Hitachi Review

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Volume 72 Number 1 March 2023

Industrial Technologies to Support Future Earth

Water and Industry Solutions for a Sustainable Society

FEATURED ARTICLES

Water Infrastructure Solutions for Digitalization in Water Services
Solutions for Resilient Management in Industry

GLOBAL INNOVATION REPORT

Work on International Standardization of Water and Sewage
Contributions to ISO Technical Committee 224

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(Photo: Kosei Nozaki)

Lorena Dellagiovanna
Vice President and Chief Sustainability Officer, Hitachi, Ltd.

In April 2022, Hitachi announced its new Mid-term Management Plan, in which "Green," "Digital," and "Innovation" were highlighted as three pillars of the company's cross-group growth strategies. Here we present a series of interviews with executive officers in charge of each core strategy. This article features the Green Strategy led by Ms. Lorena Dellagiovanna, Vice President and Executive Officer, Chief Sustainability Officer, Chief Diversity & Inclusion Officer and Head of Environment at Hitachi, Ltd. We asked Ms. Dellagiovanna about how Hitachi aims to achieve its environmental targets and her new role as Chief Sustainability Officer.

Interview and text by Eiko Hagiwara

Solving Environmental Challenges through “GX”

—Please tell us why Hitachi is focusing on “Green” in the 2024 Mid-term Management Plan, and what your responsibilities are as Head of the Global Environment Division.

Looking at world macro trends, many countries have declared carbon neutrality targets as well as allocated investments, and the importance of protecting planetary boundaries has been recognized globally. Since its foundation, Hitachi has continuously committed to solving the issues faced by our customers and society, and now environmental issue is one of the biggest challenges faced across the globe.

As part of the mandate of my new role, I have the objective to accelerate the achievement of Hitachi’s environmental targets. We plan to enable our customers to contribute to the reduction of their CO_2 emissions by 100 million tons per year by 2024 through the use of Hitachi products.

For Hitachi’s own operations, we aim to reach carbon neutrality for scope 1 and 2, and a 50% reduction through the entire value chain by 2030, compared with the base year of 2010. In the long term, we aim to reach carbon neutrality by 2050 for scope 1, 2, and 3*.

—How will you achieve those targets?

Our Green Strategy is embedded in all of Hitachi’s business segments—mobility, energy, connective industries, and digital. In all these segments, we are working on developing various technologies which will significantly contribute to the acceleration of green transition.

Also, our strategy consists of two pillars: green transformation (GX) for CORE and GX for GROWTH. Let me explain further in details.

* Scope 1 involves greenhouse gas emissions generated by an enterprise itself. Scope 2 involves emissions generated using electricity, thermal, steam, and other energy sources provided by other companies. Scope 3 involves emissions from other business activities. The emissions of the entire value chain are comprised of these three scopes.

Lorena Dellagiovanna, Vice President and Chief Sustainability Officer (Photo: Kosei Nozaki)

First, through our GX for CORE initiatives, we'll strengthen our commitment to decarbonizing our own operations. We plan to invest in energy-saving and renewable energy generation projects and accelerate CO_2 emissions reduction through value chain management, product redesign, and engagement with key customers.

On the other hand, GX for GROWTH initiatives will enable our customers to reduce CO_2 emissions through our green-related services and products. For example, we will offer End-to-End service solutions through our battery and electric vehicle (EV) technologies and invest in future green technologies, including hydrogen energy storage and conversion of hydrogen into synthesized methane, an alternative to natural gas.

Lorena Dellagiovanna Visiting World Economic Forum Annual Meeting in Davos (May 2022)

—What businesses are you specifically focusing on regarding GX for CORE and GX for GROWTH?

In GX for CORE, we promote appropriate carbon neutrality measures aligned with the characteristics of each site. For instance, energy-intensive data center sites or small areas with multiple factories require efficient energy management, so we are now working to incorporate renewable energy at these sites and encouraging asset sharing as needed.

In GX for GROWTH, we will provide systems and technologies across many different sectors, including power transmission systems such as high voltage direct current (HVDC) systems; new public transportation systems like battery-powered trams; EV motor and EV inverter technologies to accelerate the realization of the EV society; connective-industry technologies for energy savings in factory operations; and digital systems to visualize energy management.

Leading Decarbonization as a Climate Change Innovator

—Promoting Green strategy has become one of the most pressing issues for companies and governments across the world. In light of such circumstances, what unique role do you think Hitachi should play in the global environmental effort?

We take our responsibility very seriously as a global citizen to reduce our own carbon footprint, and we have set ambitious targets to become carbon neutral. As a Climate Change Innovator, I believe Hitachi needs to take more lead in decarbonization.

To achieve these ambitious targets, we will contribute to the understanding of our customers' and society's issues. With over 110 years of experience, we're a unique technology company with deep expertise in operational technology,

Dellagiovanna Talks about Her Enthusiasm toward Achieving Carbon Neutrality by 2050 (Photo: Kosei Nozaki)

information technology, and products. With our green technology and digital capacity, we will innovate and co-create solutions with our customers, partners, and the global community to achieve a net-zero society.

"Let's Work Together" to Achieve Carbon Neutrality

—Aside from your responsibilities at Hitachi, is there something you do in your personal life that is good for the environment?

As I love nature, I'm careful not to destroy it further. Here in Japan, people naturally respect the environment and can be very educated about nature conservation, including how to handle waste. Since I came to Japan from Italy in 2020, I have been learning more about the environment.

I've also loved sailing for many years. When sailing on a boat, you need to save water. If you use up all the water, you cannot cook, brush your teeth, or do anything on the boat. This is one way I learned how to conserve natural resources. I hope to bring my experience and inspire people around me with my behavior.

—Finally, could you share your enthusiasm for achieving carbon neutrality by 2050?

Climate change is a challenge that requires a global and united approach. We need to operate as One Hitachi more than ever, and the solid foundation that sustains this ambitious initiative is the commitment of all Hitachi employees.

It's also essential that we work in partnership. In addition to our employees, the external stakeholders—all our customers, suppliers, the academia, and policymakers—must be involved. That's the only way we can achieve a net-zero society. So, let's join hands together. Stop talking and take action. I'd love to invite every employee and external partner to work with us to realize carbon neutrality.

To Realize a True *Rita* Going beyond Control

Listening to Other's Voices and Meeting Them with Sincerity

Asa Ito
Director, Future of Humanity Research Center, Institute of Innovative Research and Professor, Institute for Liberal Arts, Tokyo Institute of Technology

A rapidly growing number of companies have adopted a management philosophy of resolving social issues such as global environmental problems and improving people's quality of life. Amidst this global trend, Hitachi has set planetary boundaries and well-being as the most important issues for society. What are the perspectives that must not be forgotten when implementing initiatives with a humanistic theme and contributing to society? And what should engineers strive to be in this environment? *Hitachi Review* interviewed Dr. Asa Ito, Director of the Future of Humanity Research Center at the Tokyo Institute of Technology, which explores ethics, *rita*, and diversity through multidisciplinary research using physicality and disability as clues.

In 2010, Asa Ito left the University of Tokyo Graduate School of Humanities and Sociology after earning credits in Aesthetics, the Division of General Culture. In the same year, she earned a Ph.D. in Literature from the University of Tokyo. After completing a Research Fellowship for Young Scientists at the Japan Society for the Promotion of Science, she was appointed as an Associate Professor at the Institute for Liberal Arts, Tokyo Institute of Technology in 2013. She has been in her current position since April 2016. Her books in Japanese include "The Body Theory of Unsighted Athletes" (Ushio Publishing Co., Ltd., 2016), "The Stuttering Body" (Igaku-Shoin Ltd., 2018), and "Ethics of Hands" (Kodansha Ltd., 2020).

Being of Service to Someone Is a Miracle

In recent years, an increasing number of companies have been working to resolve social issues and improve people's quality of life (QoL). How do you view the current social trend of for-profit companies pursuing well-being?

It is very important to think about the Sustainable Development Goals (SDGs) and other humanistic questions such as environmental issues and well-being. On the other hand, I am always wary about such social trends.

Professors at Oxford University in the UK remark that the university has existed longer than the country and they are not easily swayed no matter what the government or ministries say. They are very much aware that they are the "house of good sense." I believe that the proper role of a university is not to blindly follow social trends, but to question them, and that is what the liberal arts are all about. Recently, however, national universities have been increasingly focused on management, and they cannot operate without listening to the wishes of both the national government and industry. The reality is that it is difficult to say to what extent their independence can be ensured.

I also remain concerned that many companies, despite their claims to solve global issues, may be looking at things from a shortsighted perspective. For example, selling reusable shopping bags does not necessarily contribute to the SDGs. In fact, they have even destroyed the environment. It is very dangerous to justify one's actions and righteousness by saying that one's technology and products are useful to society, looking only at a narrow view from one's own standpoint, without looking at the entire picture of the problem.

To begin with, it is essentially quite miraculous when someone can do something that benefits another. There are many factors besides one's own actions, and coincidental factors are always involved. For example, an engineer who has developed a high-performance water-filtering fiber may go to a developing country and ask local people to drink water that has been filtered clean with the fiber, and they may say that it tastes bad. That is to say, it is not dirty, but it doesn't taste good. In the international development field, no matter how genuinely the people on the ground struggle with the local people, if the project is funded by Japan's official development assistance (ODA), a condition of the order may be that a Japanese company must be contracted for school construction, for instance. There is a great deal of uncertainty over whether this is really for the benefit of the local community.

As those who deal with users on the ground are keenly aware of on a daily basis, there are many issues that need to be considered behind the words "for the benefit of others."

Like Hitachi, the Tokyo Institute of Technology takes as its starting point the philosophy of improving society through technology, but improving society through technology is a complex matter involving many more factors than we can imagine.

The term "*rita*," altruism in Japanese, which has been attracting attention recently, is the key word for thinking about how complex it is to improve society through technology and how one's actions can benefit others. When the Future of Humanity Research Center (FHRC) was established at the Tokyo Institute of Technology in 2020, the first topic to be addressed was also *rita*. One of the FHRC's missions is to carefully look at what events and factors are behind an action, A, when it happens to be for the benefit of B.

If you believe that what you do is for someone else's benefit, you are probably putting the other person in your own situation. Making others do things within the framework of their own sense of goodness and righteousness can sometimes lead to domination of others. That is why I used the word "dangerous" earlier.

In reality, however, others do not always behave the way we want them to, nor can they always be pleased. Others may not share our own sense of values, and they have different situations, environments, and cultural backgrounds that we cannot all see. This is even more true when the term "others" refers to nature or living creatures. You cannot make that assumption unless they are in your own frame of reference. And, by nature, we cannot control the consequences of our actions, nor can we control others.

This sense of not being in control is very central to *rita*, which is to say, it should not be easy to say that what I do helps someone else. How we creatively deal with what we cannot control is a very important point for *rita*.

Listening to the Unheard Voice

You cannot measure how another person perceives your actions by your own indicators alone. The challenge is how to imagine worlds that are outside your mindset.

One hint for how to do this is provided by Yoshiharu Tsukamoto, a professor of architecture at the Tokyo Institute of Technology and co-chair of the architecture firm Atelier Bow-Wow.

The act of raising a building, he said, is a series of meetings, bringing all parties involved to the table to reach a consensus. The parties involved here are not only humans, but also the trees that grow there, the insects and birds that inhabit the land, as well as the dead who have lived there, and those who will be born in the future. We listen to the voices of those who cannot speak, such as nature and the deceased, and together, the people who are alive today think about how they can come to the table to reach a consensus. I believe that the human relationships that are built in this context are in fact as important as the physical architecture of the building.

Takeshi Nakajima, a professor at the Institute for Liberal Arts (ILA), also points out the importance of listening to the voices of the deceased. "We have already received so much from our predecessors, the deceased, and being aware of this makes those who have passed away altruistic beings," he says.

When we humanities researchers alone discuss "encountering others who do not exist here and now," it seems to revert to a religious issue, but what is interesting is that, when we talk with science professors, it is replaced by the issue of "sensing." Science professors love sensing, and they get very excited when they are able to sense things that were previously impossible, such as predicting thunderstorms (laughs). And when they sense something, they may sometimes express it as "hearing a silent voice." Unlike the previous discussion, the goal is only to "control" the subject, but at the bottom of their hearts, they know that just because they cannot hear the voices, it does not mean that they are not there. We feel that this sentiment is very close to *rita*. In March 2022, a symposium focusing on the silent voices was held at the initiative of a science professor.

In order to encounter these silent voices, we need to get beyond the frame of reference in which we are trapped. People often talk about unlearning, but I think that more learning is to be found in discarding what you are trapped in and what is unnecessary in your organization, rather than in building up certain capabilities and becoming more macho and powerful, which is often seen in corporate training programs.

Professors who study the universe and extraterrestrial life attend every liberal arts workshop at the FHRC because they are always looking to get beyond the image of life that they are trapped in. If you are looking for what you already think life is, you will never find it. I suppose one must see beyond one's own perspective in order to pursue certain truths.

Possibility of *Rita* Not Based on Empathy

Like "*rita*," the term "well-being" has been drawing a lot of attention in recent years.

Did you know that there are cultural differences between how we perceive things in the West and the East Asian region? Japanese people, in particular, do not think of everything in terms of individuals. One finds greater joy in the realization of the possibilities of those close to oneself, such as one's family and friends, than in the realization of just oneself. Various studies have shown that well-being is highest when the boundary between the individual and the others is blurred.

Similarly, the *rita* that we Japanese imagine is completely different from the *rita* imagined in the USA. In the USA, there is a tendency to thoroughly quantify happiness and goodness, and to seek efficiency even in *rita*. There are many websites that allow you to find out where and in what name your donation will be most effective, and you can easily narrow your search to the most appropriate recipients. *Rita*, however, does not work only with empathy.

This is a good thing in some respects, although it is disconcerting to hear such things. If we, as Japanese, act based on sympathy, we tend to donate only to those who are close to us or related to us. This is not a way to approach people who are truly in need and the critical issues of the earth that we are not aware of. Only by quantifying it can we break free from our own assumptions.

Some organizations are experimenting with new forms of giving, such as the "new theory of giving." They donate the dues collected each month to a charity somewhere, but they separate this from empathy and choose a theme that has nothing to do with *rita*, such as "laughter" or "points," and members vote among themselves to select a charity from among the candidates they associate with that theme. It is a system where I cannot control where my money goes, but listening to the explanation, I think it is nice how natural the process is for the recipients of my donations, who I would not have considered before. We believe that this change in the giver is also an important element for *rita*.

Draft Beer Controversy and Attitude toward *Nama* Beer

By the way, I heard that the Japanese word *nama* (raw) is a concept that you have been focusing on recently.

The word *nama* is a very strange word, sometimes used in a good sense, as in *nama* chocolate, ganache, and sometimes used in a bad sense, as in *nama-hanka*, half-baked. In other words, we call *nama* something that is not fixed, something that is highly indeterminate. I think that this rhetoric has become popular in recent years to commercialize products having a once-in-a-lifetime quality.

Some time ago, I did some research on how the concept of *nama* beer, or draft beer, came about. In the olden days, beer was something you drank at a beer garden, not at home. This is because consumer beer was pasteurized to inhibit yeast activity in order to prevent deterioration, and it had a strange odor and did not taste good.

Company A wanted to change that, so they used a special filter used for filtering rocket fuel to filter out yeast and bacteria and other impurities. They developed unpasteurized, yeast-free beer and marketed it as *nama* beer.

Company B, in response, argued that if the yeast was not alive, the beer was not *nama*, and developed a new *nama* beer with live yeast through major reforms in their entire production process, including distribution, by reviewing the processes to prevent the introduction of bacteria and building refrigerated vehicles exclusively for transportation in order to handle live yeast. Even so, the expiration date was only two weeks, and so they even created a system of beer coupons for the midyear gift-giving custom to ensure that the large quantities of beer given would still taste good.

This fierce battle, known as the *nama* beer controversy, was settled when the Fair Trade Commission ruled that "*nama* beer is unpasteurized." Company B's attitude of "doing whatever it takes for the sake of the yeast" is in a sense correct in how they strove to accommodate the live yeast, and I think it is very good.

Even now, when we buy raw food, we give a priority to freshness, don't we? Like, "I bought *sashimi* today, so let's go home early." *Nama* requires us to be attentive to things that can easily change.

Nature and living creatures, as well as humans and various conversations and relationships among humans, are in a sense *nama* and changeable. I think it is very important not to control this change too much, but to stay close and accompany it as something that can change on its own. This is a viewpoint that is also pertinent to caregiving, such as the attitude of those who care for the elderly.

On the other hand, because of the large number of uncertainties involved, the people involved must also be in a precarious situation. For example, if you respond in real time to another person's questions, rather than reading from a prepared script of potential questions and answers, you must begin speaking without having your thoughts in order, and that always entails risk. But that is the meaning of "encounter," and I think it means to face and respect the *nama* other person, rather than setting up the other person in your own scenario.

Rita, such as listening to the voices of the unseen, facing and approaching the *nama* other person, may be more passive than we think.

The Power of Trial and Error Together

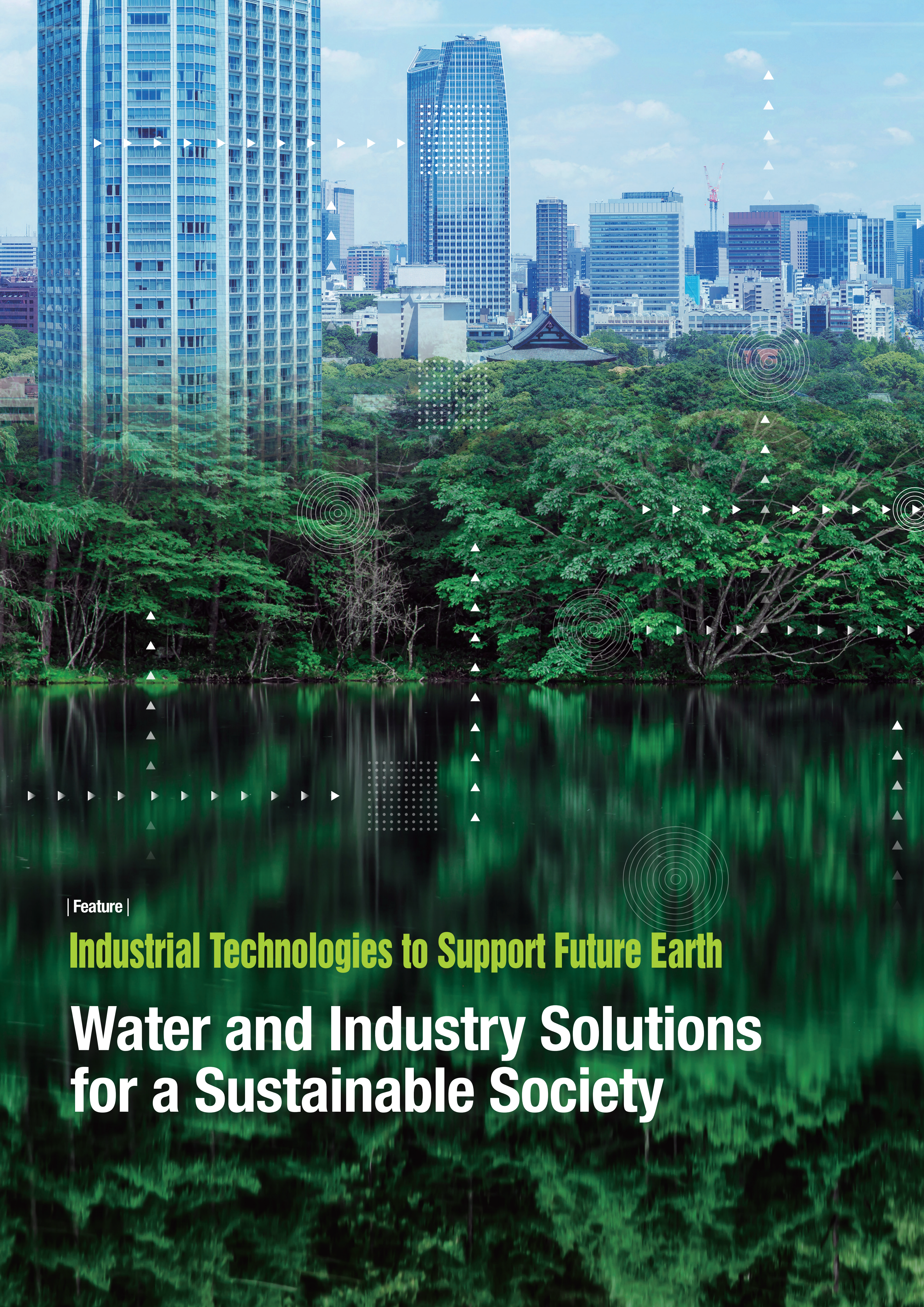
Recently, there have been calls to respect diversity from various perspectives. Under the theme of "physicality," you have been engaged in fieldwork where you talk directly with people who have various disabilities and work together with them. What insights have you gained from these experiences and what expectations do you have for companies based on these insights?

Once you dive into a constantly changing, or "*nama*," interpersonal relationship, there will be plenty of times when your own ways and rules will not work. The problem with people being together is that it is really full of problems. But it is only when we have to change our ways that we gain new insights, and when confronted with small problems, we are naturally creative. One of the interesting things about researching disabilities is that having just one disability on the table can create a situation where everyone is forced to be creative.

In this sense, rather than observing the subject matter as fieldwork, we can find more hints and discoveries by interacting with people as if we were friends and trying to do or create something together.

At this point, it is important not to quickly seek the correct answer out of the blue, but to find a solution for that specific case and a rationale for the situation through trial and error by being hands-on and trying different things. That is what I consider ethics to be.

When we create a new concept, it tends to quickly morph into a command from above, that is, become a moral obligation. The diversity that we hear everywhere is one such thing, and the more we talk about it, the more it seems to be losing its substance. In order to realize *rita*, to improve society through technology without falling into this kind of tokenism, we must put aside our desire to impose control, listen to the voices of others, and continue with trial and error together to find a solution that suits the situation. I hope that many companies will keep this in mind as they work to resolve social issues.



| Feature |

Industrial Technologies to Support Future Earth

Water and Industry Solutions for a Sustainable Society

In a rapidly changing world, the increasingly severe challenges associated with energy, food, and other resources are impacting the global environment in a variety of ways.

Hitachi, meanwhile, has published its latest Mid-term Management Plan aimed at achieving a sustainable society. In the field of water infrastructure, Hitachi is playing its part in providing sustainable safety and security to its customers and society, utilizing data and technologies that contribute to the decarbonization of water, sewage, and port infrastructure businesses with the recycling of resources and energy. Likewise in industry, Hitachi is contributing to the environment by engaging in collaborative creation with customers and other business partners to deploy total seamless solutions that combine IT, OT, and products, including digital solutions that help to build resilient supply chains.

This issue of *Hitachi Review* covers a wide range of work that is going on in the water and industrial sectors, looking at this from an environmental perspective.

MESSAGE 1

Becoming a Net-positive Company of Excellence that Underpins Sustainable Societies

Utilizing the Power of Data and Technology to Build Prosperous Societies in Harmony with Nature

Delivering Clean Water and a Clean Environment

Since its formation, the Water & Environment Business Unit has engaged in a wide variety of utilities businesses based on the vision of delivering clean water and a clean environment. In the meantime, however, the COVID-19 pandemic has had a major impact on the business environment in which we operate, bringing changes to the values of individuals and of society as a whole. In particular, there has been an acceleration globally in digital transformation (DX), the transformation of society and business by digital technology. In such a rapidly changing market, it is becoming more important than ever to keep pace with changes in the issues and needs of customers, and to be able to overcome challenges across the entire spectrum of products, operational technology (OT), and IT.

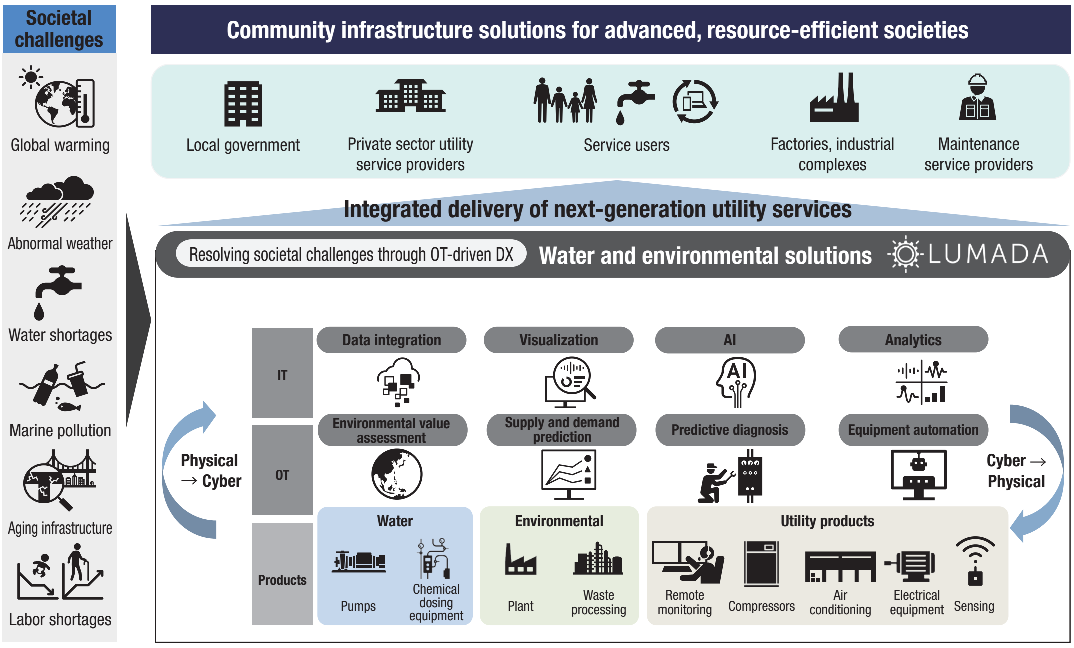
At Hitachi's Water & Environment Business Unit, we are drawing on our OT domain knowledge of environmental and clean technologies to engage in collaborative creation with business partners and customers from industry and the public sector, thereby delivering value across a broad range of applications by leveraging our combined strengths in process engineering and digital technology.

Hideshi Nakatsu
Vice President and Executive Officer,
CEO of Water & Environment Business Unit, Hitachi, Ltd.

Digital Transformation for Supplying Clean Water

The water sector has been paying greater attention to information and communication technology (ICT) over recent years as a means of delivering safe and reliable water supplies in a sustainable manner. At the Water & Environment Business Unit, we are combining IT with the experience and expertise we have built up over many years to step up our deployment of digital solutions.

One example is an operation and maintenance (O&M) support digital solution at water and sewage utilities that enables this work to be carried out in a more transparent and efficient manner with a reduced workforce while also passing on the skills of highly experienced staff. We also offer solutions for dealing with the localized heavy rainfall events that have become more common over recent years, utilizing artificial intelligence (AI) for tasks such as the diagnosis of equipment faults, water quality prediction, and operational support. In efforts extending from building local community infrastructure to creating a sustainable society, we are pursuing the integrated delivery of utilities by sharing data with other forms of social infrastructure



OT: operational technology AI: artificial intelligence

From Building Local Community Infrastructure to a Sustainable Society

(including energy, roads, rivers, and civil defense), not only water supply and sewage information.

Work toward a Clean Environment

Seeking to realize a decarbonized society, resource-efficient society, and a society that is harmonized with nature, Hitachi has published its long-term environmental targets in Hitachi Environmental Innovation 2050.

Acknowledging the environmental issues of recent years, the Water & Environment Business Unit has been accelerating its efforts to achieve carbon neutrality through measures that include use of hydrogen and renewable energy. One example is our collaboration with business partners to produce hydrogen from excess renewable electricity and to develop a hybrid generation system that can run on a mixture of hydrogen and traditional fuels. In Tomiya City, Miyagi Prefecture, we are partnering with Miyagi Consumer's Co-operative Society (Sendai City), Marubeni Corporation, and others to trial a diesel-engine generator fueled by a mix of hydrogen and waste food oil.

Along with building a supply chain for the use of hydrogen by consumers and industry, we are also participating in a demonstration project in Namie, Fukushima Prefecture that involves using advanced digital technologies to balance supply and demand for electric power. Through these efforts, we are helping to bring about a carbon-neutral society while also boosting local industry through attracting plants utilizing hydrogen, which does not emit any carbon dioxide (CO_2) when used as a fuel.

Seeking to Realize a Sustainable Society

If we are to make the transition to a sustainable society, it will be essential to engage in collaborative creation with a wide range of stakeholders, encompassing vendors, financial institutions, and green certification agencies as well as customers and other business partners. By exchanging the necessary information and data between these interrelated stakeholders, Hitachi is also active in areas such as building frameworks for resource recycling and transforming sustainability certification into value. Through these efforts, we are pursuing not only the society-wide optimization of supply chains, but also our goal of becoming a net-positive company of excellence that creates environmental value and underpins a sustainable society, establishing and fostering new ecosystems by overcoming the challenges posed by *kiwa* (the gaps between different organizations) through the deployment of total seamless solutions that utilize digital technologies across a wide range of different fields.

MESSAGE 2

Enhancing Economic Value for Customers While Reducing their Environmental Impact

Overcoming Management Challenges through Collaborative Creation and Digital Technology

Supporting Sustainable Progress in Industry

The management perspectives of customers have undergone considerable change over recent times in terms of how they think about the environment, resilience, and safety and security. With institutional investors increasingly treating climate change as an investment risk and calling for major corporations to disclose their carbon footprints, companies are responding to investor expectations for the adoption of decarbonization strategies and the disclosure of information to the extent that their decarbonization measures can sometimes serve as a means of differentiating themselves from competitors.

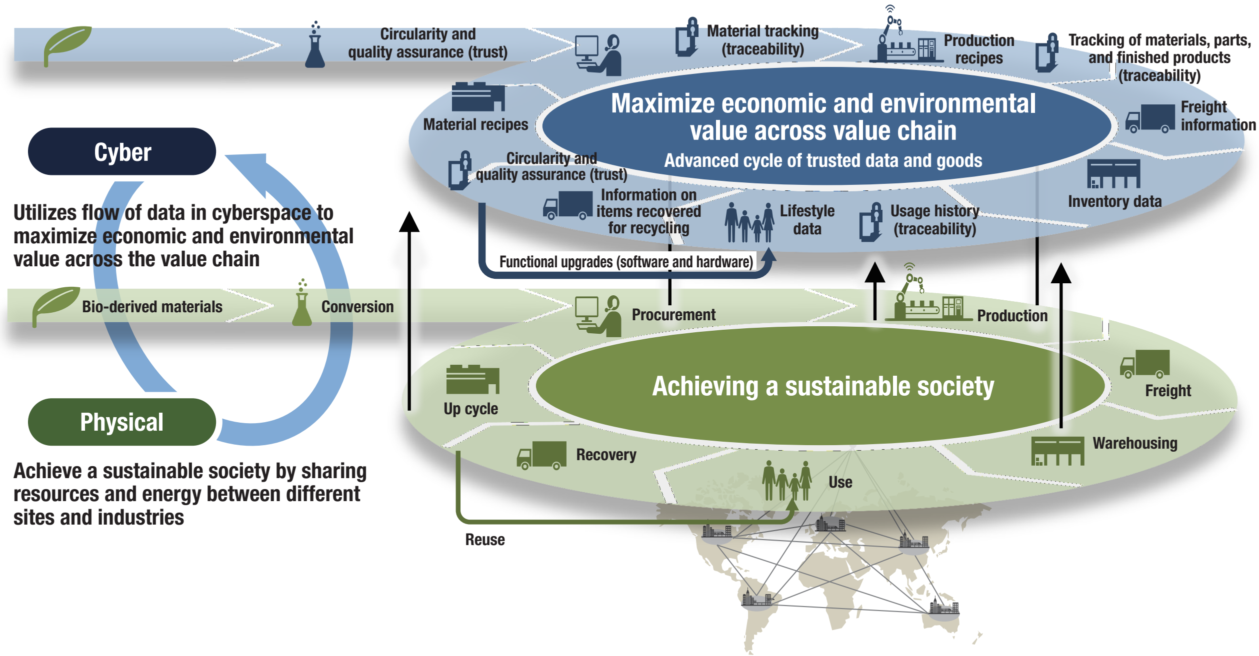
Kazunobu Morita
Vice President and Executive Officer,
CEO of Industrial Digital Business Unit,
Hitachi, Ltd.

Meanwhile, an increasing number of companies have set their own science-based targets (SBTs) for the reduction of greenhouse gas emissions in line with what is needed to meet the goals of the Paris Agreement, with target dates five to ten years into the future. The number of Japanese companies that have acquired SBT certification reached 247 as of September 1, 2022 (the third highest internationally), with a further 56 companies having committed to certification.

Unfortunately, major societal challenges that are too large for any one company to resolve continue to make their presence felt, with the issues to be addressed being both complex and interrelated. The environment and COVID-19 are two prominent examples.

Hitachi and the Connective Industries sector are taking up the challenge of creating sustainable societies while delivering personal wellbeing by utilizing data and technology, working through the Social Innovation Business to resolve these societal challenges with a combination of the latest IT, operational technology (OT), and products.

Here at the Industrial Digital Business Unit, we are leveraging digital technology to help reduce the environmental impact of our business customers while also delivering economic value in an environment where management challenges are growing increasingly complex.



Sustainable Society with Optimal Combination of Economic and Environmental Value Made Possible by Cyber-physical Systems

Facilitating DX in Global Industry and Logistics

As the environment in which business operates changes in complex and interrelated ways, as exemplified by climate change and COVID-19, societal challenges extend across different businesses and sectors. These challenges are more than a single company, organization, or sector can resolve. While this calls for total solutions that span multiple companies, organizations, and sectors, the "*kiwa*" (gap) that separate these companies and organizations from one another pose an obstacle when it comes to putting these solutions into practice.

Our aim at Hitachi is to maximize value for customers by engaging with them in collaborative creation to transcend these many gaps. The solutions we develop are based on the concept of total seamless solutions that, in addressing the problems posed by these gaps, use digital technology to provide seamless integration both vertically, from the workplace to management, and horizontally, across the companies and organizations that make up the supply chain.

What makes this possible are Hitachi's cyber-physical systems (CPSs) that leverage our strengths in IT, OT, and products. These involve the rapid and precise collection and modeling of large quantities of diverse forms of data across different companies in physical space, analysis and simulation in cyberspace to determine optimal solutions and support management decision-making, and the provision of feedback to physical space to optimize real-world operations.

One example from the field of regenerative medicine involves dynamic interoperation between production progress and treatment planning that is achieved by means of a platform for managing the entire value chain, bringing together the products and OT of cell processing centers (CPCs) that are essential to production.

Similarly, in the beverage industry, Hitachi has implemented Internet of Things (IoT) platforms for system-wide optimization that also facilitate working practice reforms and the pursuit of safety and security. This is done by collecting, integrating, and consolidating large amounts of data in a variety of formats from multiple production lines to enable traceability and to visualize factory data.

Meanwhile, COVID-19 along with heightened geopolitical risk and a greater threat of natural disaster have increased operational uncertainties and this calls for flexible management capable of readily adapting to change. Hitachi is utilizing CPSs to equip value chains with dynamic capabilities that allow for a flexible response to a variety of different drivers of change.

We are also seeking to contribute to the global market and, through Hitachi Industrial Holdings Americas, Inc., we are accelerating the deployment of total seamless solutions in our North American operations that are based around Hitachi group companies, JR Automation and Flexware Innovation, Inc.

Contributing to the Environment through Digital Technology

In pursuit of growth in which "green," "digital," and "innovations" play a key role, Hitachi is contributing to the achievement of wellbeing, enabling people to continue enjoying a good life while also respecting planetary boundaries to keep the environment safe in a way that allows for the continued existence of humanity.

At the Industrial Digital Business Unit, we are developing the technologies that CPSs require and are implementing and testing these within Hitachi so that customers will be able to use them with confidence. In doing so, we are helping to create a sustainable society that recycles resources and functions, a society in which people can pursue a wide variety of lifestyles, while at the same time taking a management perspective toward addressing customers' environment, resilience, and safety and security issues, a form of value delivery that becomes possible only when we start bridging gaps.

CONCEPT

Sustainable Future Built on Multifaceted Coordination

Digital Solutions for Resource Recycling and Decarbonization

As the global environment undergoes dramatic change, humanity is confronted with numerous challenges in the form of climate change, energy concerns, and resource depletion. To overcome these global-scale issues, it is essential for everyone living on Earth to have a sense of ownership and that all nations act in a globally coordinated manner. Against this background, Hitachi is developing environmentally conscious technologies and solutions and is engaging in collaborative creation with corporate partners and other stakeholders as it seeks to create a sustainable society. *Hitachi Review* invited Professor Masaki Takaoka of the Environmental Engineering Department, Graduate School of Engineering, Kyoto University, who also serves on the Working Group for a Sound Material Cycle Society, Central Environment Council, Ministry of the Environment, to meet with key people from Hitachi and review the progress of work on global environmental protection and also look ahead to what forms a sustainable future society might take.

Masaki Takaoka, Ph.D.
Professor, Environmental Engineering Department, Graduate School of Engineering, Kyoto University

After being appointed Assistant Professor at the Faculty of Engineering, Kyoto University in 1993, he served as an Associate Professor and in other roles before taking up his current position as Professor of Environmental Engineering. Member of the Working Group for a Sound Material Cycle Society, Central Environment Council, Ministry of the Environment, Vice-President from June 2022 of the Japan Society of Material Cycles and Waste Management

Makoto Onishi
CTO, Water & Environment Business Unit, Hitachi, Ltd.

Graduated from the Division of Environmental Engineering, School of Engineering, Osaka University in 1986. Joined Hitachi Plant Engineering & Construction Co., Ltd. in 1986. He has worked on water treatment systems, especially the research and development of systems that use membrane separation. He took up his current position in 2019.

Hideki Hanami
CTO, Industrial Digital Business Unit, Hitachi, Ltd.

Joined Hitachi, Ltd. in 1994. Worked on digital control systems and security for critical infrastructure at Omika Works before taking up his current position in April 2022. In addition to his participation in Working Group 3 at the Study Group for Industrial Cybersecurity led by the Ministry of Economy, Trade and Industry, he has also worked to promote the digitalization of manufacturing as a member of the World Economic Forum (WEF) Global Lighthouse Network.

Tomoko Suzuki, Ph.D.
Project Leader, Planetary Boundaries Project, Center for Sustainability, and Corporate Chief Scientist, Research & Development Group, Hitachi, Ltd.

After joining Hitachi, Ltd., she worked on an extensive range of environmental system developments, including systems for hydrogen production and for generating power from waste. In her current role, she is engaged in the formulation and commercial implementation of research and development strategies for resolving environmental challenges.

Distinguishing Global Challenges from Local Challenges and Considering Them Together

Embutsu: The keywords of decarbonization and resource-efficiency have attracted considerable attention in the context of achieving a sustainable society. Back in the 1960s, the term "pollution" was used for the environmental problems of the time. Hitachi has grappled with a wide variety of challenges since then, right up to the present-day issue of climate change. While environmental challenges are challenges for all of humanity, we tend to see them differently depending on our particular standpoint or perspective. Professor Takaoka, how do you see the circumstances surrounding the environmental challenges of today from your perspective in the field of environmental engineering?

Takaoka: Fifty years ago, in 1972, the Club of Rome*1 published its first major report, "The Limits to Growth." The report made the case that, "If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years." Since then, there has been concern about the depletion of resources such as metals and fossil fuels. The limits of planet Earth are something we need to be thinking about on the basis of scientific knowledge, asking how we can make effective use of finite resources.

As you noted, people perceive environmental challenges differently depending on their particular perspective. While this requires us to distinguish between local challenges and those that matter to the entire world, this does not mean the two are unrelated. One example is the question of how to dispose of artificial materials such as plastics. Seen as a local matter in the past, the issue is increasingly becoming global in scope and negotiations for an international convention on plastic pollution are currently underway. On the other hand, as different localities address environmental challenges differently and have their own forms of social infrastructure, resource recycling needs to be achieved in ways that best suit their respective circumstances.

While climate change, for example, is a major challenge that Japan shares with the rest of the world, it also faces a parallel problem in the form of a shrinking population. At the same time as population increase is pushing societies around the world in the direction of higher consumption of resources such as food, Japan faces a shrinking number of consumers. It seems unlikely that both problems can be resolved through a common approach.

Embutsu: With environmental conventions and other such measures being taken globally, where do you see scope for Japanese manufacturers to exert influence?

Takaoka: I believe that Japan is a leader in the disposal of environmental pollutants. On the other hand, there have been some remarkable advances made overseas in technologies for dealing with plastics. Rather than continuing to use existing recycling technologies and systems, Japan also needs to be upgrading its practices to keep pace with current progress.

The European Union (EU) has proposed the idea of a circular economy*2 whereby it is seeking to make solutions to the issue of environmental pollution an integral part of the economic system, including through the use of digital technologies that were not even imagined in the 2000s. In Japan, not only do we need to catch up with international developments while facing up to these societal changes, but we also need to take advantage of our own distinctive strengths to serve as a model for what new solutions might look like.

Hitachi's Efforts to Balance Environment and Business

Embutsu: Along with national and regional differences, there are also different standpoints, such as those of academia and the private sector, on how to think about and address the problem of environmental protection. Onishi-san and Hanami-san, how do you see this from a business unit perspective? Also, can you tell us about what your respective divisions within Hitachi are doing about this?

*1 A private-sector think tank headquartered in Winterthur, Switzerland.

*2 An economic system in which materials and products are recycled and economic growth is combined with a reduction in waste and pollution.

Onishi: In our 2024 Mid-term Management Plan, Hitachi set targets of achieving carbon neutrality at all our business sites (factories and offices) by FY2030 and throughout our value chain by FY2050. To help customers reduce their carbon footprint, we have also set explicit numeric targets for our contribution to carbon dioxide (CO_2) reduction in FY2024. In the Water & Environment Business Unit where I work, our business primarily involves things like tendering for engineering projects, such as water infrastructure for public sector utilities in Japan and our utilities solution business for industrial customers.

One thing that I have noticed through my involvement in this work is that public perceptions of resource recycling are changing significantly, both within Hitachi and among our customers. A lot of people have started to question why we can't create useful resources out of things that used to be disposed of or treated. For example, rather than asking how we can treat wastewater, people are wanting to know how wastewater can be processed, recycled, and reused to serve as a resource.

In the past, our business was primarily based on two-way relationships, between Hitachi and local governments in the case of the public sector and between Hitachi and companies in the industrial sector. In order to get serious about resource recycling, however, I believe we need to build systems that take account of a wide range of stakeholders, including suppliers of parts and materials and the end users who actually use the products, and indeed we are currently working to do so.

Hanami: While the industrial workplace is seeing significant advances driven by new technologies such as digital twins, I believe we have now reached a point where we need to take the next step toward resolving societal challenges.

Meanwhile, supply chains in industry encompass many stakeholders, from materials production to the manufacturing and assembly of parts and transportation to the end user, with the various participants addressing environmental issues based on their own standpoints. Each company operates its business on the basis of its own key performance indicators (KPIs), a way of doing things that is not always optimal when considering the totality of the supply chain. While individual companies will continue doing what makes sense in their own context, what has to happen next, I believe, is for us to start thinking about how to optimize the supply chain as a whole.

The key to achieving this will be common platforms that share data in cyberspace and are capable of intelligently analyzing the entire supply chain. One example relating to CO_2 emissions would be a mechanism for presenting and sharing information on how much CO_2 has been emitted in the process of making and supplying particular parts or products, something that is difficult for users to find on their own. If this platform could be combined with accurate demand prediction, I believe it could boost efficiency along all steps in the supply chain from the supply of parts and materials to distribution and delivery.

In anticipation of such mechanisms, we are working at the Industrial Digital Business Unit to create value by linking together the different types of data generated in industry and in other places where economic activity happens. Along with collecting and coordinating data and running simulations, we are creating robust and resilient supply chains by encouraging improvement not only in the vertical direction from the company workplace up to senior management, but also horizontally across different companies. To achieve this, we are working not only on

Moderator

Ichiro Embutsu, Ph.D.

Principal Researcher, Center for Sustainability – Decarbonized Energy, Research & Development Group, Hitachi, Ltd.

He is currently engaged in the research and development of water and environmental systems. His appointments include being a member of the Judging Panel on the Project Innovation Awards (PIA) by the International Water Association (IWA) and Vice President of the Society of Environmental Instrumentation, Control and Automation (EICA). Doctor of Engineering the management of production lines in physical space, but also on developing enterprise resource planning (ERP) platforms for management and on the optimization of supply chain planning.

Embutsu: So, what you are talking about is the use of digital technology to optimize and operate entire supply chains beyond what any one company can do on its own. In this context, what is happening in the area of international standardization?

Hanami: There were discussions in Europe several years ago about establishing rules for disclosing how much CO_2 is emitted in the process of manufacturing particular products. Vendors have already started to make platforms available that conform to the Gaia-X[*3] data sharing rules and the number of participating companies is rising. Similar activities have also gotten underway in Japan, including work on establishing rules for the sharing of data on the emission of CO_2 in manufacturing processes and how these numbers are to be calculated. Attention is also being paid to maintaining consistency with international rules, with the Ministry of Economy, Trade and Industry and the Ministry of the Environment participating as observers at organizations such as the Green × Digital Consortium[*4].

Resource Recycling for Maintaining Growth in a Finite World

Embutsu: Among the challenges facing the environment are problems that are not amenable to quick resolution using existing systems and solutions. Goals such as decarbonization and resource recycling demand a higher level of technology than is found in the environmental solutions that business is currently able to supply. What work has the Research & Development Group been doing in this regard?

Suzuki: Our core strategy at the Research & Development Group is to utilize data and collaborative creation to overcome the challenges facing customers and wider society, thereby helping to resolve the issues associated with planetary boundaries[*5] and with well-being. Two projects that commenced during the current fiscal year were the Planetary Boundaries Project and the Well-being Project. While planetary boundaries can be thought of as representing the limits of the earth, we take a forward-looking approach that asks how we can learn where these boundaries lie and how we can continue to grow without exceeding them. In the area of climate change, along with research based on forecasting from current societal systems, such as work toward use of non-fossil fuels, the electrification of mobility, and energy efficiency, we are also identifying areas that warrant attention by backcasting from the sort of society we want to have in 2050, and working on utilizing hydrogen as a source of energy to help achieve carbon neutrality.

With regard to well-being, the ability to choose for one's self is a vital factor in people's sense of self-esteem. It is important for people to have a range of possible futures and to be able to choose between them. To this end, we have also been working on the use of a policy recommendation artificial intelligence (AI) to present a number of future scenarios that suit different localities to help build community consensus and inform decision-making on policy.

Embutsu: You are talking about how to help people decide what they should be doing now in anticipation of the future and which path they should follow. I think it is a very admirable endeavor to be able to support government and other decision-making about policy and other matters based on scientific knowledge.

Professor Takaoka, how do you see the future of environmental protection from the perspective of environmental engineering?

Takaoka: The term "circular economy" is one that we frequently hear in recent years. If such an economy were truly circular, it would have no arteries (outflows) or veins

*3 A European project for building data infrastructure with the primary objective of securing digital sovereignty. The aim is to enable interoperability by integrating diverse cloud services supplied by companies both inside and outside of Europe on a common system, with a standardized certification mechanism that facilitates the exchange of data across industries.

*4 A consortium dedicated to the comprehensive optimization of Japanese industry and society to help achieve carbon neutrality by 2050, including through digitalization and the creation of new business models in environmental industries.

*5 A concept that attempts to quantify the safe boundaries of human activity on Earth within which humanity can continue to develop and thrive.

(inflows). Currently, however, we still have businesses that operate like arteries (using fresh resources) and others that operate like veins (able to recycle and reuse existing resources). If we are to achieve genuinely cyclic use of resources then those artery companies will need to take active steps to use only resources that are already available. Suzuki-san spoke earlier about the technique of backcasting and in that context what we want is a world where it is not possible to distinguish the arteries from the veins.

