Connective Industries

1 Online CPS for Dynamic Modification of Production Lines

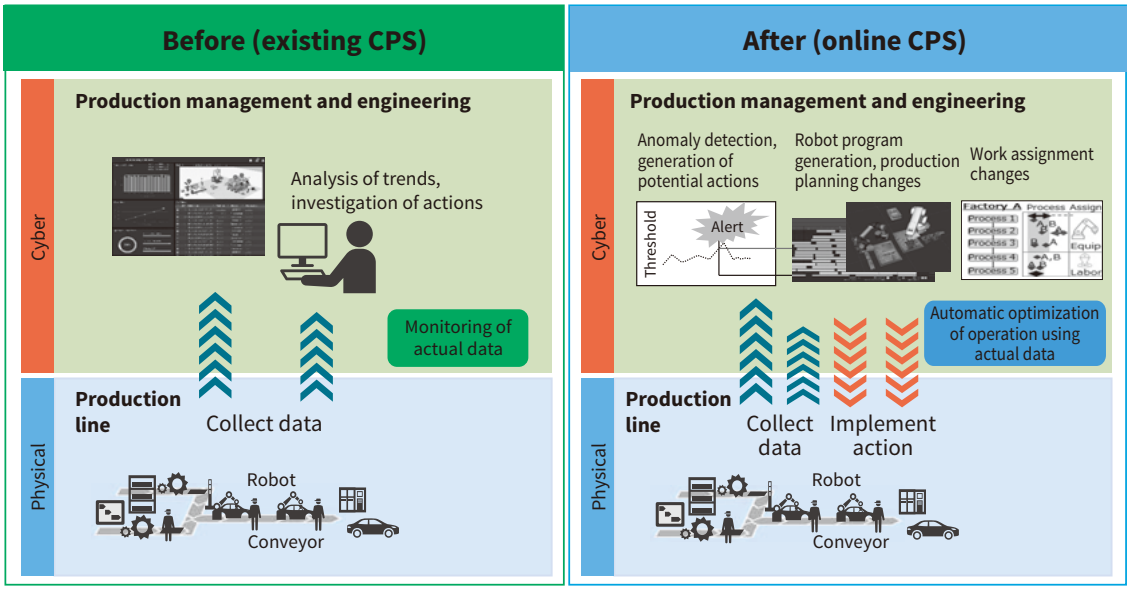
The challenges of recent years have included growing geopolitical risk, increasingly diverse customer requirements, shorter cycle times, and a shrinking workforce. In response, it is becoming more important than ever for manufacturing plants to be faster and more efficient in how they commission, operate, modify, and repair production lines. To address this challenge, Hitachi has developed practices for online cyber-physical systems (CPSs) that can dynamically modify the planning and control of production lines in response to demand fluctuations and changes in the plant itself.

While past practice with CPSs has required supervisors to monitor the actual data collected from the production line and consider what actions to take based on the analysis of trends, the problems with this are that analysis requires considerable expertise and it takes a lot of work to formulate a plan of action, during which time the line may be halted. With an online CPS, it is possible to automatically optimize the tasks of detecting anomalies, generating actions, and modifying plans. The result is a faster transition to the new plan, allowing the line to remain in production without shutdowns.

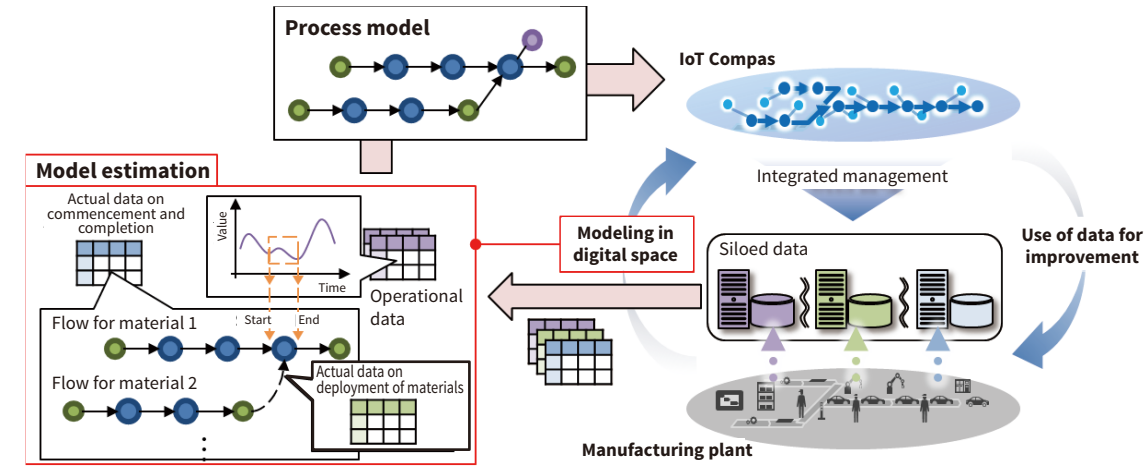
2 Automatic Generation of Process Models to Simplify Data Management

The use of data to optimize production processes has attracted interest in the manufacturing industry. However, the data generated by manufacturing plants is spread across different processes and systems, meaning a lot of time goes into collecting and managing the data. To overcome this problem, Hitachi supplies IoT Compas that simplifies the integrated management of this scattered data across all processes by linking it to process models that replicate the actual manufacturing processes in digital space, allowing it to be managed centrally.

Currently, model designers build these process models by gaining an understanding of the manufacturing processes and working out how to link the data. To improve this situation, Hitachi is undertaking research



1 Features of online CPS



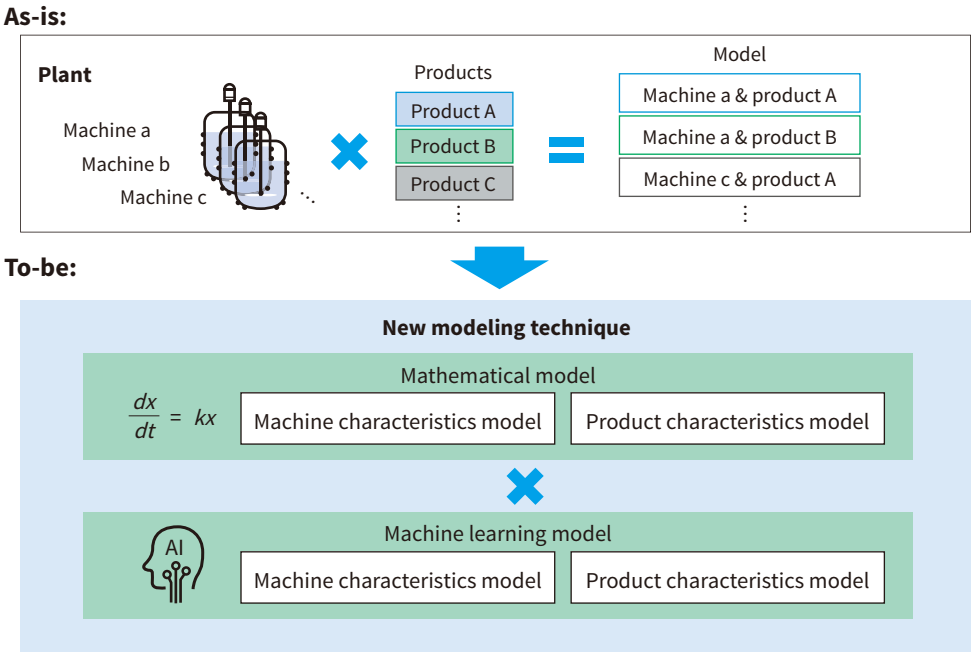
2 Using process mining to accelerate applications for IoT Compas

