# Deliver sustainable benefits through site-wide process digital twins

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Refiners have used offline process models for decades. The next generation of solutions is anticipated to operate automatically, integrate with legacy systems and provide transparency site-wide.

Although the definition of a "true" digital twin is still under discussion, industry leaders are nearing agreement on what defines a process digital twin (PDT). The PDT uses the first principles modeling approach embedded in the process simulation tool. A PDT provides a deeper level of analysis compared to raw data and basic measurements. All inputs in PDT are connected, and it operates automatically to estimate intrinsic key performance indicators (KPIs). Furthermore, PDTs operate in an open-loop advisory mode. As a result of implementation, the solution estimates the benefits or lost potential that requires the operator to take action. Additional information on PDTs is available in literature.[1]

Since process units within a refinery are highly integrated, changes in key operating variables can impact the overall refinery operation and product blending. A PDT of one unit can be used for enhanced unit monitoring, but the improvements in one unit must be evaluated at the refinery level. Refinery-wide flowsheets accurately depict this effect as all process units are interconnected. Non-linear kinetics or equilibrium models in the flowsheet represent the conversion units. Fractionation models capture the efficiency of separation between different cuts or components. Additional information on refinery-wide flowsheets is available in literature.[2]

**Benefit realization.** A major driver of performance improvement in large organizations is the visibility of consistent information. Visualization serves a critical role in identifying and effectively communicating lost potential and variables associated with performance improvement. To resolve challenges associated with inconsistent information, the PDT can be used as an analytical, computational and reporting tool.

KPIs are calculated using first-principles models, which minimize custom calculations and the reliance on individuals. Centralizing the PDT ensures all stakeholders have access to the reported results, establishing a single version of truth. Everyone using these results allows strong governance systems to avoid dependence on individuals.

The PDT facilitates an efficient and standardized methodology to ensure plant data, linear programming (LP) predictions and nonlinear model performance are synchronized. Having accurate data as inputs to the LP is critical to make informed commercial decisions regarding operational changes and production planning. Parameters calculated by the PDT provide comparison of performance of tools vs. the actual unit operation that are tracked in real time, improving the confidence level of the tools' users.

Though automation and visualization provide value, quantifying these intangible benefits can be difficult. However, opportunities identified through consulting practices applied during the PDT's construction, analysis and monitoring can provide tangible and quantifiable benefits (**FIG. 1**). Building the PDT for a unit and overall site requires an understanding of the operating strategies before analyzing the data. During the in-depth brainstorming session, marginal mechanisms and constraints are identified and later validated using the operating data.

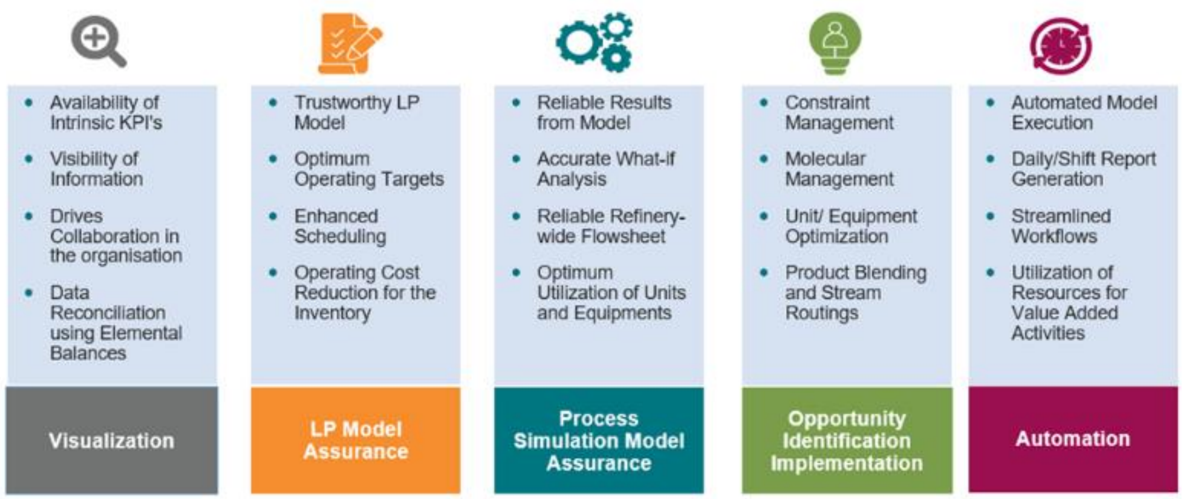


**FIG. 1.** Benefits from a PDT.

The PDT calculates KPIs to identify additional areas for improvement. This is especially true for KPIs that are difficult to estimate and are rarely calculated during normal operations, such as flooding in distillation columns. PDTs are continuously validated to accurately represent the asset over its full range of operation. Variations of selected KPIs that occur during a day, week or season highlight areas to boost the process unit's performance.

