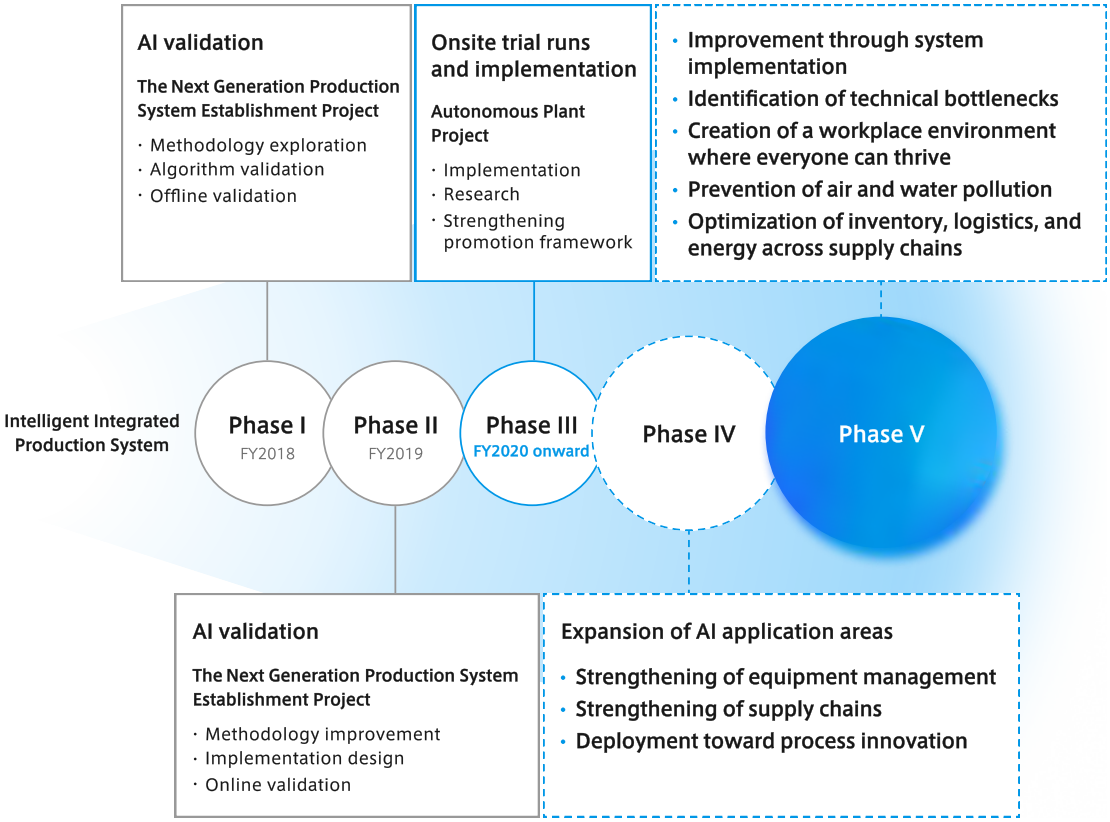
3 Human-machine Coevolution

Collaborative environment for people and AI that fosters opportunities for growth

The Autonomous Production System, which utilizes two proprietary AI applications—**PCM (Plant Capability Maximizer)** and **APS (Advanced Prediction System)**—does not optimize plant operations automatically simply by being implemented. This is because gaps can arise between optimizations derived from the know-how of seasoned operators - programmed into the AI- and actual performance data from the production floor. It is important to assiduously verify these gaps and uncover new know-how and insights that had previously gone unnoticed. This process leads to the clarification of weak points in our manufacturing operations as well as the reaction logic based on chemical engineering principles that has not yet been fully established as technology.

Milestones for building the Autonomous Production System



Effects of the PCM (Plant Capability Maximizer)

Enabling decision-making to pursue better performance indicators

The PCM can predict quality status in real time, which has made it possible to aggressively pursue operating conditions that meet both quality and cost needs. In manufacturing at chemical plants, raw material quality is not always uniform, making the control of raw materials difficult. For example, pulp, the raw material for cellulose ac-

etate, is a natural product and is easily affected by temperature and humidity, making it a challenging material to handle. Previously, the sentiment was that ensuring consistent quality was the priority, even if the costs were somewhat higher, in order to achieve stable production.