Embutsu: The term "waste treatment" will disappear and terms like resource recovery and the trading of valuable materials will take its place. The ideal will be a society in which, rather than being considered waste, sewage and sludge will be seen as treasure troves.

Suzuki: Unfortunately, the distribution and use of recycled materials also pose problems. For a waste material discharged by one industry to be used in another, for example, it first needs to satisfy a number of requirements set by that other industry, such as standards governing input materials. To address this issue, we partnered with the National Institute of Advanced Industrial Science and Technology (AIST) to establish the Hitachi-AIST Circular Economy Cooperative Research Laboratory in October 2022. To create a circular economy that can make efficient use of resources across entire value chains that span different industry sectors, we are undertaking research and development on topics such as determining what sort of society we want and what rules it will require.

Changing Now to Achieve the Future We Imagine

Embutsu: Finally, could you tell me about your outlooks for the future. Could you start by telling me about your plans at Hitachi.

Onishi: At the Water & Environment Business Unit, our future plans for managing and reducing CO_2 emissions start with measures to clarify the origins of recycled resources and provide the ability to track a variety of emissions and other data relating to the production process. We want to create value for our customers not only within Hitachi, but also through collaborative creation with our corporate partners and other stakeholders. On the technology front, we are currently working with local governments on the use of hydrogen as a low-carbon source of energy. The aim is to enable the energy consumed in a region to be produced locally by utilizing local photovoltaic power generation to produce hydrogen that can then be stored in hydrogen storage alloy cassettes and supplied to users via the existing networks of consumer cooperatives and other such organizations for use in on-site power generation. We are also leveraging biotechnology, another strength of Hitachi, to enter the field of bio-production. This involves the use of biotechnology to produce a wide range of chemicals and other such products from biomass, biologically derived material that does not compete with food.

Hanami: Given that environmental challenges are not amenable to resolution at a single stroke, the way to approach them, we believe, is first to support the work being done by different companies to overcome these challenges and then to move on to the next step of optimizing activities across the entire value chain. The reliability of data plays a crucial part when it comes to making systems more sophisticated by leveraging the capabilities of digital technologies that encompass both the cyber and physical worlds. Sharing data between stakeholders serves no useful purpose if the data cannot be trusted. One example relates to the Hitachi value chain traceability service for regenerative medicine supplied by the Industrial Digital Business Unit. Because it contains personal information, any mishandling of data from the field of regenerative medicine is unacceptable and it needs to be treated with extreme care. The various steps along the value chain are linked together using encryption techniques and traceability to keep pace with the ever-changing situation on the ground. With the concept of trust being built into the process, this involves the appropriate sharing of data acquired by accurate measurements made using rule-compliant means. By doing so, I hope that we can help to protect the environment by improving operational efficiency along all steps of the value chain while also contributing to well-being in the broader sense of the safety and security of users.

Suzuki: The growth in global population is expected to peak in the 2080s[*6]. As the population grows, it follows inevitably that demand for food and other resources will grow with it. This is predicted to worsen deforestation as people seek more land for agriculture. The questions of how to acquire resources and put them to effective use are becoming more important than ever. At the Research & Development Group, we have taken up the challenge out of a belief in the necessity of treating CO_2 as a resource that can be used to produce feedstocks for the production of food or materials. It would be wonderful if we could put biotechnology and digital technology to use in synthesizing materials able to be used in the production of food, clothing, or shelter. This idea is one of a number of research topics aimed at turning CO_2 into a resource that we are undertaking in partnership with the University of Cambridge in the UK as well as with a variety of private sector companies and startups.

Embutsu: What about how things look from academia? What can you tell us about future targets for environmental problems and the challenges that arise when putting ideas into practice?

Takaoka: Social infrastructure is not something that can be changed easily. If the current state of progress is all about innovation achieved by applying the various technologies of digital transformation (DX) to existing social infrastructure, then decarbonization and carbon neutrality are one step further on from that. Both universities and private-sector companies need to be serious about pursuing research and development that looks ahead to the future of 2050. A variety of approaches can be used to overcome challenges, such as the recycling of water and waste products, recycling carbon in order to achieve carbon neutrality, and biotechnology. Which of these approaches will work best, however, will depend on the size and characteristics of the society concerned. I hope we can continue to try a range of different initiatives in the future as we seek out the best solutions without fear of the risks.

The development of human capital is another role of universities. Societal challenges and environmental problems are not issues that can be resolved by Japan on its own, and we need to be fostering people with a global perspective on society and the environment, not just through our research, but also through practices such as international exchange, and then send these people out to work in the private and public sectors. I hope that we can continue to enjoy close collaboration between industry, government, and academia that addresses both technology and human capital.

Embutsu: Having people among our customers who care about overcoming environmental challenges changes the conversation entirely, and for this reason I would like to see more fostering of human capital by universities. We also hope to proceed through collaborative creation based on a deep understanding of the challenges facing customers, making good use of the scientific knowledge and human capital that exists in academia. Thank you for your time today.

*6 United Nations, “As the world’s population hits 8 billion people, UN calls for solidarity in advancing sustainable development for all” (Nov. 2022), https://www.un.org/sustainabledevelopment/blog/2022/11/press-release-as-the-worlds-population-hits-8-billion-people-un-calls-for-solidarity-in-advancing-sustainable-development-for-all/

ACTIVITIES 1

Aiming for Nationwide Application of Tomiya City's Model of Low-Carbon Hydrogen Supply Chain

Ensuring Safety and Security through the Use of Existing Logistics Network and Hydrogen Storage Alloy

Japan overhauled its energy policy after the Great East Japan Earthquake in 2011. As a result, the use of natural energy sources such as solar and wind power as renewable energy sources has progressed. Such energy sources, however, are unlikely to serve as main sources of power due to their characteristics. For this reason, hydrogen is becoming popular as a new energy source. At present, various initiatives are being promoted nationwide to develop a hydrogen economy. One major such initiative is to build an integrated supply chain for the production, storage, and use of hydrogen. For this article, *Hitachi Review* spoke to key people involved in each project of a demonstration project in Tomiya City, Miyagi Prefecture, which is actively promoting the development of a low-carbon hydrogen supply chain.

Hirotoshi Wako
Mayor of Tomiya City, Miyagi Prefecture
Born in Tomiya City, Miyagi Prefecture, he took over his family's agricultural business, cultivated blueberries with friends and made them into a specialty of Tomiya. At the age of 31, he started a CAD system company. Then, he established a designated confirmation and inspection body. After opening a restaurant called "The Terrace," he became involved in the Slow Food movement and served as both the first representative of Japan and a member of the International Council. After the Great East Japan Earthquake in 2011, he opened "Reconstruction Food Stall Village Kesennuma Alley," a temporary restaurant district in Kesennuma City to rebuild the disaster-stricken area and help its residents. He also founded an electric power company, and built and operated a large-scale solar power plant called "Tomiya Solar Garden." In 2015, he was elected Mayor of Tomiya Town, and then became Mayor of Tomiya City in 2016, when Tomiya became a city.

Yoichi Fujimoto
Senior Advisor, New Energy Business Development Department, Marubeni Corporation
Since he joined Marubeni in 1985, he has been steadily engaged in overseas sales in the energy sector. After investing in a mega-solar business, in 2012, which was the largest in Japan at that time, he set up the New Energy Business Development Department to develop hydrogen, fuel ammonia, and bio-jet fuel businesses, and now serves as its Senior Advisor.

Hydrogen as a New Promising Energy Source

As the global energy situation is changing dramatically, the supply chains of major traditional energy sources such as petroleum and natural gas are also changing significantly and energy-related problems are emerging as pressing issues in many countries.

Under these circumstances, hydrogen is attracting attention as a new energy source. The shift to natural energy sources such as solar and wind power has been promoted worldwide to tackle global warming. However, these energy sources still present challenges for use as main power sources because the amount of energy generated from them fluctuate according to the season and weather conditions.

Hydrogen, on the other hand, can be extracted from water using electricity and also provides other production options, as it can be produced from a number of resources, including fossil fuels such as petroleum and natural gas as well as methanol and ethanol. Moreover, hydrogen can generate electricity by combining it with oxygen, and thermal energy can be extracted from it through combustion. Since hydrogen has the advantage of emitting no CO_2 during its combustion, it is expected to significantly contribute to decarbonization, when combined with renewable energies such as biomass energy.

In December 2017, the Japanese government developed the first national strategy for hydrogen in the world. With a view to the goals of the Paris Agreement, Japan is promoting efforts in the mobility sector, such as the promotion of fuel-cell vehicles and hydrogen filling stations. The country is also accelerating its efforts to develop a hydrogen economy, including the establishment of an international hydrogen supply chain.

Hidenori Ohara

Assistant Director, Environmental Management Office, Miyagi Consumer's Co-operative Society and Co-op Tohoku Sunnet Business Federation

He joined the Co-operative Society in 1996. Two months later, he was appointed to study ISO 14001 exclusively. In 1997, the Miyagi Co-operative Society became the first cooperative to receive ISO 14001 certification in Japan. He was appointed as the chief internal environmental auditor to help other cooperatives nationwide to comply with ISO 14001 and conduct internal audits before taking his current position.

Ryusuke Gotoda

General Manager, Smart Utility Division and Carbon Neutral Business Promotion Office, Environment Solutions Division, Water & Environment Business Unit, Hitachi, Ltd.

In 1987, he joined the Matsudo Research Laboratory, Hitachi Plant Engineering & Construction Co., Ltd. to research and develop air-conditioning equipment for buildings, plants, clean rooms, and other facilities. In 2015, he started developing hydrogen technologies. Since 2021, he has been engaged in the planning and development of carbon-neutral businesses as General Manager of the Smart Utility Division, Environment Solutions Division, Water & Environment Business Unit.

Focus on Hydrogen Due to a Lack of Natural Energy

Amidst these efforts, one local government, Tomiya City in Miyagi Prefecture, has been promoting an innovative effort to build a low-carbon hydrogen supply chain based on the concept of local production for local consumption. Tomiya City was originally a village when it was incorporated as a municipality with the introduction of Japan's current municipality organization system in 1889. Adopting "The Best City in Japan to Live in" as its slogan, it continued to grow from a small town into a city. Since the 1960 census, it has been a growing city with the population increasing year by year.

Mayor Hirotoshi Wako explained why the city initiated such an effort:

"Even before I took office as Mayor, the city had been addressing environmental problems by establishing solar power plants in the private sector, for example. Especially after the Great East Japan Earthquake, we felt the increasing need to promote decarbonization and renewable energy. However, Tomiya City is not rich in natural energy sources such as wind power, hydropower, and geothermal energy. So we wondered if we could produce hydrogen from sunlight."

Around that time, Mayor Wako was informed that the Ministry of the Environment (MOE) was inviting the public to enter its competition for hydrogen supply chain demonstration projects through the Environmental Policy Division, Miyagi Prefecture. He immediately secured the cooperation of Yoichi Fujimoto, a Senior Advisor in the New Energy Business Development Department, Marubeni Corporation. Hitachi also joined the team, as the company was planning to launch a joint carbon-neutral initiative with Marubeni through its power generation business in Kyushu. The three parties started discussions with the aim of having their project adopted as a demonstration project.

Marubeni has operated power and fuel businesses over many years. The company has a successful record leading various projects through long-term investments in engineering, procurement, and construction (EPC) and independent power producers (IPPs) in the electric power sector, liquefied natural gas (LNG) businesses in the fuel sector, and petroleum development projects. Hitachi also has a long history in the energy business, including electric power.

Unfortunately, however, the initial three-party proposal led by Tomiya City was not selected in the competition. Fujimoto, who was responsible for the future design of the project, explained the reason for the rejection:

"We were originally approached by the personnel of Tomiya City who were temporarily transferred to the Tokyo Office of Miyagi Prefecture. They wanted to discuss starting a hydrogen business project with us. Initially, we wanted to use the electricity and hot water produced from hydrogen in plastic greenhouses for growing blueberries, which are a specialty of Tomiya, and in institutions for the elderly. However, it was not a good idea to include so many things. We even approached the Kakuda Space Center of Japan Aerospace Exploration Agency (JAXA), which uses the largest amount of hydrogen in the Tohoku region, and asked JAXA's Senior Vice President to use the hydrogen produced in Tomiya City. In the end, our proposal was rejected because we did not have a clear vision of its wider use for the future."

Participation by Miyagi Consumer's Co-operative Society with an Existing Logistics Network

Although their first attempt failed, the three parties started discussing a new proposal. Through the process, they came up with the idea of asking Miyagi Consumer's Co-operative Society to join the team to build a new supply chain. The new project was coordinated by Ryusuke Gotoda, General Manager of the Smart Utility Division, Environment Solutions Division, Water & Environment Business Unit, Hitachi, Ltd. He had the following to say about the project:

"Economy is ultimately the most important factor in developing a successful working supply chain. We needed to reduce the transport costs incurred to send the produced hydrogen to customers. So, we came up with the idea of asking the Miyagi Consumer's Co-operative Society, which has a nationwide logistics network, to help us make the project successful."

Miyagi Consumer's Co-operative Society is the first consumers' cooperative to receive ISO 14001 certification in Japan. Since it was first certified in 1997, the organization has been actively engaged in environmental conservation activities to solve four priority issues: reducing the total CO_2 emissions in its cooperative services; reducing and recycling waste from its business operations; developing an environmentally friendly local community; and giving environmental consideration in its merchandise business. Hidenori Ohara, Assistant Director of the Environmental Management Office at Miyagi Consumer's Co-operative Society, was responsible for the equipment operation and hydrogen delivery. He described the circumstances of his organization just before it joined the project:

"We used to promote environmental activities and suggestions within the scope of our businesses, based on the concept of ISO 14001. However, after we experienced the nuclear accident caused by the Great East Japan Earthquake, we shifted to our own promotion and expansion of renewable energy. In FY2021, we successfully reduced CO_2 emissions by 70%, compared with 2013, the year the Paris Agreement was concluded. Then, after continuing activities such as working to procure electric power based on the 'Renewable Energy 100% (RE100)' initiative and renewable energy businesses such as biomass power generation, we were invited to participate in this project."

Completion of a Low-carbon Hydrogen Supply Chain Based on the Concept of "Local Production for Local Consumption"

The four parties, including Miyagi Consumer's Co-operative Society, resumed their activities aimed at the successful adoption of their proposal. The key point of the new proposal was the way of storing hydrogen.

"While there are many ways to store hydrogen, we thought that security and safety would be essential for promoting the wider use of hydrogen in society. So we have chosen a method that uses a hydrogen storage alloy cassette to store hydrogen, while making sure to keep the pressure inside the container lower than 1 MPa." (Gotoda)

Hydrogen storage alloy cassettes are not classified as dangerous articles under the High Pressure Gas Safety Act and the Fire Service Act. Therefore, no qualification is required for handling them and they can be loaded on trucks together with water and foodstuffs, etc. Marubeni's strength as a trading company was put to good use in importing the rare metals used as raw materials in the hydrogen storage alloy.

"One of Marubeni's major tasks was to study the feasibility of the project and how to expand it in the future. Cost is a critical factor in commercialization. As the rare metals used as raw materials in the hydrogen storage alloy were produced in China, we investigated the situation during the demonstration project and found that three or four specialized trading companies in China were involved. For that reason, we negotiated the price of the metals directly with suppliers through Marubeni's Beijing Branch. As a result, we managed to receive an inexpensive quote for bulk purchases, improving the future business feasibility of the project." (Fujimoto)

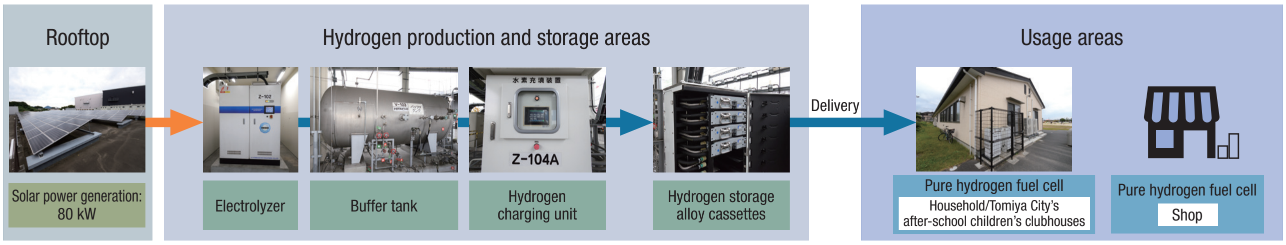
One of the features of this supply chain is that it produces green hydrogen[*1], rather than gray hydrogen[*2] or blue hydrogen[*3], which are derived from fossil fuels. To produce green hydrogen, which is a field in which Japan is lagging behind other countries, Miyagi Consumer's Co-operative Society kindly provided the use of solar power generated on the roof of one of its buildings at the Tomiya Joint Purchasing and Logistics Center of Miyagi Consumer's Co-operative Society, where a hydrogen manufacturing system and other equipment are installed.

The newly proposed low-carbon hydrogen supply chain is as follows. First, solar power generation is used

*1 Hydrogen produced using renewable energy. For example, it is produced in the process of electrolyzing water by using the electricity produced in solar power generation.

*2 Hydrogen extracted from fossil resources such as petroleum.

*3 Hydrogen produced from gray hydrogen by properly treating CO_2 emitted during its production to prevent CO_2 in the air from increasing.



Main devices	Electrolyzer	Buffer tank	Hydrogen charging unit	Hydrogen storage alloy cassettes	Pure hydrogen fuel cell For homes and after-school children's clubhouses	Pure hydrogen fuel cell For shops
Characteristics	Produces high-purity hydrogen according to the output of the produced solar power that changes constantly	Temporarily stores the hydrogen produced according to the amount of sunlight and capable of storing the amount of hydrogen required for one filling session	Simultaneously fills eight hydrogen storage alloy cassettes with hydrogen and automatically stops when the cassettes are filled with the appropriate amount	Suitable for safe, long storage of hydrogen, which is neither a dangerous article nor discharged naturally	Waste heat is used to extract hydrogen from the hydrogen storage alloy. It is exclusively used for power generation.	Waste heat is used not only to extract hydrogen from the hydrogen storage alloy, but also to heat the water used in the shop. It is used for both power generation and heat recovery.

Figure 1 | Overview of Hydrogen Supply Chain Equipment of Tomiya City

to produce high-purity hydrogen with a water electrolyzer. The produced hydrogen is stored in a buffer tank and loaded into hydrogen storage alloy cassettes in the hydrogen charging unit. From there, Miyagi Consumer's Co-operative Society personnel deliver the cassettes to homes and Tomiya City's after-school children's clubhouses. Finally, the delivered hydrogen storage alloy cassettes are used to generate power (see Figure 1). This project was submitted to the MOE's FY2017 Low-carbon Hydrogen Technology Demonstration Project in Cooperation with Local Government, and successfully adopted.

The entire series of demonstration equipment was completed in August 2018. The Tomiya Joint Purchasing and Logistics Center of Miyagi Consumer's Co-operative Society held a ceremony to commemorate the start of its operation. Toru Doi, then State Minister for Reconstruction, Yoshihiro Murai, Governor of Miyagi Prefecture, and other concerned parties attended the ceremony, which garnered wide media coverage the following day and evoked a strong public response. Hitachi, which coordinated the project, had to work hard to get everything ready in time for the ceremony.

"The city insisted that the operation launch ceremony should be held in early August just before Sendai Tanabata Festival... (laugh) Considering how short the period was between the adoption and the ceremony, we thought it would be utterly impossible at first, but we managed to do it in the end." (Gotoda)

With a wry smile, Mayor Wako explained the significance of the ceremony:

"I'm very sorry about that time (laugh), but the timing of the operation launch ceremony was very important for us to formally announce that we were about to start the low-carbon hydrogen supply chain in Tomiya City. Luckily, all major figures attended the ceremony with a splendid ribbon-cutting event. The footage of the delivery of hydrogen storage alloy cassettes filled with hydrogen to after-school children's clubhouses also helped us announce the start of the operation to a wide range of people on a large scale. I believe that many people realized Tomiya City's commitment to become an advanced hydrogen city through this demonstration project."

Expanding the Possibilities of Carbon Neutrality

During the three-year demonstration project from FY2017 to FY2019, while the low-carbon hydrogen supply chain was in actual operation, various types of demonstration data were obtained for its commercialization. Originally, the project was supposed to end after three years and the related equipment removed, but the project began to show new promise.

As the demonstration continued, the project team developed a strong desire to operate the hydrogen supply chain and deliver a stable supply of hydrogen energy and proposed an enhancement plan to make the supply chain stronger by integrating a hydrogen mixed-combustion generator. As a result, the demonstration project was extended until 2021.

"While we have established a low-carbon hydrogen supply chain in the Tomiya model, in terms of resilience, for example, if the power grid were to go down, the supply chain would come to a halt. So we decided to add a hydrogen mixed-combustion generator, which generates electricity from the hydrogen stored as a backup or from the biofuel produced from waste, so that the supply chain could continue to operate without relying on the power grid in the case of a power failure." (Gotoda)

In response to the idea of combining used deep-frying oil to support a business continuity plan (BCP), Ohara imagined how carbon neutrality should be treated in the future:

"When I heard about the idea of deep-frying oil, I thought that it was a great idea, and it also matched the resource recycling efforts being made by supermarkets and other shops. In addition to electric power, our goal is to achieve zero-carbon in vehicle fuels by 2040, including dealing with chlorofluorocarbons. I believe that ideas of adding something extra to hydrogen will expand the potential in various ways. Up to now, the reality has been that efforts to achieve decarbonization and resource recycling have been made separately. However, I think that efforts will be combined in various ways, including in parallel or multiple configurations."

Tomiya City has been conducting many hydrogen promotion and awareness activities, such as symposiums and forums, and test-riding fuel-cell (FC) buses. The city has also actively allowed people to come and observe the low-carbon hydrogen supply chain, with nearly 500 observers from 83 companies by FY2021. The city has also pressed forward and launched a new initiative to promote carbon neutrality further.

Based on its 2050 Zero Carbon City declaration in 2021, Tomiya City is developing a strategy that incorporates initiatives required to fulfill the goal of achieving net zero CO_2 emissions by 2050. Since 2022, the city has been taking action to realize this strategy. Our efforts, including a series of demonstration projects and other initiatives, have also led to the winning of several awards, such as the Grand Prize at the Seventh Annual Platinum Vision Awards hosted by the Platinum Society Network, and the Award for Excellence at the Zero Carbon Challenge Cup hosted by the MOE." (Wako)

From the perspective of a trading company, Marubeni summarized the current outcomes so far:

"We believe that our project has had considerable influence both in Japan and overseas. It also has the advantage of having practical data obtained by operating the supply chain in a way that was enlightening while identifying issues for commercialization. I have heard that the national government is about to starting to create environmental values that will compensate for the cost of hydrogen, which is not exactly cheap at present. The Tomiya model will develop into locally adapted versions throughout Japan. We would like to continue operating our equipment and also try new things as well." (Fujimoto)

Gotoda described one of their future visions:

"Tomiya City's supply chain model is not a recycling model, but a single-path model in which hydrogen is produced from solar energy and consumed in fuel cells. Although it is an excellent model in terms of carbon neutrality, it is still lacking in terms of global resource recycling. How to extract energy from waste and return it to other applications will be the key to future success. If we can innovatively incorporate circular economy features into the Tomiya model, it will become a representative case of the first proper model that is run in a green way."

Mayor Wako, who has led the project and also promoted carbon neutrality by signing the Global Covenant of Mayors for Climate and Energy in 2022, added:

"We must leverage this demonstration project and lead to the next step. However, that is not something we can do alone. We will need not only all the people of our city and companies, but also the people of Japan and the mankind to work as one to achieve this. If possible, Tomiya City is willing to be in its crucial vanguard."

Hitachi will continue to actively obtain opinions from the concerned parties such as Tomiya City, Marubeni, and Miyagi Consumer's Co-operative Society, and identify social needs to accelerate its commitment to carbon neutrality through the implementation of practical hydrogen supply chains.

Topics

Hydrogen Energy Revolution in Namie Town

Striving to Develop a Zero Carbon City

The town of Namie, in Fukushima Prefecture, is one of the regions that was considerably damaged by the Great East Japan Earthquake that occurred on March 11, 2011. While there are still areas in the town where it is difficult to return home due to the impact of the accident at Fukushima Daiichi Nuclear Power Station, the town has been steadily making efforts to rebuild. In March 2020, Namie Town issued its 2050 Zero Carbon City declaration. Since then, the town has been moving toward developing a hydrogen-energy-based community with the goal of achieving net zero CO_2 emissions by 2050. Hitachi is also participating in a hydrogen supply chain demonstration project in Namie Town, leveraging the knowledge that the company has acquired through another demonstration project to establish a low-carbon hydrogen supply chain in Tomiya City, Miyagi Prefecture.

Naka Shimizu

Director, Industry Promotion Division, Namie Town Hall, Fukushima Prefecture

After graduating from a private university in Tokyo, he started working at Namie Town Hall in 1986. For the first 24 years of his employment there, it was an ordinary rural town hall with the same people all the time. However, since the earthquake 12 years ago, everything has changed significantly. As the chief secretary to the late Tamotsu Baba, Mayor of Namie Town, he met and worked beside the Mayor with many different people from all over Japan (through earthquake assistance, first, and then rebuilding work). He also visited many different places nationwide (to express gratitude for assistance, cheer up evacuees, and inviting companies to participate). Three months before the mayor passed away, he was appointed the Manager of the Industry Promotion Division to promote Namie Town's industries (2018). Until his retirement, he will continue to strive to fulfill the two long-held goals that were set by the late mayor immediately after the earthquake: "Hydrogen Town—New Energy Town" and "Research Town Namie."

Operation of One of the World's Largest-class Hydrogen Production Plants

Fukushima Hydrogen Energy Research Field (FH2R) is at the core of Namie Town's efforts to realize a zero carbon city. FH2R uses 20 MW of solar power to electrolyze water with a hydrogen production system and produces as much as 1,200 Nm^3 of hydrogen per hour. It is one of the world's largest hydrogen production plants that can also store and supply such a large amount of hydrogen (see Figure 1).

Namie Town launched the "Hydrogen Town Namie"* plan to promote urban development based on hydrogen energy, aiming at net zero CO_2 emissions by 2050. Since the opening of FH2R in March 2020, the town has been engaged in various efforts as a demonstration field for hydrogen applications in order to identify and solve issues that arise in the phases of creation, transportation, and utilization. Naka Shimizu, Director of Industry Promotion Division, Namie Town Hall, explained the current situation of the town's commitment to the development of a zero carbon city and the use of hydrogen:

"To expand the use of fuel-cell vehicles, for instance, rapid hydrogen refueling is a must. We are currently building large demonstration refueling equipment for FC vehicles on the north side of FH2R and it will be completed soon. We also want to discuss and demonstrate what to do with the electric power used in hydrogen production."

* The plan for promoting projects related to the use of hydrogen in various sectors in Namie Town to develop a hydrogen economy and zero carbon city.

Figure 1 | Fukushima Hydrogen Energy Research Field

Although FH2R has 20-MW solar power generation equipment, it cannot continuously produce hydrogen on cloudy days or at night. Therefore, in the current situation, when solar power generation is not available, expensive electricity has to be purchased from the grid. Fortunately, however, Namie Town is rich in natural energy sources.

"Of course, we care about the cost, but Namie Town is also committed to green hydrogen, making efforts to introduce and expand the use of renewable energies such as mega-solar power generation, wind power generation, and hydroelectric power generation at the Ogaki Dam in the town. As the sea is rough in this region, we have also started conducting surveys and studies aimed at the social implementation of wave power generation." (Shimizu)

Toward the Practical Use of Hydrogen through a Demonstration Project

In July 2021, Namie Town, Marubeni Corporation, Hitachi, Panasonic Corporation, and Miyagi Consumer's Co-operative Society signed a five-party agreement, the Cooperation Agreement Regarding Namie Town Revitalization Plan, Utilizing Hydrogen for Decarbonization. The purpose of the agreement is to promote the comprehensive restoration and revitalization of Namie Town by contributing to the town revitalization plan, the construction of an RE100 industrial park, invigoration of local industries, and digital transformation (DX). Based on the agreement, Hitachi has started a Demonstration Project for the Development of a Hydrogen Supply Chain for General and Industrial Use and Adjustment of Hydrogen Supply and Demand and is planning to construct its demonstration equipment in FY2022 (see Figure 2).

The planned hydrogen supply chain will transport hydrogen in small, light hydrogen cylinders for general use and supply electric power derived from hydrogen energy, using the existing distribution lines for industrial use, which consumes a large amount of power. The project team is also planning to control power generation remotely according to the demand through demand prediction based on past data about the electricity consumption of customers and use data measurement and block chain technology to demonstrate that the supplied electric power is derived from hydrogen energy.

Shimizu had the following to say about the project, which has just begun to take shape:

"In terms of transportation, small cylinders are light and not very costly so that we can probably implement them successfully in our community. However, if the frequency of cylinder swapping can be reduced from daily to only once or twice a week, then social implementation should be even more successful. In the demonstration

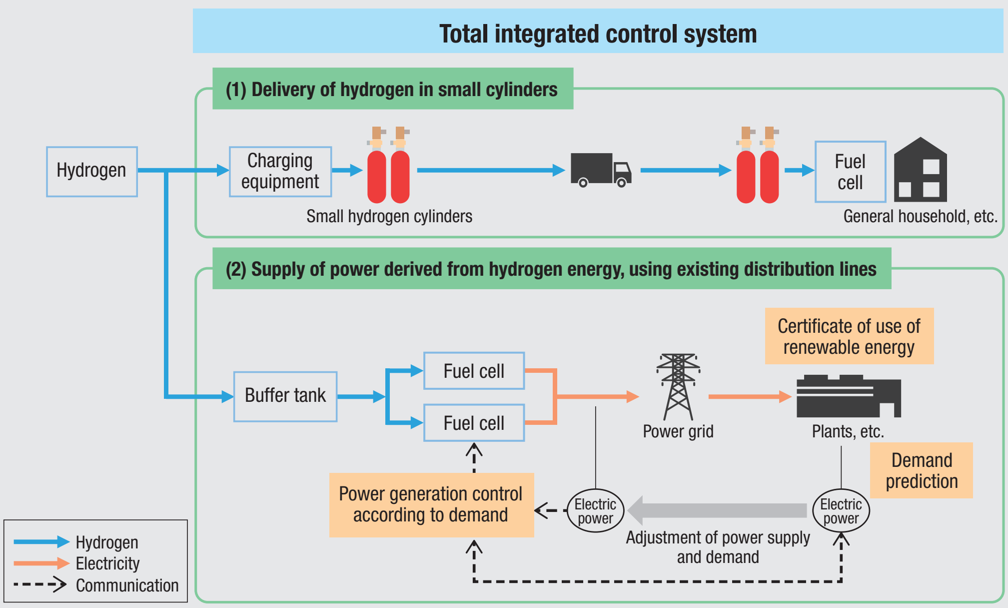


Figure 2 | **Conceptual Diagram of the Demonstration Project** for industrial use, on the other hand, we have not realized the advantages yet, and we may consider storing electric power in storage batteries."

Ryusuke Gotoda, General Manager, Smart Utility Division, Water & Environment Business Unit, Hitachi, Ltd., responded to the comment:

"Storage batteries always discharge electricity. Although they are suited to storing energy for several hours, hydrogen is better if you need to store energy for longer than that. Storage batteries are generally used in the charging rate range from 20% to 80%, whereas hydrogen can be used at any rate in the range from 0% to 100%. In this sense, hydrogen is also better. Of course, hydrogen has some disadvantages such as an efficiency decline in the hydrogen conversion process. However, we still believe that there is some advantage in sending the energy derived from hydrogen through distribution lines."

Gotoda continued by emphasizing key points in the demonstration project:

"It is very meaningful to evaluate the two supply chains quantitatively. One of our current challenges is how to link the supply and the demand. Once we solve the challenge, we will then use an energy management system (EMS), which adjusts the balance between the supply and demand, to promote the wide use of our product."

In addition to the perspective of transportation, Namie Town is also interested in the use of a hydrogen mixed-combustion generator in Tomiya City, Miyagi Prefecture from the perspective of creation, as Namie has some neglected farmland.

"We must determine how we should use contaminated farmland, including mountainous areas. Since it is difficult to grow rice on such land, we face some farming challenges. We may need to grow a large area of pasture land for producing biofuel, while reducing the cultivation cost." (Shimizu)

Based on the demonstration project in Tomiya City, Hitachi explained the advantages of hydrogen mixed-combustion generation:

"In hydrogen mixed-combustion generation, diesel oil and hydrogen are burned together, which reduces CO_2 in proportion to the amount of hydrogen that is mixed in. If biodiesel is used instead of regular diesel oil, this method of generation can produce 100% renewable biomass energy. The mixed combustion of regular diesel oil and hydrogen will be only a half-measure after all. I think that the key point is to mix biofuel with hydrogen in combustion." (Gotoda)

Ryusuke Gotoda
General Manager, Smart Utility Division and Carbon Neutral Business Promotion Office, Environment Solutions Division, Water & Environment Business Unit, Hitachi, Ltd.

Namie Town is currently re-developing the area around Namie Station and making various efforts based on the "Master Plan for Grand Design of Namie Town Area," which the town established to achieve carbon neutrality and RE100. In hope of successful re-development, Shimizu said:

"We are thinking of building and operating an EMS that mixes all kinds of renewable energy sources, including hydrogen mixed-combustion generation. Home, industry, and mobility are the three crucial sectors for promoting the wide use of hydrogen, and we would like to make achievements in those sectors, one by one, while also considering the use of hydrogen-based hybrid trains. I hope Hitachi will support us in this matter with its wide range of technologies."

Hitachi will continue to support Namie Town's reconstruction efforts and promote its commitment to developing a hydrogen economy in Japan.

ACTIVITIES 2

Collaborative Creation of SSCV-Safety Logistics Solution for Contributing to Zero Accidents

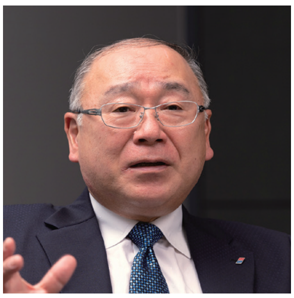
Implementing Logistics DX that Contributes to Safety, Health, and Environmental Value

As industrial structures and consumer purchasing behavior change, logistics has become an essential part of society's infrastructure. On the other hand, the logistics industry faces a number of challenges such as a chronic labor shortage, an aging population, traffic accidents caused by fatigue, and reducing environmental impact. To overcome these challenges, Hitachi Transport System, Ltd. has developed and offers SSCV for achieving DX where logistics can evolve. SSCV is a digital platform for transportation that enhances social, environmental, and economic value and consists of three pillars: smart, safety, and vehicle. Among the pillars, SSCV-Safety, which aims to achieve zero accidents, was developed with Hitachi, Ltd. as a collaborative partner and is now being sold externally as a Lumada solution. What is the background behind the creation of SSCV-Safety and how will it contribute to innovation in the logistics industry? *Hitachi Review* asked the key people involved in the collaborative project.

A Sense of Crisis Caused by a Series of Accidents

—Hitachi Transport System, Ltd. is implementing the smart & safety connected vehicle (SSCV) platform as a new initiative aimed at realizing the digital transformation (DX) of logistics. To begin with, could you tell us about this concept?

Sato: SSCV is a digital platform for transportation that consists of three pillars—smart (efficiency), safety, and vehicle (fleet management). Currently, the mainstay of Hitachi Transport System's business is third party logistics (3PL) services, and warehouse management operations account for a large proportion of its business, but in the transportation business overall, it is the trucks that carry cargo on-site that are the most important. SSCV is a next-generation platform that supports the basic premise of the



Seiki Sato
Senior Vice President and Executive Officer, and General Manager of Business Management Headquarters, Hitachi Transport System, Ltd.

Hideaki Nagumo
General Manager, Smart & Safety Solution Business Department, DX Strategy Department, Hitachi Transport System, Ltd.

Motoharu Ueda
General Manager, Enterprise Solutions Division, Industrial Digital Business Unit, Hitachi, Ltd.

Koichiro Yoshimura
General Manager, Distribution Systems Management Division, Industrial Digital Business Unit, Hitachi, Ltd.

transportation business: safe, efficient, and smooth truck operation and management. This platform makes great use of the digital technologies of Hitachi, Ltd., which joined this joint research project.

Let me briefly describe these three pillars. First, SSCV-Smart digitizes the various operations related to transportation and delivery, such as ordering, freight seeking, vehicle allocation, and operation instructions, and supports the enhancement of operational efficiency and compliance through centralized management and paperless operations. SSCV-Vehicle provides functions to optimize maintenance and improve operation rates by acquiring and analyzing vehicle travel data in real time, as well as a fleet management service (FMS) that provides integrated support for everything from vehicle procurement to purchasing.

The starting point of SSCV is SSCV-Safety, which aims to eliminate traffic accidents. The system visualizes the driver's fatigue level based on the driver's biometric data before, during, and after vehicle operation, and analyzes it with artificial intelligence (AI) in combination with sensing data such as images and vehicle behavior, and alerts the driver and operation manager in real time to prevent accidents. The system also supports the improvement of driving by reviewing and evaluating each driver's driving after operation, leading to further safety improvements.

——I understand that there was a strong sense of crisis behind the development of SSCV-Safety.

Sato: In 2015, when I was the general manager of the Higashinippon Area Headquarters, which is in charge of the East Japan area of our company, a series of transportation accidents occurred at the same operations site in the area. The frequency of three accidents in six months was extraordinary, and with the next accident occurring while investigating the cause and studying measures to prevent recurrence, I strongly felt that this was not the way to go. However, we could not find a clear cause even after interviewing the drivers involved in the accidents and checking the dashcams, and so we came to the conclusion that problems such as family illness and nursing care may have caused the drivers to become mentally fatigued, which was not visible to the naked eye, leading to reduced attention and distracted driving. On the other hand, the measures taken to prevent the recurrence of accidents were still based on the conventional mentality, such as thorough safety education and safety reminders before departure, and I felt there was a major discrepancy.

We thought that technological measures might be necessary, and so we tried the latest devices, such as devices that detect drowsiness and warn of collision risks, but no matter how much data we collected and examined, we could not find a correlation between driver fatigue and events that lead to accidents.

The turning point for us was the adoption, through trial and error, of the fatigue and stress measurement system, developed by Fatigue Science Laboratory Inc., which visualizes the level of fatigue based on the function of the autonomic nervous system. As a result of adopting the system, we were contacted by Professor Hirohiko Kuratsune of Osaka City University and Kansai University of Welfare Sciences, who was involved with the company. Professor Kuratsune, who is also a member of the board of directors of the Japanese Society of Fatigue Science, proposed joint research, saying, "Although a correlation between driver fatigue and driving errors may be observed, academic research on this has not yet been conducted." And this was the impetus behind the development of the system.

Revealing the Relationship between Invisible Fatigue and Accident Risk

——Hitachi, Ltd. also participated in the joint research, but what type of system was used?

Sato: We were able to work on this project in a collaboration between industry, government, and academia, with the cooperation of our company, Kansai University of Welfare Sciences, to which Professor Kuratsune belonged at the time, and Professor Yasuyoshi Watanabe of the Institute of Physical and Chemical Research (RIKEN), together with the participation of Hitachi's Research & Development Group.

For the first phase, we installed dashcams and other devices in some of our vehicles in FY2017 to link and analyze the biometric data of drivers measured before and after driving with image data on vehicle behavior and incidents (near-miss events) that occurred, and found a correlation between fatigue and near-miss events.

In FY2019, for the second phase, we installed the devices in all vehicles owned by our Group, and also had drivers put on wearable devices to acquire biometric data such as body temperature, blood oxygen level, blood pressure, and autonomic nervous system fatigue level before, during, and after operation, to verify the correlation between the physical state and accident risk during operation.

We learned through our demonstration experiments that it is difficult for people to sense their own physical fatigue, and even if they feel fine, they are often experiencing fatigue that is not visible to the naked eye. In the logistics industry, the aging of drivers is also a major issue, and the decline in physical fitness is a cause of invisible fatigue and sudden illness. How can we understand changes in physical state and fatigue that we do not notice ourselves, and what measures can we take in response? Hitachi Transport System is the first company in the trucking industry to focus on driver biometric data and autonomic nervous system fatigue levels as the key to measuring fatigue and to actually acquire data to prevent accidents before they occur. This was made possible thanks in part to the knowledge in the healthcare sector accumulated by Hitachi's Research & Development Group.

Nagumo: The Global Center for Social Innovation (CSI) of Hitachi also cooperated in our joint research, and we held a number of workshops at the sites of both companies, including with drivers, to field ideas and identify issues facing Hitachi Transport System using the NEXPERIENCE* method. I was impressed by the support we received to resolve these issues in tandem with the work sites, such as when the researchers visited our offices at night after the drivers had finished their work and prepared drinks and snacks to create an environment where it would be easier for the drivers, who were not used to workshops, to talk with us.

* Collaborative creation (co-creation) methodology for creating new businesses and services through co-creation with partners.

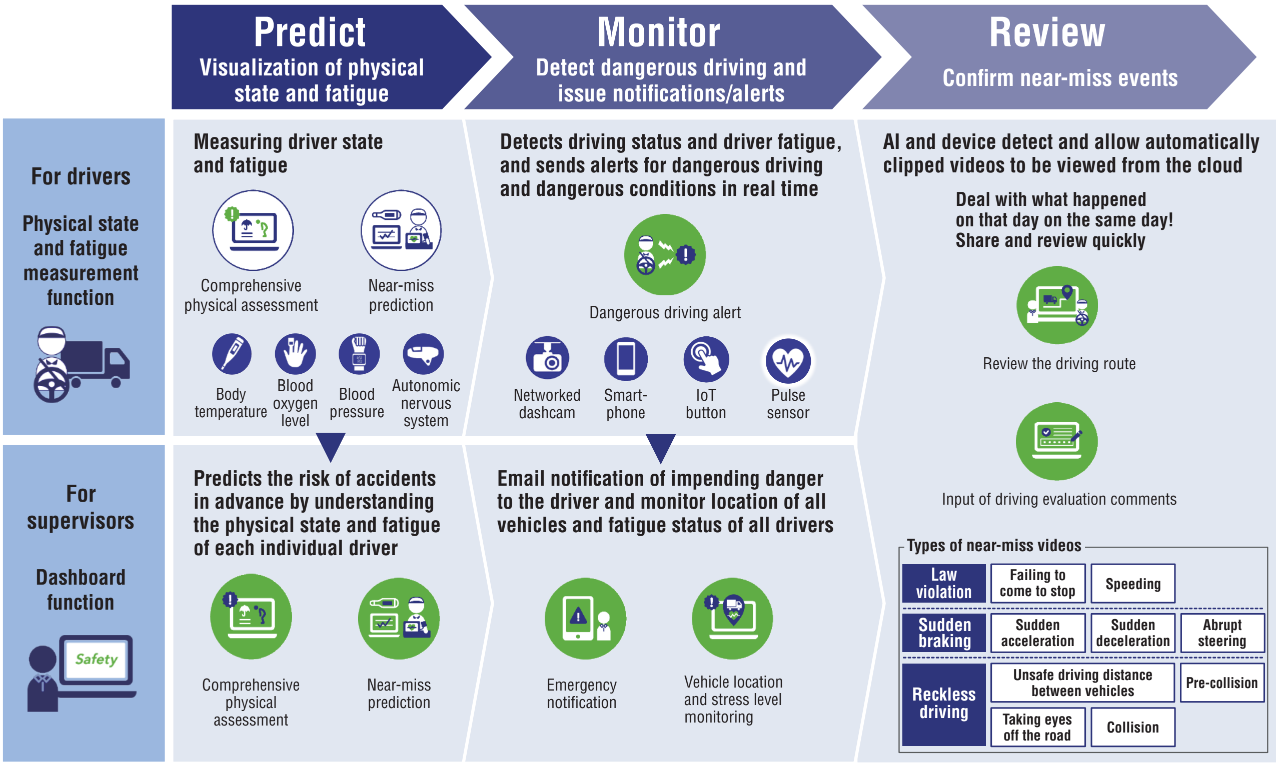
Sato: Management, drivers, and society as a whole all share the same desire to eliminate traffic accidents. Drivers willingly participated in the demonstration experiment to help us achieve this lofty goal.

—What were the key points that led to the success of the joint research through Hitachi's participation?

Nagumo: Our goal is to achieve zero accidents, a world in which drivers are neither the perpetrators nor the victims of traffic accidents. In the field of health and safety, Heinrich's Law is well known. It states, "For every single accident that causes a major injury, there are 29 accidents that cause minor injuries, and 300 accidents that cause no injuries (near-misses)." In other words, to prevent one accident, the signs of 300 near-miss events must be detected and eliminated. To achieve this, advanced technologies are essential, including devices that acquire biometric data and images to visualize the physical state, driving behavior, and vehicle behavior during operation; Internet of Things (IoT) technology; and AI and real-time data processing to analyze the acquired data. The fact that the Hitachi Group has all of these technologies and knowledge was a key point.

The knowledge and data obtained through a series of joint research projects were utilized to improve the accuracy of the analysis, and the results were compiled into a system that became SSCV-Safety. The system has been installed in all vehicles owned by the Hitachi Transport System Group, and we have maintained a record of zero accidents caused by distracted driving. In 2021, our company, Hitachi, Ltd., and Mitsubishi HC Capital Inc. began external sales of SSCV-Safety in order to contribute to transportation safety to a wider range of users beyond just our company. We are providing the service as "SSCV-Safety on Hitachi Digital Solution for Logistics," a software as a service (SaaS) type service for transportation operations in a wide range of industries, including logistics, manufacturing, distribution, buses, and taxis (see Figure 1).

This is our first attempt to provide such SaaS-type services, and we were able to achieve this with the cooperation of Hitachi's Industrial Digital Business Unit (IDBU).



IoT: Internet of Things AI: artificial intelligence

Figure 1 | Three DXs SSCV-Safety Uses to Realize a Safety Management Solution

Automatic Near-miss Detection with More than 90% Accuracy

——How did the IDBU support the commercialization of the project? Were there any difficulties in commercialization?

Ueda: At the IDBU, we are developing Lumada businesses mainly for customers in the industrial and distribution fields. One of our solutions for customers in the logistics and transportation industry is the Hitachi Digital Solution for Logistics (HDSL), which leverages the Hitachi Group's robust platform, security technology, high-speed processing technology for large volumes of data, and telematics technology that the Group has built as a provider of IT services. This solution provides functions to optimize transportation and delivery operations, such as automated delivery planning and IoT-based delivery monitoring. We thought that if we could add the results of Hitachi Transport System's safety-related research on top of this, we would be able to provide new value.

Sato: Since we were creating a service that had not existed in the world before, there were some difficulties in commercializing it, such as information security and the accuracy of automatic analysis using AI.

Ueda: Yes, that's right. This is an area of research and development, but the key was the development of technology to automatically classify and detect near-miss events using AI. The human eye can quickly determine whether a situation is dangerous or not, but it is difficult for a machine to automatically determine the degree of danger from dashcam images. To solve this problem, we developed a technology to automatically classify near-miss situations based on vehicle speed and acceleration data, location information, and map signage data. We have improved the accuracy of the analysis with the cooperation of experts by creating teaching data, defining several accident-prone situations based on actual near-miss cases, and performing machine learning for each situation. As a result, it is now possible to automatically classify near-miss cases from vehicle behavior data with a detection rate of more than 90%.

Sato: What surprised us in the actual operation of SSCV-Safety was the steady decrease in the number of incidents such as sudden acceleration or deceleration, taking eyes off the road, and speeding, which were detected in large numbers at the initial adoption of SSCV-Safety. This seems to be largely due to the advice given by the supervisor to drivers after reviewing that day's driving after they return to base. In the case of our company, the number of incidents has been reduced by 94% when comparing January 2019 before the adoption of the system in all vehicles to March 2021 after the system was adopted. Drivers seem to resist the visualization of their driving at first, but once they realize that they gain the most important value of "safety," they change their driving behavior. If this trend spreads outside the company, I believe it will change automotive society.

