WHITE PAPER

PREDICTIVE ANALYTICS AND DYNAMIC OPTIMIZATION: THE SWEET SPOT IN REFINERY PLANNING

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Refineries generate huge quantities of data, but most refiners operate in silos and consequently, refinery operations cannot capitalize on digital technologies. The digital ecosystem maturity of oil and gas enterprises - and their refineries - varies from asset to asset and from region to region. In several instances, refineries operate in isolation and are managed as a manufacturing unit with operational constraints. A digital refinery strategy developed for a single asset such as a refinery is bound to face challenges during implementation and operation.

An advanced digital ecosystem, low industry barriers, and new avenues for cross-functional products and services are flattening siloed oil and gas services and markets. In an industry strongly focused on margin optimization, refinery planning and optimization is a focus area since margin management has become a business imperative to address crude price fluctuations.

Refinery planning: A reality check

In the past decade, refiners invested in assets to monetize a wide range of crude variants. This enabled refiners to open new revenue streams and even improve operating margins. For such an initiative, planning and scheduling of refinery operations is a key process while faster linear programming (LP) models and assay analysis are also critical business factors. Oil and gas enterprises enhance operational performance using simulation models to update parameters of planning and scheduling.

It was a turning point in harnessing data from plant systems. Oil and gas enterprises implementing data integration saved millions of dollars by continually adjusting planning models to reflect actual properties of crude oil to be processed.

This approach is based on an iteration of steady state simulation models with planning models to determine the best available plan. However, it does not consider the dynamic nature of operations within a refinery, which depends on crude slate switches, equipment performance, and crude quality, all of which vary over time.

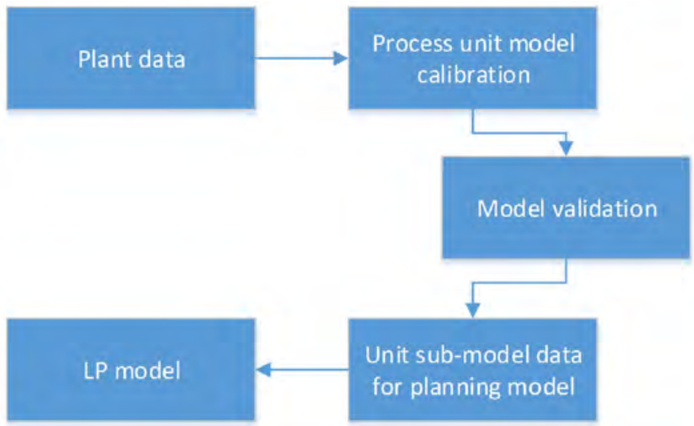

Figure 1. Integration of engineering models with planning models

Predictive analytics – Equipment and crude quality

The impact of equipment performance degradation

Refineries gather a huge amount of data through advanced process control (APC) and manufacturing execution systems (MES) to analyze equipment performance. The data can be used to predict equipment performance using dynamic models that reflect operational conditions. It is not possible using simulation models as they assume steady state of operations. Dynamic models have a self-tuning ability ensuring:

- Optimal operating conditions of the equipment are proposed without compromising safety or quality
- Areas of concern are highlighted when performance is predicted to be less than the threshold
- Predictive maintenance can support operations by utilizing advanced analytics models
- Prevention of unnecessary shut-downs and management of maintenance activities more effectively.

A refiner's ability to distill business insights as part of the constraints for refinery planning will deliver more realistic economic optimization models. These models will provide business intelligence for more accurate and informed decisions. Moreover, continuous analysis will highlight areas where investment is required for equipment upgrades.

Quality of crude oil varies between locations and time intervals

Another parameter that affects refinery optimization is the quality of crude oil which may vary from the expected or contracted quality specifications at the loading port. The contractually agreed quality specifications data is usually available in the trading system of record which is captured at the time of signing the deal. The actual crude quality data measured at discharge can be used for analysis of trends and to understand how:

- The quality for a specific grade of oil during loading varies against the contractual quality across a specified time period for a port.
- The load and discharge quality for a given trip and grade varies between two locations for a specific time period.

By adopting this approach, quality can be predicted for long-term economic planning of the refinery. The scope can be enhanced to cover the quantity for completeness as it can vary due to different conditions at loading and discharge points.