However, the PCM not only allows quality status to be understood at a glance but also predicts quality when conditions are changed, removing any resistance to adjusting those conditions. Previously, there was no perceived need to take risks by adjusting conditions as long as production was stable, whereas it is now possible to make decisions to improve each indicator even if just slightly.

Effects of the APS (Advanced Prediction System)

Reducing reactive responses during abnormalities and enabling a shift to proactive work

A major effect of the APS (Advanced Prediction System) is a significant reduction in response time when an abnormality is detected. For example, when the performance of some equipment in chemical plants dropped, operators previously had to rush to the floor to check the situation, and time was needed after that to consider countermeasures. In chemical plants, halting equipment means halting production itself, so operators search for ways to recover by adjusting other settings without halting equipment. However, because decisions had to be made based on a variety of complex and interrelated condi-

tions at that time, the consideration of countermeasures required a lot of time.

The APS, on the other hand, continuously monitors the conditions of equipment and immediately indicates the necessary recovery actions if a drop in equipment performance is about to occur. Tasks that were previously driven by reactive responses can now be shifted to proactive work.

Achievements of the APS (identification of causes for abnormalities) and PCM (derivation of optimal operating points)

1

Reduction of variability by the APS

Prevented opportunity loss for 128 batches/year through the implementation of preventive measures by detecting problems early

(Ohtake Plant Cellulose Plant)

2

Optimal operations by the PCM

Produced the desired quality by adjusting the conditions for a group of factors identified using our logic tree

3

Human growth and creation of new insights

Generated new insights through online verification and logic review meetings based on our logic tree

4

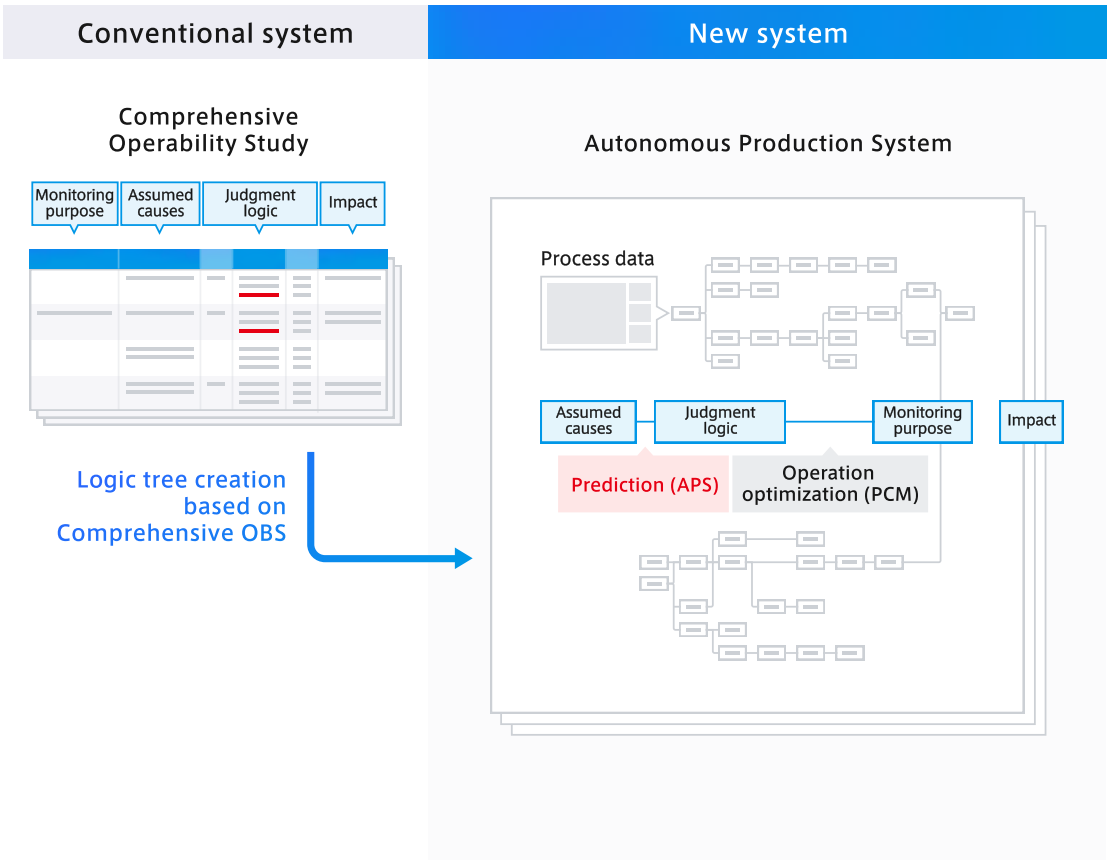
Expansion of the application scope of the Autonomous Production System