—In SSCV-Safety, you are also using a newly developed dashcam.

Yoshimura: Hitachi has been developing telematics services in collaboration with automakers for about 20 years, and has been working to strengthen these services since around 2016, providing HDSL to a variety of customers. We have also developed technology to upload large volumes of data, such as dashcam video, to the cloud and process it without delay. However, in this case, since the system is required to detect hazardous events in real time during operation, the edge-side processing capacity must also be improved. In recent years, advances in device technology have increased the memory capacity of edge devices and enabled high-speed processing, and so we are developing and using this technology in a dashcam capable of collecting and processing more data than ever before.

Nagumo: In addition to a function that detects driving infractions, such as failure to stop or speeding, based on vehicle location data and map signage data, the system also has a function that estimates drowsiness by calculating the rate of eye closure from the driver's image, and calls out to the driver to wake him or her up. Previously, it was not possible to perform this kind of diverse processing using AI installed in the edge-side dashcam. SSCV-Safety made this possible through both real-time processing by the edge AI and telematics technology that sends data to the cloud.

Ueda: As the number of vehicles equipped with SSCV-Safety increases in the future, telematics technology will become even more useful. The over the air (OTA) function also provides this foundation, making it possible to perform edge-side software updates in a short time and in a reliable manner. In this sense, this was a case of collaborative creation in which the technological foundation that we have built up meshed well with the challenges that Hitachi Transport System faced.

SSCV-Safety is a Mechanism to Accompany People

—Health management, which considers employee healthcare from a managerial perspective and strategically implements it, has been attracting attention in recent years. SSCV-Safety can be an effective solution not only in terms of safety, but also in terms of health.

Nagumo: That's right. We are currently conducting joint research with the Research & Development Group at Hitachi to build a system that can detect changes in the physical state of drivers based on biometric data acquired and accumulated on a daily basis, and identify signs of cardiac and cerebrovascular diseases. The theme of this research is to prevent driver diseases that cannot be fully assessed from annual health checkups and the accidents caused by them.

Monthly meetings are held to share information on joint projects and to generate ideas for the next functional development, and these meetings led to the implementation of a function called "SOS (Emergency) button." For example, if a driver suddenly becomes distressed or has a heart attack, pressing the button automatically clips out a video clip and notifies the supervisor in real time.

We have received inquiries about whether SSCV-Safety can be installed not only in transport vehicles, but also in work vehicles and sales vehicles. If so, it could lead to health management for engineers and service staff as well as drivers.

Yoshimura: If only the functions for checking vital signs are used, it could be used to monitor the physical state of people who do not drive for work.

Sato: The SSCV-Safety system can record time, location, and images, and so it cannot be fooled. For both employees and managers, for instance, it can visualize whether employees are taking their breaks regularly. This relates directly to health management. In the case of large trucks, even if drivers try to take a break at the legally designated time, situations inevitably arise where they cannot park because the rest area parking lot off the expressway is full. When the "IoT button" on SSCV-Safety is pressed, an image of the surrounding area at that time can be recorded, and so evidence can be left behind that the driver had no choice but to exceed the legally designated time limit. In this sense, it also helps to strengthen compliance.

It is important to think of digital visualization as creating a "mechanism to accompany people," rather than enhanced monitoring. SSCV-Safety can realize the common desire of both employees and management to protect safety and health.

Changes in Driving Also Reduce Environmental Impact

—What do you think about the current issues in the logistics industry, namely the 2024 problem and CO_2 emission reductions for achieving carbon neutrality?

Nagumo: The 2024 problem is that the Workstyle Reform Act will set an upper limit of 960 hours per year for overtime work in automobile driving work starting April 1, 2024. If the upper limit restriction shortens the driving distance per driver, it is expected to have a major impact on the industry, such as making long-distance transport more difficult. As a countermeasure, we are developing a function that links SSCV-Safety with a digital tachograph. This function is also related to SSCV-Smart, but we need to digitalize as many operations as possible to improve the work management functions.

Sato: As long-distance transport becomes more difficult, more sharing and reloading of cargo will become necessary to shorten the travel time per person, and vehicle dispatch and delivery planning will become more complex. Digitalization is also essential for this purpose.

Nagumo: For reducing CO_2 emissions, actually, SSCV-Safety also is effective in reducing the environmental impact. In addition to helping to significantly reduce incidents, reducing sudden acceleration and deceleration improves fuel efficiency, which in turn leads to a reduced environmental impact. If we also incorporate SSCV-Smart, we can expect a reduction in CO_2 emissions through paperless operations, including those of our partner companies, by converting conventional paper documents into electronic ones.

Sato: By visualizing the dynamics of vehicles, CO_2 emissions can be shared as well as cargo. In addition, there is a possibility that the selection of modal shift will increase, and in order to select the best means of transport from the two standpoints of man-hours and CO_2 emissions, it is necessary to formulate and execute a transportation plan that takes into account various factors including distance, time, environmental impact, and cost. For this purpose, we believe that a digital twin environment is necessary, and we are working to build a digital twin environment as much as possible in our 3PL business.

Bridging *Kiwa* (Gaps) with Digital Technology to Promote Logistics DX

—How can Hitachi contribute to solving the challenges facing the logistics industry?

Yoshimura: In both work style reforms and environmental initiatives, what is important is the visualization and optimization of operations through collaboration between management and the worksite. With regard to the shortening of distances, as Senior Vice President Sato mentioned, it is a question of the capability to formulate a delivery plan and implement it in on-site operations. As for carbon neutrality, the key is not only products that directly reduce CO_2 emissions, but also building up indirect measures, as in the case of SSCV-Safety. In either case, we believe that we can contribute by digital technology.

Sato: The COVID-19 pandemic has made it clear that logistics is essential work. For those of us in charge of logistics, an industry without which society would cease to function, we are required to be sustainable ourselves. To achieve this, it is important to automate as much as possible to reduce the burden on employees. Logistics is said to be a labor-intensive industry, but we need to improve the

stability of our operations by concentrating on tasks that only people can perform. Currently, the entire company is working to identify such operations.

Paradoxically, the more digitalization progresses, the more important that on-site capabilities become as a key point of differentiation. I believe that DX in logistics can be used to improve safety, quality, and productivity through automation and visualization while maintaining strong on-site capabilities. And, I believe that we can lead the industry in this effort because we are a leader in this field. SSCV-Safety's external sales are a start. If SSCV becomes the industry standard, it will contribute to society at large by eliminating accidents and reducing environmental impact, and will enhance the value of the entire transport industry. To this end, we will continue to create value through the fusion of our cutting-edge technologies in our physical domain and Hitachi's cyber domain.

—What have you learned from this collaborative creation and what are your future plans?

Yoshimura: There are many things that those of us in the information field learn only after seeing the logistics field, and so it was very important for us to understand the operational technology (OT) at worksites. If we can digitally implement the domain knowledge that Hitachi Transport System has, we can create solutions that cannot be imitated by IT-only companies.

The IDBU has been providing digital solutions to a wide range of customers in the industrial and distribution sectors, who are responsible for the series of processes from manufacturing to wholesale, retail, and the planning that connect these processes. In other words, we believe that it is important to optimize not only each individual process, but also the entire series of processes by bridging them digitally across industry *kiwa* (gaps). In recent years, consumer purchasing behavior has shifted to digital channels, and the shift to e-commerce is expected to continue in Japan. At that time, the importance of logistics, which bridges "the gaps," in a sense, from upstream logistics and warehouse management to last mile delivery, is expected to increase even further. We hope to continue contributing to increasing the value of logistics through collaborative creation.

Ueda: In industries like distribution and logistics, where the supply chain is complex and there are many stakeholders, not only large companies, but also small and medium-sized businesses must work together to promote digitalization. Otherwise, the effect of connecting the entire supply chain will diminish. There are many issues in promoting DX in small and medium-sized businesses, including costs, but I hope we can take on the challenge of eliminating these problems together.

Nagumo: As SSCV is expanded from our Group to the transport industry and to various other industries, and as the number of users increases, the amount of data that accumulates will become enormous. By utilizing this data, I expect that we will be able to create new services that will contribute to society, such as the function I mentioned earlier for detecting signs of illness.

Sato: If you only look within the same industry, you may not notice many of the changes in society. However, by exchanging opinions with people from different industries and sectors, we can see things from different angles and notice things. The word *kiwa* means "gap," and it may be that chemical reactions that create innovative products are born in the "gaps" between different companies and industries. I hope that this collaborative relationship will lead to further innovations in the logistics industry.

GLOBAL
INNOVATION
REPORT

Work on International Standardization of Water and Sewage

Contributions to ISO Technical Committee 224

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Member of Working Group 7 under International Organization for Standardization/Technical Committee 224

1 | Introduction

There has been considerable activity on international standardization over recent years in the field of water and the environment. One such body, the International Organization for Standardization (ISO), hosts technical committees (TCs) on topics such as water quality, water and sewage services, water reuse, and sludge treatment that are actively engaged in the development of standards for their respective fields.

ISO/TC 224 is the committee that deals with water and sewage services. Proposed by France and established in 2001, the committee has been in operation for more than 20 years. Japan has been involved from the very beginning, with participation coordinated across the public and private sectors, and Hitachi, Ltd. contributing to activities in Japan as well as serving as an international committee member.

This article looks back at the activities of ISO/TC 224 from the perspective of the author who served on the committee for 10 years from 2012, also giving examples of how Japan has contributed and reporting on the latest developments.

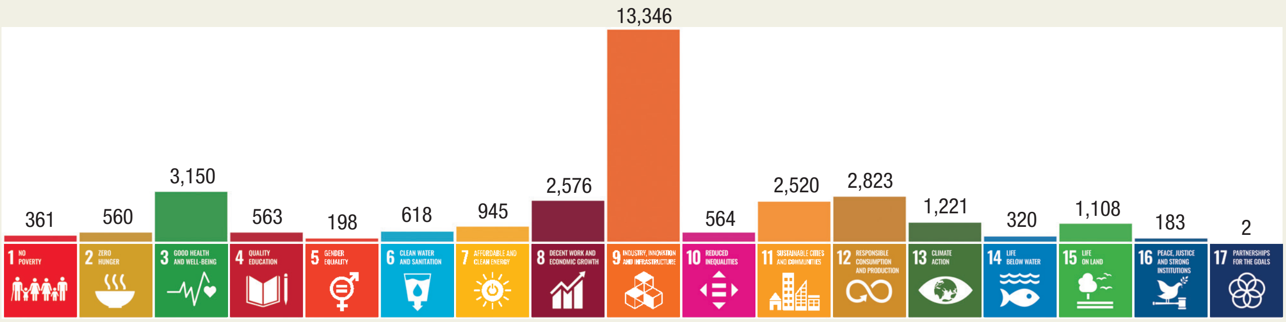
2 | Need for International Standardization

In ISO/International Electrotechnical Commission (IEC) Guide 2, the ISO defines a standard as a "document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context." International standards are needed so that products and technologies can be traded across borders and be used as intended. Parts such as batteries or screws are typical examples of standardized products. In recent times, however, the scope of standardization has expanded beyond materials and products to also encompass the evaluation and management of business processes and services.

The benefits of international standards include the manufacturing of products with consistent quality at low cost and the facilitation of management and services. Moreover, the Technical Barriers to Trade (TBT) agreement of the World Trade Organization (WTO) stipulates that participating nations formulate their domestic standards on the basis of international

Figure 1 | Number of ISO standards Directly Applicable to 17 SDGs (as of August 31, 2022)

In recent years, the International Organization for Standardization (ISO) has publicized its contribution to the SDGs by listing the number of its standards that are directly applicable to each of the 17 goals.



SDGs: Sustainable Development Goals

standards. This means that, even in their domestic economies, nations need to pay attention to what is happening with international standardization.

The ISO, the International Electrotechnical Commission (IEC), and the International Telecommunication Union (ITU) are among the main bodies engaged in developing international standards. In particular, ISO has responsibility for international standards outside the fields of electric power and electronics and has over a 160 member nations. The Japanese Industrial Standards Committee (JISC) serves as the ISO member for Japan.

Meanwhile, international standardization is not left out when it comes to working toward the Sustainable Development Goals (SDGs) of the United Nations. For example, ISO has published data on the number of its standards that are directly applicable to each of the 17 SDGs[(1)] (see Figure 1).

The goal with the highest number of applicable standards (13,346) is also the one that relates to the provision of resilient water infrastructure, namely Goal 9 (Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation). Next highest is Goal 3 (Ensure healthy lives and promote well-being for all at all ages) with 3,150 applicable standards. This goal includes action on disease caused by waterborne infections and poor water quality. Other goals that relate to water are Goal 6 (Ensure availability and sustainable management of water and sanitation for all) with 618 applicable standards, and Goal 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development) with 320 applicable standards (as of August 31, 2022).

3 | International Standardization for Water and Environment

International standardization goes beyond the formulation of product standards for things like measurement techniques or product dimensions and materials. In recent years, its scope has expanded to include service standards that take a user standpoint and the standardization of societal systems. In response to these changes, data and services were among a number of additions made to the scope of standards in Japan and elsewhere, with the Japanese Industrial Standards (JIS) being revised in July 2019 [(2)].

The scope of international standardization has also expanded in the fields of water and the environment, extending beyond product standards to include standards for services and those that address the resolution of societal challenges. Table 1 lists the main ISO TCs relevant to this area[(3)].

Table 1 | **Main ISO Technical Committees Dealing with Water (as of August 31, 2022)[3]**

Numerous ISO committees are engaged in work on international standardization in the water industry.

ISO technical committee	Description (Secretariat)	Year established	No. of participating nations
TC 5	Ferrous metal pipes and metallic fittings (China)	1947	18
TC 8 /SC 13/WG 3	Seawater desalination (China)	2015	—
TC 23 /SC 18	Irrigation and drainage equipment and systems (Israel)	1980	11 *
TC 30	Measurement of fluid flow in closed conduits (UK)	1947	21
TC 113	Hydrometry (India)	1964	15
TC 115	Pumps (France)	1964	19
TC 138	Plastics pipes, fittings and valves for the transport of fluids (Japan)	1970	41
TC 147	Water quality (Germany)	1971	36
TC 224	Drinking water, wastewater and stormwater systems and services (France)	2001	37
TC 251	Asset management (UK)	2010	35
TC 268	Sustainable cities and communities (France)	2012	38
TC 275	Sludge recovery, recycling, treatment and disposal (France)	2013	19
TC 281	Fine bubble technology (Japan)	2013	9
TC 282	Water reuse (China)	2013	23
TC 292	Security and resilience (Sweden)	2014	46
PC 316	Water efficient products—Rating (Australia)	2018	18
TC 323	Circular economy (France)	2018	73
TC 339	Small hydropower plants (China)	2022	11 **

TC: technical committee PC: project committee SC: sub-committee WG: working group

*1 The "No. of participating nations" is the total number that are participating (P) members. The numbers are not available for TC 8/SC 13/WG 3.

*2 Japan is a P member of all committees, except where indicated by * [an observing (O) member] or ** (non-member).

With regard to service standards, ISO/TC 224 was established in 2001 and has been actively working on standardization that considers the users of water and sewage services. This is covered in more detail below.

Similarly, ISO/TC 282 addresses the resolution of societal challenges, contributing to the protection of the environment by working on international standards for water reuse. In relation to the reuse of sewage or industrial wastewater, Japan participated in the formulation of ISO 20468, which provides guidelines on the performance evaluation of treatment technologies for water reuse systems. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is looking to leverage the publication of this international standard to boost the overseas adoption of Japanese water treatment technologies[4].

ISO/TC 147 has 50 years of history behind it, and its ongoing work on the international standardization of water quality has included the approval in August 2021 of a new draft standard proposed by Germany for the detection of SARS-CoV-2 in wastewater[5].

All of these can be seen as instances where standardization is relevant not only to product manufacturers and service providers, but also to service users and to the resolution of societal challenges.

4 International Standardization of Water and Sewage Services (ISO/TC 224)

4.1 Activities to Date

ISO/TC 224, the technical committee on "Service activities relating to drinking water supply systems and wastewater systems," was established in 2001 at the proposal of France. Service assessment guidelines for the providers and users of drinking water and wastewater services (ISO 24510, 24511, 24512) were published in 2007. These standards laid out the underlying principles behind the performance indicators

Table 2 | ISO/TC 224 Working Groups and International Standards Formulated (as of August 31, 2022)
A total of 22 international standards have been published, with a large number of further standards currently under development.

Working group	Description (Convener)	ISO standards under preparation or already published*
WG 1	Terminology (Canada)	**24513**
WG 2 (disbanded)	Service to users (Spain)	**24510**
WG 3 (disbanded)	Drinking water (Canada, Malaysia)	**24512**
WG 4 (disbanded)	Wastewater (Austria, South Korea)	**24511**
WG 5 (disbanded)	Examples of the application of 2451X standards (Canada)	**TR 24514**
WG 6	Asset management (Germany) Drinking water and wastewater (pipes and infrastructure) Asset management case studies Water and sewage benchmarking Examples of water supply master plan establishment Water loss management (Israel)	 **24516-1**, **-2, -3, -4** CD 24589-1, AWI 24589-2 **24523** AWI 24593 **24528**, AWI 24594
WG 7	Crisis management of water utilities (Israel) Drinking water supply (residents, temporary settlements for displaced persons, important infrastructure) Water supply quality monitoring, more resilient infrastructure	**24518**, **TS 24520,** **24527**, **TS 24519**, CD 24595 **TS 24541**, CD 24596
WG 8	Onsite domestic wastewater management (Kenya, Austria)	**24521**, AWI 24521, FDIS 24525
WG 9 (disbanded)	Decision support systems (Israel)	**TS 24522**
WG 10 (disbanded)	Flushable products (Canada)	**TR 24524**
WG 11 (disbanded)	Storm water management (Japan)	**24536**, **TR 24539**
WG 12 (disbanded)	Water efficiency management (Singapore)	**46001**
WG 14	Effective corporate governance and service to users (France)	DIS 24540, CD 24510
WG 15	Smart water management (China)	CD 24591-1, AWI 24591-2
WG 16	Climate change adaptation (Canada)	DIS 24566-1, AWI 24566-2, -3, -4
WG 17	ISO 24511 and ISO 24512 revisions (Israel)	CD 24511, CD 24512

TS: technical specification TR: technical report AWI: approved work item CD: committee draft DIS: draft international standard FDIS: final draft international standard
*Standards in bold are already published.

(PIs) used for the quantitative assessment of these services and have been adopted in national standards as guidelines for setting PIs. The assessment indicators used for Japan's water and sewage services were also referenced in the standards.

Specifically, by entering a variety of operational data into the mathematical formulae that define the PIs, they enable quantitative comparisons to be made against past performance or with the service level or facilities of other providers. Note, however, that the guidelines also advise on the need, when making such comparisons, to take due account of contextual considerations such as cultural factors and the natural environment in which the service operates.

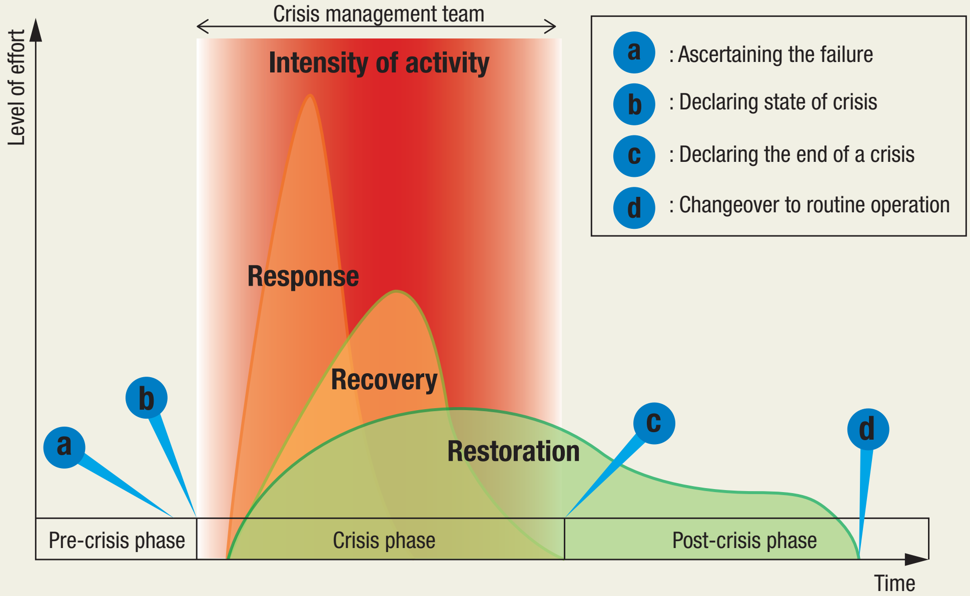
These three guidelines are currently subject to regular reviews, with Japan among the participants in this work.

Since 2008, ISO/TC 224 has also been working on standards that address specific issues such as asset management, crisis management, smart water management, and climate change adaptation. Table 2 lists the standards that are under preparation or already published by ISO/TC 224 working groups (as of August 31, 2022).

Note that the TC scopes are not fixed, changing over time. The scope of ISO/TC 224 was changed in 2017 to "Service activities relating to drinking water supply, wastewater, and stormwater systems" to clearly indicate its interest in stormwater. This was further extended in 2021 to "Drinking water, wastewater, and stormwater systems and services" so as to cover the design, specification, and construction of associated products and systems as well as the services themselves.

Figure 2 | **Sequence, Overlap, and Intensity of Activities during the Phases of a Crisis**

The figure shows the main concepts involved in the organizational response to a crisis.



Source: ISO 24520, color-coding by author

Japan has its own committees in the form of the Japan Sewage Works Association and the Japan Water Works Association and these organizations delegate people to serve as Japan's representatives at the ISO/TC 224 working groups. These people are drawn not only from Japan's water and sewage utilities and associated institutions, but also from private-sector companies, with delegates being sent by the Federation of Japan Water Industries, Inc. This has also included Hitachi, with a delegate serving on Working Group (WG) 7 (Crisis management of water utilities) since 2012.

4.2 Examples of Current Activities

This section describes recent activities undertaken by ISO/TC 224.

(1) Action on crisis management

Water and sewage services are at risk of a wide variety of emergencies, including natural disasters, plant failures, and human errors or accidents. Established at the behest of a proposal from Israel, WG 7 has developed, over the more than 10 years of its existence, a variety of international standards relating to how water and sewage utilities respond to sudden crises. During this time, Japan has reported on the extent of damage to water and sewage infrastructure caused by the Great East Japan Earthquake of March 2011, hosting a meeting of the working group at Sendai in October 2013 where members from other nations were able to view first-hand the level of damage to water and sewage treatment plants.

WG 7 published guidelines for the crisis management of water utilities (ISO 24518) in 2015 and a collection of case studies (ISO 24520) in 2017. These standards collate guidance on the management of each stage of a crisis, covering how to prepare, how to respond at an organizational level when a crisis occurs, and the subsequent steps from recovery to the restoration of normal operations. Figure 2 shows the main concepts.

In 2019, meanwhile, WG 9, which deals with related matters, published a technical specification

(TS) on the event detection process (ISO/TS 24522) that covers the early detection of anomalies in water and wastewater utilities based on a variety of measurements and reports. Based on a proposal from Hitachi, Japan presented case studies to WG 9 that included a system for detecting upstream water quality problems to facilitate halting downstream intake by water supply systems and a system for the early detection of heavy rainfall events that helps sewage systems avoid stormwater inflows. These were published as examples of good practices.

WG 7 has gone on to publish new standards, including guidelines on providing alternative drinking water services during a crisis (ISO 24527) and guidelines for continuous monitoring of water quality in drinking water distribution networks (ISO/TS 24541). Japan supplied a local case study to ISO 24527 at the request of the committee chair (Israel) and drafted part of the text of ISO 24541 in partnership with the member from Morocco.

During this time, Japan has maintained good relations with the other committee members, including the holding of discussions with water supply experts from Germany and Canada, and receiving advice from the USA and UK members on the wording of the English language text, succeeding in having case studies contributed by Japan and Hitachi reflected in the international standard.

(2) Action on environmental protection

ISO/TC 224 has also been engaged in international standardization that relates to environmental protection. Work on an international standard for the efficient use of water got underway in 2015 in response to a proposal from Singapore. This contains requirements and guidelines for efficient water management systems that water-using organizations can use to plan and implement water-saving measures. The standard was published in 2019 as ISO 46001.

Meanwhile, countries around the world are experiencing many damaging heavy rainfall events, with climate change being one factor. In 2015, Japan's MLIT partnered with sewage utilities and other interested organizations to establish WG 11 to work on standards for stormwater management. As a result of this initiative, guidelines for flood control that focused on the planning and design stages (ISO 24536) were published in 2019 and a technical report with examples of good practices for stormwater management (ISO/TR 24539) was issued in 2021.

Taking this work further, a working group to address climate change adaptation (WG 16) got underway in 2020. Work has already commenced on formulating guidelines for adapting water services to climate change impacts (ISO 24566), starting with work on developing assessment principles.

5 | Conclusions

This article has covered some of the past and present work on international standardization in the field of water and the environment, especially that of ISO/TC 224.

With international standardization, what tends to catch people's attention is the rivalry between nations and the bargaining conducted by business. However, the Japanese members of ISO/TC 224 have gone in as experts, with the expectation of presenting advanced technologies and best practices. Rather than adopting an attitude of only pursuing the interests of their own country or company, they recognize the need to cooperate with the other national delegates to create standards that will help to improve water and sewage services and the associated natural environments.

More than 20 years have passed since ISO/TC 224 was established and it continues to work actively, with more than 20 international standards published to date. ISO standards do not list the names of the committee members or nations involved in their drafting. Rather, the process is memorable for being one in which members from many different nations worked together and put years of time and

Figure 3 | **Japanese Members Attending Online Plenary Meeting of ISO/TC 224**

These Japanese members attended the 2022 plenary meeting of ISO/TC 224 online (on June 24 at the Japan Water Works Association).

effort into their development. Figure 3 shows some of the Japanese committee members attending the 2022 plenary meeting of ISO/TC 224, which was held online. Attending via screens, the meeting brought together a large number of members from across all six continents.

Hitachi intends to continue contributing to the resolution of the world's water and environmental problems, working with relevant institutions in Japan and cooperating with the delegates from other nations in its ongoing involvement in the international standardization of water and sewage services.

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Takahiro Tachi

Water Solutions Division, Water & Environment Business Unit, Hitachi, Ltd. Member of Working Group 7 under International Organization for Standardization (ISO)/Technical Committee (TC) 224 *Current work and research*: Water and environmental business operations and the supervision of research and development. *Certifications*: Expert for Standardization, Japan (SE00346). *Society memberships*: Director of the Japan Water Research Center (JWRC) and the Smart Water Promotional Association (SWPA), and a member of the Society of Environmental Instrumentation, Control and Automation (EICA) and the Catalysis Society of Japan (CATSJ).

FEATURED ARTICLES

Water Infrastructure Solutions for Digitalization in Water Services

Pollution, scarcity, and the uneven distribution of resources, the growing challenges associated with water across the world, call for rapid action in order to protect the environment. Hitachi Group, meanwhile, has been engaging in collaborative creation with customers and other business partners as it strives to maintain and improve water infrastructure and the environment through the development and supply of solutions that facilitate data use, decarbonization, and resource efficiency.
This section describes platforms for making the transition to a sustainable society, covering the latest water infrastructure solutions from Hitachi Group for ports as well as for water and wastewater services.

Overview

Hitachi's Water Infrastructure Solutions and Examples of Collaborative Creation Projects

Masahiro Goto
Takashi Matsui
Yoshitaka Matsui
Ichiro Yamanoi, Ph.D., P.E. Jp

1. Introduction

Water is one of the most important circulating resources on a global scale and is also a key part of the social infrastructure that is indispensable for sustaining human life. However, the world is faced with various issues such as uneven distribution of water resources, droughts, floods, and water pollution. In Japan, water supply and sewage facilities and pipes are deteriorating with age, the fiscal budgets available for maintaining and managing them are tight, and measures are required for ever more severe disasters. The United Nations has set up "Goal 6: Ensure the availability and sustainable management of water and sanitation for all" in its Sustainable Development Goals (SDGs)(1) and has set other water-related targets to be achieved by 2030.

Against this backdrop, the Hitachi Group announced its new Mid-term Management Plan 2024 in April 2022 in which Hitachi will support the planetary boundaries, which protect the Earth and sustains society, and well-being, a society in which each individual is comfortable playing an active role, through Green, Digital, Innovation and Lumada* initiatives. Specifically, Hitachi intends to continue to accelerate and develop its Social Innovation Business to innovate the urban and industrial sectors. This article presents the products, systems, and services (water infrastructure solutions) that support the water infrastructure sector, which plays a key role in this effort.

* The general term for Hitachi's advanced digital solutions, services, and technologies that utilize advanced digital technologies to create value from data and accelerate digital innovation.

2. Trends in the Water Infrastructure Market in Japan and Overseas

The amount of freshwater that people can use for drinking and daily life is thought to be 0.01% of the total water on the Earth, which is unevenly distributed on a global scale, and floods and droughts, which are thought to be the effects of climate change, occur frequently. The Ministry of Economy, Trade and Industry prepared a report on the 10-year review of overseas development measures for the water business and the direction of future development, and published it in March 2021(2). The market size of the water business is expected to exceed JPY110 trillion by 2030, but the market is expanding and diversifying, and the report stated that public-private cooperation and the use of partnerships are needed in order to prepare projects in partner countries.

In Japan, on the other hand, the percentage of the population with access to drinking water will reach 98.1% by the end of FY2020, and the population with access to sewage treatment (sewage system, agricultural community drainage facilities, septic tanks, etc.) will reach 92.1%(3), (4), and at the same time, the market for water supply and sewage facilities is shifting from new construction to updates. However, administrators are facing many issues, such as tight budgets for local governments, fewer available skilled staff, and a drop in water demand due to a shrinking population.

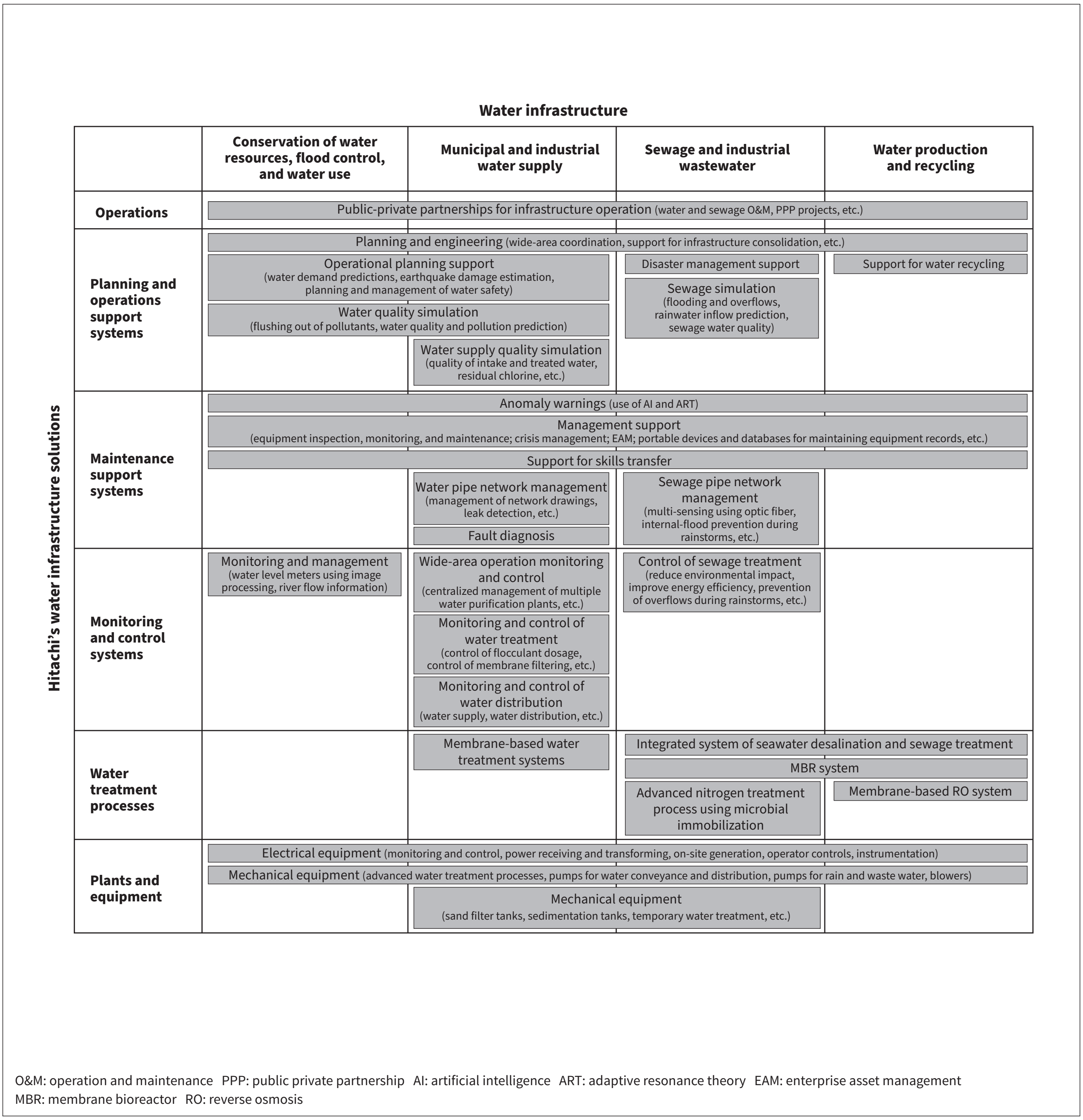
In response, the Ministry of Health, Labour and Welfare (MHLW) presented its New Water Supply Vision in 2013 and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) presented its New Sewerage Vision in 2014. Also, in October 2019, the revised Water Supply Act came into effect, which includes the implementation of wide-area cooperation in waterworks infrastructure projects, appropriate asset management, public-private partnerships, and the obligation to create a record of waterworks facilities[5]. Furthermore, following an organizational review of the MHLW, it was announced that the administration of waterworks infrastructure development and management would be transferred to the MLIT and the Ministry of the Environment in September 2022. This is the first major change in jurisdiction in 65 years, and observers will watch closely for any changes in trends from 2024.

3. Overview and Direction of Water Infrastructure Solutions

Hitachi Group has long been working to solve problems in various water infrastructure sectors, including the conservation of water resources, flood control and water use, municipal and industrial water supply, sewage and industrial wastewater treatment, and water production and recycling. It intends to contribute to comprehensive problem solving and overall optimization not only through its individual

Figure 1 — Main Technologies, Products, Systems, and Services Supporting Water Infrastructure Solutions

Since there is no single way to resolve water infrastructure issues, Hitachi will contribute to solving these problems by linking various technologies, systems, and services for the conservation of water resources, flood control, and water use, municipal and industrial water supply, sewage and industrial wastewater treatment, and water production and recycling.



products and services, but also by proposing water infrastructure solutions that link them all together.

In recent years, digital technology has been increasingly used in the water infrastructure sector, and Hitachi Group has been implementing the use and application of information and control technology in the water infrastructure sector. For example, it continues to provide simulation technology to support planning and management and to provide maintenance, monitoring, and control systems for water treatment facilities and pipes. In the process of proposing various solutions, the digital technology that has been developed in the water sector is increasingly being applied to other infrastructures and vice versa. **Figure 1** shows the main technologies, products, systems, and services that support solution proposals by sector.

4. Latest Examples of Hitachi Water Infrastructure Solutions

4. 1 Recent Initiatives in the Water Supply Sector

Japan's water utilities are facing a number of challenges, including a shortage of human resources, declining water demand, and fee revenues due to a shrinking population, increasing demand for replacement of aging water supply facilities, a review of plant operations to take into account the effects of climate change, and the need to become carbon neutral. To assist in overcoming these challenges, Hitachi, Ltd. has developed digital transformation (DX) solutions for water utilities (see **Figure 2**). This section presents the digital technologies and public-private solutions for the water operation and maintenance (O&M), water supply operation support technology using artificial intelligence (AI), and Hitachi Group's latest initiatives in the maintenance and management of water pipes.

(1) O&M digital technology and solutions based on public-private partnerships

Some measures being used to address the challenges faced by Japan's water utilities include public-private partnerships and wide-area implementation. One effective way to enhance the operational infrastructure of water and sewage utilities is to provide high-quality services and to reduce costs by leveraging the technical capabilities and expertise of private companies. Hitachi Group is focusing on digital solutions and is working to improve technology at contracted sites, such as the Hakodate City (Hokkaido) design build operation (DBO) project and full-service outsourcing for the Nakagawa Water Purification Plant (Ibaraki Prefecture Public Enterprise Bureau).

(2) Water supply operation support technology using AI

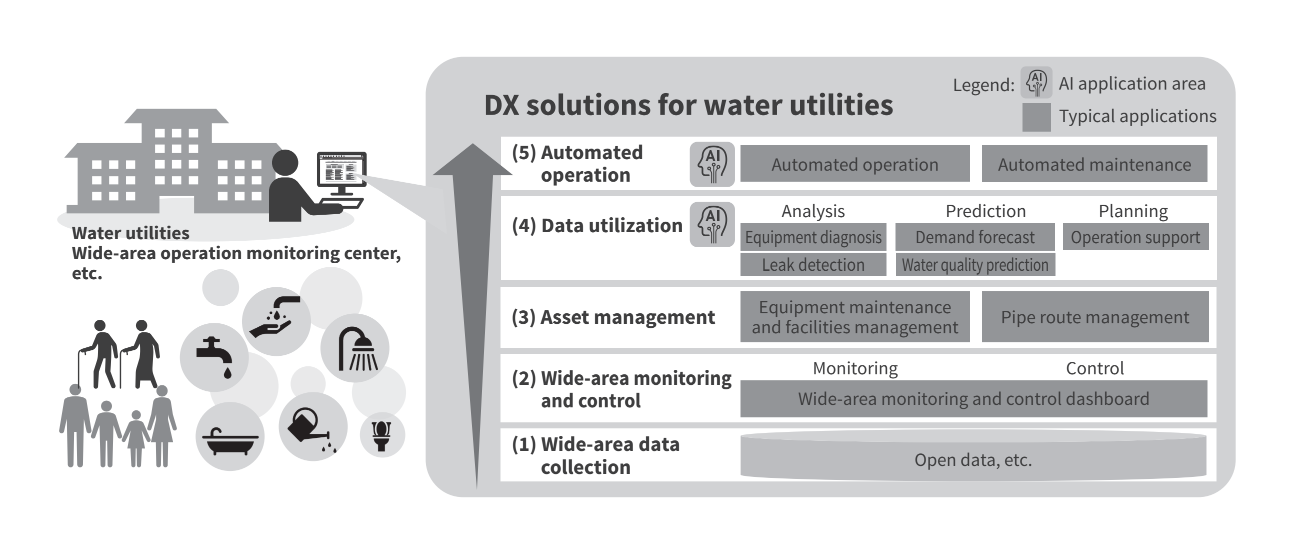
The Water Supply Act, which was revised in 2019, stipulates that water utilities must perform systematic renewal of water supply facilities from a long-term perspective and clarifies the importance of facility consolidation and reallocation. Hitachi Group is working on operation support technology for facilities and equipment and on digital technology that replaces the five senses and experience of operators with the Internet of Things (IoT) and AI, and is conducting joint research with the Osaka City Waterworks Bureau and with the Saitama Prefectural Public Enterprise Bureau.

(3) Maintenance and management of water pipes

Pipes account for about 70% of water supply assets, and this is an area where the management burden on water utilities is high. Hitachi Group's pipe management support

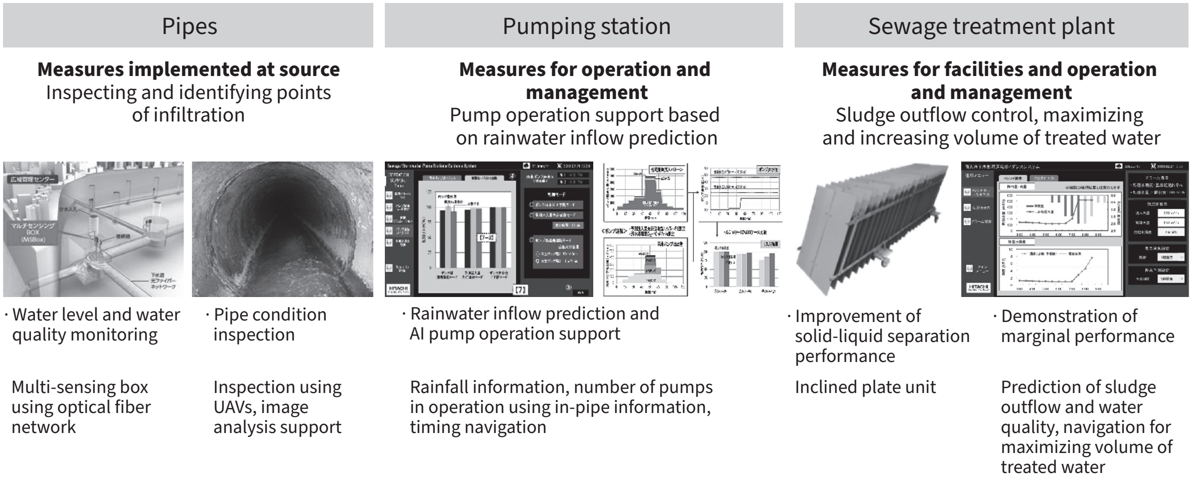
Figure 2 — Available DX Solutions for Water Utilities

The system collects operational data (water volume, water level, water quality, etc.) and inspection data from each water purification plant owned by the utility and also shares the solutions with them for enabling wide-area implementation by water utilities.



DX: digital transformation

Figure 3 — Hitachi's Rainwater Solutions for Sewage Systems (Including Those under Development and Verification)
Hitachi provides a wide range of rainwater solutions to reduce rainwater risks in sewers.



UAV: unmanned air vehicle

service helps water utilities achieve their goals of providing safe and reliable water now and into the future by linking the services and functions they provide for leak detection and pipe update planning.

4. 2 Recent Initiatives in the Sewage Sector

The sewage business, like the water supply business, is facing declining revenues, aging facilities and pipes, and a reduced number of skilled operators. At the same time, the FY2022 revision of the MLIT's "New Sewerage Vision Acceleration Strategy" sets forth the implementation of decarbonization and water infrastructure management as new points of focus and expresses its commitment to prevent and mitigate disasters by expanding efforts based on DX, asset management, climate change, and other factors. To address these issues, Hitachi Group will present its latest efforts in the maintenance and management of pipes using digital technology and the latest technologies to revolutionize sewage treatment (see **Figure 3**).

(1) Maintenance and management of pipes using digital technology

Improving the efficiency of pipe maintenance and management is an issue common to a wide range of utilities. Hitachi Group is working to develop effective solutions for pipe maintenance and management by combining digital technology and products. A sewer pipe inspection solution using unmanned air vehicles (UAVs) is a method that enables safe and efficient inspections without requiring workers to enter pipes, and it is being developed under joint research with the Bureau of Sewerage Tokyo Metropolitan Government and the Tokyo Metropolitan Sewerage Service Corporation. An optical fiber multi-sensing system is used to enable continuous sensing of the inside of sewer pipes by using the sewer optical fiber as a power source through power-over-fiber (PoF) technology. For pumping stations in combined sewerage systems, Hitachi is developing a rainwater pump operation support system that uses AI to propose appropriate start-up and shutdown plans.

(2) Latest technologies revolutionizing sewage treatment

Hitachi Group is working to find solutions to issues in sewage treatment technology from various perspectives based on digital technologies, including the coordination of software and hardware, AI, and sensing. For stormwater solutions at sewage treatment plants, in addition to hardware measures that require only minor modifications, the company is developing an operation support technology that uses software-based modeling and AI from operation management innovations to reduce the discharge load due to simplified treatment. AI sewage treatment support technology is an operation support system that combines human knowledge and AI to achieve energy-saving operation within a range that does not adversely affect water quality, and Hitachi is participating in a joint research project with the Saitama Sewage Systems Agency for the practical use of AI sewage treatment and is currently verifying the effectiveness of the system. In the area of sludge treatment operation support technology, Hitachi is developing a solution to optimize the dewatering process and reduce sludge disposal costs by using AI image analysis and operational guidance based on new sensors.

4. 3 Other Recent Initiatives

Hitachi Group is also proposing a variety of solutions in business areas surrounding water infrastructure. For example, port terminals in Japan and overseas, which are social infrastructure that have an impact on trade and economic activities and serve as a nexus for marine and land transport, face a variety of issues, and the company is working to upgrade their functions to resolve these issues.

Furthermore, the transition to a sustainable society, including decarbonization, water resource use, and resource recycling, requires the cooperation and collaboration of stakeholders across industries, including technology, operation, certification, and financial support. Hitachi Group has begun to build a trust-based platform concept that links these stakeholders.

5. Conclusions

This article presents various trends related to water infrastructure, an overview of the Hitachi Group's water infrastructure solutions, and recent examples of collaborative creation projects. The company will work together to solve the various issues faced by its customers by adding the latest digital technology to the technologies, products, systems, and services that it has developed over many years. Hitachi is committed to continue contributing to a sound water infrastructure in Japan and overseas and to attaining the SDGs.

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Digital Technologies and Public-Private Solutions for Water O&M

Japan's water supply and sewage utilities are already facing a number of challenges, including a decrease in the water supply population and decline in fee revenues due to a shrinking population, increasing demand for updating of water supply facilities, a review of plant operations to take into account the effects of climate change, and the need to become carbon neutrality. Some measures being taken to address these challenges include public-private partnerships and wide-area implementation. When private companies participate in water utilities, they can be expected to provide high-quality services and to reduce costs by leveraging their technical capabilities and expertise, which is effective in enhancing the operational infrastructure of water supply and sewage utilities. This article presents Hitachi's continued efforts to improve technology through work at contracted sites and elsewhere, with a particular focus on solutions using digital technology.

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1. Introduction

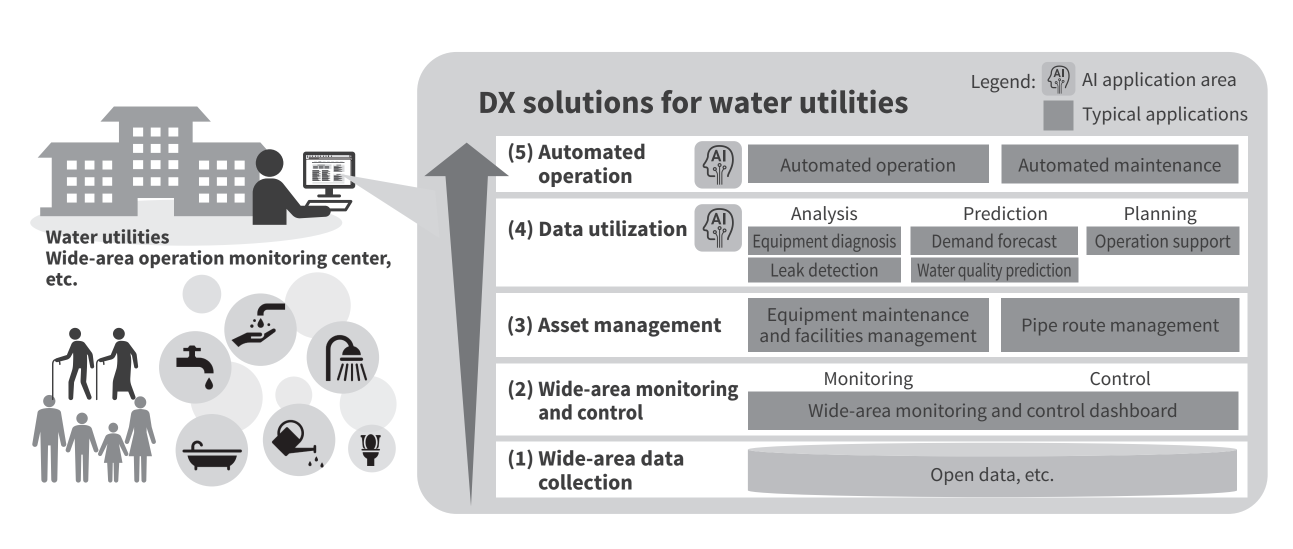
The total population of Japan peaked in 2010 (at about 128.06 million) and has been declining ever since[(1)]. This is a major challenge that many water utilities are already facing because it has led to a decline in the water supply population and fee revenues, as well as to the issue of how to pass on technological expertise due to the aging of skilled workers and staff shortages. In addition, the demand for large-scale updates to aging waterworks facilities is expected to peak in the 2020s and 2030s, requiring further budget allotments and scheduled updates of facilities. As an example, in recent years, there have been reported cases of aqueduct failures due to aging and other factors, as well as failures of water catchment facilities for headwater rivers[(2)]. In response, the government ministries and agencies that manage water utilities, in a follow-up to the Ministry of Health, Labour and Welfare's Water Supply Vision, have been conducting studies for achieving safety, resilience, and sustainability and their relation to the maintenance and repair of facilities[(3)], optimal layout planning[(4)], carbon neutrality[(5)], and other topics.