and development on ways of reducing the amount of time taken for model building, adopting a data-driven approach to model estimation that utilizes this plant data. This includes actual data on the commencement and completion of tasks and on the deployment of materials. Utilizing the results of this work, Hitachi intends to further simplify the integrated management of data by achieving an 80% reduction in the amount of time spent on the key task of process modeling.

3 Batch-specific Modeling of Reaction Process Characteristics Utilizing both Mathematical Formulas and Machine Learning

The automation of plant operation is one of the ways in which digital solutions can be applied to chemical processes. To this end, Hitachi has developed a technique for modeling batch processes.

Variability in production times and product quality due to chemical reactions not proceeding as intended is an issue of concern at plants that are operated manually.



3 Block diagram of modeling technique

One way to address this is to model the behavior of the process using mathematical formulas so that the appropriate control actions can be determined automatically. The problem with this is that plants use a wide variety of equipment to produce a wide variety of products. The need to model every combination of these makes the cost of model building very high.

In response, Hitachi has developed a way to use machine learning to model those product and machine characteristics that vary by type, and mathematical formulas for those characteristics that do not. A desktop evaluation found that this approach can deliver similar accuracy to that for mathematical formulas on their own. The result is that modeling costs less than when using only mathematical formulas, while having higher accuracy than machine learning could achieve on its own.

4 Development of FREEDi Sensor Glove for Tracking Actions of Workplace Staff

Hitachi has developed a sensor glove solution called "FREEDi" (an abbreviation of "FREE your data input") that can be used at plants where assembly or machining work is done manually to capture and present information about actions performed by workers, including the level of fingertip force exerted when picking objects up, hand movements, and the sounds made during work.

Data sent wirelessly from sensor-equipped gloves is received by a remote device where the particular characteristics of each action can be identified as needed and this information is passed to the worker or supervisor. Worker training is one use, providing a useful way to show differences in technique between an experienced worker and their trainee. It can also help to prevent manufacturing defects by detecting worker errors as they happen in the production line, such as missed actions or deviations from procedure.

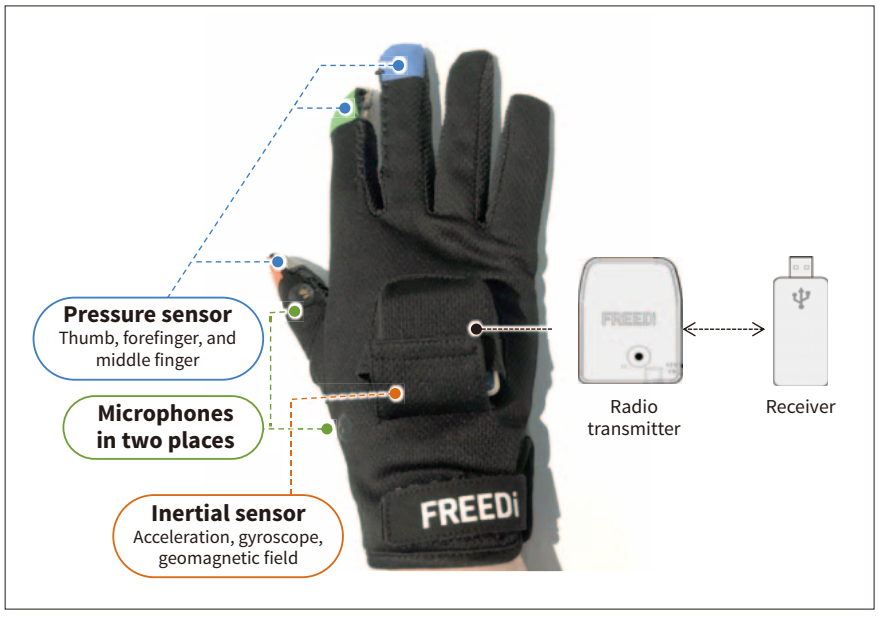
In the future, Hitachi intends to transform FREEDi into a solution that can be used in a wide variety of workplaces and address a wide range of customer needs by improving the glove's ability to detect actions and using it in tandem with other sensing methods. Hitachi also plans to create factory IoT solutions that combine the various ways in which records are collected at manufacturing plants.

5 Digitalization of Welding Expertise

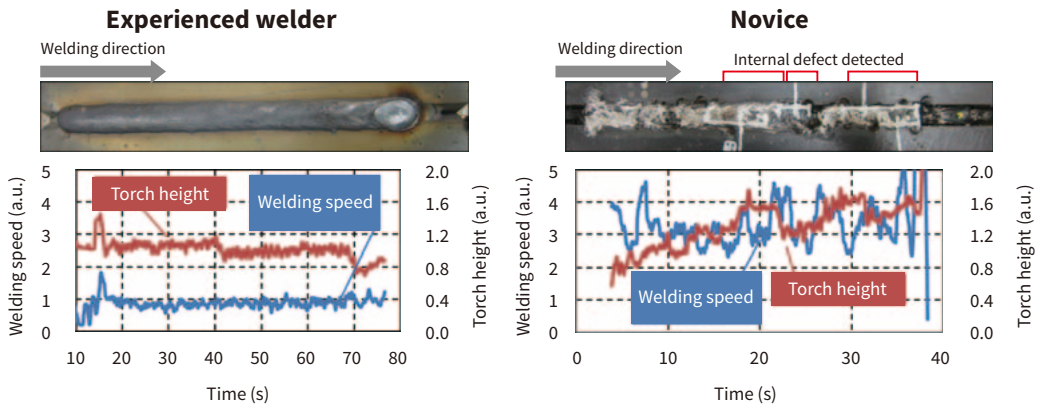
Hitachi has developed a way to digitalize welding expertise, having recognized the difficulties posed to society by the loss of skills and expertise in manufacturing as the population ages and the birthrate remains low.