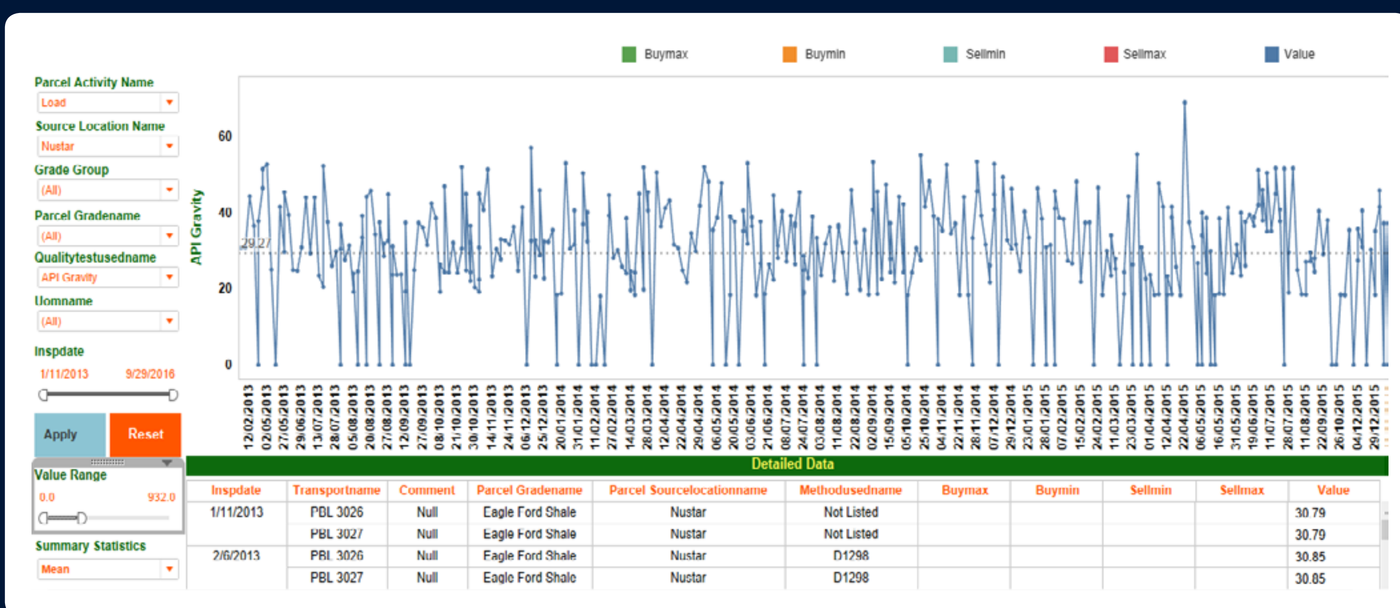

Figure 2. Refinery crude quality analysis between load and discharge ports

Data from Figure 2 can be used to generate better inputs for the refinery planning process as part of creating sub-unit models for more realistic workflows and performance based on expected yield.

The multiperiod planning model adjusted to the crude grade switches will provide more accurate economic optimization compared to a coarse monthly model usually deployed for this purpose.

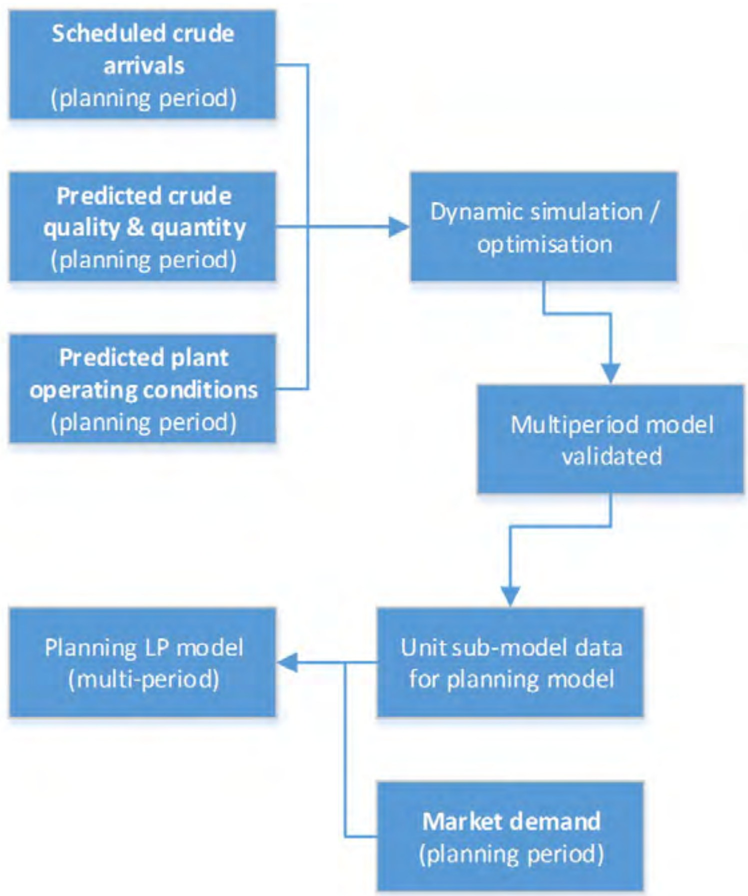

Figure 3. Dynamic simulation and/or optimization enables modeling using predictive analytics.