Public-private partnerships (PPPs) are one means of realizing sound and stable waterworks operations. Methods leveraging the technical capabilities and expertise of private companies are incorporated into waterworks operations, which until now have been mainly carried out by the public sector (local governments), to enable the provision of higher quality services and reduction of costs, thereby helping to strengthen the operational infrastructure of waterworks services. Moreover, this is also consistent with the "implementation of public-private partnerships" that is called for in the revised Water Supply Act.

This article presents the operation & maintenance (O&M) support digital solution, a technology that supports visualization, labor saving, efficiency, and passing on of knowledge in operation and management and maintenance tasks by utilizing digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), and analytics. This also describes the verification efforts in the Hitachi Group's public-private partnership projects and the future plans for implementation.

Figure 1 — Available DX Solutions for Water Utilities

The system collects operational data (water volume, water level, water quality, etc.) and inspection data from each water purification plant owned by the utility and also shares the solutions with them for enabling wide-area implementation by water utilities.



DX: digital transformation AI: artificial intelligence

2. Water Service Solutions

To provide solutions to these challenges, Hitachi, Ltd. has developed digital transformation (DX) solutions for the water supply business. These DX solutions for the water supply business include wide-area data collection, asset management, and data utilization (see **Figure 1**). One of the features of this system is the centralized management of data and bi-directional monitoring and control on the cloud while maintaining security, real-time performance, and reliability. The following is an overview of each solution.

2. 1 Support Options for Maintenance Work

(1) Visualization

The first step in a digital solution is to present the collected data to the user in an appropriate format. The visualization function integrates and visualizes the data collected by the monitoring and control system, inspection data, and water quality data. Also, since the measured values of various additional sensors installed in rivers and pumps can be easily imported, this is expected to enable enhanced monitoring of equipment and facilities and advanced management through diagnostics as described later.

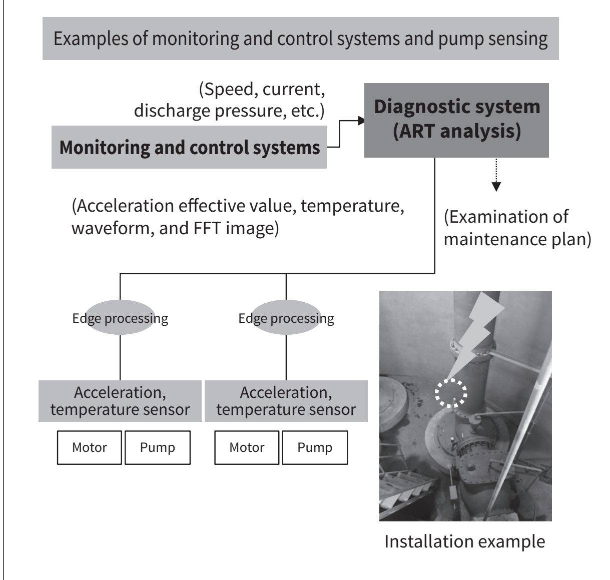
(2) Asset management

The AI-based equipment diagnostic function uses adaptive resonance theory (ART) to diagnose whether the current state of the equipment deviates from the range of the learned data. In addition to the data obtained from the monitoring and control system, data that significantly indicates the deterioration of equipment, such as the measured values from vibration sensors and temperature sensors installed on rotating machines is effective for diagnosis (see **Figure 2**)[6].

This solution also provides a function that can calculate an overall soundness index for equipment from inspection results that is used for the micro-management of facilities and equipment. By extrapolating the actual result of the soundness index, it is possible to estimate when maintenance is required from a medium-term perspective.

Figure 2 — Facility and Equipment Diagnosis Using IoT Sensors

In addition to data from existing monitoring and control systems, the system also uses measurements from Internet of Things (IoT) sensors to achieve more advanced diagnosis of equipment and devices.



ART: adaptive resonance theory FFT: fast Fourier transform

Furthermore, Hitachi has devised a method to determine the health of equipment by combining the soundness index with ART, and is currently evaluating the usefulness of this method at a water purification plant that is under contract for operation and management.

2. 2 Support Options for Operation and Management Work

(1) Operation support function

The operation support function uses statistical methods and machine learning to extract the operator's know-how (such as the types of equipment used and water level control values) from past operational performance data[(7), (8)]. The function then prepares an operation plan using the acquired conditions and presents appropriate operation guidance to the user (see **Figure 3**). Recently, Hitachi has added a method for managing the amount of water intake, filtration reservoirs, and distribution reservoirs, respectively, to minimize the number of operations while satisfying demand forecasts. Although it depends on the specifications of the water purification plant, the site where the effectiveness of this solution was verified used guidance where the number of operations was set to five times per day. By adopting this function, stable water volume control and more efficient operation can be expected even when run by unskilled workers.

(2) Water quality management

For the management of items in the water quality standards and residual chlorine concentration for water supply operations, it is important to predict the dosage of necessary chemicals and the water quality before and after treatment. The water quality management function provides this information as guidance by using physicochemical models and AI. Moreover, using the cloud to centralize information from various locations enables even more data to be used quickly. This has the advantage of facilitating the collection of data necessary for training AI and also allows more precise tuning of even conventional prediction models in response to fluctuations.

As described above, in its water service solutions, Hitachi has built support functions mainly for maintenance work and operation and management work. Hitachi will continue to improve its solutions by taking into account on-site needs and to develop and commercialize new functions.

3. Hitachi Group Initiatives

Various forms of business models for public-private partnerships are available, including partial outsourcing, in which limited areas such as operation and management are outsourced to the private sector, full-service outsourcing, in which not only operation and management, but also a wide range of maintenance and management are outsourced, design build operate (DBO), in which design, construction, and long-term maintenance of the facility after construction are outsourced to the private sector, private finance initiative (PFI), in which even financing is provided, and concessions (see **Figure 4**).

The Hitachi Group is currently involved in a wide range of projects, from partial outsourcing to DBO and PFI, with the aim of realizing a sustainable water supply based on its long experience in providing products and systems, after-sales service, and technological development in the water infrastructure sector.

3. 1 Hakodate (Hokkaido) DBO Project

Hakodate City's waterworks system was established in 1889 as the second modern waterworks system in Japan. Since then, the Akagawa Koku Water Purification Plant, Akagawa Teiku Water Purification Plant, and Asahioka Water Purification Plant have been constructed, and in

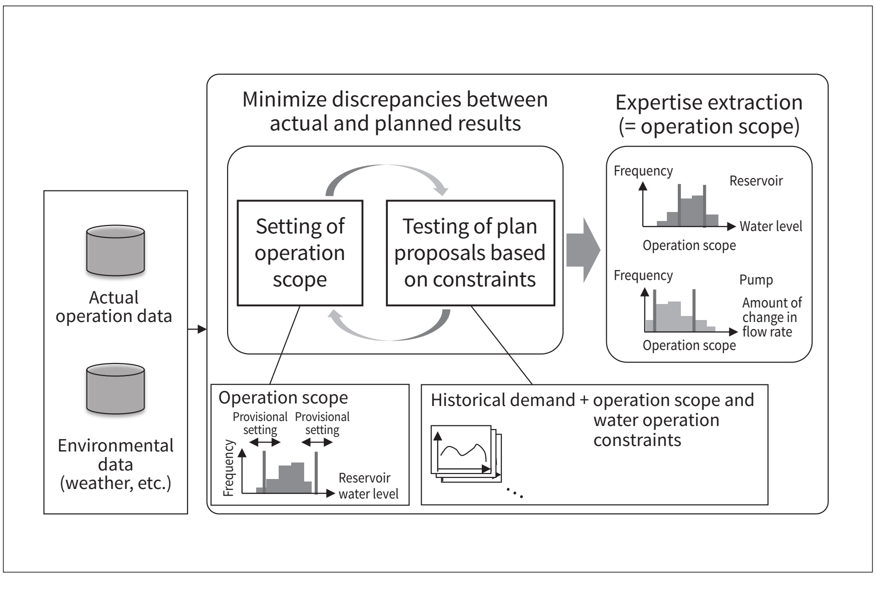
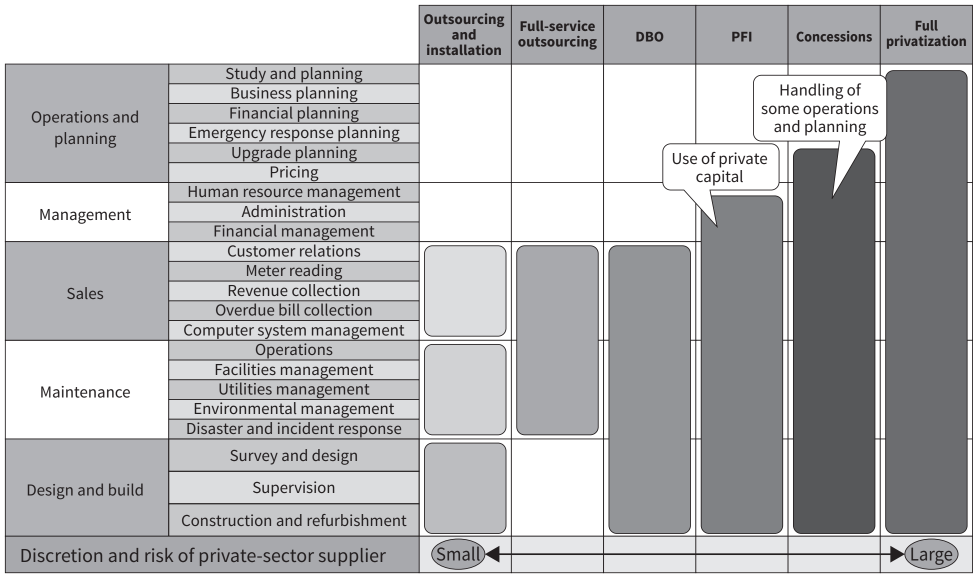


Figure 3 — Overview of Expertise Extraction in Plant Operation Support

The system extracts operational constraints from the actual operation data using machine learning, and prepares plans equivalent to those made by skilled operators. The plan is output as operation guidance for contributing to operation and management support when there is a shortage of operators or when no one is available to pass on the technical knowledge.

Figure 4 — Public-Private Partnership Business Models Offered by Hitachi

Hitachi offers solutions in a variety of forms that make it the ideal partner for water utilities. These range from partial and full-service outsourcing to DBO arrangements, PFIs, and concessions.



DBO: design build operate PFI: private finance initiative

*Prepared based on a handbook produced by the Water Supply Division of the Health Service Bureau at the Ministry of Health, Labour and Welfare for comparing different forms of collaboration in the water industry involving the private sector.

Figure 5 — Akagawa Koku Water Purification Plant and Overview of DBO Project

The scope of the DBO project extends from upgrading mechanical and electrical equipment at the water purification plant to its operation and maintenance.

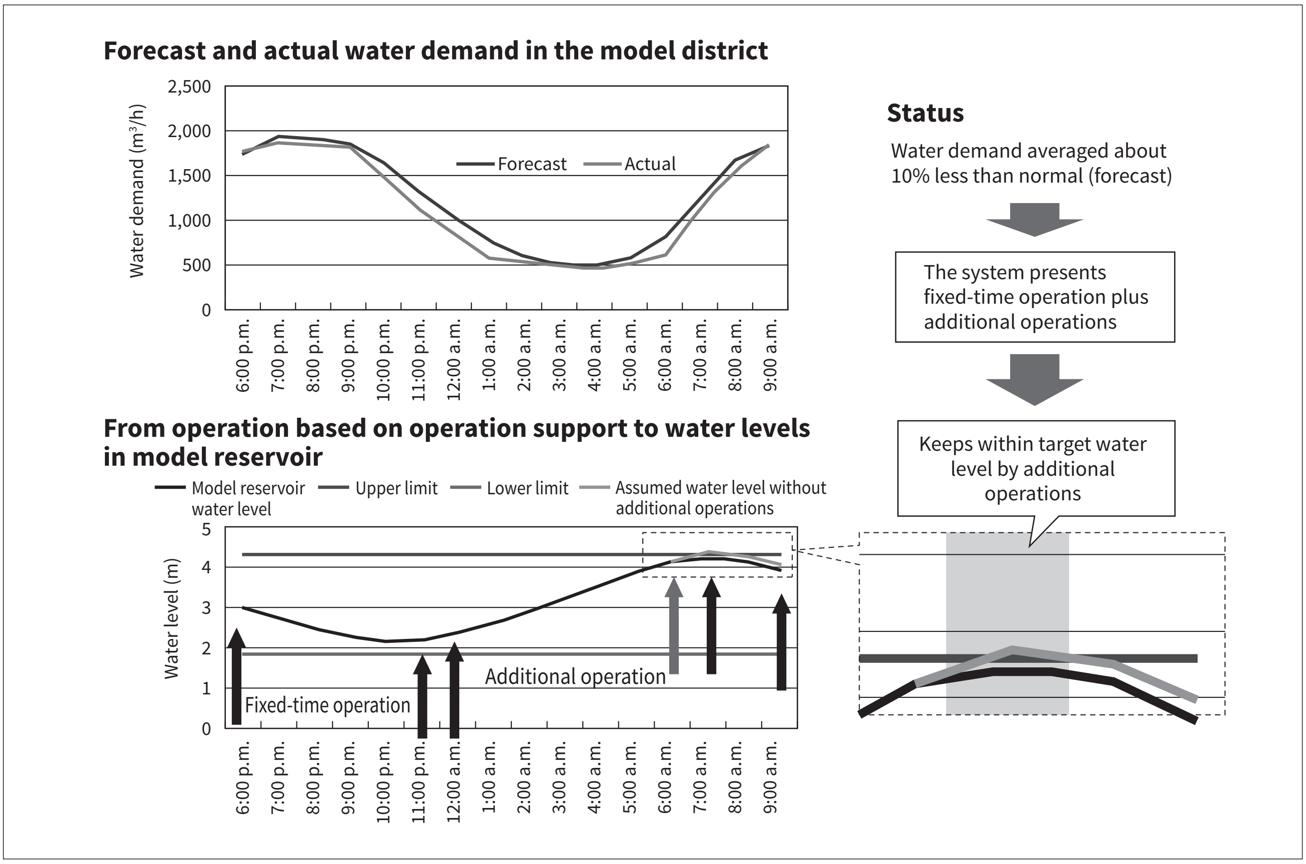
Project name	Project to upgrade Akagawa Koku Water Purification Plant
Customer	Hakodate City Enterprise Department, Hokkaido
Duration	22 years from April 1, 2019 to March 31, 2041
Location	Hakodate City in Hokkaido
Description	(1) Upgrading of mechanical, electrical, and instrumentation equipment, primarily for the filtration tanks and overall monitoring and control system at the Akagawa Koku Water Purification Plant (2) 20-year contract for the operation and maintenance of small water supply systems and the mechanical, electrical, and instrumentation equipment at Akagawa Koku Water Purification Plant and other related facilities, and also the management of the parks on water purification plant sites and the trees grown to protect water sources

2004, nine smaller water supply systems were added as a result of a merger with four neighboring towns and villages, and these plants are currently providing water to approximately 240,000 people (as of August 2022).

One of the objectives of the DBO is for Hakodate City to select and develop private companies as partners to respond to future changes in the waterworks service environment and to achieve a safe and stable supply of water and more efficient facility operation over the long term. A special purpose company, Hakodate Aqua Solution, Ltd., formed from three companies (two Hitachi Group companies and a local company), is currently implementing a 22-year waterworks project from April 1, 2019, to March 31, 2041. This project includes the updating and improvement of the facilities, machinery, and electrical instrumentation of the water purification plants. In April 2022, the updating and improvement of the filtration pond at the Akagawa Koku Water Purification Plant, which is a key water purification plant, was completed and operation was started (see **Figure 5**).

Figure 6 — Example of Results of Validation Test Using the Operation Support Function

Operation plans are prepared using statistical processing, machine learning, and optimization techniques, and guidance is provided at predetermined times. The system is expected to achieve stable operation and management by also indicating any necessary additional operations.



To verify the above-mentioned operation support technology, Hitachi ran it for a total of 10 days during water operations (only at night) at the Akagawa Koku Water Purification Plant and Akagawa Teiku Water Purification Plant, for which operation and management services are commissioned, in the form of guidance issued from a PC not directly connected to the monitoring and control system(7). As a result, although additional operations were required due to sudden changes in settings and disturbances such as water demand that was approximately 10% lower than the annual average, operation was able to meet the target water level with the target of two or less additional operations per day (see **Figure 6**). Hitachi will continue to contribute to the maintenance and development of Hakodate's waterworks system to resolve future issues facing the city.

3. 2 Full-Service Outsourcing for the Nakagawa Water Purification Plant

The Ibaraki Prefecture Public Enterprise Bureau has established 11 water purification plants (three for water supply, one for industrial water, and seven for joint water supply and industrial water) for the purpose of providing wider access to the water supply and expanding the industrial water supply area, and manages and operates the water supply business and industrial water supply business. Of these, the Nakagawa Water Purification Plant is a dedicated industrial water purification plant with a capacity of 122,680 m³/day, which started supplying water in 1966.

Figure 7 — Structure of Outsourcing Contract

The diagram shows how the joint venture between Hitachi and Akira Co., Ltd. has structured its full-service outsourcing contract for the Nakagawa Water Purification Plant.

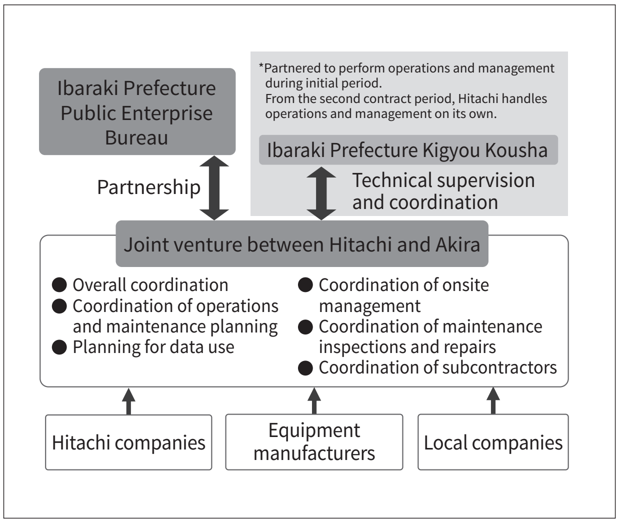


Table 1 — Overview of Full-service Outsourcing Contract for Nakagawa Water Purification Plant

The full-service outsourcing contract for Nakagawa Water Purification Plant encompasses operation, management, and maintenance.

Project name		Operational outsourcing agreement for Nakagawa Water Purification Plant
Duration		April 1, 2016 to March 31, 2019 (phase 1) April 1, 2019 to March 31, 2024 (phase 2)
Description	**Operation and management**	• Operations (central monitoring; on-site inspections; and the recording, reporting, and storage of data) • Simple water quality testing
	Maintenance	Maintenance inspections (instrumentation, monitoring and control systems, electrical equipment, emergency generators, cranes) • Periodic maintenance (electrical equipment, emergency generators, instrumentation*1, water treatment machinery*1) • Cleaning and other housekeeping (equipment cleaning, removal of silt from water intakes, management of vegetation)
	Proposals	• Use of data (collection and storage of data, maintenance support, operational support) • Energy efficiency*2 (energy-efficient operation, visualization and guidance)

*1 Only during phase 1
*2 From phase 2

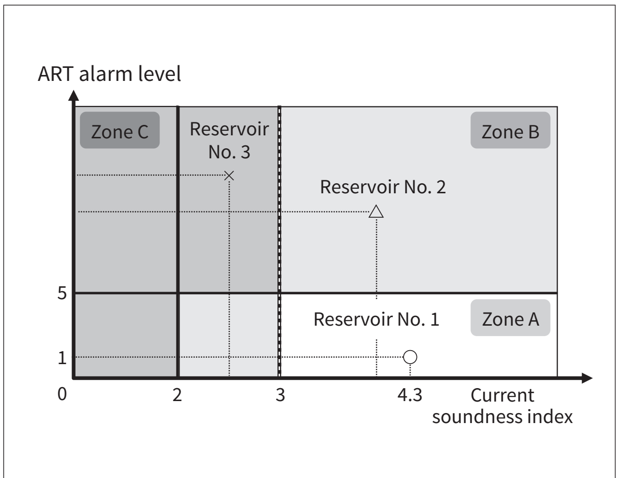
Due to the adoption of a policy to shift to full-service outsourcing in phases, a public tender was conducted for the selection of a contractor for this water purification plant, and Hitachi and Akira Co., Ltd., as a Hitachi-Akira special joint venture (JV), were commissioned to provide operation and management and maintenance services for the first phase of the project in FY2016 and the second phase from FY2019 (see **Figure 7**).

This JV is aiming for more efficient maintenance and management of water purification plants through the integration of operation, management, and maintenance. It is also making use of the resources of Group companies, such as an emergency support system that integrates the network of bases of JV-affiliated companies and centralized data management using the cloud. In addition, the JV is implementing initiatives to optimize inspection details and reduce costs through digital solutions, including examination of energy conservation in operation and management operations (see **Table 1**).

In the asset management initiatives described in the previous section, a maintenance management method that takes advantage of the respective merits of the soundness index and equipment diagnosis is used, and periodic evaluations are continued. The soundness index and ART diagnostic results are plotted and used as indicators to determine the state of equipment and future actions based on their respective positions (see **Figure 8**). At the time of writing, the system is in a favorable zone with a high soundness index and low alarm level (zone A in **Figure 8**). Going forward, Hitachi intends to use the declining soundness index and increasing alarm levels as a basis for enhancing daily inspections and adjusting the scheduled timing of maintenance.

Figure 8 — Decision Map Based on Soundness Index and ART (Conceptual Diagram)

A method for managing equipment and facilities using the soundness index and equipment diagnostic technology was developed for contributing to maintenance and servicing work and its planning.



4. Conclusions

This article has described the Hitachi Group's vision for systems in the waterworks field and its supporting technologies to be implemented, as well as examples of public-private partnership solutions. The functions required for waterworks services are expected to become increasingly sophisticated, and the Hitachi Group will continue to contribute to achieving sustainable waterworks services and improving services as the best partner for water utilities by providing water infrastructure solutions.

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The authors would like to express their deepest gratitude to the Hakodate City Enterprise Department, the Ibaraki Prefecture Public Enterprise Bureau, and other parties involved for their tremendous cooperation in the development of the various technologies described in this article.

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Water Supply Operation Support Technology Using AI

In the water supply sector, the Water Supply Act was revised in 2018 to address issues such as declining demand for water due to the shrinking population, aging water supply facilities, and the shortage of skilled workers. The revised Water Supply Act sets forth efforts for the systematic updating of water supply facilities from a long-term perspective as a responsibility of water utilities, and clarifies the importance of facility consolidation and reallocation. This article presents the latest efforts by the Hitachi Group to address these issues, describes the current status and future prospects of digital technologies that replace the five senses and experiences of operators with IoT and AI, as well as operation support technologies for facilities and equipment.

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Ayumi Watanabe

1. Introduction

In the water supply sector, the Water Supply Act was revised in 2018 to address issues such as declining demand for water due to the shrinking population, aging water supply facilities, and the shortage of skilled workers. The revised Water Supply Act sets forth efforts for the systematic renewal of water supply facilities from a long-term perspective as a responsibility of water utilities, and clarifies the importance of facility consolidation and reallocation.

When consolidation or reallocation of facilities is implemented to improve the efficiency of staff allocation, a centralized monitoring system will be established from an integrated site. The number of utilities switching to this centralized monitoring system at an integrated site is expected to increase, but there are concerns that the reallocation of personnel will result in increased workload per operator and reduced judgment performance of operators due to management by inexperienced operators. Also, since the number of skilled operators is decreasing, it is becoming more difficult to pass on knowledge and skills to less experienced operators.

This article presents the latest efforts of the Hitachi Group to address these issues, describes the current status and future prospects of digital technologies that replace the five senses and experiences of operators with the Internet of Things (IoT) and artificial intelligence (AI), as well as operation support technologies for facilities and equipment.

2. Chemical Dosage Operation Support Technology Using AI and IoT

The flocculation and precipitation process in water purification plants is a highly individualized process, and when water quality fluctuates, the amount of chemicals injected is changed based on the knowledge and experience of skilled operators. However, in recent years, the number of skilled operators has been decreasing, making it difficult to pass on their knowledge and technology. Therefore, to better pass on chemical dosage technology, Hitachi is developing an operation support technology that uses AI to learn the operation records of skilled operators and automatically calculate the flocculant dosage, and a technology that uses sensors instead of an operator's five senses to determine whether flocculation is acceptable or not.

2. 1
Support for Flocculant Dosage Determination by Neural Networks

A neural network (NN) is an AI technology that can automatically extract and model the driving operation tendencies of skilled operators with high accuracy based on data. However, there is a concern that the margin of error could be large when the raw water quality is extrapolated beyond the data range of the training period. Another issue is that the readability of the calculation process is low and the obtained result is not easily explainable. Therefore, Hitachi built an NN-based approximation formula that combines NN with an approximation formula showing the relationship between raw water turbidity and flocculant dosage, which are major influencing factors (see **Figure 1**)[1]. This formula was expected to maintain the relationship between the values of raw water turbidity and flocculant dosage even for extrapolated conditions and to prevent significant deviations in the values.

Also, a prediction model was developed to calculate the flocculant dosage using the raw water quality (turbidity, pH, water temperature, alkalinity, etc.) and the change in raw water turbidity over time as inputs. The monitoring and control data were divided into training and evaluation data. **Figure 2** compares the predicted values of raw water turbidity, which is the main influencing factor, and the flocculant dosage calculated by the NN-based approximation formula.

Figure 1 — Overview of Operation Support System for Calculating Flocculant Dosage

Hitachi provides an operation support technology that automatically calculates the flocculant dosage from the raw water quality. By combining an NN and an approximation formula that incorporates knowledge of the flocculation treatment process, operations based on the experience of skilled operators are automatically found and modeled.

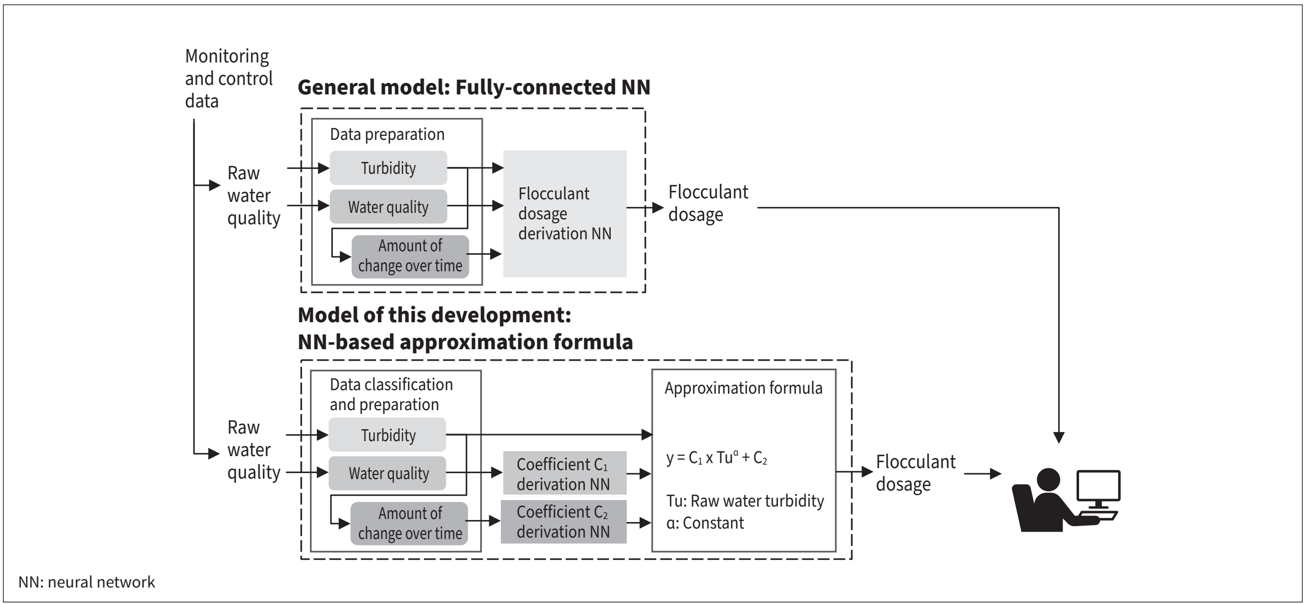


Figure 2 — Comparison of Predicted Values for Raw Water Turbidity and Flocculant Dosage

It was confirmed that the correlation between raw water turbidity and flocculant dosage was maintained using the NN-based approximation formula, even when outside the range of the training data.

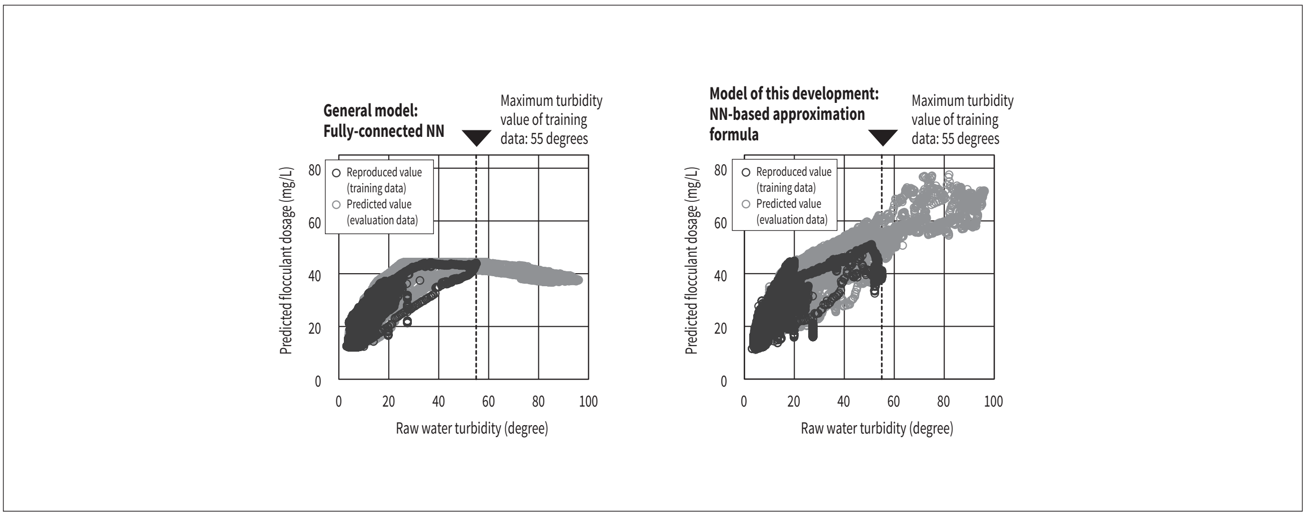


Table 1 — Comparison of Trend Extracted from Knowledge of the Flocculation Treatment Process and the NN-based Approximation Formula

The trend obtained from the sensitivity analysis of the NN-based approximation formula is consistent with the knowledge of the flocculation treatment process, and this is expected to improve the explainability of the findings.

Item		Knowledge	Results of sensitivity analysis	Trend matching
Raw water quality	Alkalinity	Low alkalinity reduces flocculation treatment performance	Higher flocculant dosage at low alkalinity	Yes
	Water temperature	Low water temperature reduces flocculation treatment performance	Higher flocculant dosage at low water temperature	Yes
	Flow rate	Insufficient or excessive flow reduces flocculation treatment performance	Higher flocculant dosage at low flow rate	No
	pH	Flocculation treatment performance is reduced when outside the preferred range (pH = 6 to 8)	Difficult to evaluate due to lack of data when outside the preferred range	No
Amount of turbidity change over time	When turbidity increases	Dosage is often too high in anticipation of further turbidity increase	Higher flocculant dosage when turbidity increases	Yes
	When turbidity decreases	Particle size tends to be smaller than normal and flocculant dosage is higher	Higher flocculant dosage when turbidity decreases	Yes

Yes: Matches trend, No: Does not match trend

The predicted values of the fully-connected NN changed to a gradual downward trend when the turbidity exceeded the maximum turbidity (55 degrees) of the training data, whereas the NN-based approximation formula maintained an upward trend. This indicates that the correlation between raw water turbidity and flocculant dosage can be maintained by the approximation formula even when outside the range of the training data.

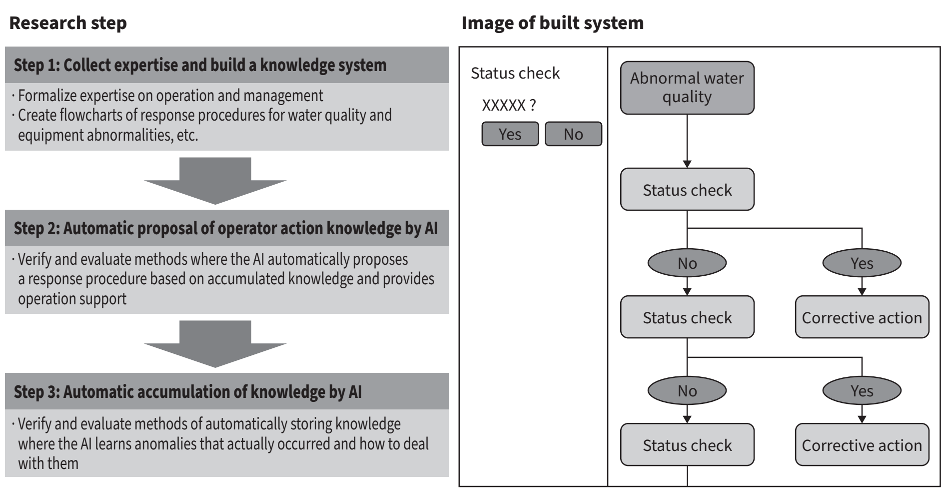
The sensitivity was evaluated to understand the influence of the rise and fall of raw water quality and raw water turbidity on the predicted results for the flocculant dosage in the NN-based approximation formula (see **Table 1**). Changes in the predicted flocculant dosage due to the rise and fall of the alkalinity, water temperature, and raw water turbidity were consistent with the findings, and this is expected to improve the explainability of the findings. It can be said that the NN-based approximation formula developed in this study was able to automatically find the operation based on the experience of skilled operators and apply it in the model.

2. 2 Evaluation of Flocculation State from Floc Images

A convolutional neural network (CNN) is a machine learning technique widely used for image recognition, and when applied to images of flocs (particle clumps produced by flocculation), it enables modeling to evaluate whether flocs are in a flocculation state, which is conventionally done visually by skilled operators. Hitachi has developed a regression-type CNN model that predicts the sedimented

Figure 3 — Steps Taken in Joint Research with the Osaka Municipal Waterworks Bureau

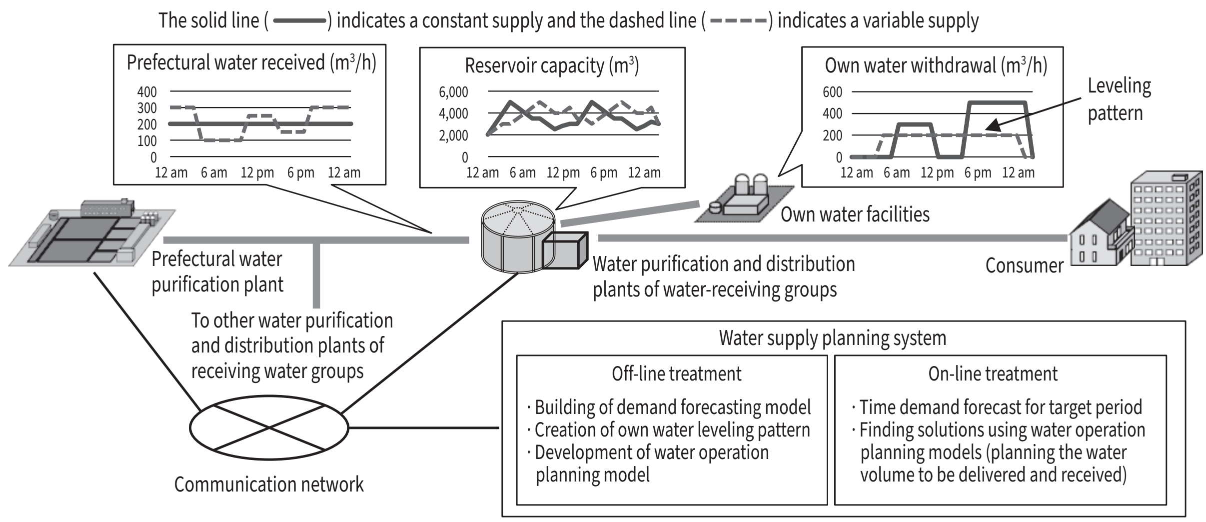
Hitachi aims to establish an operation support and human resource development method that utilizes AI technology and a knowledge system that formalizes operation expertise.



AI: artificial intelligence

Figure 4 — Overview of Water Supply Planning System for Providing Variable Water Supply

Based on demand forecasting and water operation planning technology, a water operation plan is developed to meet various constraints such as projected water demand and upper and lower limits of reservoir storage capacity to develop its own leveled water supply pattern in advance. The leveling of a provider's water supply enables downsizing of its own water facilities.



water turbidity by using the raw water quality and operating conditions (turbidity, pH, water temperature, flocculant dosage, and intake flow rate) that affect the flocculation and precipitation process as well as floc images as inputs.

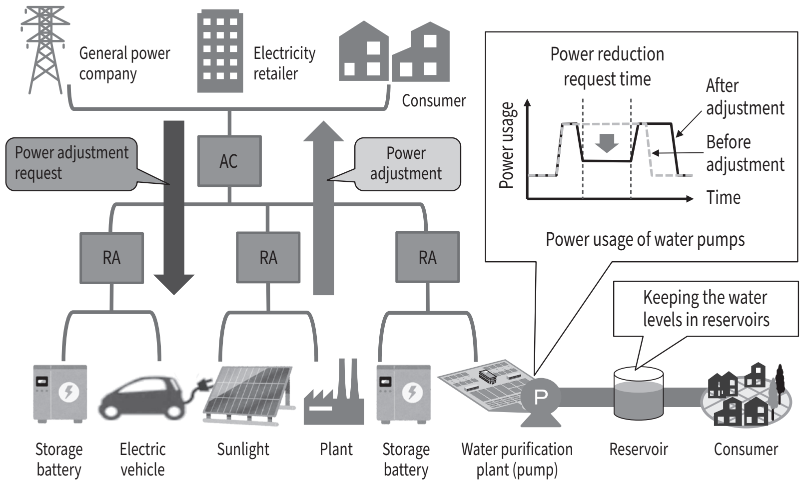
The regression-type CNN model was evaluated using floc images and monitoring and control data obtained from underwater monitoring cameras at an actual site during the summer season. The results showed that the prediction accuracy of sedimented water turbidity was improved during the period when the raw water quality was stable compared with the fully-connected NN estimation which only used the raw water quality and the operating conditions as input. This suggests that the floc images can be used to detect changes in the flocculation state that cannot be detected by the raw water quality and operating conditions alone. In this study, Hitachi will obtain floc images and monitoring and control data during the winter and snow-melting periods at the actual site to evaluate the prediction accuracy of sedimented water turbidity throughout the year.

3. Accumulating and Utilizing Knowledge of Water Purification Plant Operations

The flocculation and precipitation process as well as the operation and monitoring of water purification plants depend heavily on the individual skills of operators, but the number of skilled operators has been decreasing due to the declining birthrate and aging population, making it difficult to pass on knowledge and skills. This is what led Hitachi to start a joint research project with the Osaka Municipal Waterworks Bureau to build a knowledge system that formalizes the operation expertise of water purification plants and to automate operator action proposals and accumulation of expertise by using AI(2). The aim is to build a sustainable operation and management system with a small number of operators and utilize the knowledge system for human resource development.

This joint research aims to establish a knowledge system that formalizes operation expertise by using Hitachi's Lumada to analyze a wide variety of data through statistical analysis, AI, and other methods, based on the wealth of knowledge and data obtained by the Osaka Municipal Waterworks Bureau in the operation and management of water purification plants to date. It also aims to establish an operation support and human resource development method using AI technology. The steps of the joint research are shown in **Figure 3**. First, in Step 1, formalization of operation and management expertise and flow of response methods for water quality and equipment anomalies are created. Next, in Step 2, Hitachi verifies and evaluates a method for providing operation support by using AI to automatically propose a response method based on accumulated knowledge. Finally, in Step 3, the AI automatically accumulates the relationships between "objects" including abnormalities and "items" such as related operations and operating conditions, and verifies that the accumulated results are effective as knowledge. Also, Hitachi examines how to use the knowledge in training programs and other applications for human resource development.

Figure 5 — Entry to VPP Market Using Water Supply Facilities
In response to a power reduction request from the AC and RA, power adjustment is performed by adjusting the pump operation time while maintaining the water level in the distribution reservoir.



P: pump AC: aggregation coordinator RA: resource aggregator VPP: virtual power plant

4. Optimizing Water Use in the Water Supply Business

The water supply business is the business of supplying tap water to municipalities and other waterworks companies that supply water to general households. The Saitama Prefectural Public Enterprise Bureau acquires water sources through dam development to cope with rapid increases in population and delivers water treated at the water purification plant to the water tanks of water service companies. The environment where waterworks operate is expected to come under more severe conditions in the future, with declining water demand resulting in lower fee revenues, aging facilities, and the retirement of skilled engineers. Hitachi believes that it is important for the water supply business and the waterworks business to work together to improve the waterworks infrastructure (including consolidation and elimination), optimize its operation, and improve the efficiency of its maintenance and management throughout the entire region.

One method of efficient cooperation between the water supply business and the waterworks business is variable water supply. This is a method that modifies the current fixed-quantity supply of tap water to water-receiving organizations (municipal and other water utilities) and flexibly adjusts the amount of tap water supplied (amount of water received by municipalities) using the water distribution reservoirs at the water purification plants and water distribution plants of the receiving bodies as buffers. This reduces fluctuations in the amount of water that is withdrawn by the organization receiving water (its own water supply) in response to demand, and makes it possible to optimize (downsize) its own water supply facilities. **Figure 4** shows an overview of the water supply planning system for enabling a variable water supply. Achieving a variable water supply for tap water will enhance the continuous maintenance of the water utilities by reducing the cost of updates by municipalities and other water utilities for their own water facilities and ensuring water supply demand for tap water by the water supply companies. A feasibility study of the variable water supply system is being conducted jointly with the Saitama Prefectural Public Enterprise Bureau[3].

5. Applying Virtual Power Plant to Water Supply Facilities

With the growing awareness of global environmental issues, renewable energy equipment such as solar power generation and energy-saving devices are becoming more widespread and storage batteries are being installed to deal with power shortages. The concept of a virtual power plant (VPP) is one of the most efficient ways of using these devices and power sources. A VPP is a system that functions as a virtual power plant by bundling storage facilities such as storage batteries and electric vehicles (EVs) and treating them as a large power source, charging and discharging them according to the power usage of the market.

The structure of a VPP is shown in **Figure 5**. The VPP consists of a resource aggregator (RA), which controls power adjustment resources such as storage batteries, and an aggregation coordinator (AC), which distributes and coordinates surpluses or shortages of market power to the RA. The AC requests power adjustments as necessary according to market conditions, and the RA adjusts power by controlling the charging and discharging of power adjustment resources. Water supply facilities are assumed to be used as a power adjustment resource. Water utilities use a large amount of electricity to operate pumps and have distribution reservoirs for storing water. For this reason, significant adjustment performance can be obtained by controlling the operation time slots of water feed pumps while appropriately managing the amount of water stored in the distribution reservoirs.

Hitachi provides a water operation planning system that predicts water demand and formulates stable and efficient operation plans for pumping facilities according to the conditions of the water supply facilities. By applying this technology, water supply facilities can be used as power adjustment resources for VPPs, thereby contributing to a reduced environmental burden.

6. Conclusions

Going forward, Hitachi's water business will incorporate information and control technology into its monitoring and control systems and Lumada's comprehensive digital solutions for water and sewage utilities, and as a comprehensive water service provider, contribute to solving customer issues and creating a resilient social infrastructure.

Acknowledgment

The authors would like to express their deepest gratitude to the Osaka Municipal Waterworks Bureau, the Saitama Prefectural Public Enterprise Bureau, and others for their cooperation and support in its efforts to accumulate and utilize knowledge on the operation of water purification plants and to optimize water operation in the water supply business as described in this article.

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Digital Solutions for Maintenance and Management of Water and Sewage Pipes

Water and sewage pipe assets, which account for the majority of the assets of water utilities in Japan, were mostly constructed during the post-World War II period of rapid economic growth, and consequently, there are growing concerns that they are aging. Moreover, the aging of the workforce and reduced staff numbers are also issues that require urgent measures to provide safe and secure water supply and sewage systems. This article presents five examples of solutions developed to solve issues faced by water and wastewater utilities in their pipes. All of these solutions are effective in enabling appropriate pipe maintenance and management operations and can be widely used by water and sewage utilities.

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1. Introduction

The majority of the assets of water utilities in Japan are water and sewage pipe assets that were mostly constructed during the period of rapid economic growth after World War II, and consequently, there are growing concerns that they are aging. As a result, urgent measures are required to provide safe and secure water supply and sewage systems. On the other hand, the aging of the workforce and staff shortages have become issues, and there is a strong need to pass on skills and improve the efficiency of maintenance and management operations. In this context, Hitachi is working daily to develop and commercialize services for more effective operations of utilities by combining the digital technologies and products that it has developed on its own.

This article describes five of these efforts that are considered to be widely and commonly utilized in the maintenance and management departments of utilities. First, this article presents Hitachi's leak detection service and pipe management support system for improving the efficiency of water pipe maintenance and management. This is followed by the use of drones for inspecting pipes, which have been difficult to inspect by humans, fiber-optic multi-sensing for providing a reliable power supply, and a rainwater pump operation support system as a flood prevention solution that takes into account the structure of the pipe during localized heavy rains.

2. Services to Support Maintenance and Management of Water Pipes

This section presents Hitachi's leak detection service and pipe management support system, which are provided as maintenance and management support services for waterworks.

2. 1 Leak Detection Service

The leak detection service constantly monitors water pipes using a proprietary ultra-sensitive vibration sensor, and consists of a leak detection sensor with communication functions and a monitoring platform in the cloud(1).

Specifically, a sensor installed on a water control valve of a water pipe measures the vibrations propagated from the point of leakage, and assigns a score to the result from analysis of the measured data. The score is transmitted from the sensor to the monitoring platform and displayed on a screen to visualize the presence or absence of suspected leaks. This service enables utilities to remotely monitor the status of underground pipes without having to go to the site. Also, since the scope of suspected leaks can be narrowed down, the service is expected to improve the efficiency of investigation work for confirming the point of leakage.