A major feature is the ability to use techniques such as motion capture for the highly accurate measurement of feature values for welding actions identified on the basis of practical knowledge, and to make this information available.

A comparison of how an experienced and novice welder handle a welding torch found that, whereas the actions of the expert were steadier, with less variation in the torch height and welding speed, the novice welded more than



4 FREEDi glove



5 Comparison of welding actions of experienced and novice workers

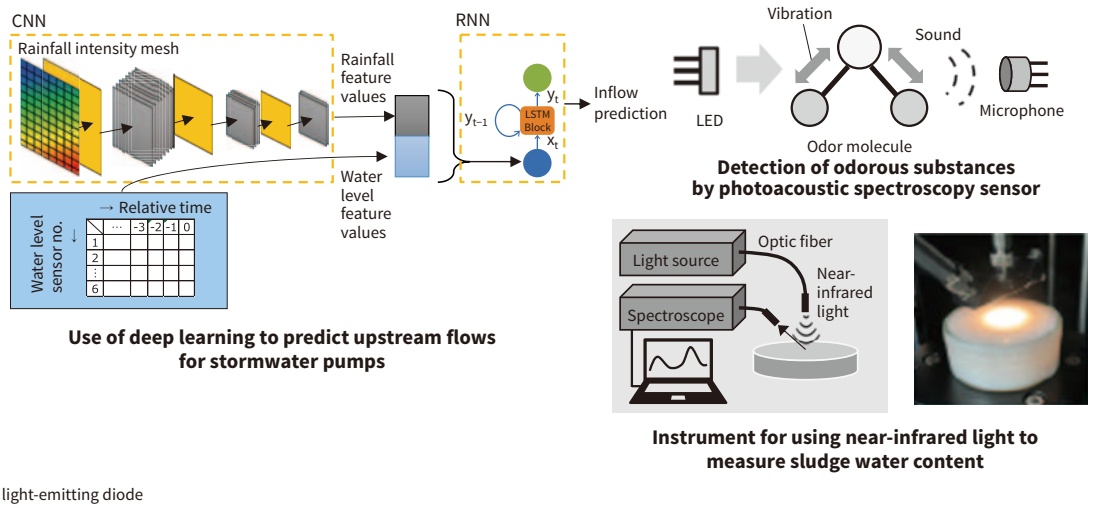
twice as fast and also lifted the height of the torch as they worked. Quality issues in the form of internal defects were also found in the work of the novice welder. These were believed to be the result of incomplete fusion, a consequence of insufficient heating of the weld due to the higher weld speed and torch height used by the novice.

This demonstrated that the technique can be used to assess weld quality based on the welding action. In the future, Hitachi intends to make use of this technique to facilitate the more efficient transfer of skills in the manufacturing workplace.

6 Digital Solution for Water Supply and Sewage Contributing to Sustainable Public Safety and Security

While maintaining a healthy environment supported by water and sewage infrastructure that underpins safe and secure ways of life is essential to the sustainable progress of society, the many challenges to achieving this include increasingly severe and frequent heavy rainfall events, workforce shortages due to a falling population, the retirement of experienced staff, and action on reducing greenhouse gas emissions. To address these societal challenges, Hitachi supplies water and sewage system operators with digital solutions that support many different aspects of their operation and maintenance work, including information presentation, labor-saving and efficiency measures, and skills transfer.

One example is the work currently under development on systems for predicting pumping station inflows, with models that combine convolutional neural networks (CNNs) and recurrent neural networks (RNNs). By assisting with the operation of stormwater pumps, these methods can help prevent flooding due to heavy rainfall events. For the operational management of plant and machinery, where the practice is for inspection staff



LED: light-emitting diode

6 Technologies for water supply and sewage solutions

to conduct regular onsite inspections that use smell to check for problems and identify when something has changed, Hitachi is responding to the needs of utilities experiencing workforce shortages by developing systems that use compact odor detectors based on techniques such as photoacoustic spectroscopy. For sewage sludge, a renewable resource that people want to see put to good use, Hitachi is also working on a system that utilizes a simple technique based on near-infrared light to measure sludge water content (an important parameter) and guide the operation of sludge dewatering systems. Along with helping to improve operating conditions, this is also intended to facilitate skills transfer.

7 Generation System Using Fuel Derived from Renewable Energy

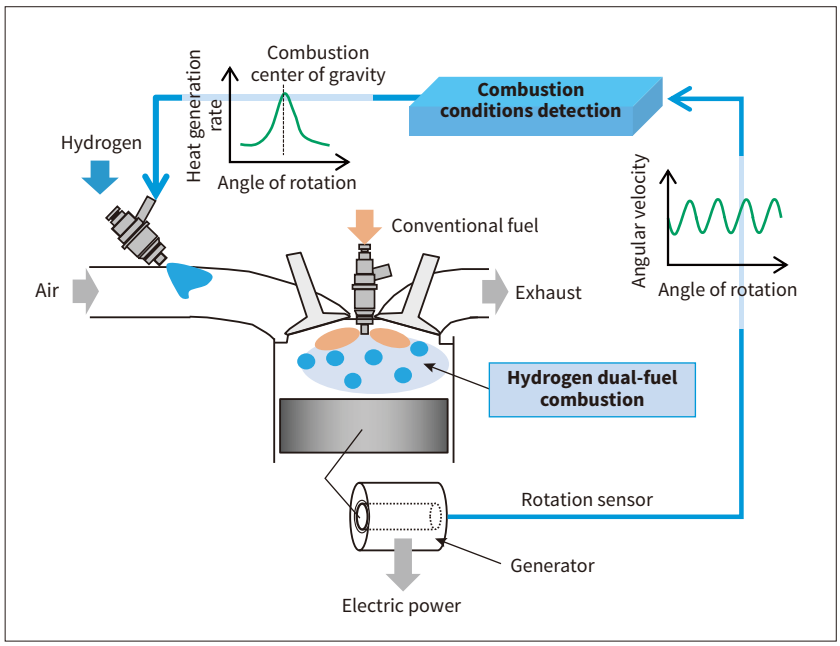
Hitachi is investigating the use of fuel derived from renewable energy to help achieve carbon neutrality, one aspect of which is the work it is doing with the stakeholders involved in the hydrogen supply chain on demonstrating its viability. This has included the practical implementation and operation of hydrogen dual-fuel generation systems that have a high level of compatibility with existing infrastructure. These systems work by burning hydrogen along with a conventional fuel (such as biofuel or diesel). As they are also able to operate on conventional fuel alone, they allow for a gradual transition to carbon neutrality.

