1 Purpose and Overview

Leveraging all know-how to find optimal solutions

The Autonomous Production System is based on the Intelligent Integrated Production System of Daicel Production Innovation, which was completed in 2000. In chemical plants that manufacture chemical products, raw materials are fed into equipment and undergo various processes, including reaction, extraction, distillation, and drying processes, to create products. In many of these processes, it is impossible to directly see inside the equipment. This is a major difference between assembly- and machining-based types of manufacturing, which allow you to directly observe products during production and assess the situation, and process-based manufacturing, such as in chemical plants.

For this reason, in chemical plants, operations are managed by monitoring data from a variety of sensors installed in each unit of the production equipment, and the know-how required for stable equipment operations while maintaining quality is accumulated within the minds of the operators responsible for plant operation. The Intelligent Integrated Production System created through Daicel Production Innovation is a framework that transforms the tacit knowledge of seasoned operators into explicit knowledge, enabling anyone to make appropriate operational decisions.

Assembly-based manufacturing	Process-based manufacturing
	
A type of production in which materials are processed into components, which are then combined to complete one product Automobiles / home appliances / electrical equipment / precision instruments / machine tools	A type of production in which products are manufactured by changing the properties of substances through chemical reactions and other processes Petroleum refining / steel / chemicals / energy

Daicel Production Innovation enabled stable operations and reduced significant quality issues, but it did not enable the full use of all the know-how distilled from seasoned operators. It is common for quality and cost decisions to be a trade-off, such as when improving quality leads to higher costs. Optimizing both characteristics requires the consideration of a vast number of elements. This made it difficult to systematize and implement. This is because it was necessary to process complex and massive calculations in a timely manner to aim for optimal operations that achieve further reductions in energy consumption, resource use, and costs while pursuing high quality based on existing know-how and skills. With the computers available in 2000, the processing power for this task was limited.

However, Daicel possessed data accumulated over more than 20 years.
All the know-how of seasoned operators was visualized through a Comprehensive Operability Study (Comprehensive OBS), which systematically organizes plant operations in terms of safety, stability, quality, and cost, and at the Daicel Aboshi Plant alone, this amounted

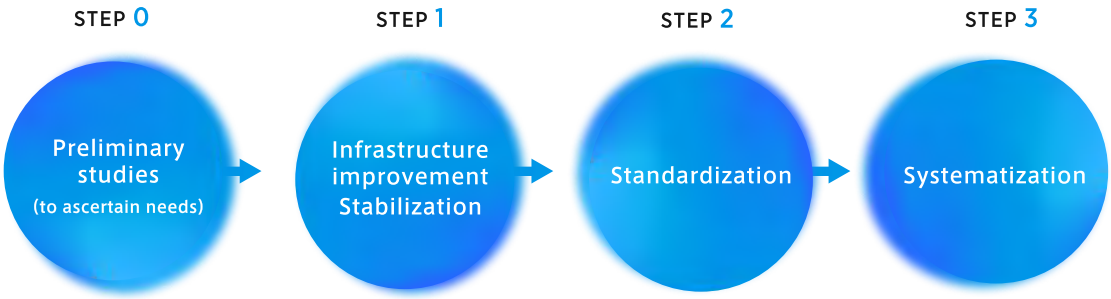
to 8.4 million bits of know-how.

The Autonomous Production System was born from the idea of making full use of the many years of organized and accumulated know-how leveraging state-of-the-art AI.

A team centered on young workers fostered at manufacturing sites collaborated with the University of Tokyo to develop an original AI application, and in August 2020, they completed the Autonomous Production System, an evolution of the Intelligent Integrated Production System of Daicel Production Innovation. Based on the 8.4 million bits of know-how distilled from seasoned operators, this system visualizes cause-and-effect relationships in manufacturing and uses proprietary AI to predict and calculate optimal solutions for them.