This service was awarded the Minister of Education, Culture, Sports, Science and Technology Prize at the 51st Japan Industrial Technology Awards organized by Nikkan Kogyo Shimbun, Ltd.(2) and is scheduled to be widely deployed in Japan and abroad as a service that contributes to achieving a safe, secure, and resilient social infrastructure.

2. 2 Pipe Management Support System

Since pipes were installed in a concentrated manner during certain periods of time in the past (around 1975, 1998, etc.) to increase the water supply coverage, it is expected that the pipe replacement period will also be concentrated during certain periods of time in the future. As a result, the annual investment in updating pipes is expected to be extremely high only during certain periods, making long-term update planning difficult.

The pipe management support system that is presented here helps to resolve this issue by calculating the base year for pipe renewal and leveling the amount of investment related to pipe renewal, thereby supporting the preparation of pipe renewal plans.

Specifically, information on underground pipes made of various materials and joints, as well as actual leakage incident data accumulated from the above-mentioned leak detection service monitoring platform, are added to evaluate the incident rate of pipes using a proprietary method of statistical analysis and to calculate the base year for pipe renewal. Based on the calculated base year for pipe renewal, the amount of investment in pipe renewal is leveled by making the annual investment in pipe replacement by each utility as uniform as possible. The leveling of the investment amount is based on an amount that minimizes the life cycle cost (LCC, the total cost of the pipe, including initial installation, maintenance, and management) as much as possible.

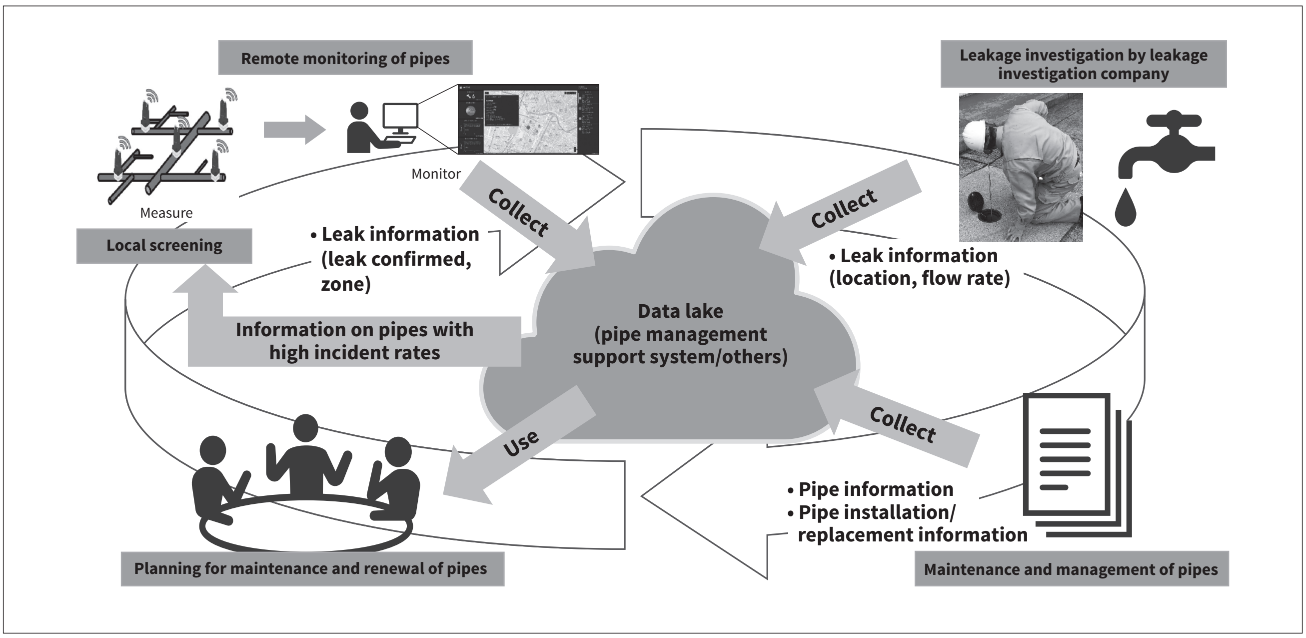
The system automatically calculates the amount of investment in pipe renewal for each fiscal year, which contributes to higher efficiency for the person preparing the pipe renewal plan, and it is also important to emphasize that this system can contribute to the transparency and accountability of the utility's operations. Utilities of a highly public nature are expected to be able to use the information from this system to provide clearer and more persuasive explanations not only internally, but also to representative assemblies and citizens during the budget formulation and approval process.

Going forward, Hitachi will provide this pipe management support system as a data lake that will help utilities optimize and advance their water pipe maintenance and management by consolidating and utilizing all pipe-related data (see **Figure 1**).

3. Services to Support Maintenance and Management of Sewage Pipes

Next, this section introduces available solutions to support the maintenance and management of sewer pipes, such as

Figure 1 — Services to Support Maintenance and Management of Water Pipes
This figure shows the data flow and examples of use.



Hitachi's sewer pipe investigation service, which uses drones, multi-sensing using optical fiber, and pump operation support during rainwater events.

3. 1 Sewer Pipe Investigation Solution Using Drones

Up to now, the maintenance and management of sewer pipes have been conducted primarily through visual inspections by humans or by video camera equipment. However, the high water levels, high flow rates, and high concentration of hydrogen sulfide in some sewer pipes make them difficult to investigate because of the high risks they entail for humans. To address this issue, Hitachi is developing a sewer pipe investigation solution using drones in collaboration with the Bureau of Sewerage Tokyo Metropolitan Government and the Tokyo Metropolitan Sewerage Service Corporation. Specifically, the system consists of (1) a drone specialized for flying inside sewer pipes and photographing the inside surface of pipes, and (2) an installation device for getting the drone into and out of the ground. The drone can be operated on the ground without a person entering the sewer pipe while images taken from the front of the drone are viewed on a monitor to enable images of the inside of the sewer pipe to be taken safely.

The main functions of each system component are as follows.

(1) Drone

- Flight function: 500-mm diameter, approx. 2.5-kg overall weight, six rotor blades
- Control function: Distance sensor to measure the distance in the direction of the walls and ceiling, and two-point positioning control to maintain the distance at a constant level
- Recording function: 21-megapixel general-purpose camera

(2) Installation device

- Out-of-sight maneuvering support function: Monitor on the ground that displays images from the front of the drone
- Communication function: Transmitter/receiver that can wirelessly transmit images taken from the front of the drone to the ground
- Retrieval function: A take-up device that can eject and rewind the drone retrieval cord connected to the drone

Using this drone and the installation device, Hitachi conducted a recorded flight to a maximum distance of 224 m away from the base in an in-service combined trunk sewer (cross-sectional width 5.0 m, height 4.5 m, depth 25–30 cm) and confirmed that the drone could fly back and forth stably without touching the walls, ceiling, or water surface, and could capture images of a simulated crack (5 mm wide black line drawn on a blank sheet of paper) equivalent to damage rating an A from the Bureau of Sewerage Tokyo Metropolitan Government. Despite the high humidity inside the pipe compared to the ground, there was no condensation on the investigation camera due to pre-heating and other measures, and the camera was able to capture images of good quality.

This solution enables the safe inspection of the inside of sewage pipes even in environments that are difficult for humans to investigate. Since the sewer pipes in such environments are more likely to be deteriorated, the solution will contribute to more accurate planning of repair and reconstruction work. In the future, Hitachi plans to conduct recorded flights of sewer pipes of various shapes and sizes to further clarify issues and apply the results in actual operation. Furthermore, Hitachi intends to combine the system with image processing technology that automatically identifies potential areas of deterioration from the recorded images to support more efficient investigation work (see **Figure 2**).

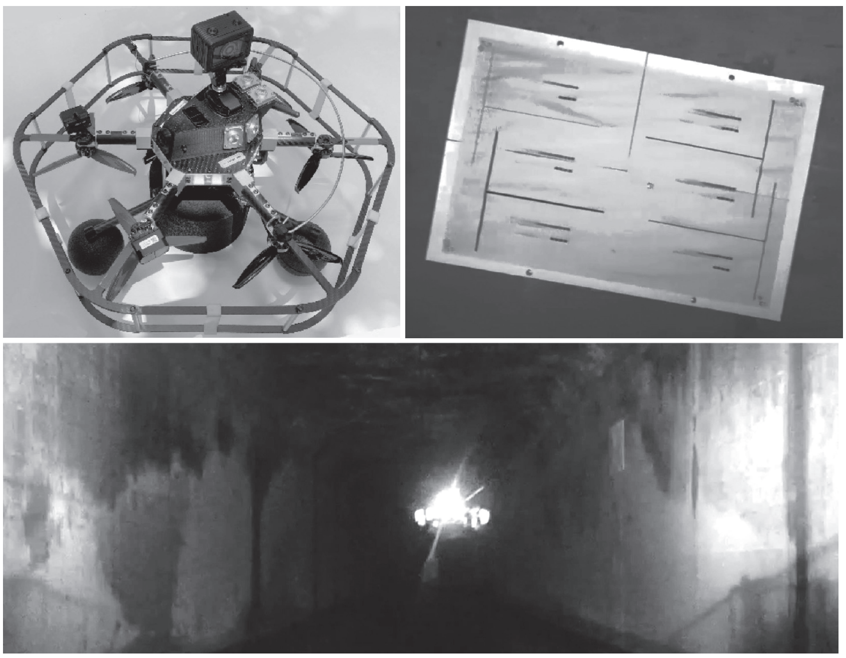


Figure 2 — Drone, Simulated Crack, and Flight Conditions
The drone is shown at the top left, the simulated crack at the top right, and the flight conditions in the sewer pipe in the bottom image.

3. 2
Fiber-optic Multi-Sensing System

3. 2. 1 Visualization of Pipes Using Sewer Optical Fiber

For maintenance and management of sewer pipes, visualization is required to assess the water level, water quality, and even the environment inside the pipe using gas sensors and to manage such information. However, when sensors and transducers are permanently installed in a pipe for visualization, there is no continuously available power source, and a means of communication is also required. This led Hitachi to focus on the use of optical fibers installed in sewer pipes. Hitachi resolved this issue by using optical fiber not only as a general communication channel, but also as a supply channel for sensing power using power-over-fiber (PoF) technology.

Sewer optical fiber is an optical fiber cable laid in sewer pipes for communication between sewer facilities. The installation of fiber-optic cables is proceeding for the purpose of upgrading and improving the efficiency of sewer facility management, and as of the end of FY2020, a total of approximately 2,227 km of fiber-optic cables have been installed nationwide, mainly in urban areas such as Tokyo[3]. Also, because the optical fiber is buried underground, it is highly secure in the event of a disaster. Even during the Great East Japan Earthquake, there were no communication failures, and they played a major role in communicating among facilities and monitoring facility status conditions[4].

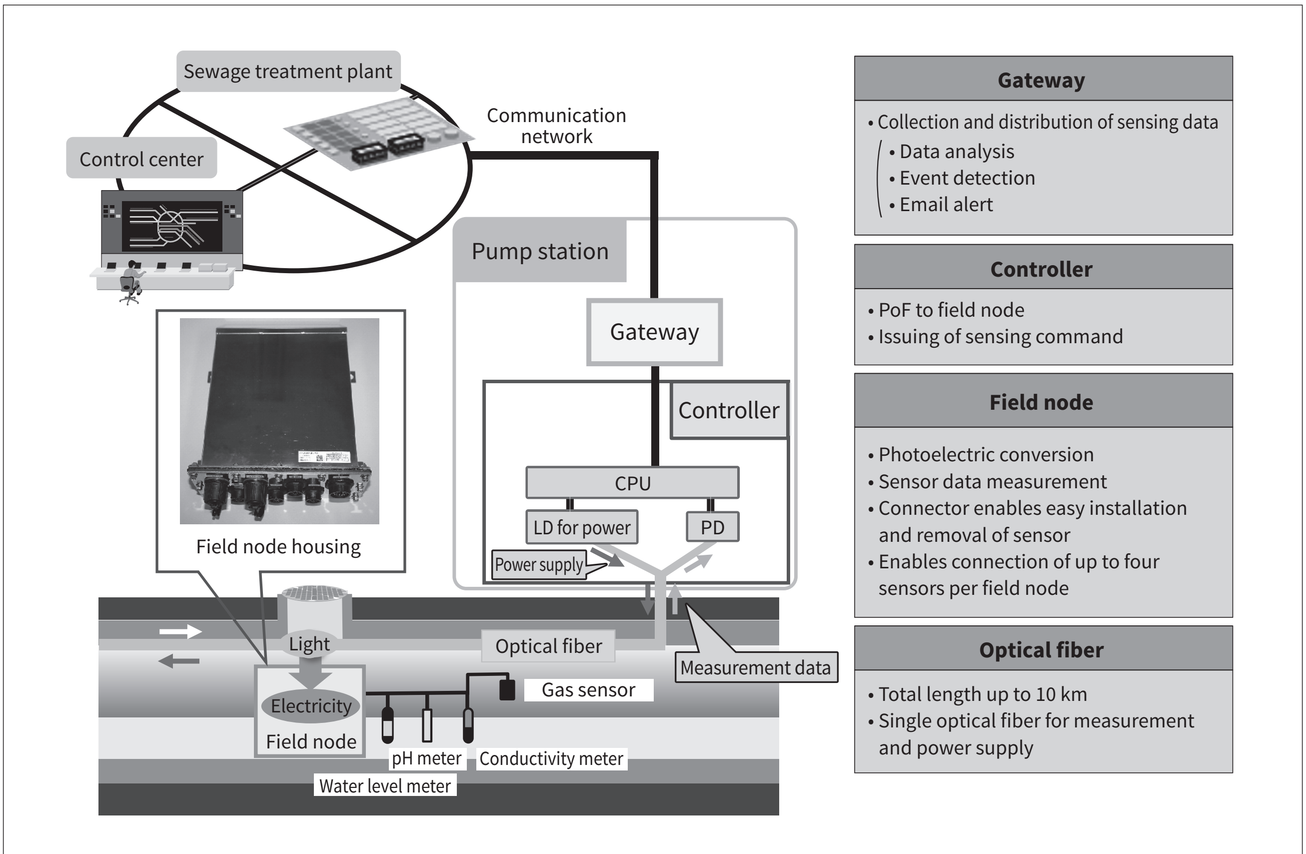
3. 2. 2 Features of the Fiber-optic Multi-sensing System

The system consists of field nodes, controllers, and a gateway, and uses PoF technology to provide power and communication from the controllers to the field nodes via a single optical fiber using wavelength division multiplexing communication (see **Figure 3**).

Up to four sensors (detachable with waterproof connectors) can be connected to each field node to measure the status conditions of pipes. The sensors include water level, conductivity, pH, and gases (hydrogen sulfide and cyanide).

For example, water-level meters and conductivity meters can be used to determine rainwater inflow, and pH meters can be used to determine abnormal water quality. The measurement of hydrogen sulfide using a gas sensor provides important information for identifying the source of foul odors in building cesspits and for managing corrosion in sewer pipes. The field node is in a waterproof housing so that it can be installed in locations where it may be submerged in water. This configuration enables the building of a flexible system capable of connecting up to five field nodes within a total length of 10 km to a single fiber-optic cable.

Figure 3 — Fiber-optic Multi-sensing System
Real-time monitoring of sewage pipe conditions through sensing using fiber-optic communication and power-over-fiber (PoF).



LD: laser diode PD: photo diode CPU: central processing unit

The gateway accumulates the measurement data and provides it to a control center, sewage treatment plant system, or other location. The system is equipped with a measurement data analysis function in the gateway, and is capable of detecting unknown water, abnormal water quality, early rainwater, etc., and sending out e-mail alerts.

3. 3 Rainwater Pump Operation Support System

3. 3. 1 Current State and Issues of Combined Sewer System

Pump stations in combined sewer systems that handle both sewage and stormwater must give priority to preventing flooding in the sewage treatment area by quickly removing rainwater that has fallen in that area. However, depending on the level of rainfall, operation must also address risks such as submerging sewage pump stations and increasing the environmental pollution load due to untreated simple effluent(5). Even now, there are cases where pumps are operated manually by skilled operators due to difficulties in automatic operation such as localized heavy rainfall, but there is concern that such expertise may be lost in coming years due to the mass retirement of skilled operators as a result of the declining birthrate and aging population in Japan.

To address the above issues, Hitachi is developing a rainwater pump operation support system that uses artificial intelligence (AI) to predict inflow and provide operators with appropriate plans for starting and stopping rainwater pumps.

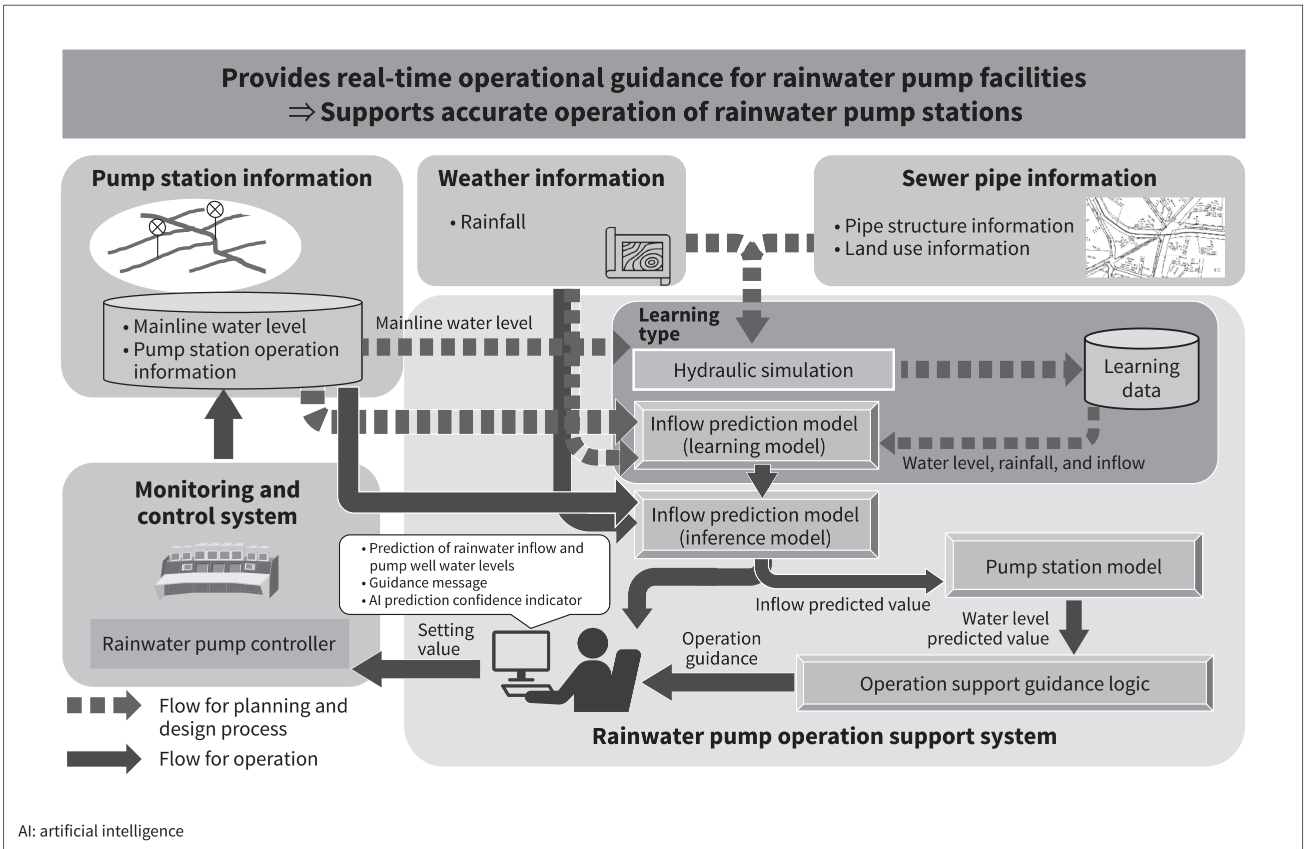
3. 3. 2 Features of Rainwater Pump Operation Support System

The frequency of rainfall at which rainwater pumps operate is not sufficient as training data for AI. Therefore, hydraulic simulations based on actual data on mainline water levels and rainfall, as well as sewage pipe information such as land use and pipe structure, are used to calculate inflows for various rainfall patterns, which are then used as training data (see **Figure 4**).

During planning and design, actual data from pump station operation (starting/stopping of pumps/generators, amount of effluent/water delivered, opening of water gates, etc.), mainline water level (collected by fiber-optic multisensing system, etc.), rainfall (rainfall radar), and data generated by hydraulic simulation are used as learning data to create an inflow prediction model (learning model).

During operation, the system predicts the inflow rate by inputting real-time data using the learned model as the inference model, predicts the pump well water level and other parameters using the pump station model, and provides the timing of pump startup and shutdown from the operation support guidance logic according to the prediction results. The operation support guidance logic, which applies

Figure 4 — Rainwater Pump Operation Support System
In addition to actual data, hydraulic simulation results are also used as training data to create an inflow prediction model (learning model).



the expertise of experienced operators, can select and provide guidance in accordance with the operation policy, such as prioritizing water level or effluent quality. The accuracy of the inflow rate prediction will be improved by continuously adjusting the parameters based on the data accumulated through the usage of the operation support system.

This system helps visualize the reliability of AI predictions and is equipped with a human machine interface (HMI) that allows the operator to intervene as needed, enabling the operator to achieve pump operation in which the AI and the operator cooperate with each other while keeping the certainty of the AI predictions in mind.

4. Conclusions

This article has presented examples of digital solutions developed for the maintenance and management of water and sewage pipes. These solutions are currently being developed for water utilities in Japan, but Hitachi will devise ways to provide services in a more flexible manner based on the unique circumstances of each customer. Also, with an eye on international expansion, all of those involved in this project will work together to build services that can be used by more customers and to continuously improve the quality of these services.

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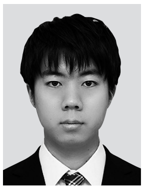

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Latest Technologies for Innovation in Sewage Treatment

In order to continue to provide a safe, secure, and sustainable sewer infrastructure, a variety of issues need to be addressed, including increasingly heavy rainfall, preservation of water quality in public waters, realizing abundant oceans, response to climate change (decarbonization and energy conservation), and the shrinking number of skilled operators and labor saving. Hitachi aims to solve these issues using various approaches, including hardware (such as equipment installation), software (such as data utilization, modeling, and AI), and sensing for connecting software and hardware. This article describes the current status and future prospects of these technologies that will revolutionize Hitachi's sewage treatment solutions.

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1. Introduction

Amid a growing number of challenges, including increasingly heavy rainfall, preservation of water quality in public waters, a shrinking number of skilled operators, aging facilities, declining population and income, and actions to prevent climate change and to achieve decarbonization, the mission of sewage systems to contribute to building a society capable of sustainable development, as stated in the "New Sewerage Vision" prepared by the Ministry of Land, Infrastructure, Transport and Tourism in 2014, is becoming increasingly important.

The acceleration strategy to achieve this is continuously reviewed, with climate change, water environment management, and decarbonization as key challenges that were particularly emphasized in the 2022 review(1). The heavy rains that are becoming the norm due to climate change will not only increase the risk of inland flooding, but also increase environmental risks if stormwater is discharged without adequate treatment. Also, the challenges of water bodies, such as nutrient deficiencies and red tides, vary depending on the region and season. Appropriate water environment management according to actual conditions, such as sewage treatment control, is required to achieve clean and abundant oceans. Furthermore, sewage treatment plants, which account for 0.7% of Japan's electricity usage, are expected to play a role by converting sludge into a renewable energy source in addition to decarbonization through energy conservation, and the effective operation of water treatment and sludge treatment is also important. In this situation, the above-mentioned acceleration strategy cited sewage digital transformation (DX) as one method of attaining these objectives.

The Hitachi Group, which supports the operation of sewerage systems that are required to play an increasingly key role, is working to overcome these challenges from various perspectives based on digital technology, including the linkage of software and hardware, artificial intelligence (AI), and sensing. This article describes these innovative state-of-the-art technologies and their future prospects.

2. Sewage Treatment Technology for Reducing Discharge Load During Rainy Weather

2. 1 Hitachi's Solutions for Stormwater Control

Amid a progressively changing climate and aging pipes, the Ministry of Land, Infrastructure, Transport and Tourism has issued draft guidelines on dealing with water inflows during rainfall events[2]. In recent years, stormwater control measures have been implemented not only for combined sewer systems, but also for separate sewer systems. In addition to management technologies for pipes and pump stations, Hitachi is developing operation support technologies as stormwater management solutions for sewage treatment plants using model equations, AI, and other methods that focus on operation and management innovations, which are economical software measures combined with hardware measures that can be implemented with only minor modifications (see **Figure 1**). This section presents Hitachi's stormwater management solutions for sewage treatment plants, which are responsible for purification in the treatment process.

2. 2 Overview of Rainy Weather Treatment Issues and Developed Technologies

In the treatment process during rainy weather, activated sludge outflow from the final sedimentation tank must be controlled while maximizing biological treatment and reducing the discharge load associated with simple treatment discharge. To meet this need, Hitachi has developed and verified a inclined plate unit[3] that improves solid-liquid separation performance in the final sedimentation tank with minor modifications. It has also developed an operation support system[4] that derives the maximum treated water volume within a limited range by using model equations such as the sludge outflow estimation model[4]. The sludge outflow estimation model reproduces the settling and advection of activated sludge in the final sedimentation tank and predicts the concentration of suspended solids (SS) overflowing from the final sedimentation tank.

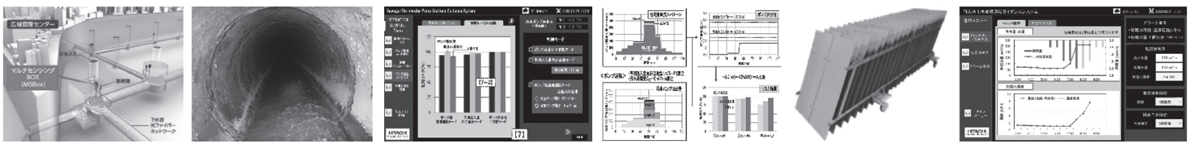
2. 3 Verification of Development Technology

First, an example of the verification results of the inclined plate unit is shown in **Figure 2**. The inclined plate unit was installed in the final sedimentation tank of a sewage treatment plant (combined type) that had problems with solid-liquid separation performance in the final sedimentation tank. The quality of the treated water was compared with that of an existing sedimentation tank under the same operating conditions. As a result, the quality of the treated water in the inclined plate sedimentation tank was improved compared to the existing sedimentation tank, and the discharge load (from treated water) of biochemical oxygen demand (BOD), an indicator of organic matter, was reduced by 41%.

Next, **Figure 3** shows the verification results of the operation support system. This is a separate sewer system, but in a sewage treatment plant where simple treatment discharge occurs during a heavy rainfall, the maximum treated water volume (1.2 times that of conventional systems, equivalent to a 70% reduction in the amount of simple treatment discharge) was derived within various constraints using various models, including a model for estimating sludge discharge. The validity of this finding was verified with

Figure 1 — Hitachi's Rainwater Solutions for Sewerage Systems (Including Those under Development and Verification)
Hitachi provides a wide range of rainwater solutions to reduce rainwater risks in sewers.

Pipes	Pumping station	Sewage treatment plant
Measures implemented at source Inspecting and identifying points of infiltration	**Measures for operation and management** Pump operation support based on rainwater inflow prediction	**Measures for facilities and for operation and management** Sludge outflow control, maximizing and increasing volume of treated water

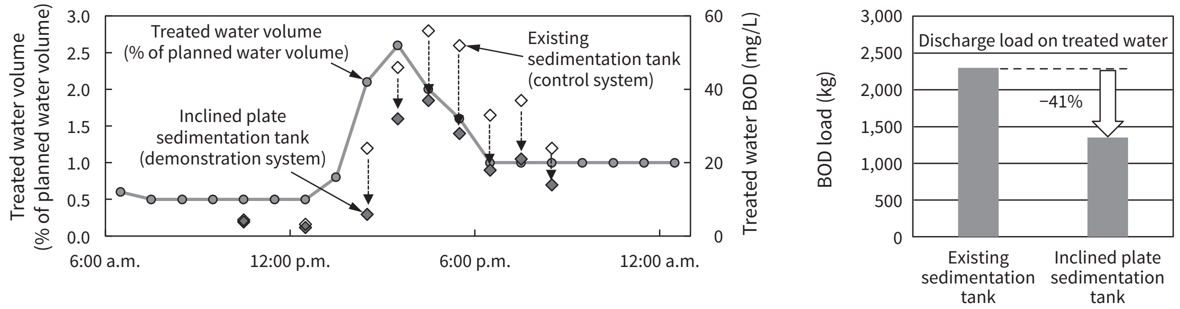


- Water level and water quality monitoring — Multi-sensing box using optical fiber network
- Pipe condition inspection — Inspection using UAVs, image analysis support
- Rainwater inflow prediction and AI pump operation support — Rainfall information, number of pumps in operation using in-pipe information, timing navigation
- Improvement of solid-liquid separation performance — Inclined plate unit
- Demonstration of marginal performance — Prediction of sludge outflow and water quality, navigation for maximizing volume of treated water

UAV: unmanned air vehicle AI: artificial intelligence

Figure 2 — Effect of Reducing Discharge Load by Installing Inclined Plate Unit (with Actual Equipment Verification Results)

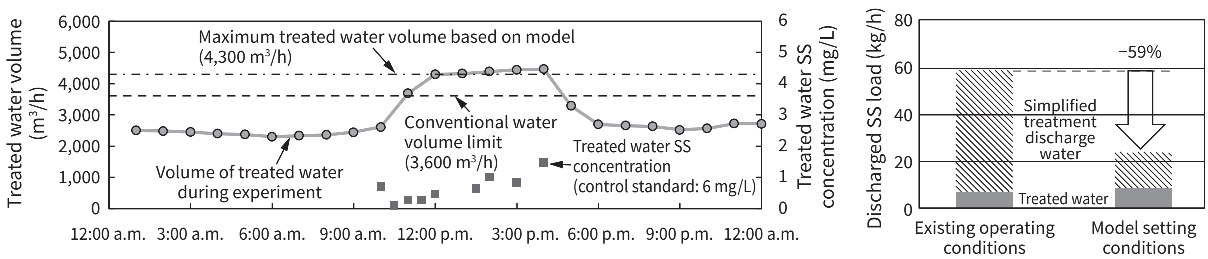
The increased solid-liquid separation performance of the inclined plate unit improved the quality of the treated water and reduced the discharge load of BOD on the treated water by 41% compared to the existing sedimentation tank (control system).



BOD: biochemical oxygen demand

Figure 3 — Verification Results by Actual Equipment at Maximum Treated Water Volume Based on Sludge Outflow Estimation Model, Etc.

Based on model calculations, the maximum water volume was set at 1.2 times the conventional volume (equivalent to a 70% reduction in simple treatment discharge), and verification was conducted using actual equipment. As a result, the SS concentration in the treated water was below the control standard (the same applies to organic matter, nitrogen, and phosphorus concentrations), and the SS load in the discharge was also significantly reduced.



SS: suspended solids

actual equipment under operation. As a result, the treated water quality was below the control standard value, and the hourly discharge SS load (total of treated water and simplified treatment discharge water) could be reduced by 59% when discharging simplified treatment water. Consequently, this confirmed the validity and effectiveness of the model-based treatment water volume setting.

In the future, Hitachi will enhance the applicability of the developed technology by installing it in actual facilities and further verifying and improving it, thereby contributing to maintaining water quality, reducing the discharge pollution load, and improving operational efficiency in sewage treatment during rainy weather.

3. AI Sewage Treatment Support Technology for Efficient Operation

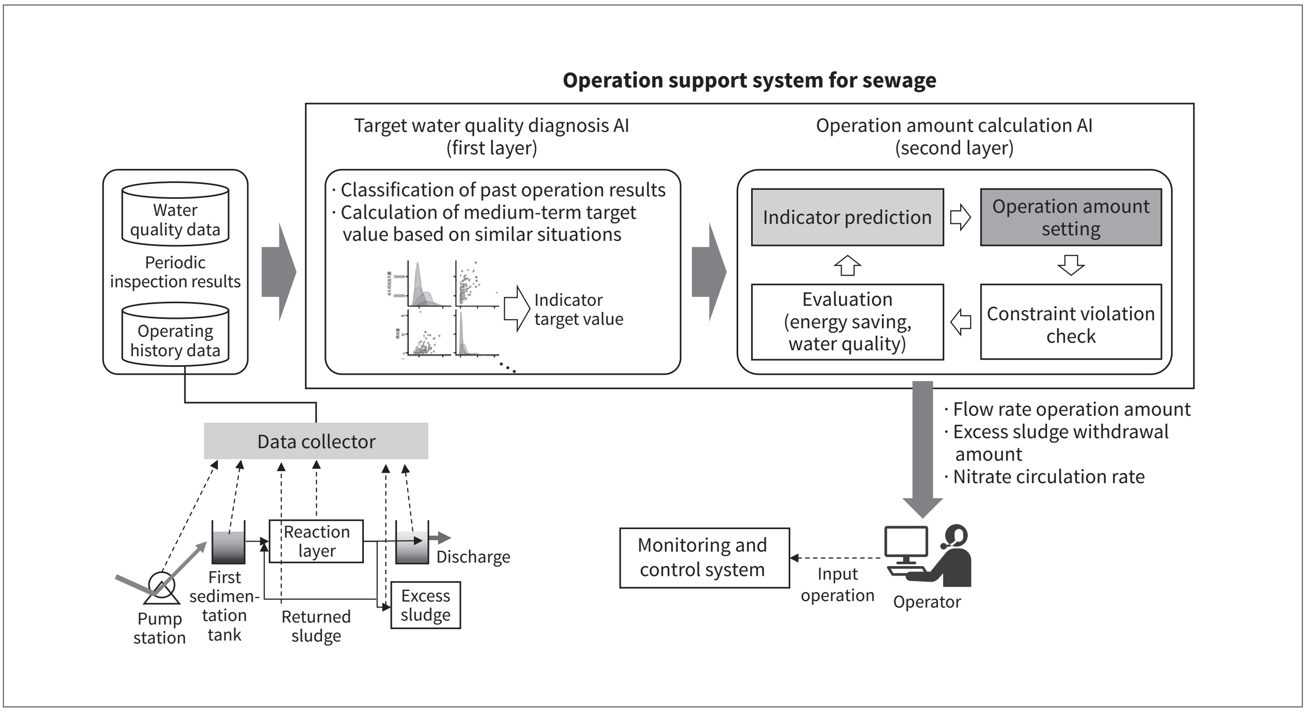
3. 1 AI Sewage Treatment Support Technology

On a daily basis, sewage treatment plants use blowers to supply the air necessary for sewage purification and use pumps for sewage inflow. Traditionally, skilled operators have been responsible for this work, but currently, there is a shortage of operators due to the shrinking labor force. Expectations are therefore rising for AI-based support to improve maintenance and management efficiency and to pass on skills. Hitachi provides cloud-based digital solutions to support operation and maintenance (O&M), and is developing technologies to support maintenance and management operations from both facility management and operation and management perspectives. This section presents Hitachi's AI-based operation support technology for sewerage systems.

The purpose of sewage treatment is to treat organic matter and nutrient salts such as nitrogen and phosphorus in sewage using activated sludge, which consists of microorganisms, and to purify the water to a quality that can be discharged into rivers. Good water quality can be obtained through the proper operation of blowers, circulation pumps, and other equipment, but qualitatively, there is a trade-off between water quality and energy usage. Therefore, the challenge is to set the target water quality within a range that does not affect the environment, and then to run the equipment in an energy-efficient manner with reduced operation. To address this issue, Hitachi is developing a hybrid

Figure 4 — AI-based Operation Support System for Sewerage Systems

The first layer calculates the medium-term target values based on operating history data collected from the water quality data and monitoring and control systems. The second layer calculates the operation amount that will save energy in achieving the medium-term target.



operation support system that combines human knowledge of sewage treatment and AI (see **Figure 4**).

In this system, the first layer (AI diagnosing target water quality) first analyzes the operating history of past sewage treatment plants based on the physical and chemical characteristics of sewage treatment and human knowledge, and establishes medium-term target values for water quality according to the season. Next, in the second layer (AI calculating the operation amount), the system learns operational data of sewage treatment facilities obtained at regular time intervals, and maintains a prediction AI that estimates the state of the facilities when certain operations are performed. Using this prediction AI, an optimization AI is used to find the equipment operation amount that saves energy within the range where no abnormalities in water quality occur (i.e., no deviation from the medium-term target values derived by the AI that diagnoses the target water quality), thereby realizing energy-saving operation.

3. 2 Demonstration in Joint Research with Saitama Sewage Systems Agency

Hitachi is participating in a joint research project for practical application of AI-based sewage treatment to verify the effectiveness of the developed technology conducted at the Arakawa Water Cycle Center (located in Toda City, Saitama Prefecture and having a treatment capacity of approx. 950,000 m^3/day), managed by the Saitama Sewage Systems Agency. This joint research will apply AI to some of the sewage treatment lines at the Center and run them on a trial basis for one year to study whether they can reduce greenhouse gas emissions, lower maintenance and management costs, and improve operational efficiency. The demonstration system has been operating during the evaluation period, from January 2022 to January 2023 (as planned at the time of proposal) to confirm the effectiveness.

4. Efficient Sludge Treatment Operation Support Technology Using AI

4. 1 Hitachi Solutions for Supporting Sludge Treatment Operations

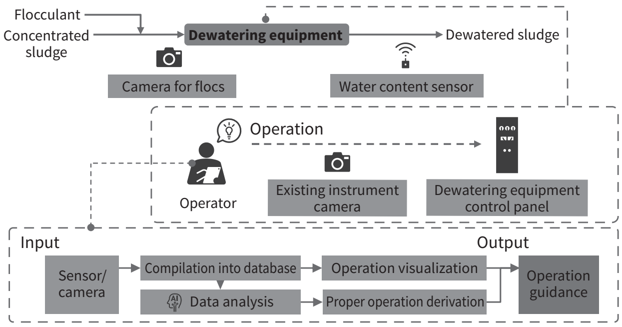
In sewage treatment projects in Japan, as the population declines and sewage fee revenues decrease[(5)], improving profitability by streamlining sewage treatment and reducing maintenance and management costs is an urgent issue. Among these costs, sludge disposal costs account for a relatively high proportion of total maintenance and management costs, and recent trends suggest that efforts to reduce sludge disposal costs by using full-service private-sector outsourcing will accelerate in the future[(6)].

This study focuses on the dewatering process and dewatering machine operation, which are standard parts of the sludge treatment process for developing service business and technology by optimizing this process using Internet of Things (IoT) and AI technologies.

Figure 5 — Configuration and Role of Dewatering Machine Operation Guidance

With the goals of detecting changes early in dewaterability of sludge and enabling even unskilled operators to operate the dewatering machine with operation guidance, Hitachi has developed a sensor capable of monitoring flocculation using AI-based image analysis and online continuous measurement of water content and has developed dewatering machine operation guidance based on the analysis of accumulated data.

		Conventional dewatering machine operation	Development goals or expected effects
(1)	Flocculation monitoring	Visual determination (expertise)	Determination by sensor and AI
(2)	Water content measurement	Spot measurement (lab measurement)	Continuous measurement by sensors (online)
(3)	Operation adjustment	Determination by skilled operator based on experience (expertise)	Even unskilled operator can operate with assistance of the guidance
(4)	Operation time	Daytime operation only Long adjustment time	Enables longer time with reduced load Reduced adjustment time



Filtration-type dewatering machines, such as screw presses, have the characteristic of increasing the dewatering rate by properly conditioning the dewaterability of sludge through pretreatment such as flocculation, and by increasing the pressing pressure and pressing time[(7)]. On the other hand, two issues that arise are that (1) the dewatering machine has been operating based on the settings configured at start-up, making it difficult to perform conditioning and operation according to changes in sludge dewaterability, and (2) only a limited number of operators understand the details of the dewatering machine and are able to operate it during the hours when skilled operators are working. Therefore, with the goals of detecting changes early in the dewaterability of sludge and enabling even unskilled operators to operate the dewatering machine with operation guidance, Hitachi has developed a sensor capable of monitoring flocculation by AI-based image analysis and online continuous measurement of water content (percentage of water content in the sludge after dewatering) as an indicator of dewatering success or failure. It has also developed dewatering machine operation guidance based on analysis of accumulated data (see **Figure 5**).

4. 2 Overview of Issues and Development Technologies for Individual Elements Comprising the Guidance System

In the dewaterability conditioning process by flocculation, the dewaterability of sludge can be estimated by means of sedimentation tests of flocs (particle masses produced by flocculation). However, because the tests are time-consuming, the quality of the sludge is determined by visually inspecting the flocs, which is dependent on the expertise of skilled workers. Therefore, Hitachi is studying the image analysis of flocs to see if it is possible to extract features that correlate well with the dewaterability of sludge from image data acquired by a camera.

Also, because it takes time to measure water content in the laboratory and obtain the results, dewatering is determined onsite based on the feel and appearance of the dewatered sludge, which is dependent on the expertise of skilled workers. Consequently, Hitachi is developing a sensor based on near-infrared spectroscopy for on-line continuous measurement of water content. In this development, Hitachi is studying how to attain measurement accuracy that enables practical use even with a relatively inexpensive spectrometer by devising a method for analyzing the spectra measured by the spectrometer.

Furthermore, Hitachi is examining the possibility of using AI to build operation guidance for dewatering machines based on the data accumulated by combining existing instrument data with the results of image analysis of flocs and water content sensor data. In particular, continuous measurement of dewaterability and water content of sludge, which until now could only be obtained at a few points per day, is expected to improve the quality and quantity of data and increase the accuracy of AI analysis.

This technology is being developed for release in FY2023 as a service business for reducing sludge.

5. Conclusions

This article presented an overview of innovative digital-based technologies that are necessary to continue to provide a safe, secure, and sustainable sewage infrastructure. Based on its extensive track record in products, systems, and services in the water infrastructure field, the Hitachi Group intends to continue contributing to the fulfillment of the mission of sewerage systems, which is to help build a society capable of sustainable development.

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Enhancement of Port Functions Utilizing Digital Technology

Ports, as the connection point of marine and land transportation, are social infrastructures that have an impact on trade and economic activities. In response to the global environmental and societal challenges that have emerged in recent years, port terminals in Japan and overseas are facing a variety of challenges, and there is a growing interest in efforts to upgrade their functions. This article presents Hitachi's efforts and concepts addressing the challenges faced by the port industry, and describes the solution technologies developed, application examples, and future prospects.

Hiromichi Teratake
Masahiro Horino
Kazuhiko Yoshii
Hiroto Naito

1. Introduction

In terms of tonnage (t), ocean freight transport accounts for about 90% of international trade volume and 99.6% of Japan's trade volume (as of 2020)(1). Greenhouse gas (GHG) emissions from international maritime transport account for about 2.9% of total global emissions(1). In response to growing environmental awareness in recent years, the International Maritime Organization (IMO) adopted a GHG reduction strategy in 2018 that aims to reduce total GHG emissions from international shipping by more than 50% by 2050 (compared to 2008 levels). At port terminals that accept marine cargo transport, Hitachi is working to improve the infrastructure for accepting hydrogen, fuel ammonia, and other substances, to decarbonize industries located at ports, and to enhance port functions for attaining decarbonization as a part of an effort to form a carbon neutral port (CNP) that will reduce overall GHG emissions to zero(2).

This article describes the efforts to upgrade port functions that are contributing to CNP formation and operations through port operations efficiency.

2. Efforts to Enhance Port Functions

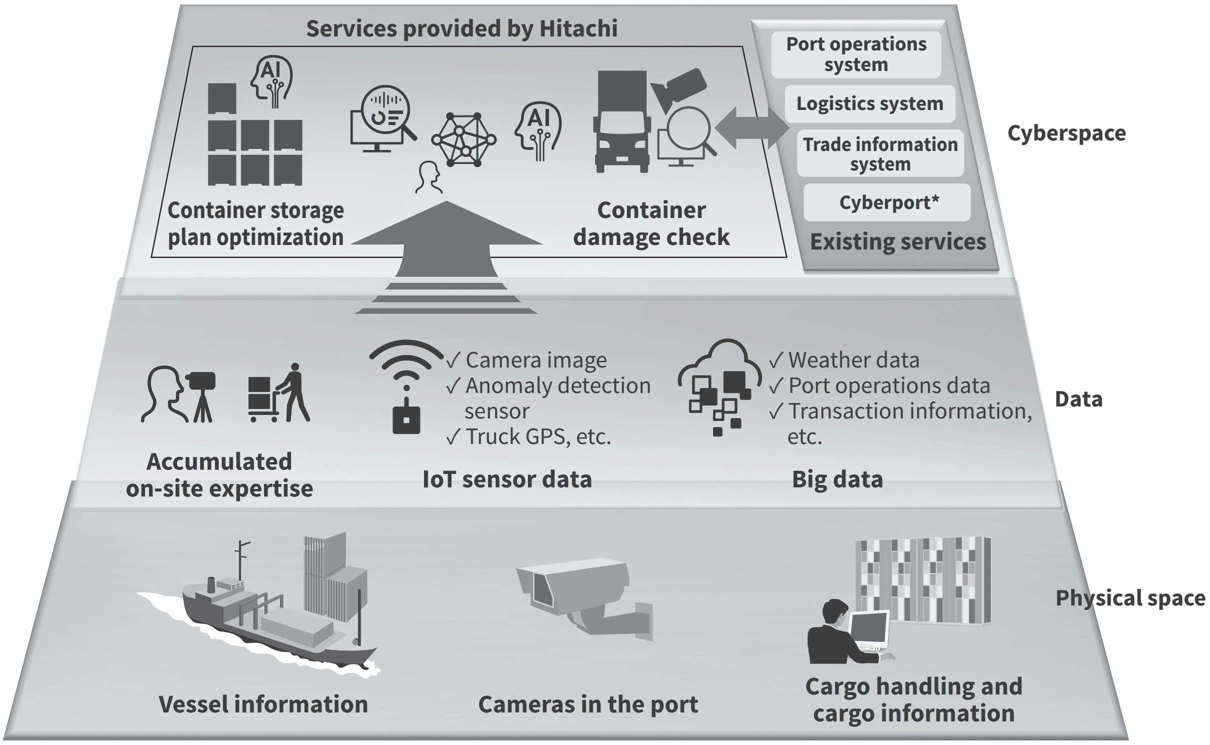
Port terminals are faced with the challenges of minimizing cargo handling time, minimizing turn time, an indicator of operational efficiency, improving the utilization rate of cargo handling machinery, and implementing energy saving measures that contribute to CNP.

Hitachi is implementing Lumada, which is a general term for solutions, services, and technologies that leverage Hitachi's advanced digital technologies to create value from customer data and accelerate digital innovation(3). In the field of port operations, Hitachi is aiming to realize digital transformation (DX) that supports on-site operations and workers by utilizing digital technology with a variety of real-world information acquired through cameras and other sensors (see **Figure 1**). Hitachi has defined current and future tasks, and is developing a container storage planning optimization solution and a container damage check solution (CDCS), both of which are expected to be highly effective through DX (see **Figure 2**).

In the storage of cargo containers, the number of container tiers tends to be high at Japanese ports due to the

Figure 1 — Hitachi's DX Vision for Ports

Various data obtained from physical space are digitally processed in cyberspace and fed back to the site to enhance port operations and provide new value to operators.



DX: digital transformation AI: artificial intelligence IoT: Internet of Things GPS: global positioning system

*A platform for linking port-related data to improve overall port logistics productivity by streamlining operations through the computerization of port logistics procedures among private operators.

limited land area. Usually, containers that are ready to be unloaded earlier are placed on the higher tiers, and those that are expected to take longer to be unloaded are placed on the lower tiers. Consideration is needed to reduce the number of times containers need to be transshipped (i.e., the number of times they need to be rehandled). Currently, such placement plans are prepared based on the formalized knowledge and the experience of skilled workers. Going forward, in order to cope with increasingly complex supply chains, artificial intelligence (AI) is expected to flexibly adapt to ever-changing cargo information and reduce the burden on workers by supporting their planning work.

