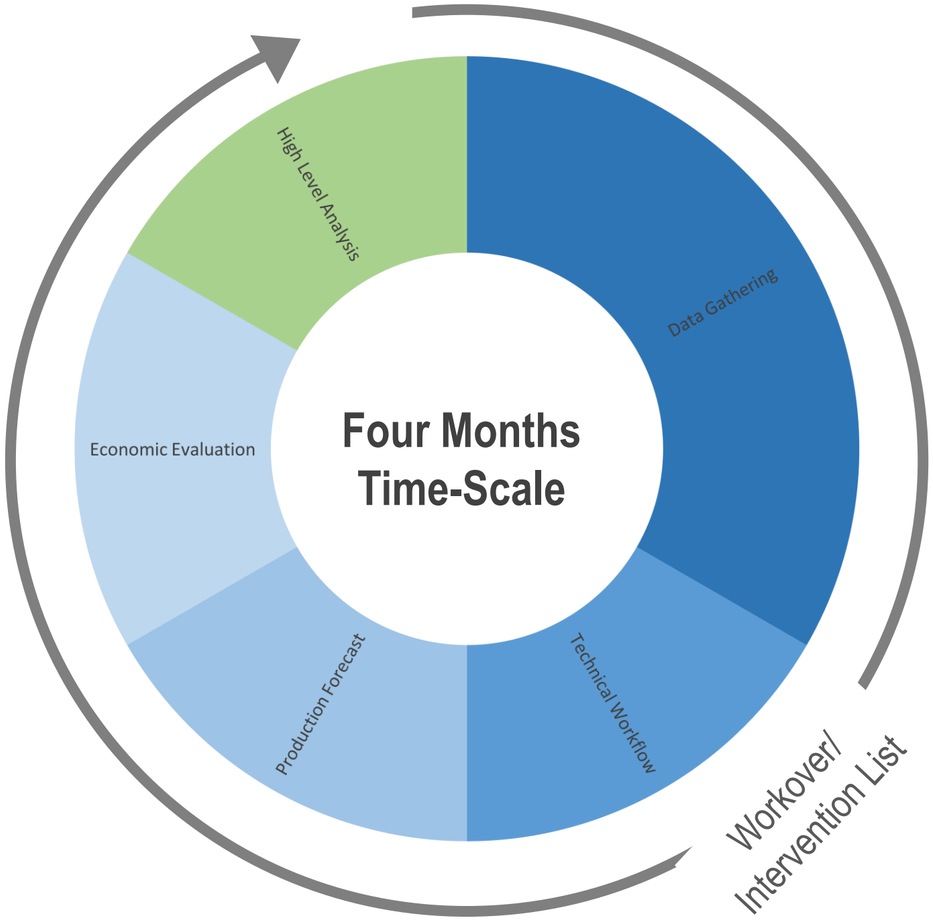
Total Opportunity Cost ($)