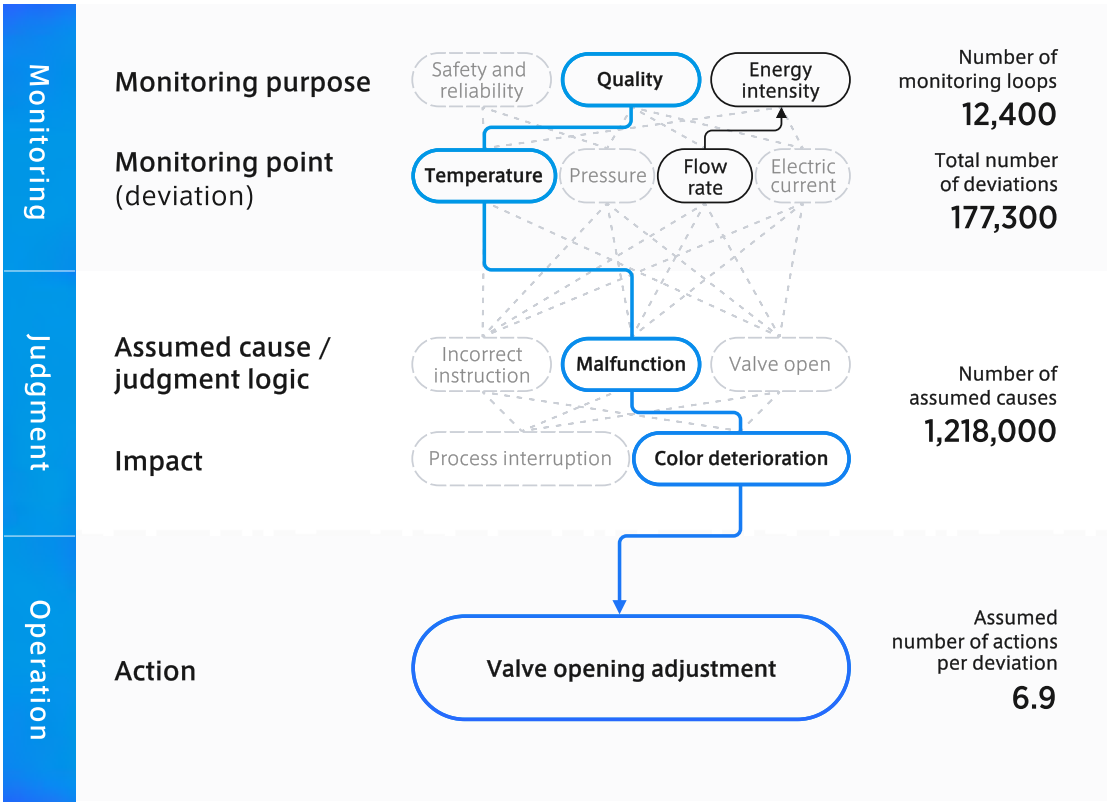
About Daicel Production Innovation: the foundation of the Autonomous Production System

Daicel Production Innovation advances through four steps: **preliminary studies** to ascertain the necessity of innovation, **infra-structure improvement and stabilization** to strengthen pro-duction infrastructure by reducing the on-site workloads identified in the studies, **standardization** of operations to universalize the stabilized state, and **systematization** to prevent regression from standardized practices.



Among them, step 2, **standardization**, is the step where the know-how of seasoned operators in plant operations is revealed, enabling anyone to perform the tasks. Key points for operation management, such as sensor information, are summarized for each operating pattern of connected plant groups from the perspective of safety, stability, quality, and cost and the viewpoint of manufacturing types and operating loads, and the decision-making flows executed by operators on the production floor are distilled and revealed. At this time, a Comprehensive Operability Study (Comprehensive OBS) is employed to systematically organize operations.

Decision-making flow within the Comprehensive OBS and total numbers revealed



Number of case studies at Aboshi Plant **8,367,000**

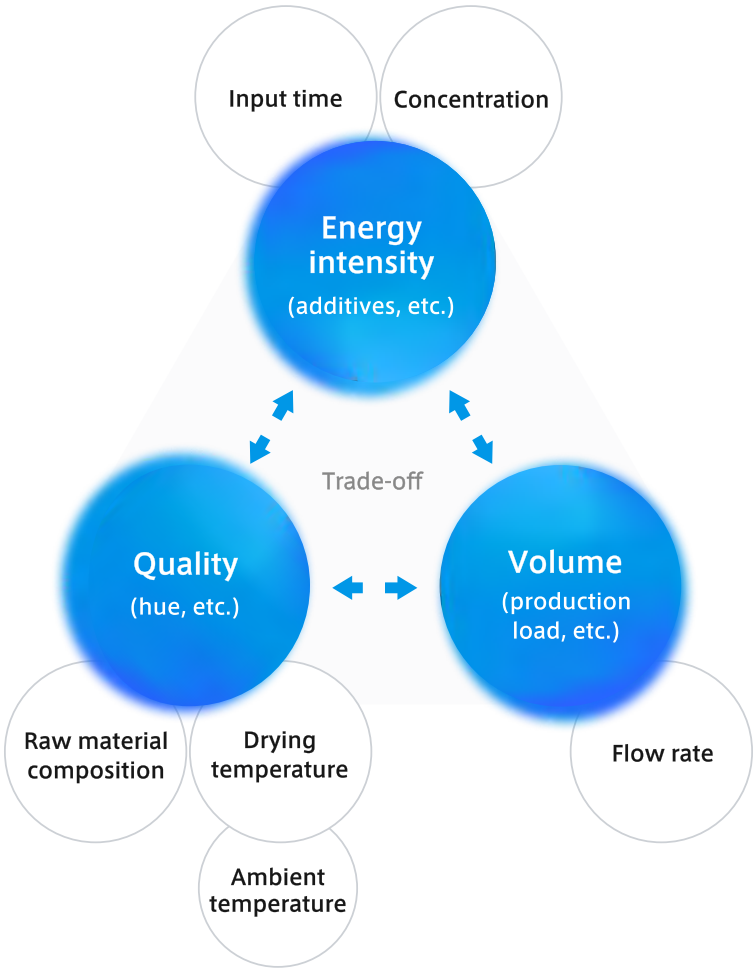
Furthermore, in step 3, **systematization**, the Intelligent Integrated Production System was built to prevent regression from the standardized operating methods. It is a system that supports the decision-making of operators. Based on the concept of a "system that makes the information needed visible to those who need it when they need it," it is a system that standardizes past know-how into manufacturing technology.