When checking for damage to containers, if a marine container shows scratches, dents, corrosion, or other damage, it is necessary to suspect damage to the loaded cargo during the transportation process. At port terminals, checking the damage status of containers and communicating it at the handover stage is an essential management responsibility among the involved parties. Generally, for container terminals, during loading/unloading of the ship and loading/unloading at the gate, the external appearance of loaded containers is inspected, and the inside of empty containers is checked for stains and water leakage. Since inspection is an important task, efficiency must be improved while ensuring a safe and secure working environment. Hitachi believes that it is essential to accumulate data through a remote inspection system as a preliminary step and develop the system step by step, aiming for inspection support in the future by using AI and other technologies to automatically alert the operator of suspected damage locations.

2. 1 Container Storage Optimization Solution

To cope with complex port operations, Hitachi has developed an AI model for planning warehousing by combining multiple AI models and mathematical optimization techniques (see **Figure 3**). Using big data such as container attribute information, the AI model has functions that use machine learning for predicting after how many days import containers will be unloaded and for planning the optimal container placement based on the results of the container unloading prediction date. The system is expected to improve operational efficiency by enabling operators to refer to information such as warehousing plans based on container unloading prediction results or work instructions for cargo handling equipment based on objectives such as reducing environmental impact.

In the verification, a learning model based on container information held by the terminal operation system (TOS), which is a port operation system, will be built and evaluated.

Figure 2 — Overview of Solutions

Hitachi is working to organize its customers' operations and upgrade container damage check operations and container placement planning operations, where DX is expected to be very effective.

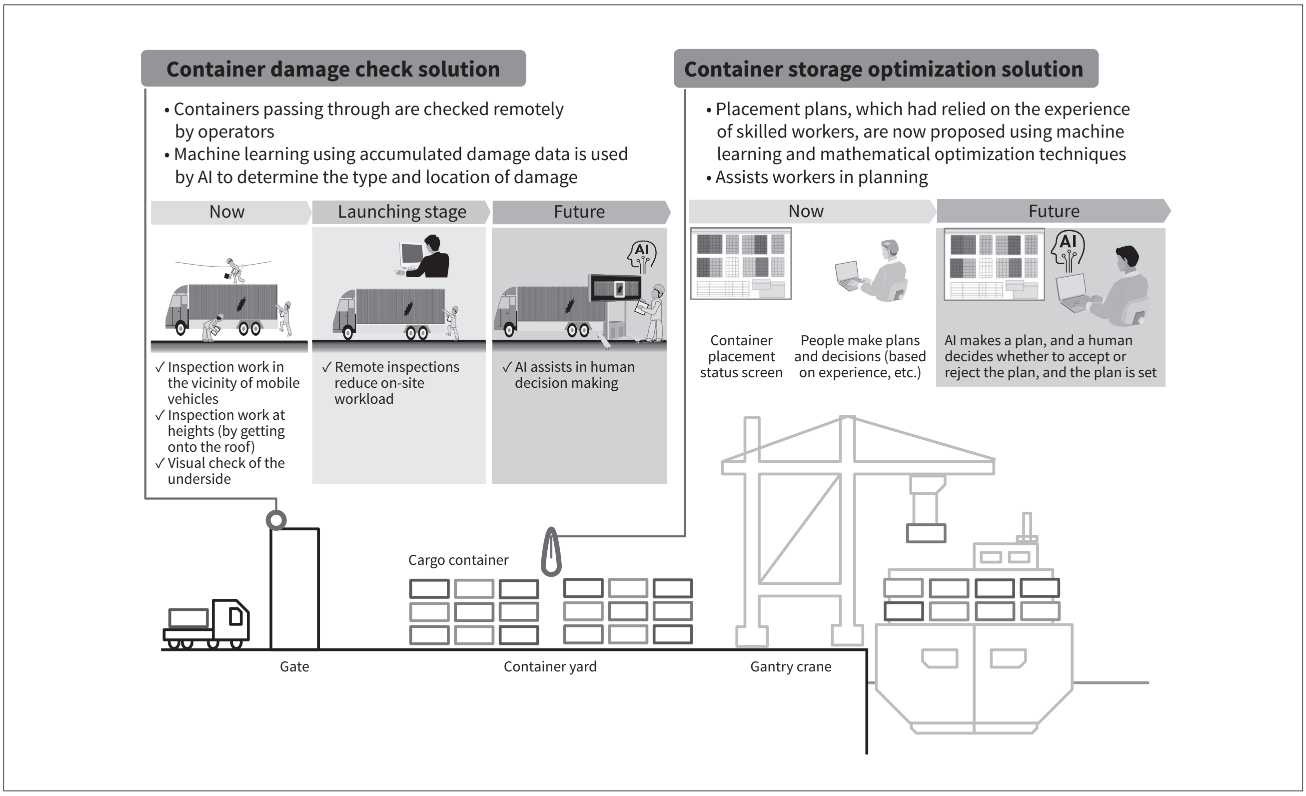
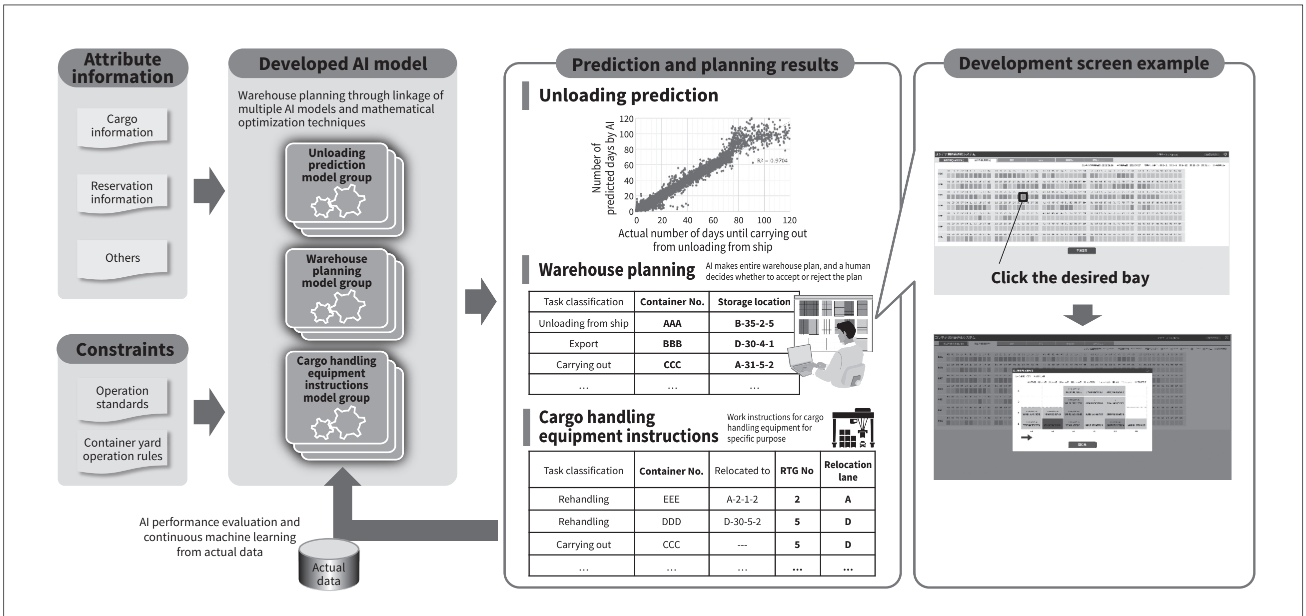


Figure 3 — Container Storage Optimization Solution Diagram

A plan is prepared based on operational constraints from various operation information obtained at the container terminal, and the results are displayed by a Web GUI.

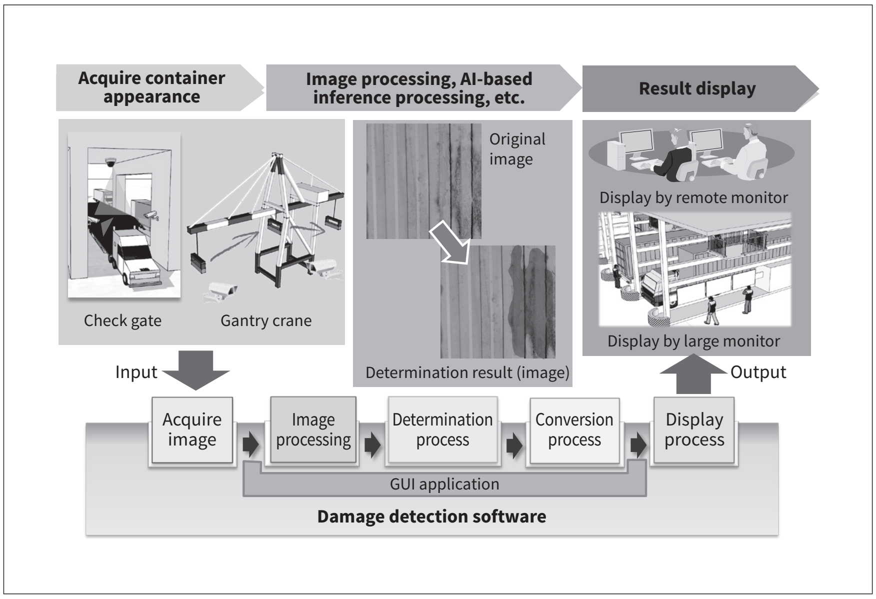


GUI: graphical user interface RTG: rubber-tired gantry crane

One indicator for optimizing storage locations is to evaluate the rate of decrease in the number of times containers are stored by comparing the actual container locations based on historical data and the container locations indicated by the trained AI. Currently, off-line verification using data from multiple port terminals has shown that the number of times containers are rehandled can be reduced by about 10–15%. Since the results obtained at present are based on constraints and assumptions, Hitachi plans to conduct a review of the various conditions and the evaluation system.

Figure 4 — Container Damage Check Solution Diagram

GUI applications are converted into libraries for each process to meet the diverse needs of customers.



Going forward, Hitachi believes that it will be useful to develop an operations planning support application in which AI suggests to the planner the planning methods used by skilled workers.

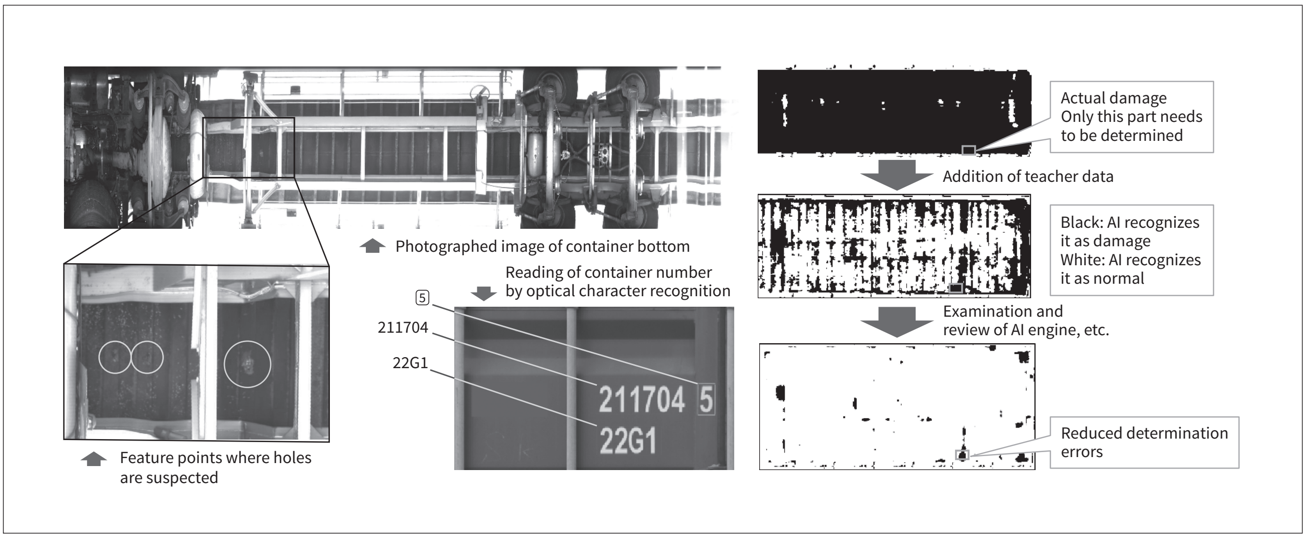
2. 2 Container Damage Check Solution (CDCS)

A schematic diagram of the CDCS is shown in **Figure 4**. Since damage checks are mainly conducted at check gates and during cargo handling operations on the wharf side, Hitachi is developing a system that detects damage locations based on video acquired at each location and that displays the results on a remote monitor or on a monitor at the work site. The damage detection software includes image processing of captured video and image data, determination processing to judge the presence or absence of damage through machine learning, conversion processing to superimpose the results on the image, and display processing to enable the results to be checked by humans. The installation status, setting conditions, and methods differ among service providers. Customized libraries are applied to meet the specific needs of each customer.

Figure 5 shows an example of the results of the study on photographing the bottom of containers in the underside inspection solution, reading container numbers using optical character recognition technology, and study results of damage assessment using AI. Hitachi plans to work toward the practical application and implementation of these technologies in the future.

Figure 5 — Example of Evaluation Results

This shows an example of photographing the bottom of a container (left), result of reading a container number using optical character recognition (middle), and determination of damage using AI (right).



3. Conclusions

This article presented examples of the use of digitalization technologies that utilize operations data and AI as part of efforts to enhance port functions. Hitachi will continue to contribute to resolving societal challenges through more advanced data-based control technology (operational technology) and the development of technologies to implement DX. Through these efforts, Hitachi hopes to contribute to society and people involved in port work through social innovations that will shape the future of the port industry.

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Development of Platform for Sustainability Transformation

Carbon neutrality has already been incorporated into the economy and management, but economic activities are now being called upon to go beyond just decarbonization and to implement efficient water resource use and resource circulation. The transition to this type of sustainable society cannot be achieved by a single company, but requires the cooperation and collaboration of stakeholders across industries, including technology, operation, certification, and financial support. This is what led the Hitachi Group to devise and begin the implementation of a platform that connects these stakeholders based on trust. This platform consists of three layers: a vision layer for ecosystem and rule formation, a digital layer for information and value distribution, and a physical layer for solutions in the real world. This article describes the details of the concept and, in particular, the theory and implementation of applications in the digital layer.

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1. Introduction

Decarbonization efforts have already been incorporated into the economy and management, with the Japanese government declaring a goal of reaching carbon neutrality by 2050[1]. Furthermore, there is a rapidly accelerating movement, particularly in Europe, to require economic activities to make the transformation to a sustainable society (sustainability transformation, SX), including efficient water resource use, biodiversity, resource circulation, and human rights issues. To comprehensively capture the impact of economic activities from multiple perspectives, Hitachi has developed a method for quantifying economic, social, and environmental value. This is a tool that can be applied to the evaluation and decision-making of economic activities and policies at the project, company, organization, regional, and national levels, and it uses a single numerical value to compare not only decarbonization, but also various other values.

However, SX cannot be achieved only by indexing individual economic activities. A value network must be built that enables multiple stakeholders to cooperate and implement reforms in economic activities based on indices. In other words, a platform must be established for the optimal flow of products, information, and funds through the interconnection of economic activities that contribute to SX.

When doing so, the distribution of trust in terms of whether or not the product and services contribute to SX becomes important. At the 2019 World Economic Forum Annual Meeting in Davos, former Prime Minister Abe proposed that data free flow with trust (DFFT) is the most important issue for new economic activities. In response to this, a trust governance framework was proposed in the white paper that was published on building trust[2]. The ideas described in this article are based on this trust governance framework.

2. Platform for Sustainability Transformation

2. 1 Targets and Structure

Consumers, national governments, local governments, media, and non-governmental organizations/non-profit organizations (NGOs/NPOs) are also important stakeholders in achieving SX, but first, Hitachi will focus on the four stakeholders that are indispensable for SX [see **Figure 1** (a)]. Solution providers offer products and solutions, and operating companies execute their operations using these products and solutions. The stakeholders who evaluate and certify the SX contribution of these products, solutions, and business operations are certification bodies, and based on these certifications, financial institutions provide funds to appropriate businesses.

For solution providers, a certification that their products and solutions contribute to SX will have the advantage of increasing the value of their products and appealing to SX-oriented customers and operating companies. For operating companies, it allows them to appeal to consumers and other end customers and to obtain SX-specific financing. Also, certification bodies can expand the scope of certification and automate part of the certification process. Financial institutions will benefit from the availability of loans that are in line with stewardship codes and other regulations. This initiative is thus an infrastructure for distributing trust information, such as contributions to SX, as well as a marketplace where the four stakeholders can conduct business transactions.

This concept consists of three layers of activities [see **Figure 1** (b)]. The physical layer consists of real-world solutions and business operations, including hardware such as equipment, for which various specific use cases are being implemented. The digital layer consists of three more layers. The cyber-physical layer captures the real world in the information space through sensors and other devices, the value layer converts digital data into value, and the trust layer ensures the transparency and confidentiality of data. The vision layer is a place for building a community of people who share the same values, specifically an ecosystem of consortiums, standardization, rule formation, and legal regulations. To realize SX, it is not enough to have IT, operational technology (OT), and products in the physical and digital layers. Governance from the vision layer is important. This concept is a service for enabling trust that is secured by certification, in other words, certification as a service.

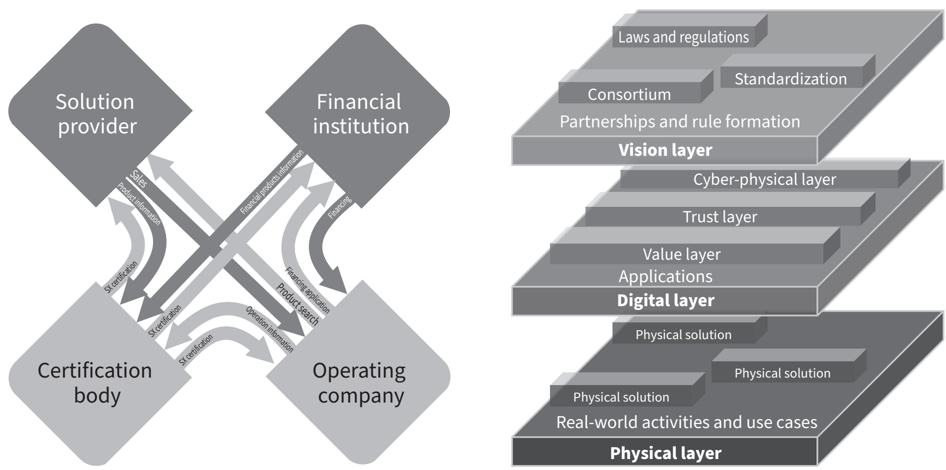
2. 2 Framework for Trust

Even if each stakeholder contributes to SX through economic activities, especially if they are directly related to profits, it is still possible that their actions may be regarded as greenwashing* on social media and may cause a firestorm of criticism. This is a trust issue, and it is necessary to correctly communicate and disseminate the fact that they are contributing to SX.

* The process of giving the appearance of being environmentally friendly, when in fact the company is not, and thereby misleading environmentally conscious consumers.

Figure 1 — Target Stakeholders and Three-layer Structure

(a) Information on solution providers, operating companies, and financial institutions, which are the target of this concept, is securely communicated to the certification body, which will certify their contribution to SX. (b) This concept consists of three layers: vision, digital, and physical.

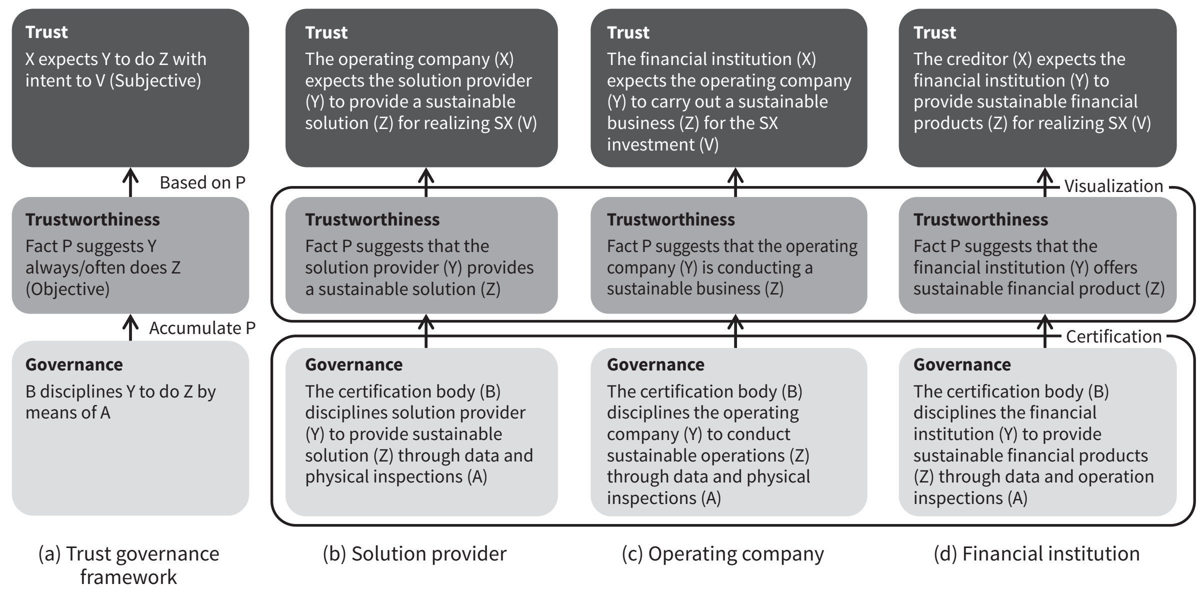


(a) Stakeholders (b) Three-layer structure

SX: sustainability transformation

Figure 2 — Trust Governance Framework

This shows (a) trust governance framework from the World Economic Forum (WEF) White Paper[2] and trust structure examples of its application to this concept: (b) solution providers, (c) operating companies, and (d) financial institutions.



This concept uses the trust governance framework proposed in a white paper jointly issued by the World Economic Forum, the Ministry of Economy, Trade and Industry, and Hitachi, Ltd.[2]. Trust is subjective and is based on objective facts (trustworthiness) [see **Figure 2**(a)], and governance allows these facts to accumulate.

The trust structure of each stakeholder is shown in **Figure 2** (b), (c), and (d) to illustrate how this is applied to this concept. In order for people to trust that a company is contributing to SX (top row of **Figure 2**), facts must be accumulated (middle row of **Figure 2**). Here, visualization is an important function to communicate the accumulated facts to other stakeholders. Furthermore, the objectivity and credibility of the facts are ensured through data verification and on-site and physical inspections by certification bodies (bottom row of **Figure 2**).

3. SX Certification Applications for Economic Activities

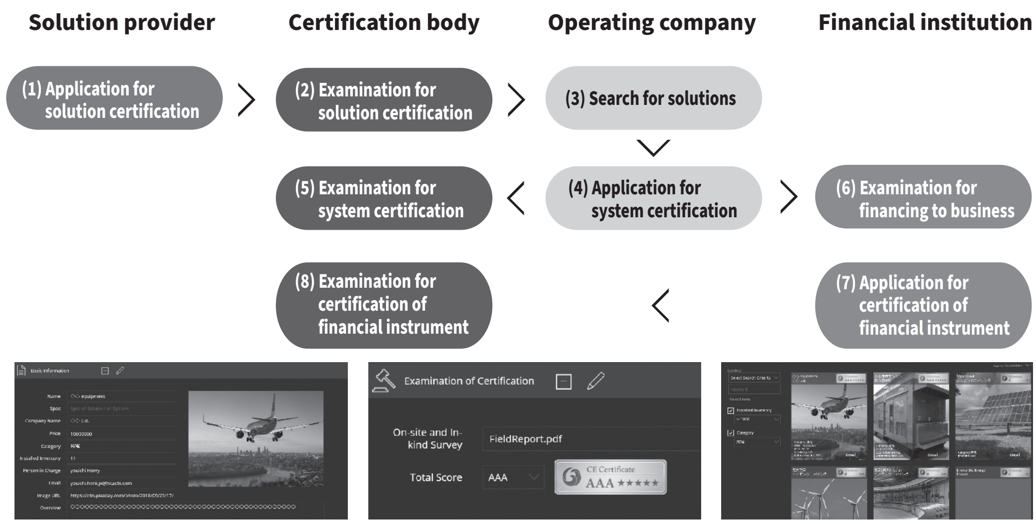
3. 1 Application Overview

This section describes the applications developed based on the concepts described in the previous section. As shown in the top portion of **Figure 3**, applications (1) through (8) were developed for four stakeholders. Application (3) is a marketplace that connects solution providers and operating companies, and the other seven applications are for distributing trust.

First, a solution provider enters information on its products and solutions, effectiveness indices, and other information related to their contribution to SX, and submit an application to the certification body [(1)]. In response, the certification body recalculates the indices and conducts on-site and physical inspections based on the information provided by the solution provider and examines whether each item contributes to SX [(2)]. An operating company searches for information on certified products and solutions and adopts them [(3)]. After adopting the product or solution, the operating company enters information on the contribution to SX, and applies for both, certification of the contribution to SX for the entire business, and for financing [(4)]. Based on the information provided by the operating company, the certification body recalculates the indices, conducts on-site and physical inspections, and examines the contribution of each item to SX [(5)]. Also, the financial institution examines the business plan of the operating company and determines the most appropriate financial product and whether or not to provide financing by referring to the results of the examination by the certification body [(6)]. At this stage, the financial institution also applies for certification of the financial product that it offers [(7)], and the certification body examines and certifies it [(8)]. For each application, a digital product passport (DPP) is issued to certify that the solution or product contributes to SX. Standardization of DPPs is currently being promoted by the International Organization for Standardization (ISO, ISO 59040), the International Electrotechnical Commission (IEC, IEC

Figure 3 — Applications of the Concept

The following are examples of applications (top row) and screen displays (bottom row) on the digital layer of this concept. From left to right, the screen display examples are: application for certification [(1), (4), (6), (7)], examination for certification [(2), (5), (8)], and solution search [(3)].



82474), and the International Telecommunication Union-Telecommunication Standardization Sector (ITU-T).

3. 2 Visualization of Resource Circularity

In addition, two representation methods were implemented to visualize resource circularity. One is the Sankey diagram, which shows the flow of resources procured and shipped by an operating company, broken down by resource. This diagram shows what kind of resources an operating company procures and ships and is used by certification bodies and financial institutions for examinations. In the example in **Figure 4** (a), the left side is the input (procurement) resources, the upper half is the circular inflow of reused

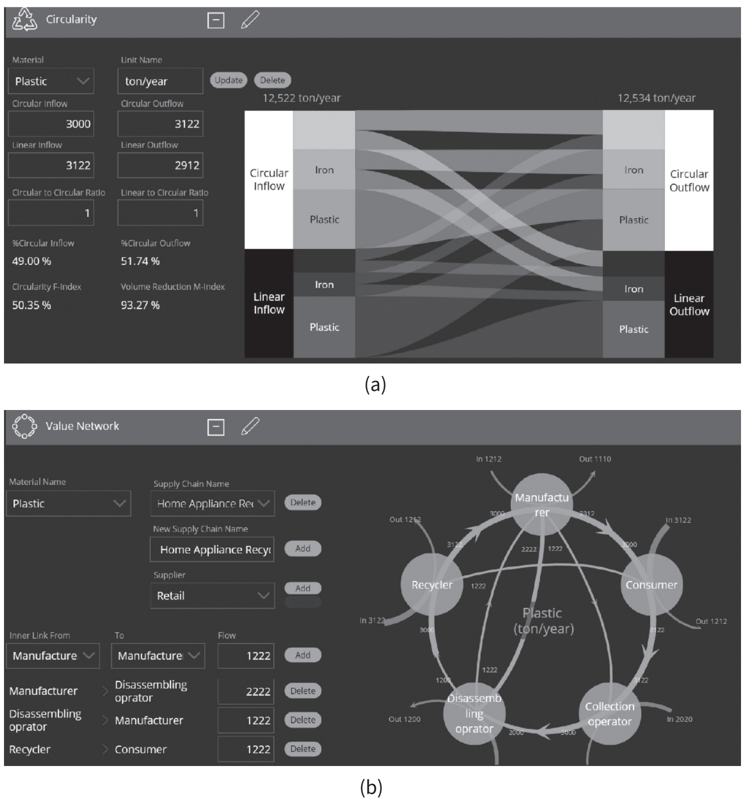


Figure 4 — Visualization Example of Resource Recycling

These show a (a) Sankey diagram indicating the flow of resources procured and shipped by an operating company by resource type, and (b) an example of visualization of the flow of resources for the entire supply chain.

resources, and the lower half is the linear inflow, such as virgin material. The right side shows the resources to be output (shipped), with the upper half showing the circular outflow of reusable resources, and the lower half showing the linear outflow of non-reusable resources such as landfill or incineration.

The above is the input/output flow of a single operating company, but a new visualization method showing the flow of the entire supply chain (value network) is shown in **Figure 4** (b). The circular ring and the flow inside the circle are the circular in-flow and circular out-flow for each resource, and the flows entering and leaving the circle from outside the circle are the linear in-flow and linear out-flow, respectively. This allows certification bodies and financial institutions to examine not only individual operating companies, but also the resource circulation of the entire supply chain.

4. Conclusions

To investigate the acceptability of this concept, interviews were conducted with stakeholders from about 30 companies. As a result, while solution providers and operating companies have high expectations for the marketplace to provide and adopt sustainable solutions, solution providers have shown a sense of caution about leaking technical information about their products and services to competitors. Therefore, it is important to implement security technologies, such as blockchain, to prevent information leakage to parties other than certification bodies that examine and certify sustainability. Also, there was a high expectation that solution providers' products and services and businesses operated by the operating company can be objectively certified as sustainable by a third party. The certification bodies came to understand that the function of ensuring data trust for issuing certifications is effective. Financial institutions have conducted sustainability audits from various perspectives in the past, but they have been extremely time-consuming and labor intensive, and there are high expectations for a reduction in labor and an increase in the number of financing sources.

Going forward, Hitachi will implement the three layers, vision, digital, and physical, in various industries, including the efficient use of water resources, in order to achieve the objective of this activity, which is to realize a platform that establishes a mechanism to convert sustainable proof into value and distribute it in order to realize a circular economy and society for the next generation, and enables the providing of sustainable products and services through collaboration among various stakeholders.

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FEATURED ARTICLES

Solutions for Resilient Management in Industry

Acknowledging the global growth of environmental awareness, an increasing number of industrial companies are prioritizing carbon neutrality and resource recycling, creating widespread demand for solutions to environmental challenges. As part of this movement, Hitachi is responding to the needs of its corporate customers with digital solutions that make the systems that support society more efficient and help to build resilient supply chains. This section describes Hitachi's recent activities in the industrial sector, including solutions for decarbonization and cyber-physical systems for overcoming environmental challenges.

Overview

Hitachi Solutions for Environmental Challenges Facing Industrial Sector

Takahiko Fujiwara
Takahiro Tachi

1. Introduction

With its mission of "Contributing to society through the development of superior, original technology and products," Hitachi supplies a variety of technologies and solutions for industry as it plays its part in addressing the environmental problems that are among the critical challenges facing society.

For example, Hitachi's digital solutions equipped with the latest technology are helping reduce carbon dioxide (CO_2) emissions by improving the efficiency of the systems that support society. Hitachi is also helping to decarbonize industry by putting these digital solutions to use in building resilient supply chains.

Meanwhile, Hitachi is addressing such global problems as the increasing rate of resource extraction, use, and disposal. This involves working with customers and wider society to create a water- and resource-recycling society, including through the creation of value chains that achieve circularity in resource use.

This article describes digital solutions for industry that help to reduce the load on the environment as well as Hitachi's technologies and the role it is playing in the creation of a circular economy.

2. Hitachi Digital Solutions for Industry that Help Reduce the Environmental Load

The operating environment and values of companies in the industrial sector are changing significantly against a backdrop of increasing uncertainty in people's lives, including a rising awareness globally of the environment, societal changes resulting from COVID-19, and heightened geopolitical risk. To help companies overcome these complex and wide-ranging management challenges, the Industrial Digital Business Unit at Hitachi operates on the basis of improving customer value through the supply of total seamless solutions that draw on its combined strengths in IT, operational technology (OT), and products. It contributes to social innovation by serving as a full-service provider of robotics system integration (SI) and digital solutions that integrate IT and OT.

Taking a broad view of industry and how it can reduce the load on the environment, what is important is to work toward carbon neutrality across the entire supply chain from start to finish rather than leaving it to the individual companies involved to reduce their own CO_2 emissions.

By utilizing a variety of solutions powered by digital technology to improve the efficiency of customer business processes, Hitachi's Industrial Digital Business Unit is helping to reduce the load that industry imposes on the environment by shortening both the time and distance for those business processes that are environmentally damaging.

One example of how Hitachi helps reduce the load on the environment in manufacturing is through the supply of solutions that support the scheduling and execution of production and sales in response to fluctuating demand. These solutions make production, distribution, and other operations more efficient, and optimize inventory.

In product distribution, the environment also benefits from reduced food losses and the avoidance of overstocking through automatic ordering that uses artificial intelligence (AI) to predict demand. This optimizes inventory and ensures that ordering matches requirements.

In the healthcare and pharmaceutical sectors, Hitachi is helping the environment through rigorous quality management (traceability) and by optimizing the entire value chain for products associated with regenerative medicine using a platform for the comprehensive and centralized management of cell handling and trace information.

The digital technologies used to achieve this optimization take the form of Hitachi cyber-physical systems (CPSs). The optimization of real-world operations is achieved by collecting and modeling the large quantities of information in diverse forms derived from business processes in physical space, conducting analyses and simulations in cyberspace to find optimal solutions that are then used as feedback to physical space (see **Figure 1**).

Past practice for optimization like this has focused on particular business processes within a company, with improvements being made across the vertical axis from the workplace up to management. What is called for now, in contrast, is improvements such as CO_2 reduction and greater flexibility that span entire supply chains encompassing multiple companies. However, the problems to be solved are becoming more complex and challenging as the scope of optimization expands, the variety and quantity of data to be collected and analyzed grows, and the number of companies involved increases. Another factor that makes the optimization of entire supply chains difficult is the existence of discontinuities between business processes, departments, and companies, what in Japanese are called "*kiwa*" (gaps). Hitachi achieves system-wide optimization by using CPSs to span these gaps and solve complex and difficult problems.

While market uncertainties are growing and the issues to be resolved are becoming more complex and multifaceted, Hitachi's Industrial Digital Business Unit intends to combine reduced environmental impact with greater economic value while also supporting business process improvement by customers. Key to achieving this is connectivity across the solutions and products used to present and analyze information from the production workplace across the entire value chain.

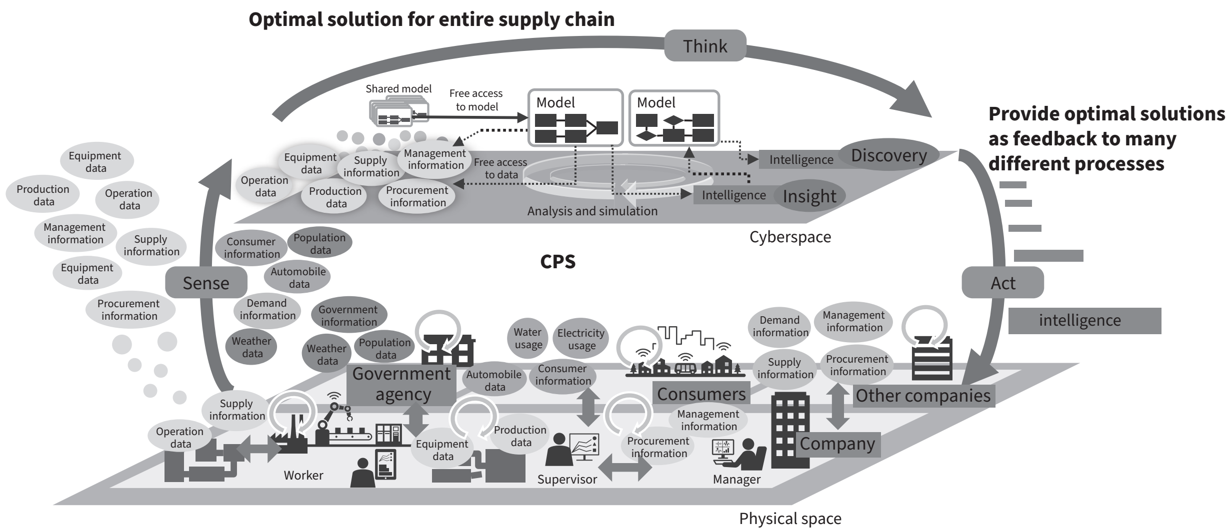
3. Hitachi Technologies for Industry and its Role in Achieving a Circular Economy

The circumstances surrounding resources have changed significantly in recent years. The difficulty of procuring necessary resources has emerged as a critical issue for many industries. The factors behind this include the rise in resource consumption due to global economic development and population growth, along with commodity price inflation driven by heightened geopolitical risk.

Likewise with used products, resource recovery has become a global issue. One example is the pollution of the ocean by discarded plastic waste and its impact on marine life.

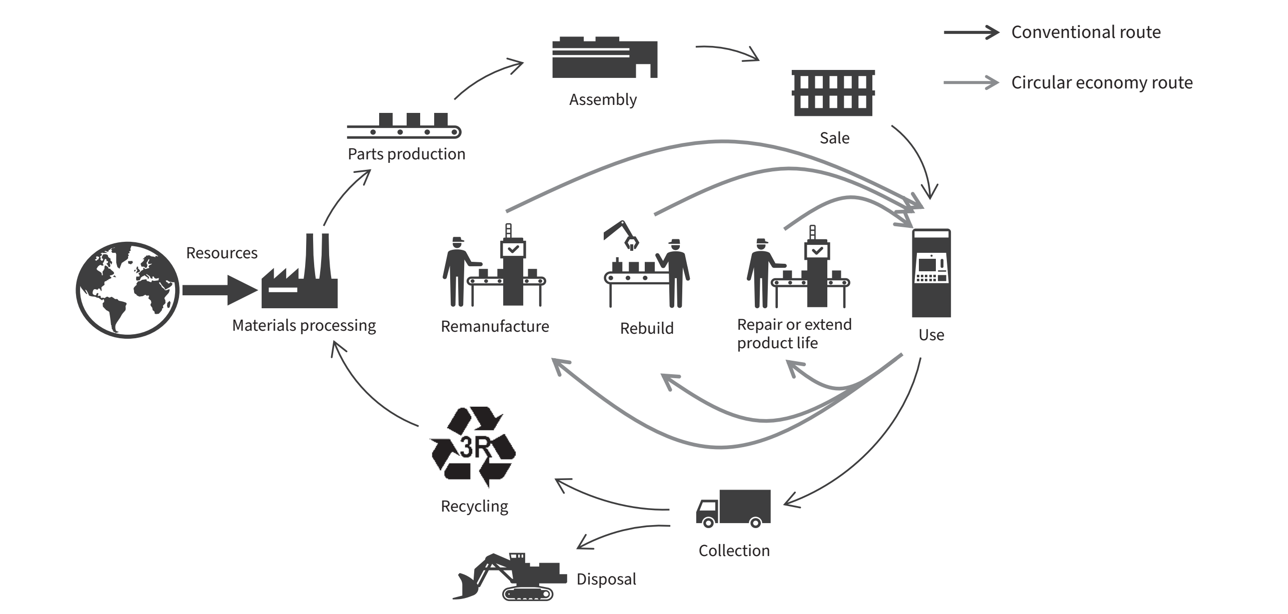
Figure 1 — Use of CPSs for Optimization

Hitachi is building new businesses and ecosystems by delivering reliability and flexibility in ways that can be utilized by the wide range of businesses that make up the supply chain, and also through its real-time capabilities for the analysis in cyberspace of large quantities of operational data collected in diverse forms and its use to obtain optimal solutions for feedback to operations.



CPS: cyber-physical system

Figure 2 — Circular Economy
The diagram shows other ways in which resource circularity can be achieved in addition to conventional recycling routes.



The establishment of supply chains that extend from acquiring raw materials to the production of end products is one of the increasingly critical tasks shared by a variety of different industries and the logistics sector, as is the creation of a resource-recycling society that provides for products to be turned back into usable resources after use.

To help with this task of creating a resource-recycling society, Hitachi is working to make greater use of recycled materials in "resource arteries" (for the manufacture and sale of products) as well as achieving longer product life and reduced resource use. Likewise with "resource veins" (for the recovery and recycling of materials), Hitachi is promoting practices such as product reuse and remanufacturing.

For the recycling of home appliances, Hitachi developed a means of recovering chlorofluorocarbon gas from refrigerator insulation and patented the basic process. It also established home appliance recycling businesses in Japan's Tochigi Prefecture and in Hokkaido and Tokyo in 1999.

These businesses obtain useful materials from automated teller machines (ATMs) and other IT equipment as well as from home appliances, recovering the rare earth metals contained in air conditioners and also recycling medical devices and smartphones.

Figure 2 shows a diagram of how a circular economy works. This encompasses not only conventional recycling (turning waste into useful materials), but also other ways in which the circularity of resource use can be achieved, such as remanufacturing, rebuilding, repairing, and extending the life of products. Hitachi is engaged in ongoing work on the recycling of industrial products, including home appliances, which is inspired by the circular economy.

4. Conclusions

The challenges facing the world are becoming increasingly severe and complicated amid rising market uncertainties driven by factors such as climate change, COVID-19, and geopolitical risk.

Hitachi has been working on utilizing its latest digital solutions to help create a circular economy and reduce the impact that customers have on the environment. The company has also taken up the challenge of combining human wellbeing with the creation of sustainable societies by making full use of data and technology, working to resolve societal problems through its Social Innovation Business that leverages IT, OT, and products.

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Energy Management System that Supports Transition to Carbon Neutrality

Efforts are being made on a global scale aimed at minimizing the temperature rise due to global warming. In particular, an increasing number of countries, regions, and companies are setting targets for 2030 and 2050 as they work toward reducing greenhouse gas emissions and achieving carbon neutrality. Companies are seeking to achieve carbon neutrality by reducing their own emissions (Scope 1 and Scope 2 emissions) and making the transition to renewable energy. However, they are also being called upon to achieve carbon neutrality in terms of emissions across the entire supply chain (Scope 3), including raw materials and the use of their products, and to audit the quantity of greenhouse gases emitted in the course of supplying their products and services. This article focuses on energy management systems and describes support for efforts to achieve carbon neutrality at the company level in particular (Scope 1 and Scope 2 emissions).

Hiroshi Yunoue
Sho Kuroiwa
Tomoya Yamasaki

1. Introduction

Efforts to curb the increasing severity of climate change have been growing, including an agreement to limit global warming to 1.5°C above pre-industrial levels by 2030, adopted at the 26th United Nations (UN) Climate Change Conference of the Parties (COP26)(1) held in Glasgow, UK from October to November, 2021. At the same time, alongside the adoption by national governments of policies aimed at achieving carbon neutrality by 2050, there are also rising expectations for voluntary action by society as a whole.

In Japan, the Fifth Strategic Energy Plan(2) was approved by the Cabinet in July 2018, in advance of COP26. The Sixth Strategic Energy Plan is now being formulated and includes the objectives of reducing emissions of greenhouse gases by 46% from 2013 levels by 2030 and achieving carbon neutrality by 2050.

Meanwhile, if companies are to live up to these societal expectations, they will need to make the transition to carbon neutrality not only in their own operations, but also across their entire supply chains. This article describes energy management systems that help to overcome the challenges associated with achieving carbon neutrality within individual companies.

2. Challenges Associated with Achieving Carbon Neutrality

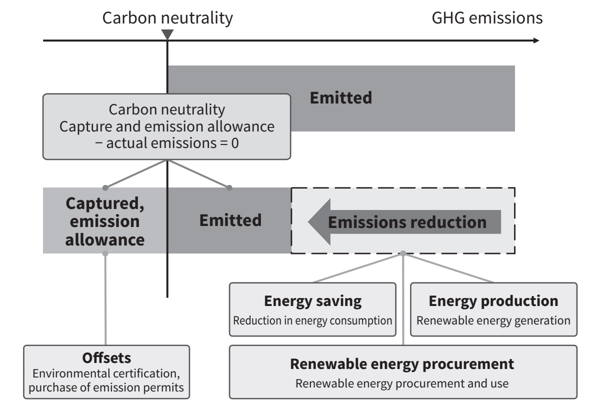
There are four different approaches that can be taken to achieving carbon neutrality. These are energy saving to reduce energy use at companies, energy production whereby companies generate their own carbon-free renewable energy, procurement of carbon-free renewable energy, and offsetting carbon emissions. Achieving carbon neutrality requires a sensible mix of these different approaches (see **Figure 1**).

Among these different approaches, energy saving is particularly important and warrants a high priority because, along with reducing the cost of implementing the other measures, it also frees up resources for doing so. At companies that have already put a lot of effort into energy saving, on the other hand, the issue that deserves prompt attention is when and how to install or purchase carbon-free energy.

Meanwhile, given the variability of renewable energy, the risk of imbalances in the supply and demand for electric

Figure 1 — Ways of Achieving Carbon Neutrality

Achieving carbon neutrality will require a sensible mix of four different approaches.



GHG: greenhouse gases

power is rising. While renewable energy will need to become a major form of grid-connected electricity generation if society is to become carbon neutral, this will make the risk of imbalances in electricity supply and demand even higher than it already is, posing a challenge for society relating to the maintenance of grid stability.

3. How Energy Management Systems Can Help

3. 1 Achieving more Intensive Energy Saving

Energy management in the past has often been no more than a tool for providing insight into what is happening or for investigating different ways of doing things, with the benefits only coming from work being put in on the ground. To achieve more intensive energy savings, however, the scope of these systems is increasingly being extended to include control, combining demand prediction and optimization techniques to also help implement such measures and reap their benefits.

3. 2 Maximizing Use of Energy Production and Optimizing Renewable Energy Procurement

There is a need to make energy management systems more sophisticated by combining the demand prediction and optimization techniques mentioned above with information such as renewable energy generation predictions and electricity market prices. As well as making full use of all renewable energy produced and avoiding curtailment, such systems can also be used to minimize the cost of purchased renewable energy.

3. 3 Providing Balancing Capacity Needed for Renewable Energy to Play a Large Role in Electricity Supply

An electricity balancing market was established in Japan in April 2021 to provide the adjustment capabilities (balancing capacity) needed for frequency control on electricity transmission and distribution networks and to balance supply and demand[3]. This provides a mechanism for the grid-level procurement and operation of balancing capacity across multiple areas and a market for buying and selling demand response capacity in order to reduce balancing costs by promoting transparency and competition based on market principles. The establishment of this market has made it easier to cope with the fluctuating output of renewable energy.

While the output of renewable energy varies depending on weather conditions, the market allows the electricity transmission and distribution system to maintain grid stability by acquiring balancing capacity from electricity users in real time. As well as giving users the opportunity to play their part in addressing societal challenges, the provision of balancing capacity also generates revenue that users can reinvest in carbon neutrality. That is, whereas they would have received no compensation in the past, the market now allows users to sell whatever balancing capacity they have available.

4. EMilia Integrated Management System for Energy and Equipment

4. 1 System Overview

One system for achieving carbon neutrality as described above is the EMilia integrated management system for energy and equipment[4] that Hitachi has been supplying since 2017 (see **Figure 2**). To date, Hitachi has installed community energy management systems (CEMSs), factory energy management systems (FEMSs), and building energy management systems (BEMSs) (see **Figure 3**).