A refinery-wide flowsheet is a preferred tool for evaluating opportunities. It captures how changes to one process unit will affect other units and in product blending. Due to the interdependencies of various operating parameters within process units, changes are assessed one step at a time using the flowsheet. This approach is used to identify improvements in operating strategies rather than achieving optimum values from the simulation. Although the flowsheet provides quantitative analysis of an opportunity, it is essential to focus on identifying better strategies rather than targeting specific values. It is also important to establish a unique margin improvement indicator (MII) that can demonstrate improvement in the operating strategy. The flowsheet provides a quantitative analysis of the change in MII vs. yield shifts for refinery products.

**Benefit sustainment.** The benefits realized through the deployment of a PDT require a methodology to sustain them. While most gaps become evident from the operating data, closing these gaps requires continuous monitoring. To ensure opportunities are continuously sustained and the benefits are realized, the application is equipped with profit tracker software[a]. Using a proprietary methodology, the software[a] continuously calculates and tracks the opportunities' status and benefits. Monitoring gaps through this software[a] extends beyond measured variables such as pressure, temperature and flow to focus on its value.

The individual opportunities are configured in the profit tracker software[a], along with the MIIs, which are some of the important inputs. Primary and secondary MIIs are identified. Then, stakeholders agree upon each opportunity before tracking. Any incorrect MIIs may overestimate or conceal the opportunity's value.

During the opportunity evaluation phase, the benefits are estimated using an agreed price-set. The product prices and cracks regularly change. The profit tracker software[a] allows benefit tracking using different price-sets, such as the base price-set used during evaluation and constantly updated actual prices.

The software[a] automatically provides the status of each opportunity. The implemented benefit or lost potential are estimated site-wide, creating a cultural change where unit monitoring is combined with its impact on profitability.

**Sustainment of solution.** Sustaining digital technologies is as important as its implementation. When introducing new digital technologies like a PDT, support is needed from both the people and work processes.

Various work processes that use a PDT for unit monitoring, model assurance and maintenance must be established. Each step in the process must be mapped using a responsibility assignment (RACI) matrix. This comprehensive chart identifies the individuals or teams as responsible, accountable, consulted and informed for each step. The organization must agree upon which action items must be documented and communicated. While documentation is important, ownership of the process is more important with regards to work processes. Hence, the people involved in the PDT deployment, utilization and maintenance are critical.

PDT requires stakeholder engagement at different levels. Familiarization with the overall program as well as seeking and incorporating feedback are key steps in PDT rollout. Furthermore, communicating how the PDT will streamline their workload rather than increase it is required. Deploying the PDT must be supported with comprehensive training to empower end users to use the information and tools independently. A transition phase that transfers ownership from the PDT development to its continuous use improves the ownership of the solution.

## CASE STUDY

Saudi Aramco and the co-author's company collaborated to develop site-wide PDTs for the Riyadh Refinery Division (RRD), located in Kingdom's central area. The RRD produces light and middle distillates from crude oil using various fractionation and conversion process units. RRD operations, RRD technical services, RRD process automation, Aramco Advanced Solutions support and the co-author's company collaborated on this project.

As a primary project objective, improving the refinery's profitability was achieved with the following goals:

- Estimate intrinsic KPIs for the unit monitoring
- Maintain the model's accuracy
- Identify opportunities and sustainable benefits
- Automate and visualize unit performance.

The project started with roundtable discussions for various process units. During these sessions, key operating strategies to be included in the PDT were discussed. This was followed by the analysis of operating and design data.

The project team prepared a preliminary design based on the project's objective and goals. The KPIs to be configured in the PDT were derived based on the co-author's company's best practices, data analysis and roundtable discussions. A workshop was conducted to brainstorm and agree upon the KPIs for the PDT. The KPIs were used to determine the model's complexity. Furthermore, data quality parameters (DQPs) and model performance indicators (MPIs) were also identified in the preliminary design.