Superior refinery scheduling

Steady state operations do not provide refinery planning accuracy

Refineries continuously switch between sources of crude oil and intermediate feedstock to optimize gross margins. Operations at a refinery are highly non-linear, requiring calibration of the overall process. Although simulations can be used to gain insights, dynamic optimization provides a step change in managing the process. Simulation models assume a steady state operation during the planning horizon of the LP model and are based on historical data to calibrate certain parameters or calculate properties. It can be inaccurate especially during the switch between grades of crude oil for multiple reasons. Dynamic steady state operation can increase profitability by optimizing the cost of crude oil and utilities against certain product prices.

The yardstick for performance of any model is matching the quality of crude oil as closely as possible to the expected range. Predictive analytics can be used to accurately estimate quality of oil, as discussed earlier. Predictive analytics combined with dynamic steady state models can improve refinery economics and more specifically, refinery scheduling.

Getting the crude oil quality right

Once crude oil characterization data determines the suitability of crude oil to be processed, the specific grade of crude oil enters the stock together with other grades of crude oil. The overall crude properties vary and if there is a lack of assay data, it will determine the operating conditions. While a lot of effort goes into maintaining consistent quality of crude oil, it cannot be guaranteed, resulting in quality variations.

The transition of the refinery from one grade of crude oil to another using steady state models to manage the schedule results in equipment operating in sub-optimal conditions and inability to maximize the expected yield. It results in the loss of critical key components that can be used to generate higher margins. We can address this challenge by adopting a different approach in refinery scheduling where the LP runs more frequently and receives continuous input from dynamic optimization models that offer better visibility of operating conditions. These models will run in conjunction with market models, which will reflect in the market demand improving the margin by adjusting the objective function to meet demand and product mix requirements.

Making the process faster to respond to changing crude oil and market conditions

In this iterative process, a schedule is produced on a daily or shift basis (mainly around blending and batch or semi-continuous processes) to capture changes in market demand. These decisions feed into the dynamic optimization model which in turn determine optimal operating conditions for equipment using up-to-date information. The iterative process can be automated to converge based on certain criteria.

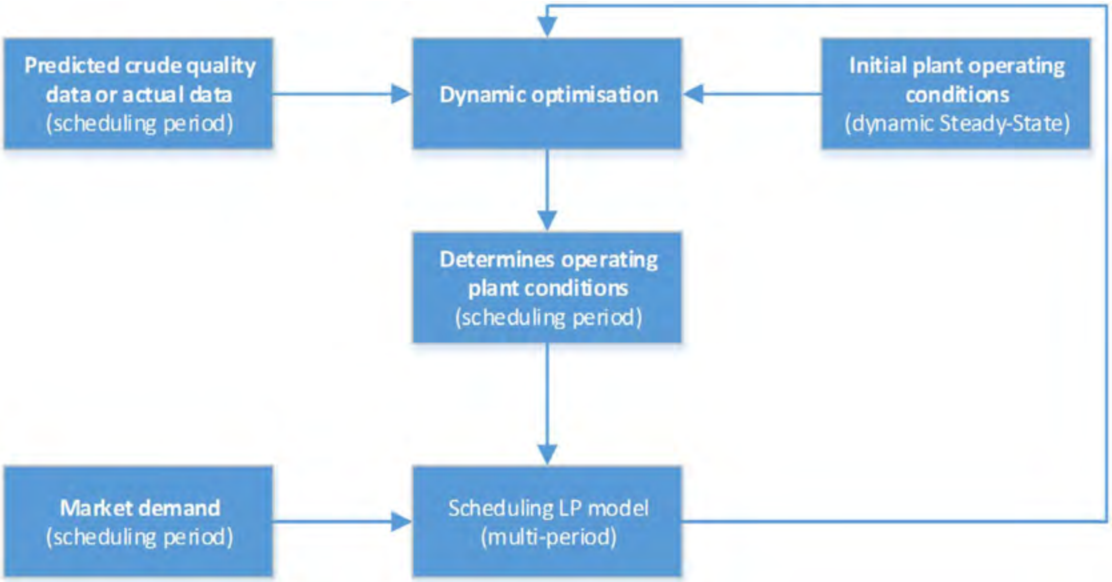

Figure 4. Refinery scheduling can benefit the most from dynamic optimization

Initial research conducted with models to predict the performance of crude distillation units reveals above par accuracy, which holds promise for significant improvements in overall margins.

Why predictive analytics and dynamic optimization

As enterprises become data-driven, barriers are coming down between organizational and operational siloes.

- Weak and fragmented analytics are being replaced with unified physical and virtual worlds where planning and operations are tightly coupled.
- Asset performance is at the center of a cloud-based connected ecosystem with the refinery performing a pivotal role in maximizing oil value either for fuel or petrochemicals.
- Volatility in the price of oil makes the selection of crude oil grades highly diversified leading to a number of different grades and qualities, often interchanging in short timeframes.
- Demand is changing rapidly and frequently as the market also uses advanced analytics to optimize supply.

New mathematical optimization approaches powered by a huge amount of data and computational power will create new business opportunities to maximize profits.

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Acknowledgement

The authors thank Professor Costas Pantelides of Imperial College London and Managing Director of Process Systems Enterprise for his feedback and insights.

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