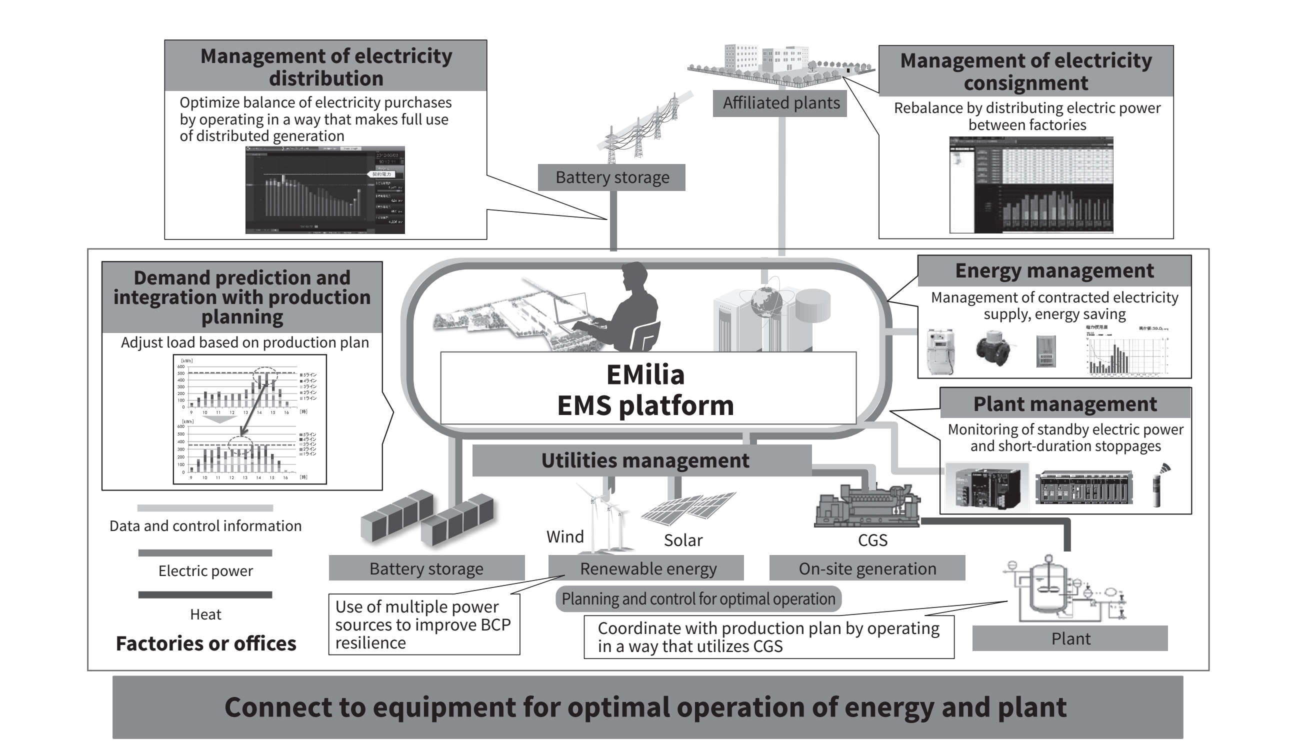
EMilia has functions that go beyond visualization, it is also equipped with functions for more intensive energy savings. In addition to demand prediction linked to the weather and production scheduling, it also incorporates an optimal operational planning function for minimizing costs and carbon dioxide (CO_2) emissions that can control the operation of utility supply equipment and provide feedback to production scheduling.

4. 2 More Intensive Energy Savings Achieved by Optimal Operational Planning and Control with Maximum Utilization of Energy Production

When it comes to achieving carbon neutrality, there will likely be a limit to how much can be accomplished by past

Figure 2 — Overview of EMilia

EMilia connects to various equipment at a site to support the optimal operation of energy and equipment.

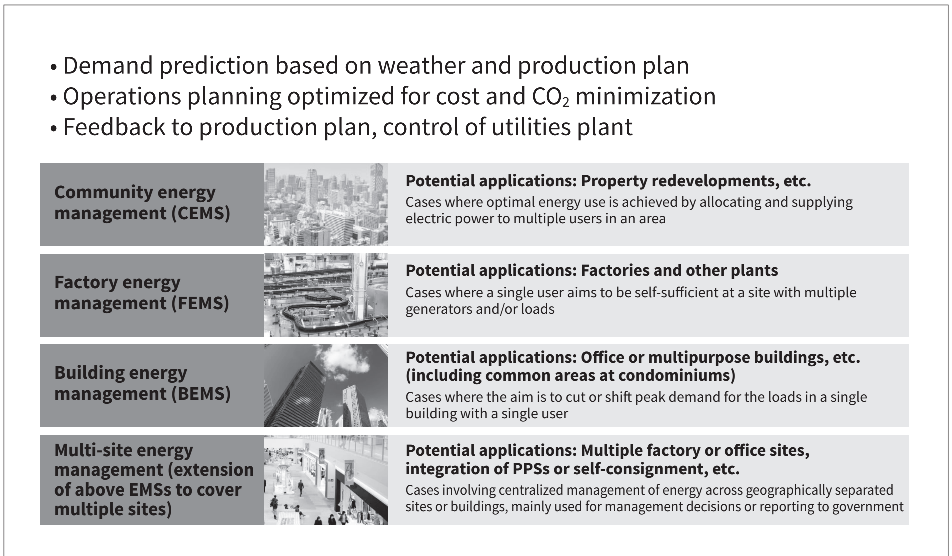


CGS: cogeneration system EMS: energy management system BCP: business continuity plan

approaches to energy management that targeted energy savings made by eliminating waste and inefficiency.

EMilia, on the other hand, can maximize benefits by delivering more intensive energy saving, cost savings, and full utilization of energy production through the seamless integration of control with optimal operational planning based on ever-changing external circumstances (including energy prices and CO_2 pricing and emission factors), energy demand, and the operational constraints and performance characteristics of utilities (see **Figure 4**).

EMilia is able to address more complex customer challenges because it combines the relevant functions in a single system in a way that best suits customer requirements. These include demand prediction for heat and power, calculation of how best to use equipment, and the scheduling and control of equipment operation.

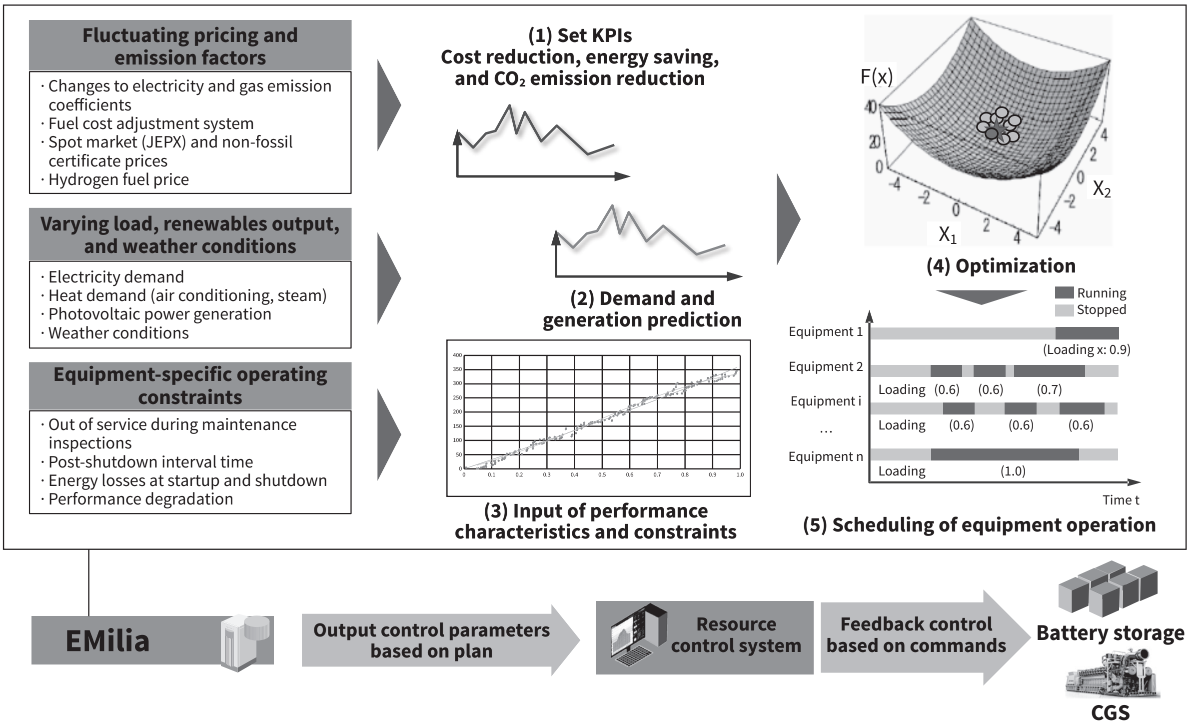


CEMS: community EMS FEMS: factory EMS BEMS: building EMS PPS: power producer and supplier

Figure 3 — EMilia Use Cases and Features

EMilia is suitable for a variety of use cases and supports the optimal operation of energy and equipment.

Figure 4 — Energy Saving by Means of Optimal Operations Planning and Control
The aim is to make energy savings by formulating an optimal operations plan and controlling equipment accordingly.



KPI: key performance indicator JEPX: Japan Electric Power Exchange

4. 3 Functions for the Balancing Market

EMilia continues to evolve. An upgrade in FY2021 added functions for the balancing market to better serve customer needs and facilitate the transition to renewable energy as a leading source of electricity generation[5] (see **Figure 5**).

Aggregation coordinators (ACs) participate in the balancing market by bundling the balancing capacity (demand response) that can be provided by the resource aggregators (RAs) they represent. They offer this capacity on the market and, once a contract is agreed, determine how much each RA will adjust their electricity demand to meet balancing requests as they come in. The RAs, for their part, determine how much balancing capacity they can offer in each time period and inform the ACs of this at the bidding stage. When a contract is in effect, the RAs control their electrical loads to provide the amount of balancing capacity requested by the ACs. The ACs and RAs earn incentives for the balancing capacity they supply but must pay penalties for any failure to deliver on their capacity commitments.

EMilia supports the OpenADR 2.0b protocol for system interoperation with ACs and provides the following functions for the balancing market.

(1) Calculation of following-day balancing capacity availability

This function uses the results of demand prediction and optimal operation planning to calculate how much balancing capacity can be provided by adjusting equipment operation.

(2) Prioritization of balancing capacity dispatch and support for determining available capacity

When providing balancing capacity, it is necessary to consider the potential for higher costs that will arise as a consequence of operating equipment in a way that deviates from the optimal. In the case of battery storage, for example, additional costs arise from the electric power that is lost during battery charging and discharging. Similarly with cogeneration systems, increasing output to provide balancing capacity will also bring higher costs because of the increased fuel consumption and in some cases may result in excess heat going to waste.

EMilia runs simulations of the various cost increases associated with providing balancing capacity and calculates the price level at which doing so becomes uneconomic, assuming that the lowest cost capacity will be used first. It also provides support for determining the available balancing capacity when bidding on the market (see top part of **Figure 6**).

(3) Control during time periods when balancing requests are received

The system issues control commands based on the above capacity dispatch prioritization.

(4) Function for managing balancing capacity

This function manages the provision of balancing capacity during time periods when balancing requests are

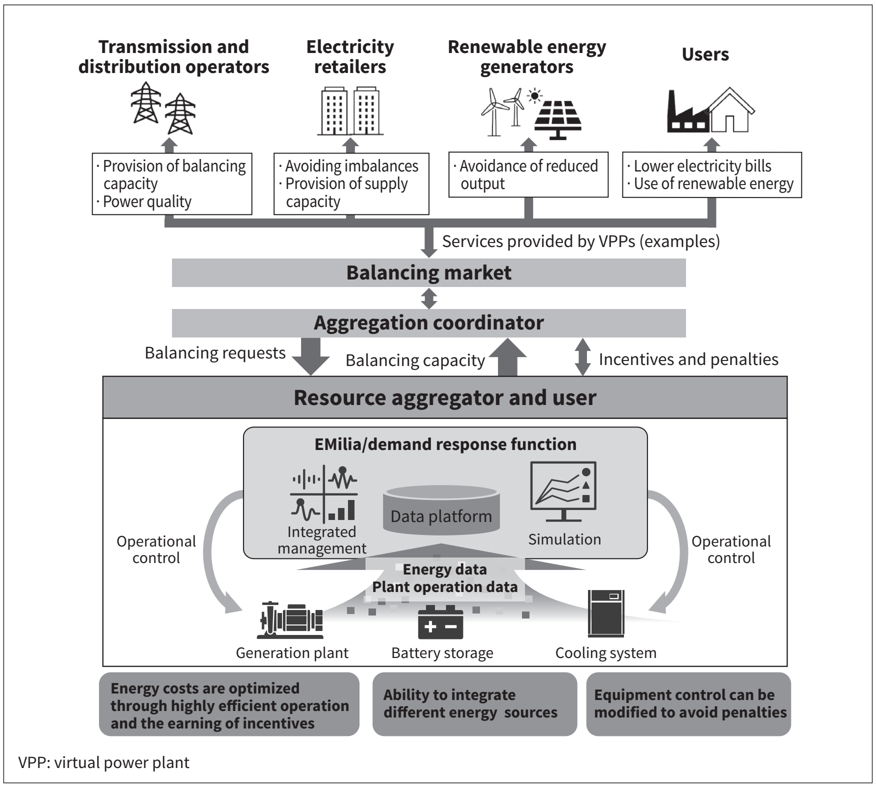
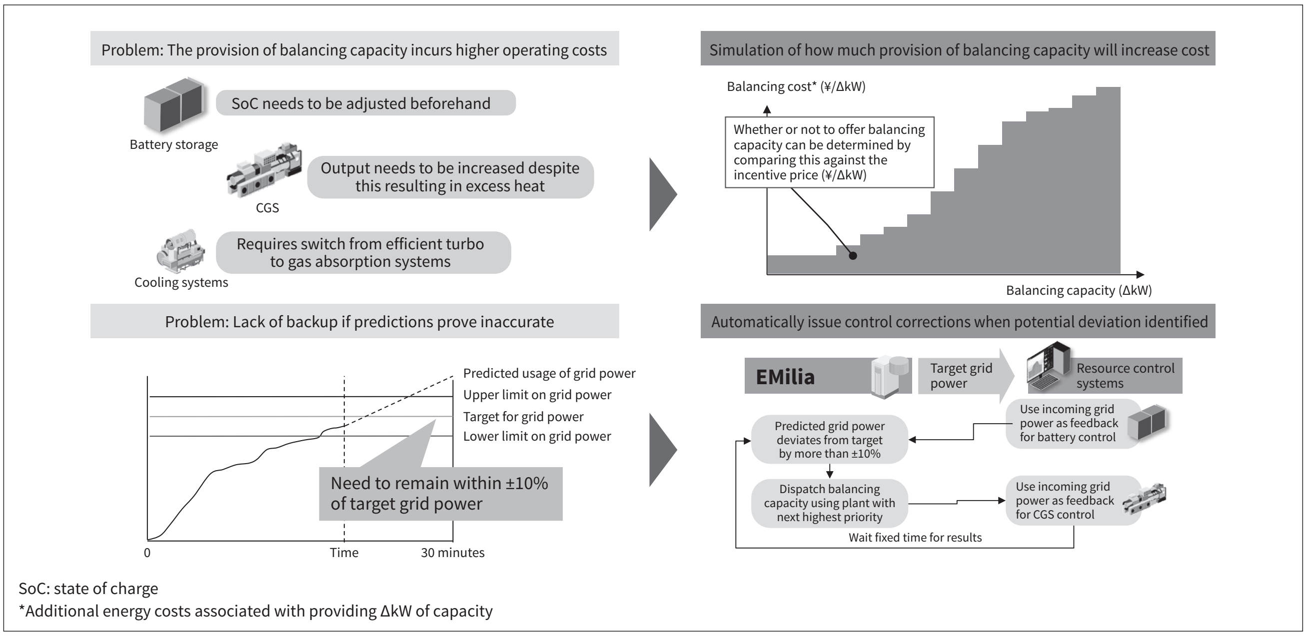


Figure 5 — EMilia Upgrades for Balancing Market

An upgrade in FY2021 added functions for the balancing market to better serve customer needs and facilitate the transition to renewable energy as a leading source of electricity generation.

Figure 6 — Functions for the Balancing Market

Functions are available for taking cost increases into account when predicting balancing capacity and also for making adjustments during operation.



received and performs control in a way that minimizes any deviations (see bottom part of **Figure 6**). This is done by outputting control corrections that are calculated to keep the predicted usage of electric power from the grid to within ±10% of the target, taking account of the requested balancing capacity. If unable to remain within this band using existing equipment, commands are issued to deploy further capacity in accordance with the predetermined priorities.

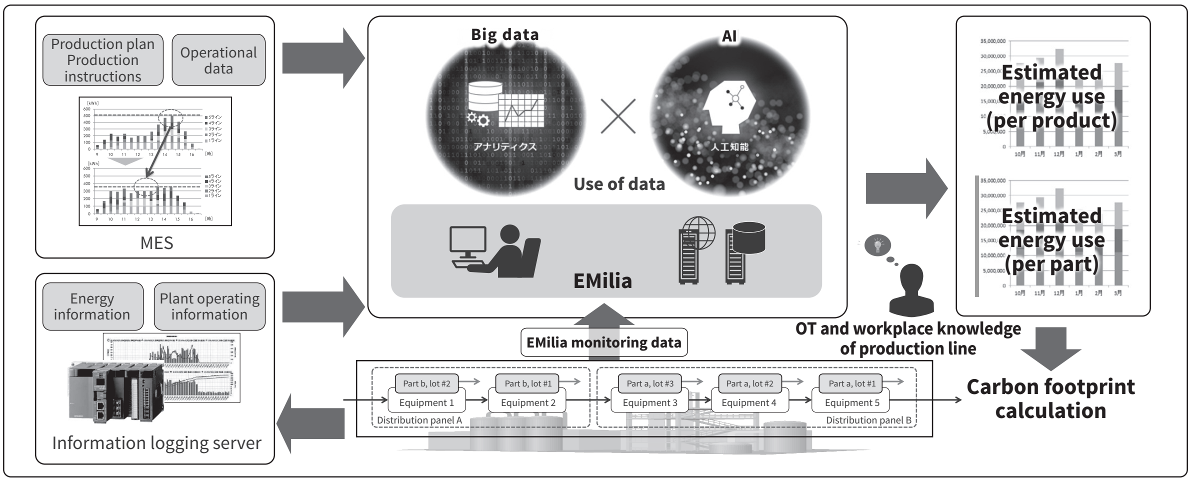
4. 4 Support for Calculating Carbon Footprints

Things like the certification of carbon-free status and the calculation of carbon footprints require that the quantity of CO_2 consumed or emitted in a production process be determined and that this quantity be linked to operational data.

To meet these customer requirements, EMilia interconnects with external systems to link the time-series data

Figure 7 — How Carbon Footprints are Calculated

EMilia supports the calculation of carbon footprints by linking operational data to data on energy use.



MES: manufacturing execution system AI: artificial intelligence OT: operational technology

it collects on energy consumption in production to the operational data held by the manufacturing execution system (MES) or other plant systems. By doing so, it is able to facilitate the calculation of carbon footprints by estimating how much energy is consumed on a per-product or per-part basis (see **Figure 7**).

There is growing demand from customers wanting to use carbon footprint information in their disclosures to stakeholders or as a way to identify potential improvements. As the need for energy management is only expected to increase in the future, it is anticipated that these systems will become an integral part of the management infrastructure at companies.

5. Conclusions

This article has described how energy management systems can help customers in their efforts to achieve carbon neutrality. Achieving carbon neutrality is an urgent task for companies and it is something that needs to be addressed as part of business continuity.

Through the supply of its various solutions, Hitachi intends to continue its support for resilient businesses and sustainable growth by meeting the challenges that arise from the changing business circumstances faced by customers.

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Collaborative Production Line Building with Online Cyber-Physical System for Resilient Manufacturing and Logistics Operations

The changing circumstances of the manufacturing and logistics industries, which include labor shortages and fluctuating demand, call for ongoing operational resilience. In response to such challenges, Hitachi's approach to production line building is based on engaging in collaborative creation with the customer from the concept stage. Hitachi has also been developing an online cyber-physical system that can reconfigure resources and adjust production plans to minimize the impact of delays or other problems that occur due to changes or variability in production conditions. This article uses examples to present the work being done by Hitachi on combining robotics systems with digital technologies.

Nobuhiro Kakeno
Daiki Kajita, Ph.D.
Nobuaki Nakasu
Shuji Okutomi
Yoshiaki Higashi

1. Introduction

The manufacturing and logistics industries are experiencing complex and complicated social challenges that include labor shortages, the retirement of skilled and experienced workers, demand for mass customization, and rapid demand fluctuations.

In such an environment, these industries need to adopt sophisticated practices that allow them to maintain ongoing operational resilience in the face of changing circumstances. This includes building production lines capable of mixed-flow production while also utilizing existing equipment to keep investment to a minimum, ensuring the ongoing reliability of equipment operation, the optimization of materials, ordering, and worker assignment, and responding promptly to unexpected changes. Achieving this calls for a combination of automated lines and operational systems that can simulate and execute optimal operating scenarios that dynamically correspond to changing circumstances, something that is difficult to achieve by relying solely on the vocational skills of skilled workers or by installing equipment that simply takes over or automate tasks that were previously done manually by workers.

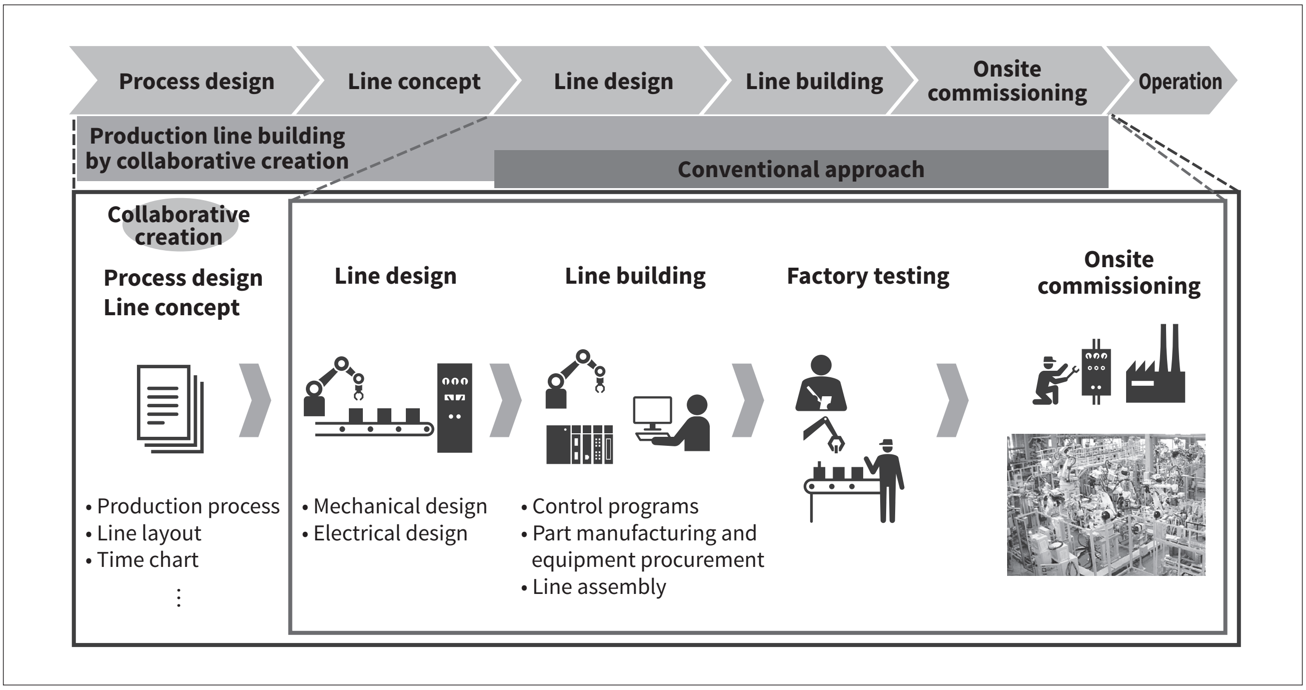
This article describes how, utilizing solutions that combine robotics system integration (SI) with digital technologies, Hitachi is supporting the building and operation of production and logistics lines that enable customers to respond flexibly to changing circumstances.

2. Production Line Building through a Collaborative Approach with Customers

Production and logistics lines and their operations are major differentiating factors affecting product quality, production volume, and cost. Manufacturers or logistics operators with

Figure 1 — Production Line Building Using Collaborative Creation

This approach seeks to build optimal production lines through communication with customers, engaging in collaborative creation with them from the process design and line concept stage.



strong engineering capabilities are capable of in-house process design, line concept, and line specifications and work with equipment vendors or line builders on the design and building of the lines.

The technical complexity of developing process designs and concepts for production lines that can dynamically respond to changing demands or enable mixed-flow production is increasing because deep expertise and know-how in how to utilize equipment and digital technology are required given cost, resources, and performance constraints.

Hitachi's approach is to collaboratively work together with customers from the earliest stages such as process design and line conceptualization to build optimal lines. For example, the use of digital engineering tools from this early stage allows Hitachi and customers to materialize line concepts into something tangible in a short period of time and also reduces the risk of rework as line performance and systems can be validated online before the actual line is built (see **Figure 1**).

Hitachi also aims to make this collaborative process more efficient and effective by using its own simulation technology to identify optimal line configurations and layouts with the desired functions and performance.

3. More Efficient Dynamic Line Operation Using Online CPS

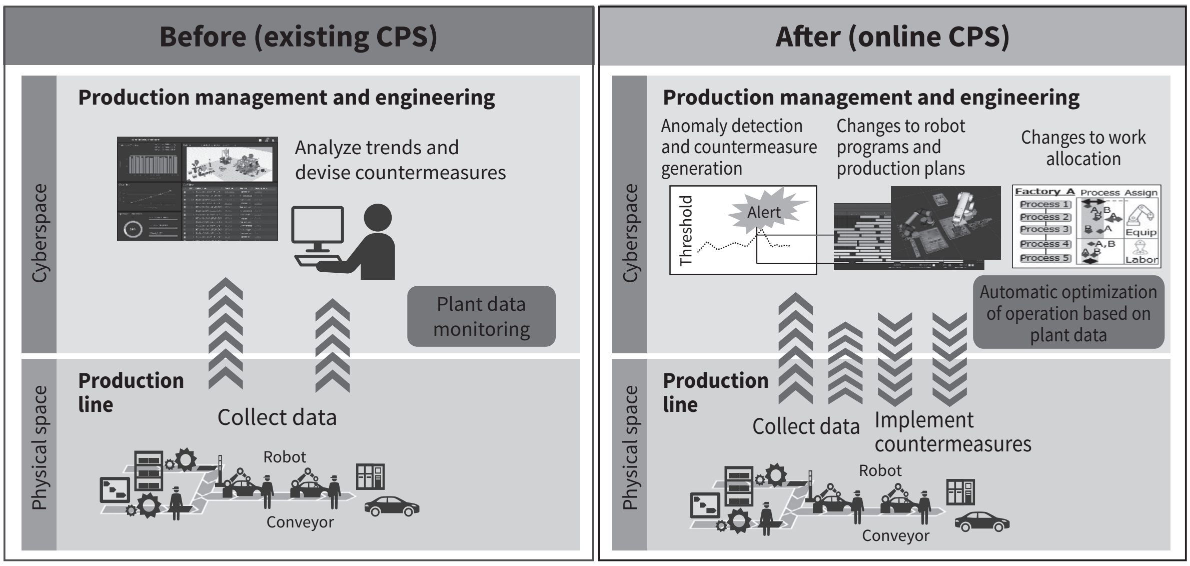
Manufacturing and logistics facilities are forever at risk of delays in production or dispatch due to issues such as plan changes, operational problems, or poor planning accuracy. The sort of plan changes that might occur include a change to the type or quantity of products to be manufactured or dispatched due to fluctuating demand, the handling of irregular requests such as expedited goods, or line delays due to parts shortages or missing inventory. Operational problems may include staff absences or rework caused by production errors as well as equipment faults, brief shutdowns, or adjustments to the line prompted by defects. Similarly, poor planning accuracy may be the result of products having to go through equipment more than once or cycle times being exceeded due to variability in how long different workers take to complete particular tasks.

To deal with delays caused by problems like these, line operation needs to be able to minimize their consequences through the reallocation of resources or by making changes to the plan.

Past practice was to rely on the skills of particular individuals. For example, it would involve the line supervisor keeping track of production progress and the operation of different items of equipment to identify when delays occur and to devise and implement a response accordingly. What is needed for business resiliency, however, is for the line to operate in a way that allows it to adapt to changes like these automatically and with a short cycle time. In response, Hitachi has developed an online cyber-physical system (CPS) that incorporates a virtual line in cyberspace, using this to collect and analyze sensing and production progress data from the equipment along with information on equipment operation. By doing so, it can reconfigure resources and issue plan changes (see **Figure 2**).

Figure 2 — Benefits of Online CPS

The online CPS provides systems for line operation that can adapt to change in a timely manner by working rapidly through the cycle of first using data collected from the physical equipment as a basis for identifying anomalies and devising countermeasures in cyberspace, and then automatically implementing the resulting work allocation and program modifications.



CPS: cyber physical system

The online CPS is a digital solution for overcoming challenges that have been difficult to address in the past. It does this by using information obtained from the line as a basis for automating and speeding up the information cycle of analyzing production data in cyberspace, identifying the optimal line configuration and operation scenario, and using this as dynamic feedback to subsequent line operation. In practice, it is made up of the three solutions described below together with functions for linking these together and filling in the "*kiwa*" (gaps) between management systems by controlling the line in a way that integrates the physical and informational realms.

(1) Data collection solution for keeping track of what is happening in the plant

This uses a model to conduct an integrated analysis of sensing data collected in a synchronized manner by time-sensitive networking (TSN) and provides the virtual sensing solution that is needed to detect delays, identify their causes, and come up with a response. The data collected by this solution can be used as a basis for making corrections to the virtual line model, keeping track of production progress, and monitoring operations for signs of potential problems such as failures or equipment faults.

(2) Simulations in cyberspace to determine optimal allocation of equipment and labor and optimal operation

When expedited items need to be handled in the gaps between volume production, schedules can be modified based on the operational circumstances in the factory or line. Also, unexpected changes can significantly reduce productivity and equipment faults can lead to lower utilization or shutdowns on production lines. In situations like these, the incorporation of line-building technology into the online CPS makes it possible to react to such changes by reassigning resources with speed and flexibility. That is, functions for automatic work assignment and the automatic writing and distribution of programs expand the available responses to include things like changing the number of steps delegated to particular robots, changing the number of robots deployed, or adjusting the division of labor between people and machines.

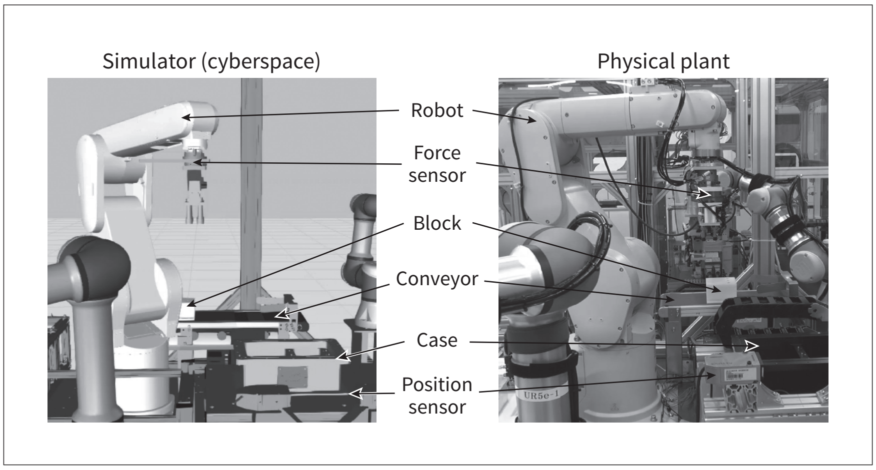
(3) Autonomous robotics solution and manual work instruction solution

When robot programs are created using the virtual production line model, some fine tuning is required on the actual line as minor differences between the virtual model and physical equipment can be a cause of operational problems. Also, frequent brief delays can occur due to minor variations between parts or in equipment operation. To address such problems, Hitachi supplies ways of avoiding these delays by automatically correcting for these minor variations in real time. As well as preventing these short delays, this also avoids the need for tuning when program changes are made.

As a solution for instructing workers on how to perform manual work, Hitachi supplies an assembly work navigation system that depicts operating procedures using animations and storyboarding[(2)]. By automatically creating an animation showing the sequence of assembly steps determined from the three-dimensional (3D) model of the product, this can quickly generate data for a wide variety of procedure changes.

Figure 3 — Example Online CPS Use Case

A vertical articulated robot picks up blocks delivered by conveyor and places them in a case. This physical configuration is replicated in cyberspace. Degradation of the conveyor over time shifts the position to which the blocks are delivered and this results in an overload during the block placement step.



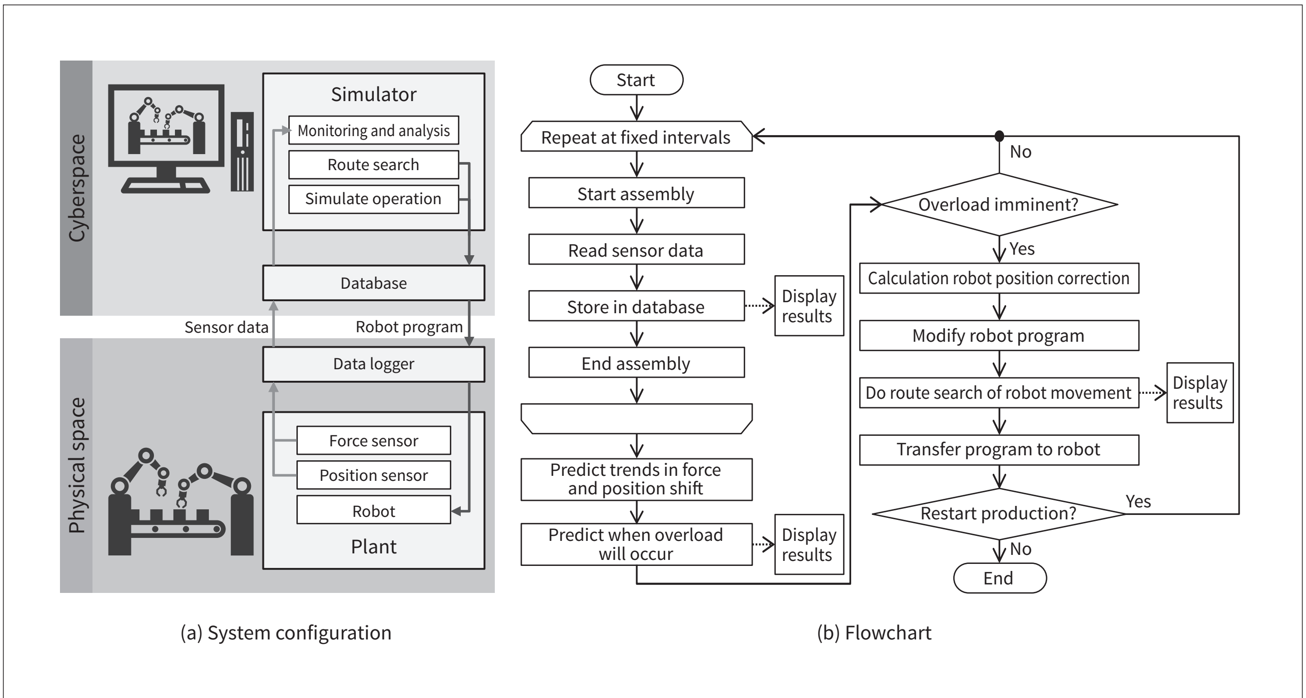
4. Example Applications of Online CPS by Hitachi

This section presents a manufacturing industry use case for the online CPS described above. It involves the analysis of downtime on an assembly line and automatic countermeasures. **Figure 3** shows the layout of the assembly line.

The assembly line has a vertical articulated robot that picks up parts (blocks) delivered by conveyor and places them at the required location on the product (a case). A stopper halts the blocks at the desired location at the end of the conveyor. The robot picks up blocks from this location. Each block has a positioning hole and the case has a matching pin. The robot places each block so that these are aligned. Unfortunately, repeated operation over a long period causes the stopper to progressively shift position, resulting in performance degradation. This is caused by things like contact between the blocks and stopper or bumping by the robot when it picks up a block. The result is that the position from which the robot picks up the blocks shifts away from the intended position. This in turn results in contact with the positioning pin on the case when placing a block, leading to frequent short outages due to overloading. While this can be dealt with physically by production engineers repositioning the stopper or in software by adjusting the robot picking position, these measures are an issue because they take a few hours to perform.

Figure 4 — System Configuration and Flowchart of Online CPS Use Case

Data is collected from the sensors on the physical equipment and stored in cyberspace for use in analysis and trend prediction. This in turn provides the basis for automatic corrective action whereby corrections are made in the robot program and implemented in the physical equipment. As a result, downtime can be avoided without human intervention.



To resolve the problem, the online CPS was used to analyze the shift in stopper position and a system was developed that avoids outages by adjusting automatically to match the actual conditions. **Figure 4** (a) shows a diagram of the system. This system includes a force sensor fitted at the end of the robot arm to measure the forces involved when the physical equipment picks up or places blocks. A position sensor was also installed next to the robot to measure the block picking action. The data from these sensors was monitored continuously and stored in a way that linked the picking position to the magnitude and direction of the block placement force. In cyberspace, meanwhile, the physical situation was modeled in three dimensions to enable route searches to be performed and simulation of the operation using the robot operation program as input.

Figure 4 (b) shows a flowchart of how the system works. During operation, sensor data is continuously collected and stored. As repetition of the task causes the stopper to shift out of position over time, the force measurement in one particular direction progressively increases. The position sensor readings also change progressively. By collecting this data over a period of time and correlating the values, it is possible to predict the direction and distance of this incremental stopper movement. As ongoing operation will result in an overload outage when the force exceeds the limit, automatic corrective action is taken before this limit is reached. For this system, it involves calculating a correction to the robot's block picking position based on the predicted direction and distance of stopper movement. The correction is incorporated into the robot operation program in cyberspace and an automatic route search is performed for the new robot picking position. If simulation confirms that the new operation will work correctly, the automatic fix is updated on the physical system.

Use of this system helps to maintain reliable line operation by avoiding downtime without human intervention. While this use case involves an assembly task, Hitachi is also looking at extending it to other work such as materials handling or welding. More information about this particular application can be found in the references[3].

5. Conclusions

In response to the changing environment for manufacturing and logistics, Hitachi intends to continue supporting the business resilience and ongoing growth of its customers through the development of online CPS solutions and by adopting an approach to production line building that combines robotics SI with digital technologies and is based on collaborative creation.

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Development of WIGARES Platform for Digital Capture of Operational Know-how and Its Application for Plant Automation

How to pass on the expertise of experienced workers is one of the challenges facing the manufacturing industry. At many plants, data is spread across different legacy systems and it is up to people to collate this information for use in decision-making. To address this issue, Hitachi utilizes a technique it has developed called SIMT for the integrated management of data scattered across various existing systems to enable the digital capture and representation (digitalization) of operational know-how held by individuals. It has also developed a centralized information management platform, WIGARES, that automatically provides users with the information they need to perform their work, when they need it. One of Hitachi's Lumada solutions, WIGARES enables the digitalization, sharing, and integrated management of operational know-how. Along with marketing it to a wide range of manufacturing industries, Hitachi is also contributing to building a sustainable society by working to enhance business value and build resilience (business continuity) in manufacturing by integrating WIGARES and other digital solutions with the aim of automating plant operations through the implementation of cyber-physical systems.

Naoya Aoyama
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Koji Amano
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1. Introduction

Manufacturing needs to achieve sustainable practices by 2050, as exemplified by carbon neutrality and the circular economy. This has heightened efforts toward digital transformation (DX) and made it more important than ever.

While this has been happening, Hitachi has been striving to enhance people's quality of life (QoL), utilizing digital technologies and collaborative creation through Lumada* and other initiatives to implement sustainable manufacturing, improve the quality of work done by people in the manufacturing industry, and raise living standards.

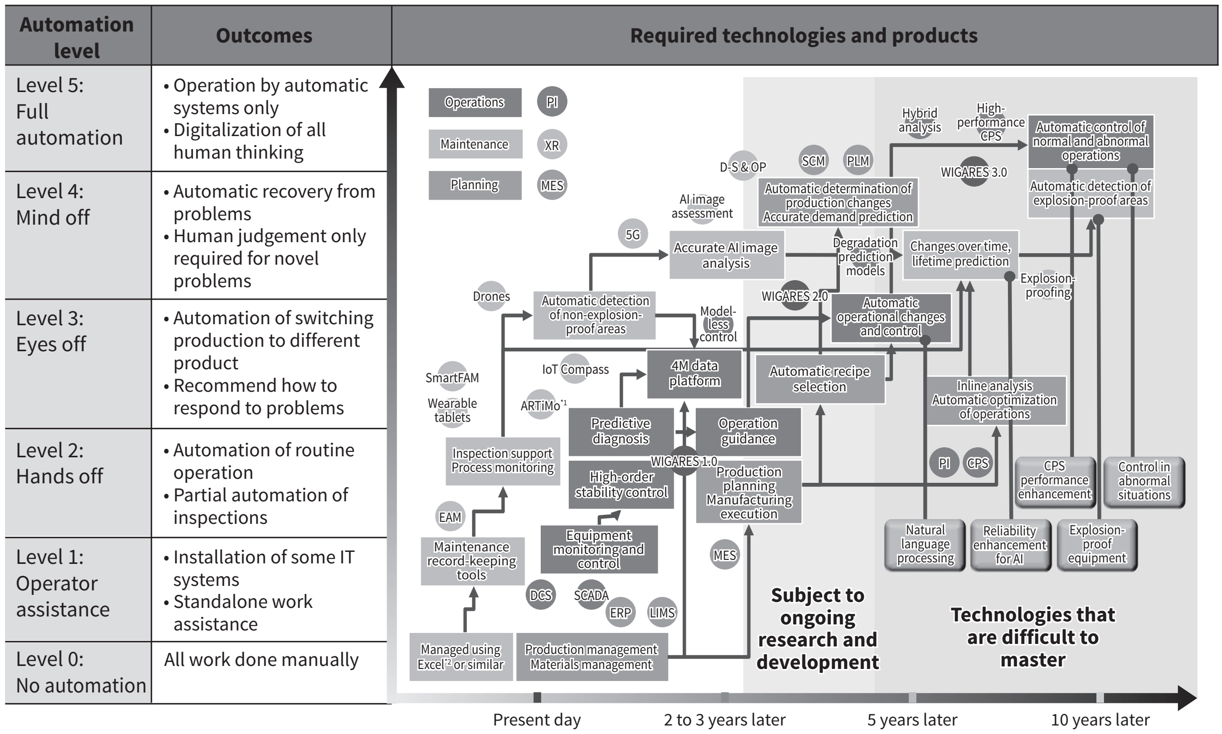
* The general term for Hitachi's advanced digital solutions, services, and technologies that utilize advanced digital technologies to create value from data and accelerate digital innovation.

2. Future Manufacturing Workplaces and the Challenges They Face

It is anticipated that the future of manufacturing will involve shifting toward greater automation of operations, especially those on the factory floor. When operational problems occur, systems will help humans to respond by offering useful information. Systems will also provide the support needed for subsequent actions to proceed smoothly. Such a future will likely see a merging of the cyber and physical realms, with reduced workforce requirements as digitalized tasks are delegated to advanced systems. The role of humans will be to focus on creating new value by addressing key issues such as the environment, resilience, safety, and security.

Figure 1 — Roadmap for Plant Automation

The roadmap is based on assessing the current situation to determine what should be done to automate plant operations.



PI: process informatics XR: extended reality MES: manufacturing execution system D-S & OP: digital sales and operation planning
SCM: supply chain management PLM: product lifecycle management CPS: cyber-physical system EAM: enterprise asset management
SCADA: supervisory control and data acquisition DCS: distributed control system ERP: enterprise resources planning
LIMS: laboratory information management system IoT: Internet of Things 5G: fifth generation AI: artificial intelligence
4M: human, machine, material, method

*1 ARTiMo: Predictive diagnosis system supplied by Hitachi

*2 Excel is a registered trademark or trademark of Microsoft Corporation in the US and other countries.

Figure 1 shows a roadmap for automating plant operations. Progress on the digitalization of operations will be an important factor, involving the exchange of data between the edge systems in the plant and external systems that include information systems or systems located outside the company. Other important factors for achieving this roadmap include identifying the problems and other issues based on a comprehensive understanding of the situation in the plant, setting achievable targets, and having plans in place to step up through the successive automation levels.

One of the issues in the manufacturing workplace is that of tasks relying on the expertise of specific individuals. Tasks like manufacturing operations, maintenance, and production management draw on knowledge and expertise built up through experience by long-serving staff and involve accessing systems, documentation, and other departmental resources. With the aging of experienced workers and the shrinking of the working population, the digitalization and sharing of this expertise held by individuals poses a critical challenge that must be addressed if the loss of know-how is to be prevented and operational efficiency is to be improved.

3. WIGARES Centralized Information Management Platform

3. 1 Value Creation by WIGARES

This section describes how WIGARES (a name derived from the words “wisdom,” “gather,” “refine,” and “space”) came to be developed. Past practices aimed at achieving consistency in workplace skills have included creating manuals to document the expertise of experienced workers, the installation of new systems to improve operational efficiency, and the collation of data by converting documents into digital form. Unfortunately, there is a limit to how much can be accomplished by measures like these and the reality is that the expected benefits have yet to be reaped. The main reason for this is that people act like hubs, coordinating the different tasks to be accomplished. If this situation is allowed to continue, it will likely result in a variety of losses. As well as isolating expertise, having particular people dedicated to certain tasks will also delay information sharing and diminish the capacity for creating value.

Accordingly, WIGARES was developed as a tool for improving operational efficiency across a wide range of areas that works by converting this operational know-how to digital form.

The first of the expected benefits is to eliminate the tendency for work to be done by particular people and maintain skills at a high level (leveling up). While the differences in experience between older and younger workers can be difficult to bridge, WIGARES can enhance the level at which work is performed, giving experienced staff access to the quickest and best ways of doing things. The system also facilitates leveling up by allowing younger staff to take advantage of information derived from the experience of long-serving workers, thereby significantly improving the standard of their work.

A second benefit is easier access to information about specific tasks. WIGARES can provide the required information to the people who need it in real time. By freeing them from having to track down the required manuals or past examples, this improves operational efficiency.

In this way, using WIGARES in the workplace enables the digitalization of operational know-how and delivers value in a variety of different forms that align with key performance indicators (KPIs), such as reduced overtime and faster work sharing, thereby also enhancing corporate value.

3. 2
SIMT—Core Technology Used in WIGARES

WIGARES derives the value discussed above from the use of structured identifier management technology (SIMT). WIGARES is made up of three elements: self-learning, links, and the structured identifiers (IDs) that serve as keys linking data to tasks. A structured ID is a unique identifier assigned to data or information handled by WIGARES. That is, it is a name for data that can be understood by computers. A link defines know-how in the form of an interrelationship between a pair of structured IDs at any level in the structure. For example, the knowledge that a particular situation tends to result in a particular fault can be stored as a From-To relationship. Self-learning, meanwhile, is the automatic identification of links relating to the definition of terminology used in tasks or the way in which words are used. WIGARES also has engineering tools for users to build SIMT for each plant on their own. These are essential for creating an environment for SIMT.