Abnormal combustion caused by changes in ambient temperature or in the amount of hydrogen supplied to the engine are an issue on this system. Accordingly, Hitachi has also developed a technique for detecting combustion conditions that can identify such abnormalities in real time. The way this works is that the controller is equipped with a mechanism for detecting the combustion center-of-gravity time in real time based on changes in angular velocity measured by a sensor attached to the generator shaft. By working in tandem with the hydrogen supply system to adjust the supply of hydrogen when abnormal combustion occurs, this enables the safe use of hydrogen to generate electric power under variable ambient conditions.

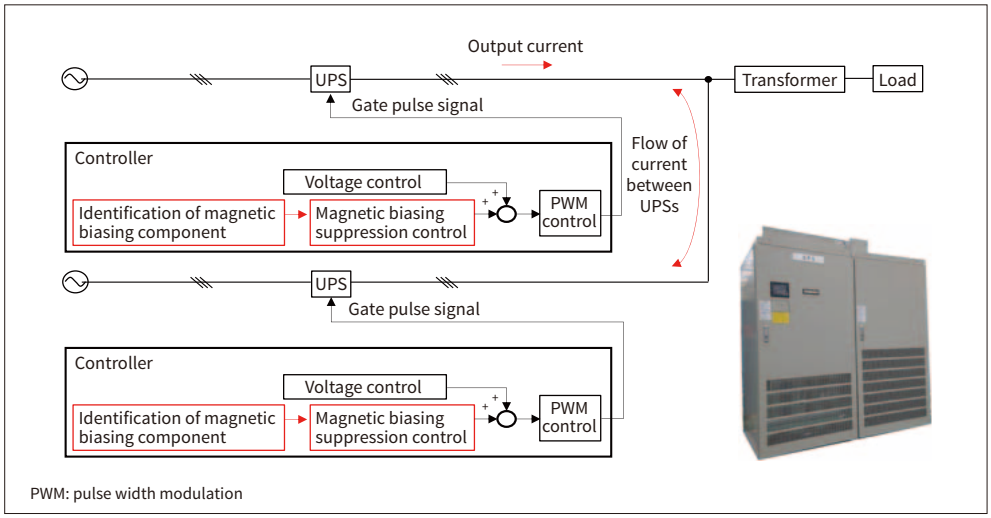
8 Compact and Highly Efficient 500-kVA UPS for Data Centers

Hitachi supplies uninterruptible power systems (UPSs) in a range of sizes to suit customer requirements, having developed a series of compact and highly efficient models designed for high reliability and capable of being connected in redundant configurations. Demand has been particularly rising from the large data centers that have come to play a key infrastructural role over recent years due to advances in digital technologies such as artificial intelligence (AI) and the IoT together with the growing prevalence of remote working and e-commerce. This has led Hitachi to develop a 500-kVA UPS for large data centers that combines high efficiency with small size.

To achieve a small size, the new UPS features a technique for suppressing magnetic biasing in the load



7 Block diagram of hydrogen dual-fuel generation system



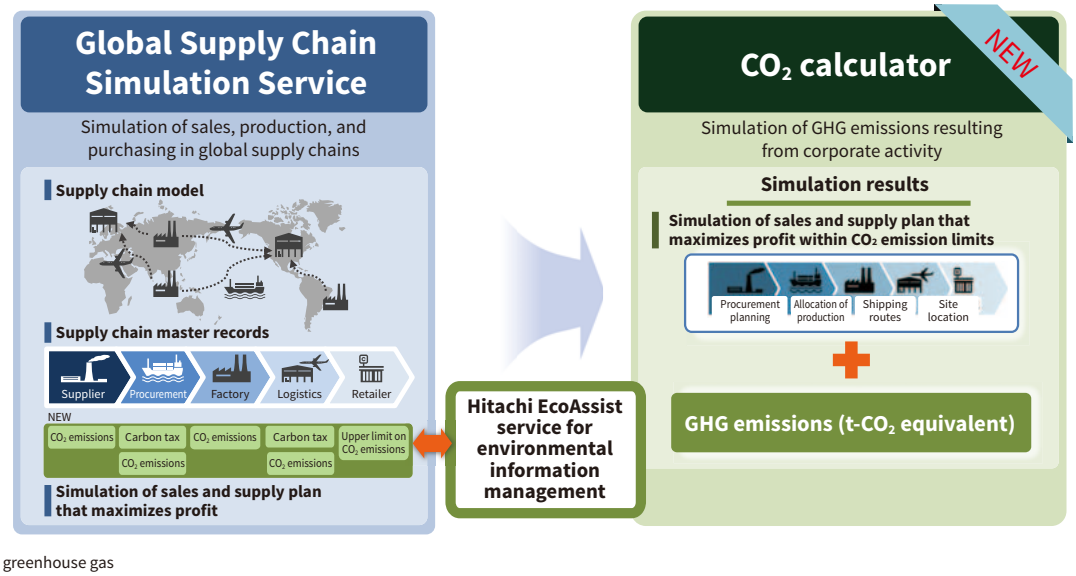
8 Magnetic biasing suppression and 500-kVA UPS

transformer without the need for a reactor. While this requires the magnetic biasing component in the output current to be determined, this is made difficult by the current that flows between UPSs connected in parallel. To overcome this problem, Hitachi developed a way to eliminate the influence of this cross-flow current and an associated magnetic biasing suppression technique. This eliminates the need for a magnetic biasing control reactor in the UPS.
(Hitachi Industrial Products, Ltd.)

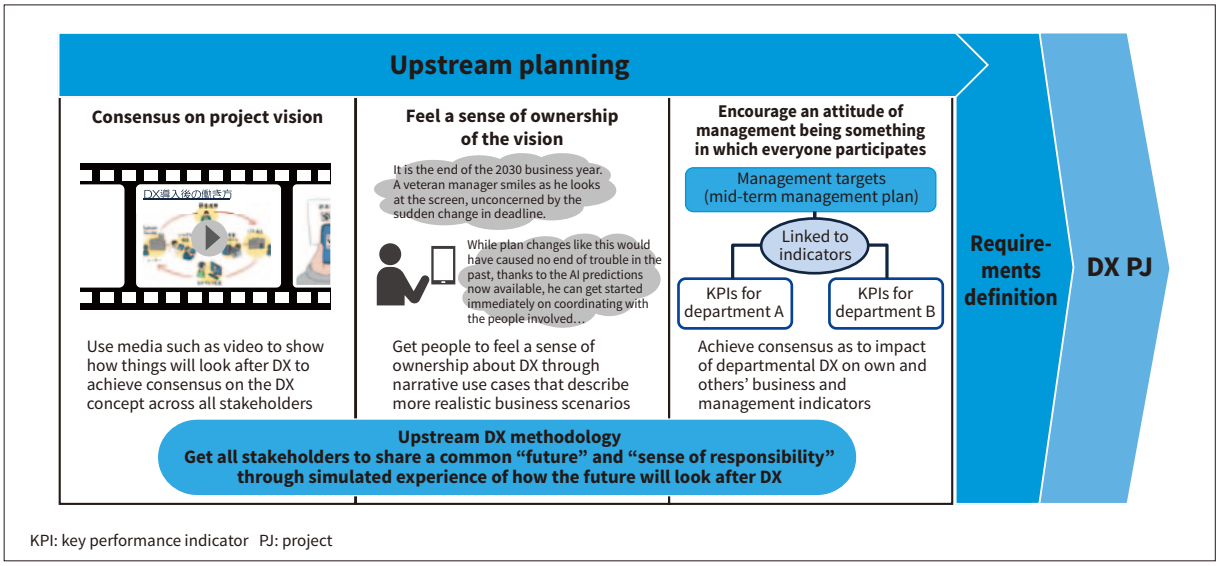
9 Global Supply Chain Simulation for CO_2 Reduction