The PDT prepared for RRD included rigorous simulation of reactors using first-principles kinetics or equilibrium-based models within the co-author's company's simulation software[b]. The simulation also included major distillation columns, fired heaters and other key equipment in the process units. The reactors were calibrated based on the operating data, and the simulation performance was continuously validated. Simulation also reflected the results estimated by the LP model to monitor its accuracy.

The important inputs for the model execution were identified in collaboration with RRD operations and technical services. The models were integrated with the historian to convert the transition from offline to online mode. Infrastructure was prepared for the deployment of the models onsite. Models were scheduled for auto-updates to streamline the execution, KPI estimation and dashboard updates.

KPIs, DQPs and MPIs were configured in the models to monitor the process units, equipment performance, data quality and model health conditions. These parameters included reconciled values and intrinsic KPIs for equipment performance. Dashboards deployed alongside the models were linked with the parameters estimated by the models. The dashboards provided consistent information to end users, including refinery staff and various central support team members, as shown in **FIG. 2.**

**FIG. 2.** PDT dashboards.

All models developed for the project were combined in a refinery-wide flowsheet. The main feed for the flowsheet was crude, and the product streams simulated in the flowsheet represented the refinery's finished products. **FIG. 3** shows a screenshot of the flowsheet.

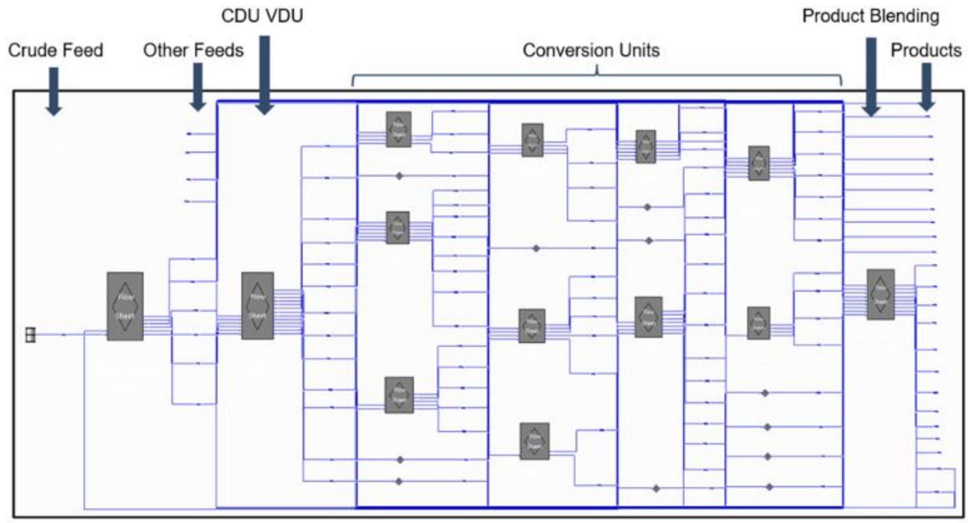


**FIG. 3.** RRD's refinery-wide flowsheet.

The main purpose of the flowsheet was to evaluate enhancement opportunities, which were selected through a screening process. Detailed techno-economic evaluations were discussed with different stakeholders, and select opportunities were approved for implementation.

The payback period of the program was less than 3 mos based on the identified and approved benefits. In addition, deploying the PDT offered intangible benefits such as improved data reconciliation, identifying erroneous measurements, data visibility, collaboration and automation.

A digital tracker was deployed to monitor the status of the opportunities daily. The profit tracker generated monthly reports for each opportunity and the overall program. This methodology sustained benefits implemented through a PDT.

The project development included various stage-gate reviews and agile methodologies to incorporate the feedback. Incremental delivery was adapted in which a prototype was delivered in the early stages for alignment with the project team. Detailed training sessions and assessments were conducted to improve ownership of the solution. The project also included the delivery of work processes and RACI matrix for solution sustainability.

**Takeaway.** Refiners are increasingly showing a keen interest in a PDT driven by the need for streamlined production operations, coupled with recent advancements in data collection and reporting technologies. Implementing a site-wide PDT facilitates the integration of process units, which enables global optimization. This strategic approach for PDT deployment not only improves the refinery's profitability but also provides sustainable benefits and solution. Additionally, PDT fosters improvements in data reconciliation, model assurance, information visibility and collaboration. **HP**

**NOTE**

a. Profit Tracker®
b. Petro-SIM®

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2. Chellani, J. and A. Al-Sariyahi, "Best practice for refinery flowsheets," *PTQ*, Q3 2019.

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