Within the Intelligent Integrated Production System, the importance of monitoring points is divided into three levels.
Monitoring points related to safe and stable operations are considered Priority I, those related to quality and cost are considered Priority II, and those related to optimal operation are considered Priority III.

However, based on the processing power of computers in 2000, the scope of support provided by the system was limited to judgements and operations for Priority I and Priority II.

This is because each of the decision-making elements that lead to optimization of quality, energy intensity, and volume—the monitoring points for Priority III—involved trade-off relationships. For example, the time taken to pursue higher quality could reduce the production volume. In addition, the computing power available at the time was insufficient to fully utilize all the available know-how and skills.

Example of the relationships among quality, energy intensity, and volume



Word List

Daicel Production Innovation

This is Daicel's proprietary production innovation method, which achieves significant improvements in production efficiency and quality by organizing, standardizing, and systematizing the know-how cultivated on the chemical plant production floor to optimize the entire supply chain.

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.

Extraction process

This is a process used to select and extract specific components or substances from raw materials or mixtures. Solvents or other agents are used to efficiently separate the target substance.

Drying process

This is a process that removes moisture from raw materials or products to dry them. It is a critical process for maintaining quality and improving shelf life.

Intelligent Integrated Production System

The Intelligent Integrated Production System is a system built through Daicel Production Innovation. Based on the know-how accumulated to date, it supports operators in their decision-making.

Reaction process

This is a process in which raw materials chemically combine or decompose to transform into new substances with different properties. In a plant, various reactions are controlled to obtain the target products or materials.

Distillation process

This is a process that separates and purifies liquids by utilizing the differences in the boiling points of their components. The mixture is heated to form a gas that is subsequently cooled to form a liquid, allowing each component to be isolated.

Assembly-based manufacturing

This is a type of production in which finished products are created by assembling processed parts. It is widely adopted in the manufacturing of a variety of industrial products, including automobiles, home appliances, and precision equipment.

Process-based manufacturing

This is an industrial sector that mass-produces materials and products through chemical reactions or physical manipulations such as heat and pressure. This sector includes oil refining, chemicals, and steel.

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.

Tacit knowledge

Knowledge or know-how based on experience, intuition, and instinct, which is difficult to explain through words or manuals.

Trade-off

This is a relationship in which improvement of one aspect comes at the expense of another. This requires decision-making that strikes a balance, such as between cost and quality or between safety and efficiency.

Sensors

These are devices that detect conditions, such as temperature, pressure, flow rate, light, and vibration, and convert them into numerical values. They are indispensable for automatic control and quality management in a plant.

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.

Explicit knowledge

This is knowledge expressed in words, diagrams, or data so that it can be understood by anyone. It facilitates the sharing and passing on of tacit knowledge.

Optimal solution

This is the most desirable answer or method chosen from a wide range of options. This concept is essential for achieving efficient operations in production planning and problem-solving.

Standardization

This refers to establishing specific criteria that can commonly be used by anyone to maintain an orderly state for anything that would otherwise become diversified, complex, or disorganized. By unifying work procedures, rules, and other things so that everyone can perform tasks in the same way, it contributes to stable quality, improved efficiency, and training of the next generation.

Energy intensity

This is an index for the amount of materials or energy required to produce a single unit of product. It serves as fundamental data for efficiency, cost management, and environmental measures.