As society pursues decarbonization, the manufacturing industry is being called upon to reduce the emission of carbon dioxide (CO_2) in its supply chains. While one way to reduce emissions is by producing locally to eliminate the emission of CO_2 during shipping, it is important to combine emissions reduction with economic efficiency as changes like this may result in higher procurement and production costs.

To address this issue, this solution uses mathematical optimization to automatically identify the supply chain configuration that maximizes profits while remaining within specified upper limits on the emission of CO_2 from specific sites or regions. In addition to being able to assess the CO_2 emissions associated with raw materials, procurement channels, production processes, equipment, and sales and freight routes, the solution also links to the EcoAssist-Enterprise-Light service for environmental information management from Hitachi Solutions, Ltd. to support the maintenance of master records on CO_2 emissions.



9 Overview of CO_2 calculator function in Global Supply Chain Simulation Service



10 Diagram of upstream DX methodology

In the future, Hitachi intends to contribute to the decarbonization of society by using this solution to support the review and restructuring of supply chains in the manufacturing industry.
(Hitachi Solutions, Ltd.)

10 Upstream DX Methodology Crucial to Success of DX Projects

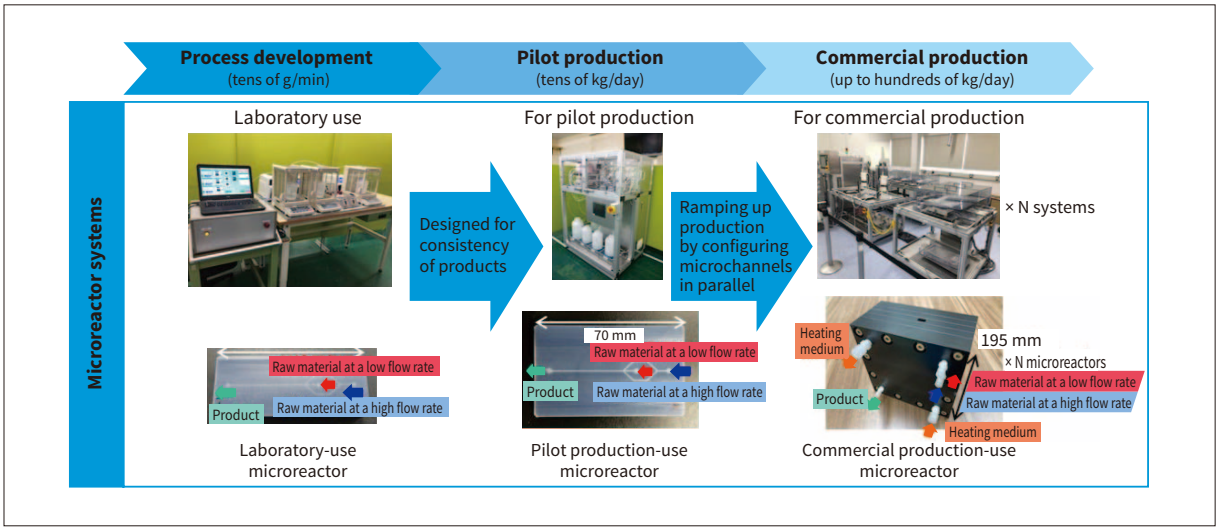
A key to the success of digital transformation (DX) projects is to discuss the concepts involved with a range of stakeholders during the early (upstream) stages of the project to build a consensus. To facilitate this, Hitachi has developed an upstream DX methodology whereby companies can clarify their vision for what it is they are seeking to accomplish with DX, accelerating the subsequent actions by getting their customers thinking with one mind as to what is entailed.

This methodology gets the participants to feel a sense of personal ownership by providing a simulated experience of the future world that DX is seeking to bring about. This is done by bringing the customer and Hitachi together to work through two processes: the formulation of a vision derived from management considerations and a narrative that describes what their post-reform operations will look like, starting with the assignment of respective responsibilities. It also confirms that staff and management are pursuing the project as a unified team by tracking the relationships between the various performance indicators used by stakeholders from different departments and levels of management at the company. This provides logical clarity as to the impacts that the different DX reforms will have on the business from a financial perspective.

The methodology was used in a project with an industrial machinery manufacturer. Quick agreement was achieved on a DX strategy that would simultaneously address management concerns and the problems that staff experience in the workplace, and the methodology also helped with the subsequent project implementation. In the future, Hitachi intends to continue contributing to DX at its customers as it further enhances the methodology.

11 Development of Microreactor Systems for Pilot and Commercial Production

Hitachi has developed plastic microreactors suitable for use in both pilot and commercial production that are able to mix two different raw materials at high flow rate ratios. As a continuous-flow chemical reactor that works by rapidly mixing raw materials in microchannels with precise control of reaction temperature, the microreactor can dramatically improve efficiency of production for pharmaceuticals and other products. The use of a sheath flow channel in which the flow of one of the raw materials is sandwiched between the other means that mixing can be performed with a wide range of flow rate ratios. Being made from highly corrosion-resistant polyethylene or polypropylene, the microreactors can also be treated as single-use (disposable) items, as is required in the manufacturing of biopharmaceuticals. For use in pilot production, it is designed to deliver products that are consistent with those of the already developed laboratory-use microreactor. In commercial production, the production volume can be ramped up by configuring microchannels in parallel.