EV = NPV * (1 – Risk Factor) * Historical Success

Enhancement Opportunity of Existing Well Portfolio Processes

Previous State

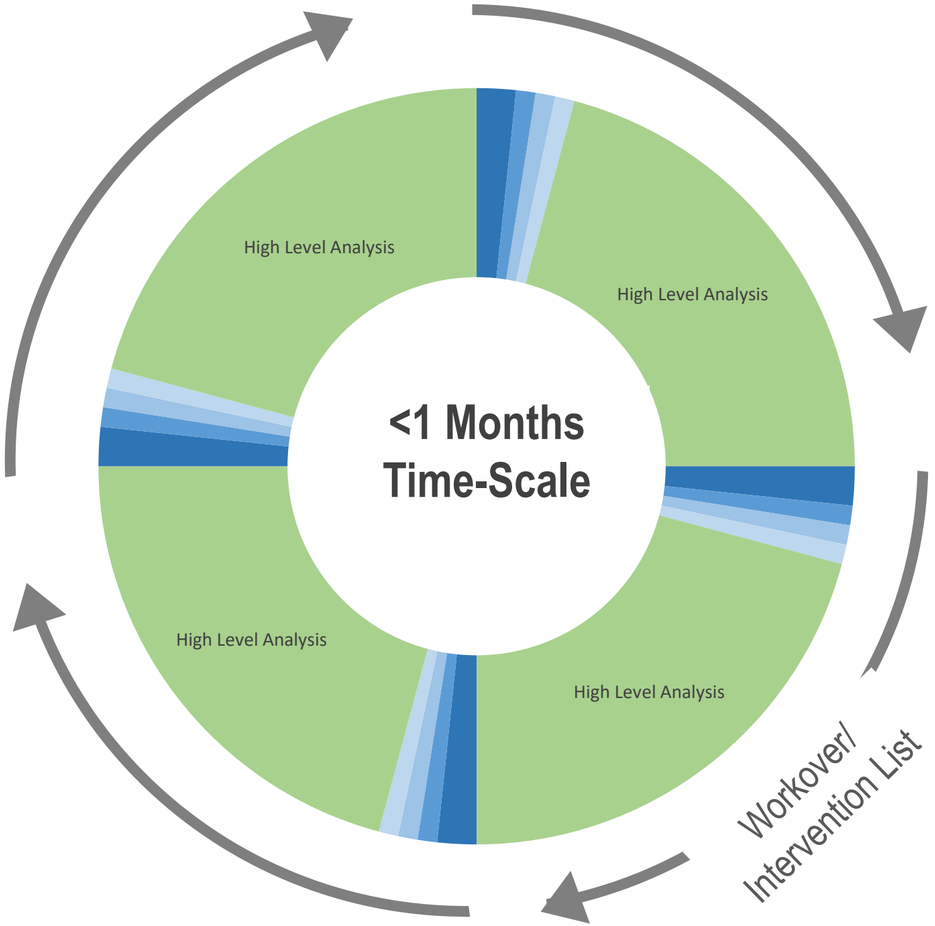
One Opportunity List Generated



Solution

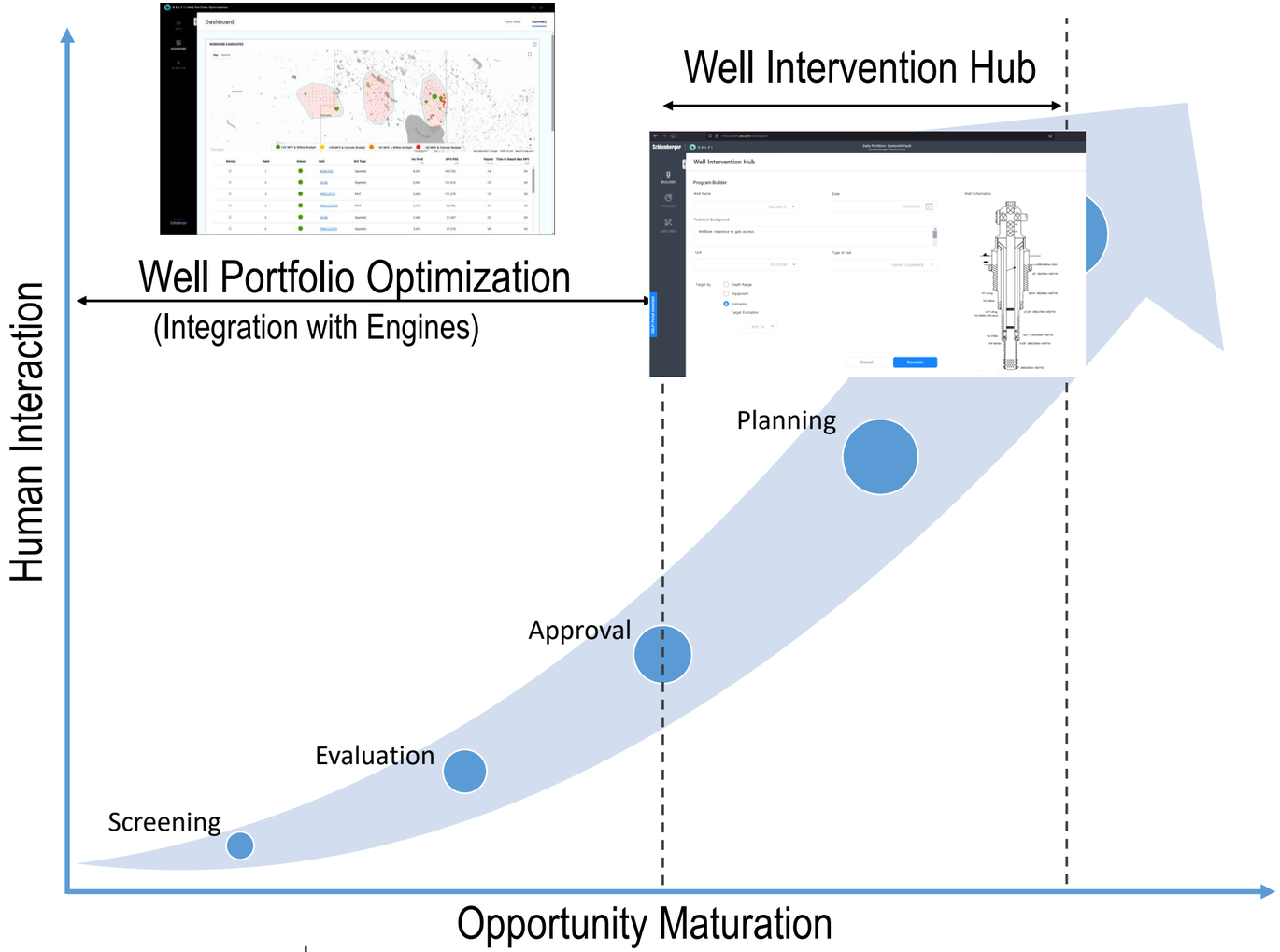
Well Portfolio Optimization

Four Opportunity Lists Generated



Production Enhancement

Automate Maturation Process



Stage 1 Rapid Screening (Analytics)

- Identification of underperforming wells
- Recommendation, Potential Gain, Chance of Success
- Based on historical lookbacks

Stage 2 In-depth Evaluation

- Detailed technical and economical study
- Develop business case for select candidates & prioritize
- Generate comprehensive report

Stage 3 Approval/Rejection

- Final opportunity evaluation by decision makers
- Analysis refined in context of current economic setting
- Opportunity sent back to screening pool or escalated

Stage 4 Intervention Planning

- Detailed job design
- Plan logistics (Materials, Equipment, People)
- Risks and mitigations

Stage 5 Intervention Execution

- Execute and track planned intervention
- Lookback (Actual vs. Planned)
- Enrich knowledge base

Thank you, questions?