Horizontally deployed the System across plants with diverse production formats to promote efficient AI and system improvements through the sharing of challenges

A cycle of growth is created by gaining insights from AI

and having the AI learn the human insights deepened through that process

In the Autonomous Production System, the AI logic has been developed with the aim of preventing it from becoming a black box. One of the key elements that made this possible is Daicel's proprietary logic tree, which was created based on a Comprehensive Operability Study. In this proprietary logic tree, causal relationships, from cause to effect, are organized into a tree structure for abnormalities occurring in the plant. In other words, whereas we previously looked at one step before and after, this has now been extended to looking at five steps before and five steps after so the cause-and-effect relationships can be better understood.



To optimize plant operations or detect operational abnormalities, multiple factors must be taken into consideration. For operators, it can sometimes be difficult to understand why a certain result occurred. By visualizing the phenomena that occur based on Daicel's proprietary logic tree, it becomes possible to understand the flow of cause-and-effect relationships, almost as if looking inside the mind of a seasoned operator.

Furthermore, by promptly having AI learn and utilize new know-how, machines evolve while people grow by achieving even more advanced manufacturing. The Autonomous Production System is a system that creates a continuous cycle in which people and machines grow together.

Objectively viewing and understanding the principles (connections of cause-and-effect relationships) presented by AI without being bound

by conventional wisdom provides the push to execute ideas like "Wouldn't it be better if we did it like this?" or " Wouldn't it be possible to try this approach next time?" As an example, it has led to major improvements, including the optimization of raw material usage rates and other factors in the manufacturing of cellulose acetate. Through implementation of the Autonomous Production System, we believe that the work of operators will change even further in the near future.

At present, monitoring and detection of abnormalities in plant operation are performed by people; however, AI will also be applied to the know-how involved in such abnormality detection. By further increasing the range of tasks that can be entrusted to machines, operators should be able to devote more time to creative work that only people can perform. In a market where needs are constantly changing, we are aiming for a production floor that thinks for itself and collaborates with sales, procurement, purchasing, and logistics departments, as well as with customers, to respond to change and create added value unique to Daicel. By increasing opportunities for operators to actively test their own ideas through the Autonomous Production System, Daicel's manufacturing capabilities will become even stronger.

Word List

PCM

Plant Capability Maximizer. This is one of the proprietary AIs used in the Autonomous Production System. It predicts indicators for safety, quality, production volume, and costs in real time, deriving optimal operating conditions to maximize each of these indicators.

Operators

These are on-site operators responsible for the operation, monitoring, and management of plants and facilities. They include field operators, who walk the floor conducting inspections on-site, and board operators, who monitor operating conditions, make judgments, and control operations from a control room.

Reaction logic

This is a framework for thinking and decision-making that organizes how chemical reactions and other processes proceed. It serves to maintain safety and quality.

APS

Advanced Prediction System. This is one of the proprietary AIs used in the Autonomous Production System. During production implemented in accordance with the operating conditions planned by the PCM, deviations from the plan can occur due to equipment failures or various environmental changes. To suppress these deviations, the APS detects early signs of abnormalities and adjusts the operating conditions to ensure operation as planned.

Know-how

This is a collective term for the knowledge, skills, and ingenuity gained through practical experience and on-site operations. These elements are essential for performing tasks safely and efficiently, and by organizing them into words or data, they become easier to share and pass on to others.

Chemical plants

These are plants and facilities designed to mass produce chemical products and materials by processing raw materials through various processes, including chemical reactions. Such facilities require safe and stable operations as well as optimized energy efficiency.

Cellulose acetate

Cellulose acetate is a semi-natural polymer manufactured using cellulose (plant fiber) derived from inedible biomass and naturally occurring acetic acid as raw materials. It is an environmentally and human-friendly material with high biodegradability. Featuring excellent chemical resistance and flame retardancy, it is used as a material for films, fibers, and other products as well as a raw material for plastics.