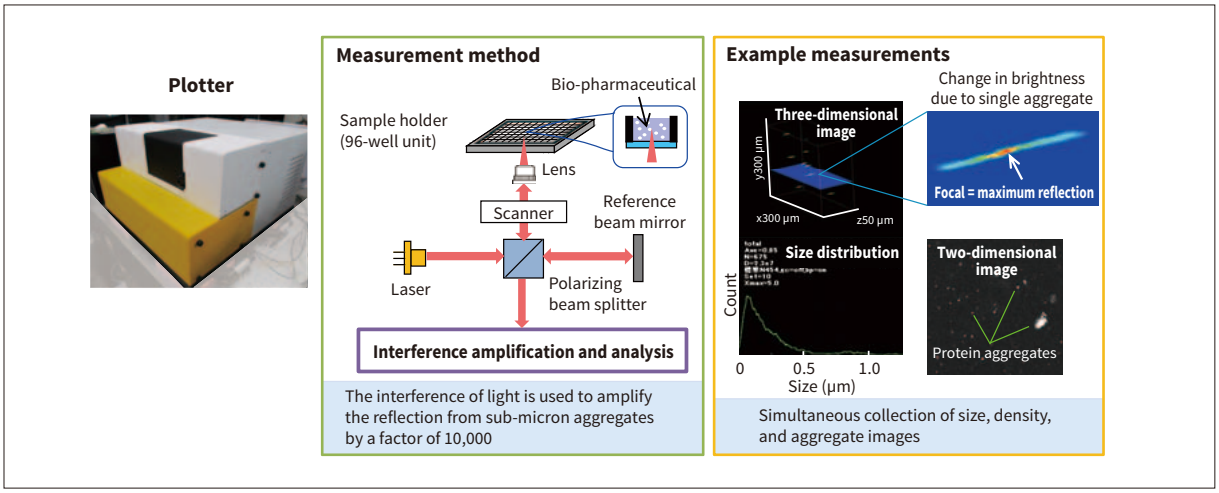
11 Microreactor systems that shorten the time from product development to commercialization

Hitachi has also developed a pilot production system equipped with three pilot production-use microreactors and a commercial production system with two commercial production-use microreactors. Compared to a conventional batch method, these systems can shorten the time taken from product development to commercialization and reduce the quantities of raw materials and waste products. In the future, Hitachi intends to continue testing its microreactor systems and expanding their applications.

12 Development of Aggregate Measurement Technique for Bio-pharmaceuticals

The focus of new drug development is undergoing a major shift away from low-molecular-weight drugs and toward bio-pharmaceuticals based on bio-technology. Having a convenient and accurate way to measure and control the size and density of the protein aggregates present in bio-pharmaceuticals is important to ensuring their efficacy and safety. While different techniques are used to measure protein aggregates depending on their size, the lack of a suitable means of measuring in the sub-micron (0.1 to 1 μm) range has been an issue.

To address this, Hitachi has utilized its own technology for high-resolution laser interferometry to develop a technique (three-dimensional homodyne light detection) that is able to perform measurements on drugs without the need for preliminary steps such as filtering or drying. It works by rapidly scanning the contours of the drug with a laser beam to build a three-dimensional image. Interferometry is used to amplify the scanning signal strength by a factor of about 10,000, enabling detection of the weak reflections from sub-micron protein aggregates. The three-dimensional image is then analyzed to identify the individual protein aggregates and the strength of the reflected light is determined to measure their size



12 Three-dimensional homodyne light detection

and density. Hitachi hopes to commercialize this technology in the near future to help improve the safety of bio-pharmaceuticals.

13 Testing Solution Using Tabletop Electron Microscope for Simple, Sensitive, and Rapid Antigen Testing

Rapid antigen testing is used for a wide variety of purposes, including testing for infectious diseases, food poisoning, and pesticide residue. The presence of viral or bacterial antigens is indicated by a color change in the testing kit's test line. This color change occurs when marker particles that bind the antigen accumulate along with the antigen in the test line. Unfortunately, antigen detection does not work when the quantity of antigen is small because the color change in the test line is too hard to see.

In response, Hitachi has participated in joint research with Hamamatsu University School of Medicine to develop a way to achieve high sensitivity in rapid antigen testing. The technique works by using a tabletop electron microscope to count the number of metallic marker particles. By doing so, it is able to achieve sensitivity similar to that of polymerase chain reaction (PCR) testing. Testing has also been made quick and simple by automating the acquisition and analysis of electron microscope images, tasks that in the past required special expertise.

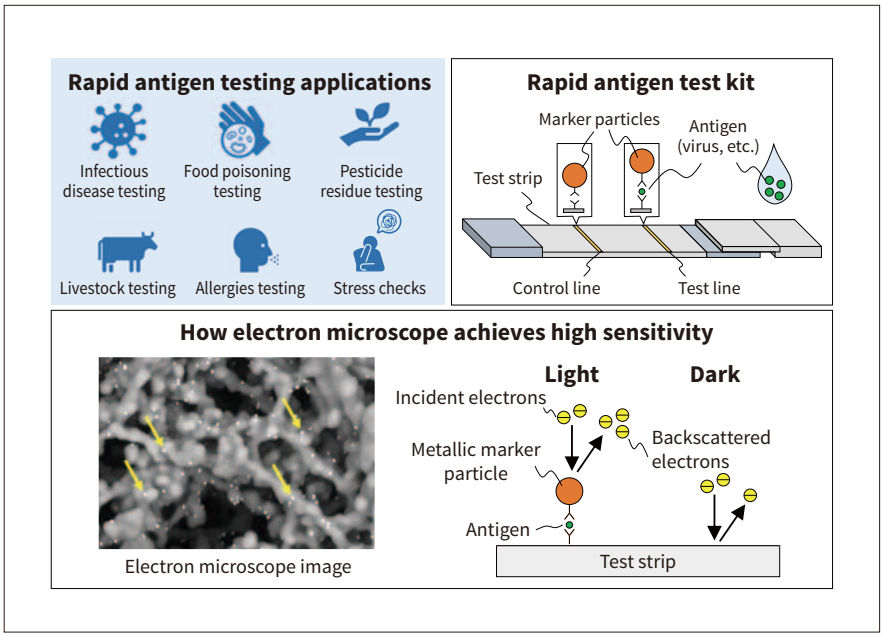
In the future, Hitachi plans to supply new solutions that utilize the data collected using this method in applications such as infectious disease and food testing.

14 Highly Efficient Materials Search Using Chemicals Informatics

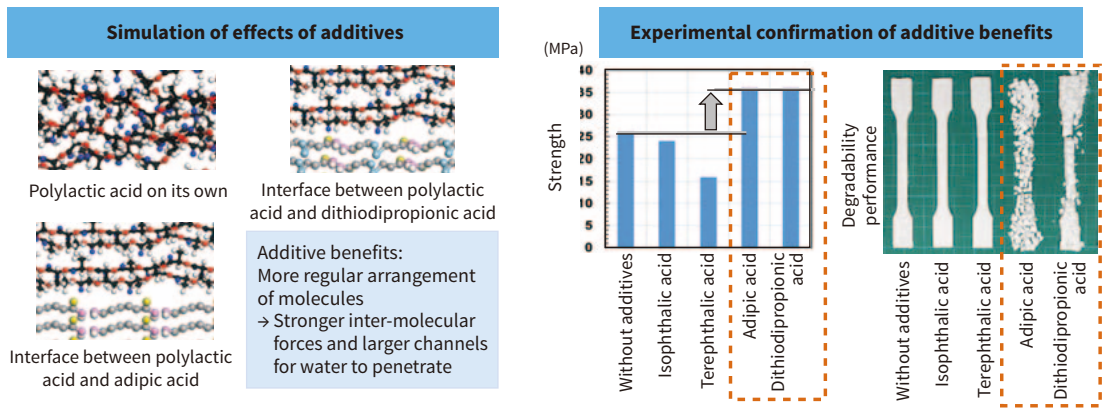
To help achieve carbon neutrality, Hitachi has used the Chemicals Informatics (CI)* materials search AI to look for additives that will improve both the strength and biodegradability of polylactic acid, a plastic produced from biomass. This led to the identification of adipic acid and dithiodipropionic acid additives. In a molecular simulation of the effect of these additives on the plastic, it was found that they increase inter-molecular forces by causing the molecules to arrange themselves a more regular pattern while also enlarging the channels that allow water to penetrate. By doing so, they improve both strength and water absorbance (an indicator of degradability). Experimental testing based on these findings likewise found that the additives increase strength in tensile testing while also improving degradability. This served as a demonstration of how effective CI can be as a tool for materials search.

Furthermore, the process from search to experimental testing was completed in only two months, indicating that the time taken for materials design can be significantly shortened compared to what it would have been had CI not been used (estimated at about three years). Hitachi intends to make use of CI in a wide variety of material search and design applications as it works to achieve carbon neutrality.

* Chemicals Informatics is a software package and service supplied by Hitachi High-Tech Corporation.



13 Rapid antigen testing applications and how high sensitivity is achieved



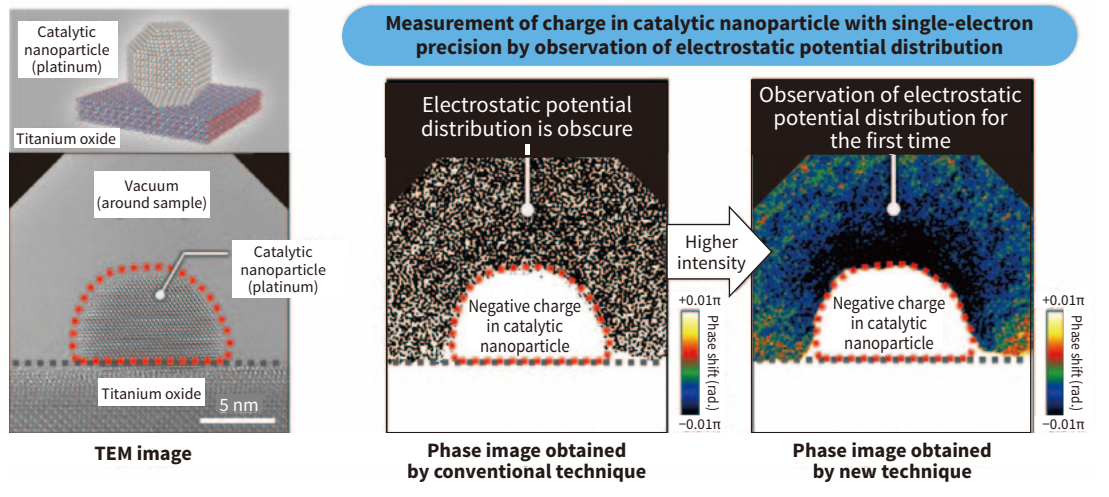
14 Results of simulation and experiment for additives identified by CI

15 Advanced Electron Microscopy for Environmental Applications

Catalysts, which promote a wide variety of chemical reactions, play an especially important part in overcoming global-scale challenges such as environmental cleanup and increased food production. To accelerate catalyst development through innovation in measurement techniques, Hitachi has worked with Kyushu University, Osaka University, and Akashi College of the National Institute of Technology (KOSEN) to achieve an order-of-magnitude improvement in the phase measurement accuracy of electron holography, a method for using transmission electron microscopy (TEM) to observe electrostatic potential distribution in a material. The method involved a unique research strategy that combined the latest techniques in electron microscopy with methods from information science for the extraction of extremely weak signals. This extreme sensitivity was then utilized to accomplish ground-breaking measurements whereby the extremely weak electric charges in the catalytic nanoparticles involved in chemical reactions were counted with single-electron precision[*1].

Electron holography is also a useful tool for measuring very small magnetic fields. In work that included Tohoku University, Hokkaido University, and the Japan Fine Ceramics Center, it has also been put to use in an extraterrestrial application involving the magnetic analysis of samples collected from the Ryugu asteroid by the Hayabusa 2 spacecraft. This succeeded in observing circular magnetic domain structures with high magnetic stability in particles of magnetite (Fe_3O_4) contained in the sample, and in making high-resolution measurements of the magnetic flux distribution of the adjacent magnetic fields[*2].

It is hoped that electron holography will also help in future research aimed at determining the magnetic field



15 Image of electrostatic potential distribution around catalytic nanoparticle obtained by electron holography

environment and empirical temperatures in which the sample was formed in the Ryugu asteroid 4.6 billion years ago.

*1 This research received funding from the Core Research for Evolutionary Science and Technology (CREST) of the Japan Science and Technology Agency (JST) (JPMJCR1664) and was published in the October 13, 2022, online edition of the journal Science. R. Aso et al., Science 378 (2022) 202.
*2 This research was undertaken by the Stone Analysis Team, a sub-team of the Hayabusa 2 Initial Analysis Team, with the electron holography measurements receiving funding from JPMXS0450200421 and JPMXS0450200521. The work was published in the September 22, 2022, online edition of the journal Science. DOI: 10.1126/science.abn8671

16 Refrigerant Leak Detection Technique for Remote Monitoring/Predictive Diagnosis IoT Solution "exiida" for Air Conditioning

Responding to a revision of the Fluorocarbon Emissions Control Act, which now permits automation of simple inspections currently performed visually, Hitachi has developed a technique for using remote monitoring data to detect refrigerant leaks.

The technique works by training on sensor data collected while the equipment is operating normally. When checking for leaks, it identifies signs of anomalies by detecting whether or not this data diverges from the acceptable range, using the existing fast-local subspace classifier (F-LSC) method to calculate the degree of divergence from the normal operation. Another feature of the technique is that an indicator of the refrigerant leak amount was created based on knowledge of how the cooling cycle works. This was done by identifying sensor data that is strongly correlated with the quantity of internal refrigerant, a parameter that is difficult to measure directly. When a sign of anomaly is detected, the system determines whether or not refrigerant has leaked by working through the flow chart for identifying changes in refrigerant amount from the refrigerant leak feature values. Testing using actual operational data found that the devised feature values can be used to determine refrigerant leaks with a high degree of sensitivity.

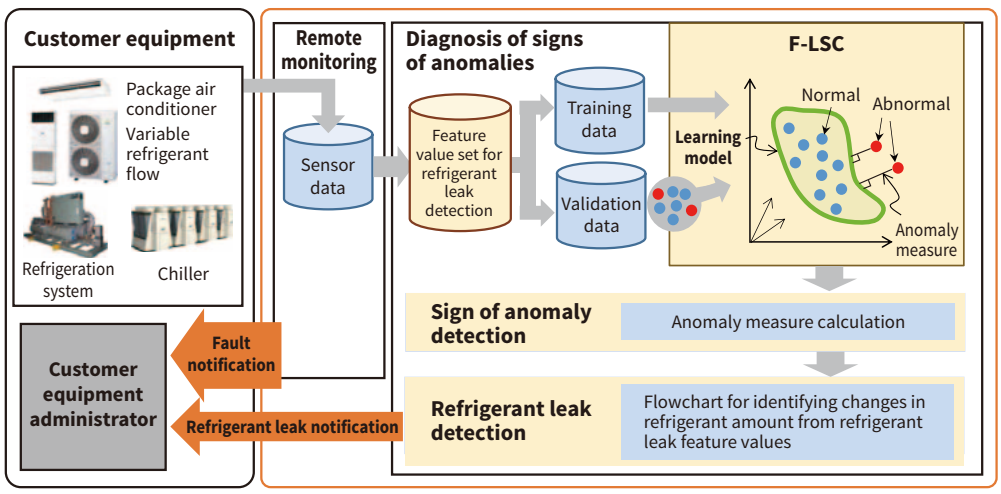
Hitachi is planning to make this new technique available in the services provided by its exiida for the remote monitoring and predictive diagnosis that has been updated for compliance with the August 2022 revision of the Fluorocarbon Emissions Control Act.

To deliver greater value for customers, Hitachi plans to develop diagnostic techniques for identifying the causes of a wider range of problems than just refrigerant leaks, and to implement them at an early date.

17 Designing for Greater Use of Renewable Materials

Plastic has long been used in home appliances and a host of other products. Unfortunately, when this plastic, which is produced in large quantities, is disposed of after use, it becomes a source of environmental problems such as soil or ocean pollution and contributes to global warming through the release of CO_2 when burned.

Accordingly, Hitachi has been working to bring about a highly circular economy by making greater use of renewable plastics in popular home appliances. With the PV-BH900SK cordless stick cleaner, Hitachi took on the challenge of increasing the percentage of renewable



16 Block diagram of refrigerant leak detection system included in Hitachi's exiida remote monitoring and predictive diagnosis

17 PV-BH900SK cordless stick cleaner

plastics to more than 40%, using it for external as well as internal parts without compromising the product's quality of appearance.

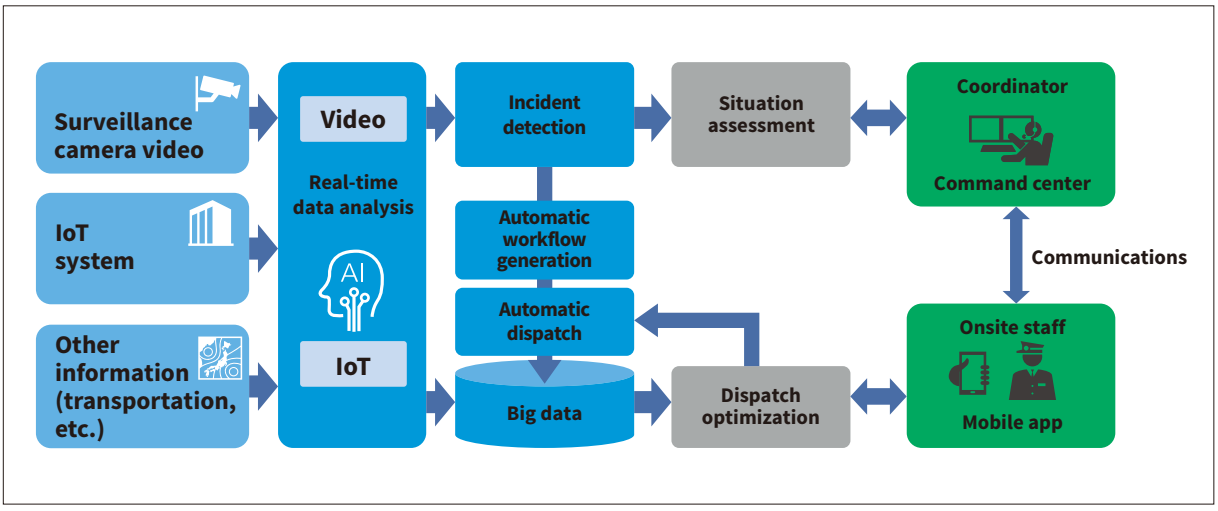
These efforts to bring about a highly circular economy while achieving strong visual appeal have been recognized by a Gold Award (Minister of Economy, Trade and Industry Award) at the Good Design Award 2022 run by Japan Institute of Design Promotion.

18 Development of Solution for Integrated Command and Control Centers through Co-creation with Singapore Institute of Technology

Making efficient use of human resources in the fields of public health and safety and in public transportation and other social infrastructure services is an important issue for Southeast Asia as it rapidly urbanizes. To address this societal challenge, Hitachi has developed a solution for integrated command and control centers.

A staff dispatch function finds the optimal way to allocate staff and make more efficient use of available resources by modeling the constraints in terms of event priorities and staff capabilities, and then solving this as a problem in mathematical optimization. As the time it takes to obtain a solution increases exponentially as the number of events increases, Hitachi adopted a spatio-temporal segmentation algorithm to enable solutions to be obtained in real time. The company has also partnered with the Singapore Institute of Technology on the collaborative creation (co-creation) of a solution for dealing with COVID-19 that sends out staff to help disperse crowds when large numbers of people in close contact are detected in surveillance video. The effectiveness of the solution has been demonstrated in practical trials.

In the future, Hitachi intends to further develop this solution through co-creation with customers.



18 Architecture of solution for integrated command and control centers