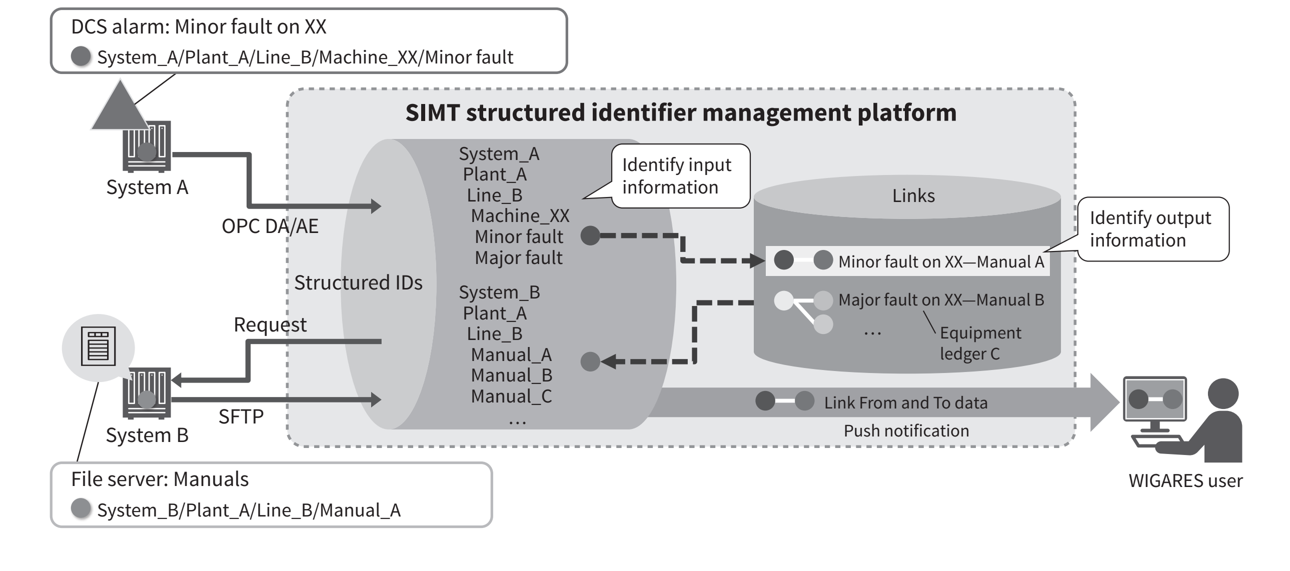
Figure 2 shows an example of a push notification that utilizes structured IDs and links.

In this example, the user notification of an alarm issued by a control system is also accompanied by the relevant manual. First, a fault alarm is received from a distributed control system (DCS) in system A. The nature of the alarm is determined from the input information (From) by means of its structured ID. Next, the links are checked to determine what knowledge data is associated with the input information. This identifies manual A as the output (To) information (knowledge) associated with the input alarm. A structured ID is also used to determine where manual A is stored and the manual data is retrieved from system B. Finally, the retrieved manual and the input alarm are linked (From-To) and passed to the user by means of a push notification.

Using this function means that the human tasks that used to be the hub between systems can be delegated to the systems themselves. For example, past practice when

Figure 2 — Example of SIMT Data Handling Utilizing Structured IDs and Links

A use case in which the user is also provided with the relevant manual when notified of an alarm issued by a control system.



SIMT: structured identifier management technology OPC: open platform communications DA: data access AE: alarms and events SFTP: SSH file transfer protocol an operator became aware of an alarm issued by the DCS would have been to contact a supervisor or one of the maintenance staff or to go to a bookshelf or file to look up what to do. Using SIMT, in contrast, it is possible to decide how to respond immediately as the alarm is notified to other departments the instant it is issued and accompanied by the required manuals or past data. The benefit of this should be a leveling-up of work performance as, even if the operator is young and inexperienced, they can take the same action that a long-serving worker would take.

3. 3 WIGARES Features and Use Cases

Figure 3 lists the features and strengths of WIGARES. One of these is the ability to integrate with existing systems. WIGARES can be combined with other systems currently in use without needing major modifications. Moreover, because it is based on linking items of know-how together, adding or removing information is easy. As this know-how is linked to user attributes, it is also possible to fetch the information users need, when they need it.

The following are two examples of how WIGARES can be used after it is installed. The first use case is shown in **Figure 4** and involves using WIGARES for advanced maintenance practices. A standalone predictive diagnosis system still requires human expertise to determine what to do when anomalies are detected. With WIGARES, however, relevant information can be provided such as the operational or maintenance actions that need to be taken when a potential problem is detected. This means that anyone is able to take prompt action by following instructions that are provided when the problem is detected.

Figure 5 shows the second use case, which involves the optimization of operations through interoperation across multiple systems. Activities that in the past were handled by separate systems can be linked together and treated as a single sequence of steps. This particular use case involves the periodic transfer of inventory information, dispatch records, and production schedules from the manufacturing execution system (MES) to a system for predicting out-of-stock items. The prediction system then automatically queries a human, machine, material, and method (4M) database to

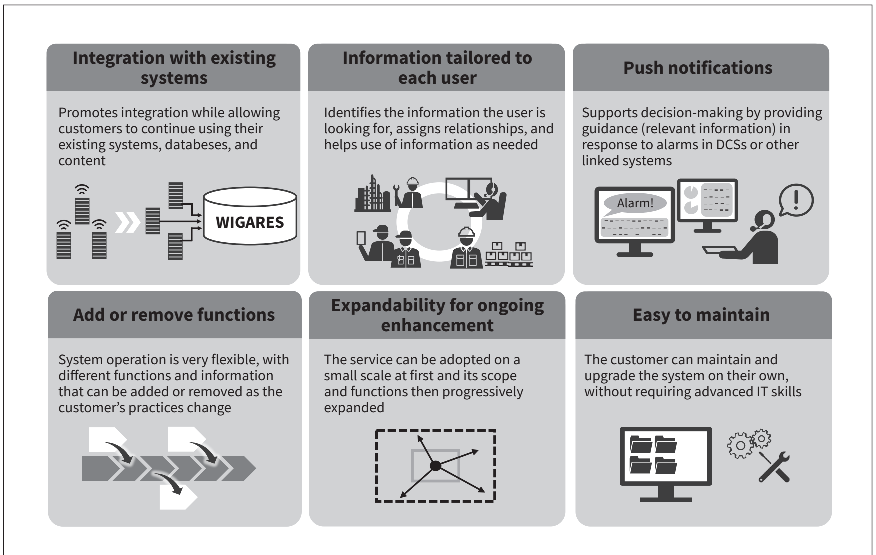


Figure 3 — WIGARES Features and Strengths
The figure shows key features and strengths of WIGARES, including its ability to integrate with legacy systems.

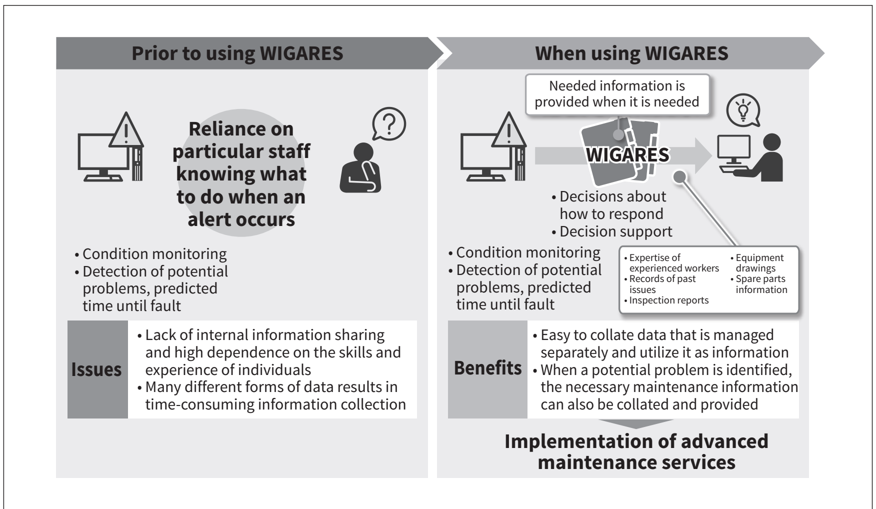


Figure 4 — Advanced Maintenance Practices through Interoperation with Predictive Diagnosis System
Details of potential problems identified by the predictive diagnosis system are passed to WIGARES and presented to users along with the necessary maintenance information.

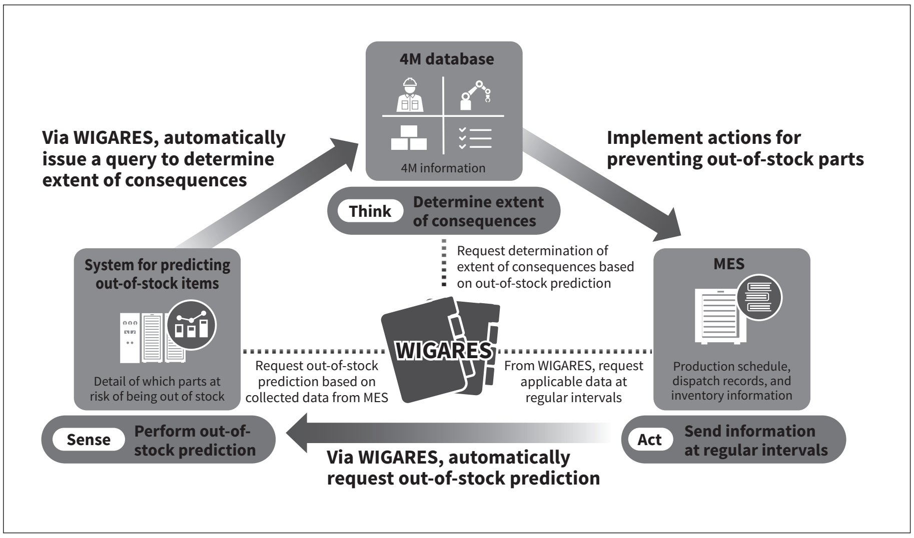


Figure 5 — Operational Optimization through Interoperation of Multiple Systems

The performance of complex tasks that span multiple systems is facilitated by integrating information from different sources, such as the MES, 4M database, or system for predicting out-of-stock items, consolidating sequences of steps that in the past were done on separate systems.

determine the extent of the consequences for any items at risk of being out of stock. Then, by using the 4M database to prevent items from going out of stock and to provide feedback to the MES, this automatically supports the maintenance of appropriate inventory levels.

In FY2020, WIGARES was installed on a trial basis at a major chemical manufacturer for the purposes of maintaining reliable plant operations and undertaking working style reforms. Testing of its use for the digitalization of operational know-how relating to specific items of plant is ongoing.

4. Conclusions

WIGARES is a solution that delivers more value the more it is used. Rather than seeing its installation as a goal in itself, WIGARES can play a central role in automating plant operations, growing by learning new operational know-how from ongoing use, and leading ultimately to the digitalization of many different aspects of the business. By doing so, it provides a pathway not only to more efficient operation and the passing on of knowledge, but also to the automation of plant operations through the digitalization of operational know-how.

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Simulation-based Production Scheduling Solution for Flexible Production

Today's business environment is characterized by increasing uncertainty, including worldwide parts shortages, growing diversity in customer preferences, and public demands for products to take account of the environment. Confronted with this, manufacturers, especially those in the automotive industry, have an increasing need for flexible production practices that allow them to adapt to fluctuating demand and operational changes. When scheduling flexible production, operational considerations call for the ability to cope with the complexity of production scheduling while also being able to respond quickly when needed. Similarly, the challenge for production management systems is to be able to start on a small scale and then to scale up with flexibility as the production line is expanded. In response, Hitachi is developing a simulation-based optimization engine for the scheduling of flexible production and a scheduling solution that will be made available as a microservice. This article presents an overview of the solution and the plans for the future.

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1. Introduction

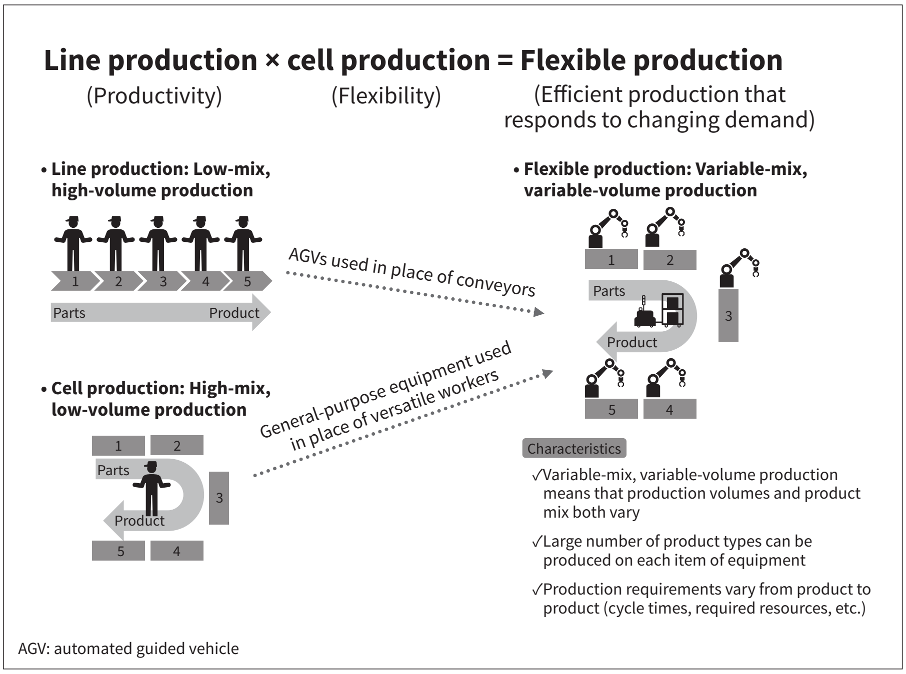
1. 1 Conditions in Manufacturing Industry and Implications for Flexible Production

The pace of change in society over recent years has been remarkable, with the manufacturing industry experiencing unprecedented levels of uncertainty and instability. Along with restrictions on corporate activity due to COVID-19, supply shortages for semiconductors and other inputs driven by rising global demand, shorter product lifecycles, and growing diversity in customer preferences, companies are also being called upon to fulfil their social responsibilities by supplying products that take account of the environment. On top of this, manufacturers, especially those in the automotive industry, require variable-mix, variable-volume production capabilities in order to supply a diverse range of products in the quantities required[(1), (2)]. This has led to heightened interest in flexible production practices that can adapt to demand fluctuations and operational changes.

This article focuses in particular on the issues associated with achieving flexible production, covering the operational and production management system challenges of production scheduling, also giving an overview and describing the future plans for a digital scheduling solution that is currently being developed to address these issues. In developing this solution, Hitachi is drawing on knowledge of information and operational technology (IT and OT)[(3)] that it has built up over many years of working in manufacturing.

Figure 1 — Features of Flexible Production

Flexible production enables variable-mix, variable-volume production, with the flexibility to adapt to production schedules that change on a daily basis. This is done by combining the attributes of low-mix, high-volume production lines, and cell production for high-mix, low-volume production.



1. 2 Overview of Flexible Production

This section gives a general introduction to flexible production, an approach to manufacturing that enables variable-mix, variable-volume production. Production lines achieve high levels of efficiency using conveyers and other equipment dedicated to the production of a limited range of products. Cell production, in contrast, allows for the manufacture of a wide range of products by versatile workers. The aim of flexible production is to combine both of these attributes at the same time. In flexible production, automated guided vehicles (AGVs) and materials handling systems are used in place of conveyors and productivity is enhanced by automation. By using general-purpose equipment in place of special-purpose equipment or skilled workers, it also enables high-mix production at a level close to what would be achieved by those skilled workers (see **Figure 1**). This provides the flexibility for variable-mix, variable volume production in accordance with production schedules that change on a daily basis.

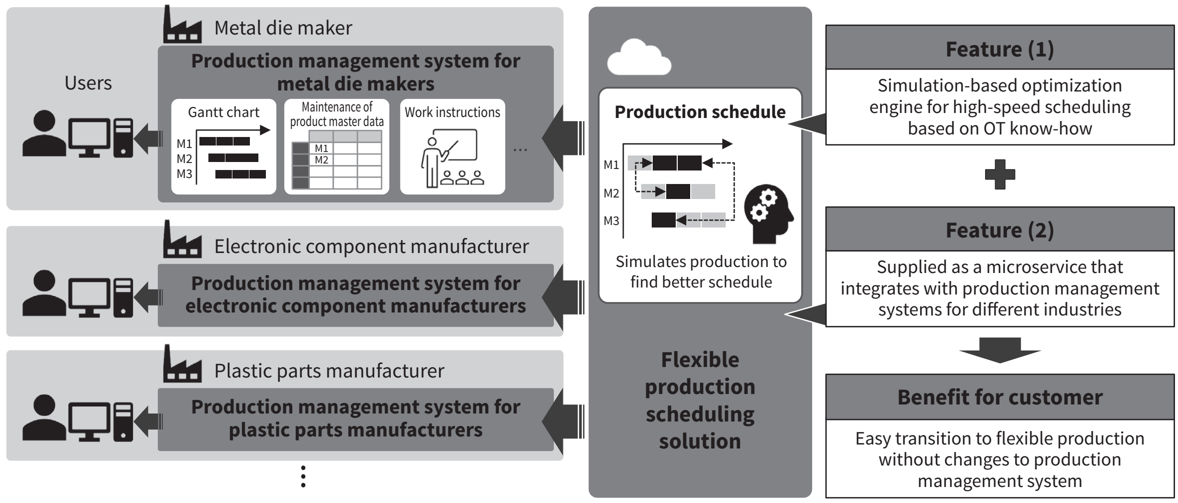
1. 3 Difficulties of Transitioning to Flexible Production

This section describes the operational and production management system challenges of production scheduling when making the transition to flexible production. Because flexible production is all about variable-mix, variable volume production, production volumes and product mix vary on a daily basis in response to fluctuating demand. Moreover, as the installation of general-purpose equipment increases the number of different products that can be manufactured using the same equipment or line, it provides a higher degree of production freedom. However, it also adds to production scheduling constraints, with a need to consider production conditions that are specific to each product, such as cycle time, required resources, and whether setup changes are needed. The downside of this is greater planning complexity, a consequence of the huge number of possible combinations of which products to produce, on which equipment, and in which order. Even experienced technical staff find it difficult to devise production schedules under such circumstances. Furthermore, this calls for the flexibility to revise production schedules in response to sudden changes in supply and demand conditions or, in the event of downtime due to equipment faults or other problems, to generate new schedules that can recover without interrupting production. How to ensure that scheduling can respond quickly in such circumstances is a key issue.

Meanwhile, companies interested in flexible production span the full range from end-product manufacturers to parts suppliers. Depending on the size of their business and the conditions under which they operate, some of these will likely pursue flexible production lines on a large scale while others will make a gradual transition in which existing and flexible production lines coexist. In either case, there is a growing need to ensure that the existing production management system maintains its usability for plant-based users. To address this, what is needed is to develop a system specifically for use with optimization engines that can obtain solutions satisfying the various production scheduling constraints needed for flexible production to work, and to make these easy to integrate with existing systems so as to reduce the time and cost of implementation and allow the transition to start on a small scale. Also desirable is flexible scalability so that the required functions and resources

Figure 2 — Overview of Flexible Production Scheduling Solution

The flexible production scheduling solution can integrate with production management systems for different industries to generate production schedules quickly. This provides a way for customers to adopt flexible production practices for scheduling while continuing to use the functions of their existing production management system.



OT: operational technology

can be made available when needed, and in the quantities required, based on how fast production is ramped up.

2. Flexible Production Scheduling Solution

Two critical issues when making the transition to flexible production are: (1) the ability to cope with the complexity of production scheduling while also being able to respond quickly when needed, and (2) the ability for the system to start on a small scale and then scale up as needed. The flexible production scheduling solution was devised to address these two challenges (see **Figure 2**).

To address the first issue, the solution features the use of simulation to assess how well the production line will function and a simulation-based optimization engine that can generate production schedules quickly, utilizing Hitachi OT know-how to improve productivity. Similarly, the second issue of scalability is addressed by making the solution available as a microservice that provides a standalone production scheduling function that can interoperate with the production management systems used in different industries. These features can smooth the transition to flexible production by adding a production scheduling function suitable for this purpose as an upgrade to the existing production management system with which the customer is already familiar. The following sections describe these features in more detail.

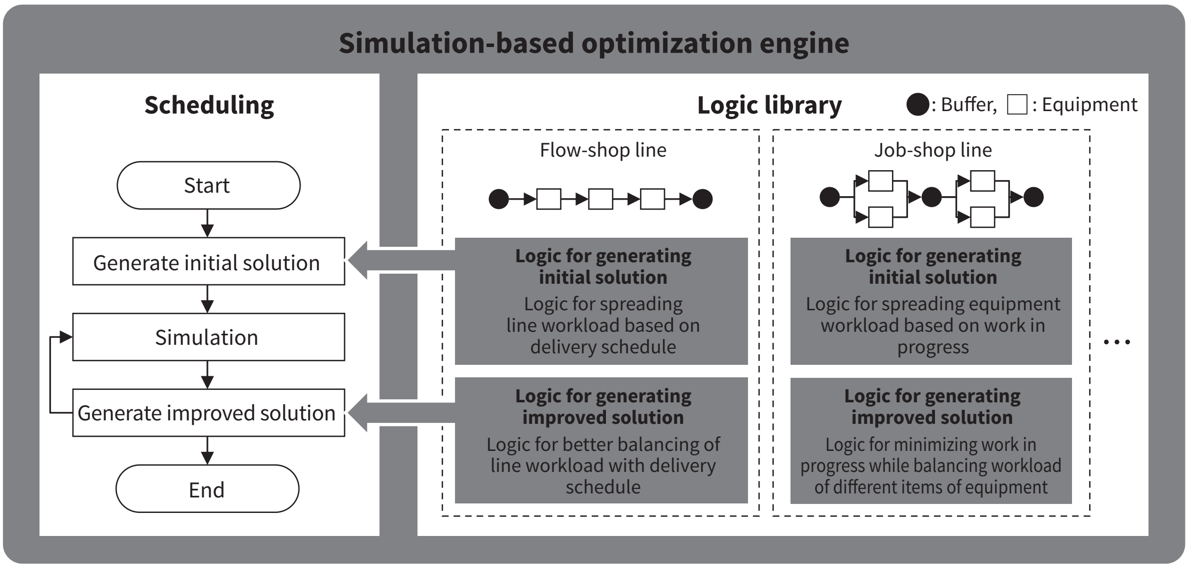
2. 1 Simulation-based Optimization Engine

Existing production scheduling systems intended for flexible production combine the use of meta-heuristics for scheduling with detailed prediction of complex goods movements(4), (5). The problem with this approach, unfortunately, is the long computation times it requires, such that workable schedules are not available in time.

In contrast, the simulation-based optimization engine shortens the computation time by augmenting the conventional search algorithm with scheduling logic based on the characteristics of the line concerned. **Figure 3** shows a block diagram of the optimization engine. The engine is made up of a library of scheduling logic for different line characteristics and a scheduling function that utilizes this logic. In the example of a flow-shop line that manufactures a number of different products, because each of these products needs to be worked on for a different length of time, the schedule needs to distribute this workload in a way that also meets the delivery schedule. In this case, an initial solution is generated in which products enter the line in delivery date order and the work is spread between each of the line workstations. A solution search is then performed on the basis of the tradeoffs between these two objectives. For a job-shop line, in contrast, the requirement is to spread the equipment workload while reducing the quantity of work in progress. In this case, the initial solution is generated by assigning equipment based on the amount of work required for each product. The order in which each one is worked on is determined so as to minimize the amount of work in progress left waiting between process steps. A solution search is then performed based on the tradeoffs. By selecting the appropriate logic for the type of line being scheduled, an optimal schedule can be produced quickly.

Figure 3 — Block Diagram of Simulation-based Optimization Engine

The simulation-based optimization engine is made up of a library of scheduling logic for different line characteristics and a scheduling function that utilizes this logic. The complexity and responsiveness requirements associated with flexible production are dealt with by selecting logic appropriate to the line being scheduled.

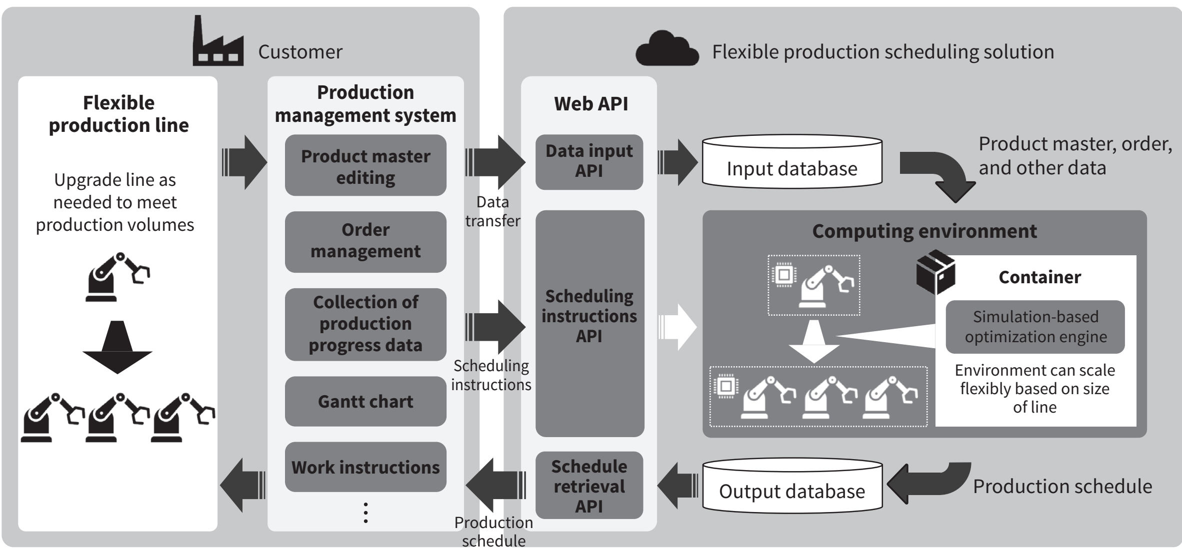


2. 2 Delivery as Microservice

Making the transition to flexible production requires changes to the existing production management system, including the addition of a production scheduling function suitable for flexible production lines(6). The conventional way of doing this would have been to upgrade the system to use third-party scheduler software running on the on-premises hardware. Unfortunately, because of the expense and the long time it takes to implement the upgrade, it is difficult to adopt flexible production on a small scale initially. The lack of flexible scalability also poses a problem because the system needs to be progressively updated as the scale of production ramps up.

Figure 4 — Block Diagram of Flexible Production Scheduling Solution

The flexible production scheduling solution uses a container implementation for the simulation-based optimization engine to obtain the required computational resources as needed for scheduling production based on the instructions from the customer.



API: application programming interface

In response, Hitachi developed the flexible production scheduling solution as a microservice. This configuration provides the ability to start small and then scale up. The simulation-based optimization engine has a container implementation that runs in the cloud and interfaces with the existing production management system by means of an application programming interface (API). **Figure 4** shows a block diagram. Along with the computing environment for the container implementation of the simulation-based optimization engine, a web API is also included for managing the microservice. This web API is used to obtain the product master records and order information needed for scheduling and returns a result in the form of a production schedule. This enables customers to perform flexible production scheduling without having to make major changes to the systems with which they are already familiar. The microservice configuration also allows for the container environment to be set up with sufficient computational resources based on the scheduling instructions from the production manager at the site. This means that computational capacity can be scaled in step with upgrades to the flexible production line.

3. Conclusions

This article has presented an overview of a flexible production scheduling solution, describing what Hitachi has been doing to enable better and more sophisticated scheduling practices that are in step with the trend in manufacturing toward flexible production.

As it works toward the full-scale commercial deployment of the solution, Hitachi intends to continue assessing the benefits of the solution and value that it is currently undertaking through collaborative creation with customers. These plans include testing how well the solution interoperates with existing production management systems. This is being done to verify ways in which the many companies that are interested in flexible production can adopt the solution without having to make major changes to their existing production management systems.

Hitachi also intends to utilize digital solutions to facilitate greater sophistication and automation of production management tasks. These future plans involve utilizing the production schedule data obtained by the deployment of this solution together with production line data to go beyond production scheduling to investigating and trialing ways of improving the quality of the product master data that is critical to scheduling and facilitating its efficient maintenance.

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Delivery Scheduling Service with EV Truck Charging Time

Amid ongoing efforts to reduce CO_2 emissions across a range of industries, the fact that transportation emissions of CO_2 in logistics account for 17.7% of the total in Japan means that there is an urgent need for actions such as promoting green logistics and transitioning to EV trucks. Unfortunately, making the switch to EV trucks for distribution faces a number of challenges, including short range, which limits the area they can service, and the time taken for charging, which reduces their efficiency. To help create a sustainable society, Hitachi has developed an advanced logistics service provisionally named Hitachi Digital Solution for Logistics-EV that uses digital technology to address the practical challenges facing green logistics. This article describes the work being done in this area.

Kazuya Uyama
Akane Seto
Hikaru Kokubu
Yoshifumi Fujii

1. Introduction

The Japanese government has set targets for reaching carbon neutrality by 2050 and a 46% reduction in greenhouse gas emissions by 2030 (relative to FY2013). A variety of carbon dioxide (CO_2) emission reduction and other initiatives aimed at achieving these targets are underway across a range of industries. In logistics, there is an urgent need to reduce the amount of CO_2 emitted by vehicles used for freight and to make the transition to practices that take account of the environment.

Since around 2006, the logistics industry has sought to address environmental problems by making the industry greener and more efficient through "green logistics." Among the key pillars of green logistics are modal shift, joint delivery, and consolidation. Modal shift refers to replacing the transportation of freight by trucks or other vehicles with more environmentally friendly alternatives such as railways or ferries and other forms of shipping. Joint delivery means carrying freight from multiple consignors to a common destination in the same truck. Similarly, consolidation means improving the efficiency of delivery by combining geographically dispersed hubs and reorganizing the distribution network. What these have in common is that they have reduced CO_2 emissions by changing how logistics services work. Across the industry as a whole, however, there is a limit to how much can be achieved by restructuring logistics services and this has led to growing momentum behind the switch from internal combustion engine (ICE) vehicles to electric or fuel-cell trucks.

Vehicle manufacturers, meanwhile, are also stepping up their action on the environment. In places like North America in particular, major logistics companies and electronic commerce businesses are among those adopting and transitioning to electric vehicle (EV) trucks. The adoption of EV trucks has also started in Japan, mainly by large logistics companies for use in last-mile delivery.

However, if the use of EV trucks is to be encouraged and become more widespread, there is an urgent need to overcome the problems they pose. These include short range, high up-front costs, and less efficient delivery.

This article describes work on a delivery scheduling solution that addresses these issues and is being undertaken as part of efforts to achieve sustainable logistics that cares for the environment.

2. Challenges that EV Trucks Pose for Delivery Operations

2. 1
Trends in EV Truck Use for Delivery

The need for decarbonization is highlighted by the fact that transportation accounted for 17.7% of total CO_2 emissions by Japan in FY2020, with freight vehicles making up 39.2% of this (6.9% of total emissions by Japan)[1]. The Japanese government's Green Growth Strategy Through Achieving Carbon Neutrality in 2050 sets a target of 100% of new light commercial vehicles being powered by electricity or non-carbon fuels by 2040, with heavy vehicles to follow[2]. In line with this strategy, moves toward the adoption of small EV trucks for last-mile delivery are accelerating, including work on putting the charging infrastructure in place.

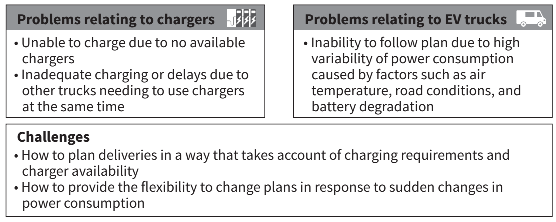
Unfortunately, the electrification of commercial vehicles is lagging behind that of passenger vehicles. Most existing EV trucks draw their electric power from onboard batteries that are charged using chargers. The carrying capacity of EV trucks is limited by the space taken up by the battery. Together with their long charging times and short range, this makes it difficult to use EV trucks for deliveries in the same way as ICE vehicles. Furthermore, because most delivery work happens during the day, with the vehicles being recharged at night, potential issues include a lack of chargers and the risk of exceeding the contracted level of electric power consumption. If vehicles are unable to fully recharge overnight, the effect this has on following-day deliveries incurs opportunity costs for the operator. In response, to make delivery by EV truck more efficient, Hitachi has developed and deployed a service that provides integrated management of both delivery and charging, including by planning routes in a way that takes account of charging and remaining battery capacity as well as vehicle operation.

2. 2
Challenges for Delivery by EV Truck

Figure 1 illustrates some of the problems and challenges associated with delivery by EV truck.

EV trucks may need to have their batteries topped up during operating hours to extend their range if they are to avoid opportunity costs, such as when an EV truck has insufficient charge at the commencement of a delivery run or if it is required to travel distances in excess of 100 km. Unfortunately, the inadequate charging infrastructure currently available means that there may not be chargers available nearby to provide the needed top-up. Even if there are nearby chargers, they may be unavailable due to already being in use by other vehicles, leading to queuing and delivery delays. Accordingly, deliveries need to be scheduled in a way that pre-emptively takes account of charger availability and charging times.

Figure 1 — Problems and Challenges when Using EV Trucks for Delivery
The scheduling of deliveries by EV trucks needs to take account of power usage, which varies due to the weather and road conditions, as well as the availability of chargers.



EV: electric vehicle

Also, because the amount of power used by an EV truck varies widely depending on factors such as air temperature, road conditions, and battery degradation, the accuracy of power consumption prediction also needs to be improved through accurate tracking and monitoring of actual operations. The flexibility to modify schedules is also needed due to the risk of unplanned circumstances causing sudden changes in power consumption.

Hitachi Digital Solution for Logistics (HDSL) is a suite of advanced logistics services, one of which, HDSL-EV, is a delivery optimization service that supports EV truck scheduling. HDSL-EV was developed by Hitachi to overcome the challenges described above. The following sections describe HDSL and HDSL-EV.

3. Factoring Charging Time into Delivery Scheduling (HDSL-EV)

3. 1
Overview of HDSL

HDSL, Hitachi's suite of advanced services for collecting, storing, and analyzing customer data on logistics operations, currently offers the following services for delivery by ICE vehicle.

(1) Service for safety, operations, and fleet management

This service optimizes operations and makes them more efficient by providing a view of what is actually happening in the field, including by sharing the operational expertise of experienced staff and assessing driving performance.

(2) Delivery optimization service

This service automates delivery scheduling and makes deliveries more efficient by automatically generating efficient schedules, a task that previously relied on expert staff.

(3) Delivery information sharing platform

This service enables joint deliveries, allowing consignors and delivery companies to exchange freight information in the cloud and seamlessly integrate previously isolated data covering every step from ordering to delivery. By doing so, it improves transportation efficiency and reduces CO_2 emissions.

By automating vehicle dispatch, the delivery optimization service in particular can free companies from reliance on specific individuals. It is able to generate workable delivery schedules by combining the expertise of experienced staff with the analysis and use of data collected from actual deliveries.

3. 2 Factoring Charging Time into Delivery Scheduling (HDSL-EV)

The delivery optimization service for EV trucks (HDSL-EV) has functions both for generating delivery schedules from scratch at the planning phase and for revising schedules on the fly based on circumstances that arise during the actual delivery phase. In both cases, the schedules are generated automatically and factor in the charging of EV trucks (see **Figure 2**).

In practice, this allows EV truck deliveries to keep the loss of efficiency to a minimum by collecting information about the availability of chargers from the energy management systems (EMSs) of local charging facilities and optimizing deliveries in a way that allows for the need to stop at a charger. The routes, choice of charger, and charging schedules for EV trucks are adjusted to spread the load across the different charging facilities, avoiding situations where more than one EV truck needs to use a charger at the same time and thereby reducing waiting times and additional travel.

HDSL-EV also has a function for predicting power consumption based on a number of relevant vehicle and route parameter inputs. By doing so, it is able to generate highly workable schedules based on the calculation of power consumption and range estimates that closely match actual outcomes. Through interoperation with dynamic management functions that collect vehicle data such as battery state of charge (SoC) and state of health (SoH), Hitachi intends to provide the ability to determine what is happening in real time and adjust schedules accordingly.

Hitachi also plans to extend this function in anticipation of the future use of battery swapping systems by those EV trucks that are equipped to use them.

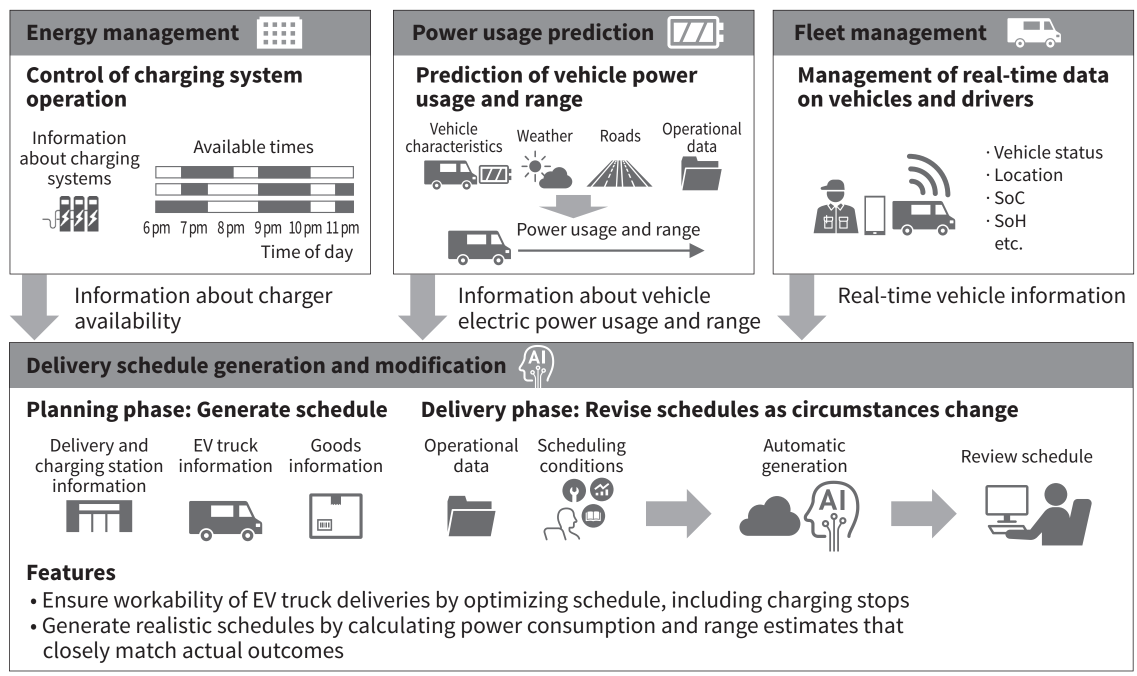
3. 3 Example Applications for HDSL-EV

By providing automated delivery scheduling that keeps any efficiency effects to an absolute minimum, HDSL-EV supports the adoption of EV trucks by customers concerned about decarbonization. The following are two example applications for the service (see **Figure 3**).

The first involves a delivery run that stops at multiple destinations. If charging is only done at the depot, the shorter range of EVs compared to ICE vehicles limits the number of destinations that each vehicle can visit. By increasing the number of vehicles deployed, this decreases delivery efficiency. If HDSL-EV is adopted, it can extend vehicle

Figure 2 — Functions and Features of HDSL-EV

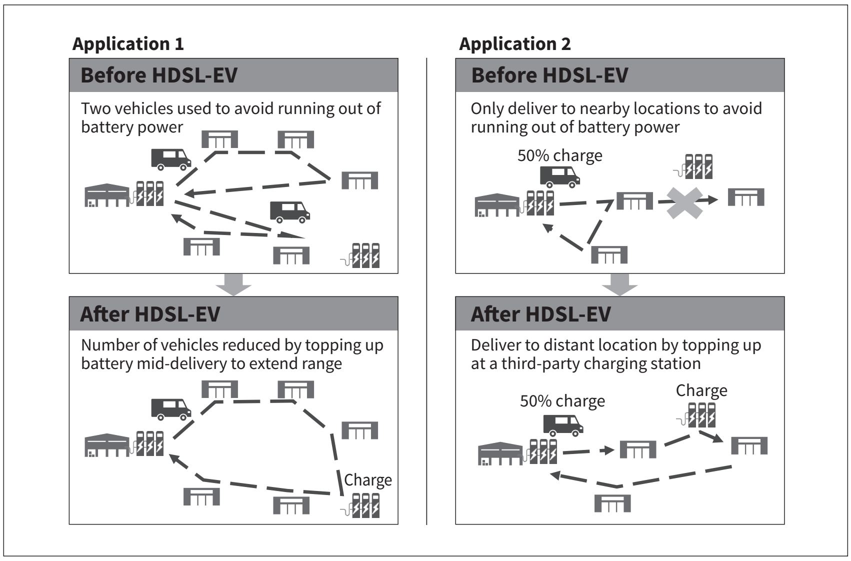
HDSL-EV is equipped with functions for generating and modifying delivery schedules, predicting power consumption, and fleet management. In addition to coordinating these different functions, HDSL-EV can generate highly workable EV truck delivery schedules that keep any loss of efficiency to a minimum by using information from the energy management systems of local charging stations. It can also track what is happening in real time and adjust schedules accordingly.



HDSL-EV: Hitachi Digital Solution for Logistics-EV SoC: state of charge SoH: state of health AI: artificial intelligence

Figure 3 — Applications for HDSL-EV

Because it allows for vehicles to extend their range by stopping to recharge during a delivery, the adoption of HDSL-EV reduces the total number of vehicles required and enables deliveries to distant locations.



range by optimizing the charging schedule and choice of charger, also minimizing additional working time for drivers and their vehicles. This enables deliveries to proceed with no loss of efficiency as the number of destinations visited can be increased to the extent that the carrying capacity of the EV truck allows.

The second application considers situations where the depot lacks sufficient charging systems. If ICE delivery vehicles are to be replaced by EV trucks, it is possible that there will not be enough electric power in terms of the number of chargers or the contracted level of electrical load. With HDSL-EV, however, it is possible for delivery operations to use third-party charging systems to make up for this electric power shortfall, and to do so in a way that keeps increases in the number of vehicles and operating time to a minimum.

4. Conclusions

Along with collecting, storing, and analyzing data on logistics operations, HDSL-EV can also incorporate data from other systems. For example, the collection and exchange of data on things like charging systems (either third-party or on-site), battery usage, and remaining charge in EV trucks allows the choice of charger and charging schedule to be coordinated, helping to avoid unnecessary waiting time, and spreading energy use. Plans for the future include interoperation with EMSs to spread energy usage on the basis of both how much electric power is used in the buildings that host charging systems and how much is used for EV truck charging, leading ultimately to the balancing of energy usage across society as a whole. Hitachi also intends to develop HSDL-EV into an ecosystem for green logistics while seeking to seamlessly bridge the “*kiwa*” (gaps) between different activities, especially in logistics, and make the supply chain as a whole greener and more efficient.

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Item Traceability for Reducing Production Losses and Risk of Defective Product Dispatch

Given the potential for problems on the production line to result in losses due to rejects or equipment downtime as well as the risk of defective products being shipped, how to rapidly identify the causes of problems and determine the scope of their consequences are major concerns in manufacturing. In response, Hitachi has developed an item traceability solution that addresses this challenge by utilizing IoT data to provide a high level of traceability. This article describes the solution and the future potential for factory-wide optimization envisaged by the smart factory maturity model.

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Chihiro Arihara
Ken Ibara
Haruka Miyazawa

1. Introduction

With the manufacturing industry facing increasingly diverse customer needs over recent years along with labor shortages and falling numbers of experienced staff caused by the shrinking of the working-age population, boosting the efficiency of flexible production, improving quality management and assurance, and making the best use of production resources are all key issues for the value chain.

Of these, improving quality management and assurance comes with a variety of requirements that derive from the heightened concern for safety, security, and quality among customers. This is happening against a background in which work is going into improving quality accountability, appealing to safety as a way of enhancing brand image, and gaining certification under strict international standards that help expand sales.

The top priority here is to improve the level of traceability. There are two forms of traceability corresponding to the vertical and horizontal directions respectively. Horizontal traceability refers to data on the goods that are manufactured as they move through the value chain, including raw materials, parts, intermediate goods, and end products, while vertical traceability tracks the operational data captured and held at each step along this chain.

While many manufacturers have installed manufacturing execution systems (MESs) to implement lot-level traceability across their production processes, it is rare for horizontal traceability to extend back to raw materials at suppliers or forward to products after they have been shipped. Similarly with vertical traceability, it is also rare for traceability data to be so fine-grained as to allow product and quality information to be tracked at the level of individual items. In other words, the installation of an MES on its own still does not provide enough data to follow the history of individual products (items), nor to undertake the analyses and actions needed to address the key value chain challenges. The main reason for this is that, while progress may have been made on installing particular systems or automating certain processes, these amount to no more than localized improvements. What is needed, rather, is to establish the infrastructure for integrated management of traceability information.

Implementing this higher level of traceability should be worthwhile not just in terms of accountability, in the sense of being able to track information from raw materials to the shipping of finished goods, but also can be expected to deliver benefits in its own right. These include reducing the costs of repeated inspections or reject products and making it quicker to isolate the causes when problems arise in the production process.

For example, when a problem happens on a production line, a wide variety of production data needs to be collected to determine the cause of the problem, such as details of rejected products, production node data such as filling machine valve numbers, or inspection system data. All of this takes time. This fault-finding work requires a comprehensive understanding of conditions on the line as a whole, a skill that is limited to certain people. Even more time and cost are incurred when problems become more than just operational matters and instead develop into quality issues, with additional inspections being needed along with work to determine the extent of the consequences. Accordingly, workloads, costs, and rejects can be reduced by using horizontal traceability to tie together data from different steps in the production process, and through the transparency provided by maintaining up-to-date vertical traceability in the form of item production and quality inspection history data.

Moreover, the consequences can be very severe if products suspected of being defective get out into the marketplace, and this is another important consideration in the tracking of information not only in the production process, but also from raw materials to shipped products. If products affected by production problems leave the site and get as far as the customer, the result can be a lot of work and heavy costs associated with contacting customers and performing repairs under warranty. Recalls by the automotive and other industries are a prime example, one that is frequently reported in the media. Such incidents can also develop into a major corporate problem, causing a loss of trust by customers and suppliers. Accordingly, by ensuring that traceability allows for a rapid response, significant benefits can be anticipated from keeping such negative consequences to a minimum.

The challenges to implementing the advanced forms of traceability discussed above are the collection of data, the integrated management of traceability information, and the automation of its presentation. This article describes an item traceability solution for factories that offers ways of overcoming these challenges.

Key features of this solution are that it puts in place infrastructure for the collection and integrated management not just of information from all of the plant and equipment in the factory, but also of quality and production data obtained from IT systems, and that it provides functions for viewing and monitoring production and inspection records at the level of individual items. By doing so, the solution helps to improve utilization and lower inspection costs through the early detection of anomalies and rapid fault-finding with item-level analysis of production history.

The technical issues include expansion capabilities and how to present large quantities of different types of traceability data while ensuring it is up-to-date. The ability to scale seamlessly is an essential requirement for expanding the scope of both horizontal traceability (from individual processes to multiple sites) and vertical traceability (types and quantities of data handled).

2. Item Traceability for Item-by-item Tracking of Production and Inspection History

Item traceability provides details of production history and quality results indexed by keys such as product ID or production node, presenting information about production and quality at the level of individual items. It is able to monitor this information in real time and detect anomalies in the production process.

Figure 1 shows a block diagram of an Internet of Things (IoT) factory data platform from Hitachi that combines the Hitachi Digital Solution for Manufacturing/IoT (HDSM/IoT) and Hitachi Digital Supply Chain/IoT (DSC/IoT).

2. 1 Overview of Item Traceability Solution

The item traceability solution is able to identify where problems arise and determine the extent of any consequences at the level of individual items, using trace IDs to link production and quality management information from the plant and provide a view of production nodes, production results, and quality results.

The solution also allows the monitoring intervals, monitoring duration, and number of divergences to be specified for the upper and lower control values set for production and quality measurements in the production process. Through continuous monitoring of this information and by issuing alerts when abnormal trends are evident, this reduces losses due to rejects or equipment downtime as well as the risk of defective product dispatch by identifying equipment problems more quickly and detecting trends before they lead to problems.

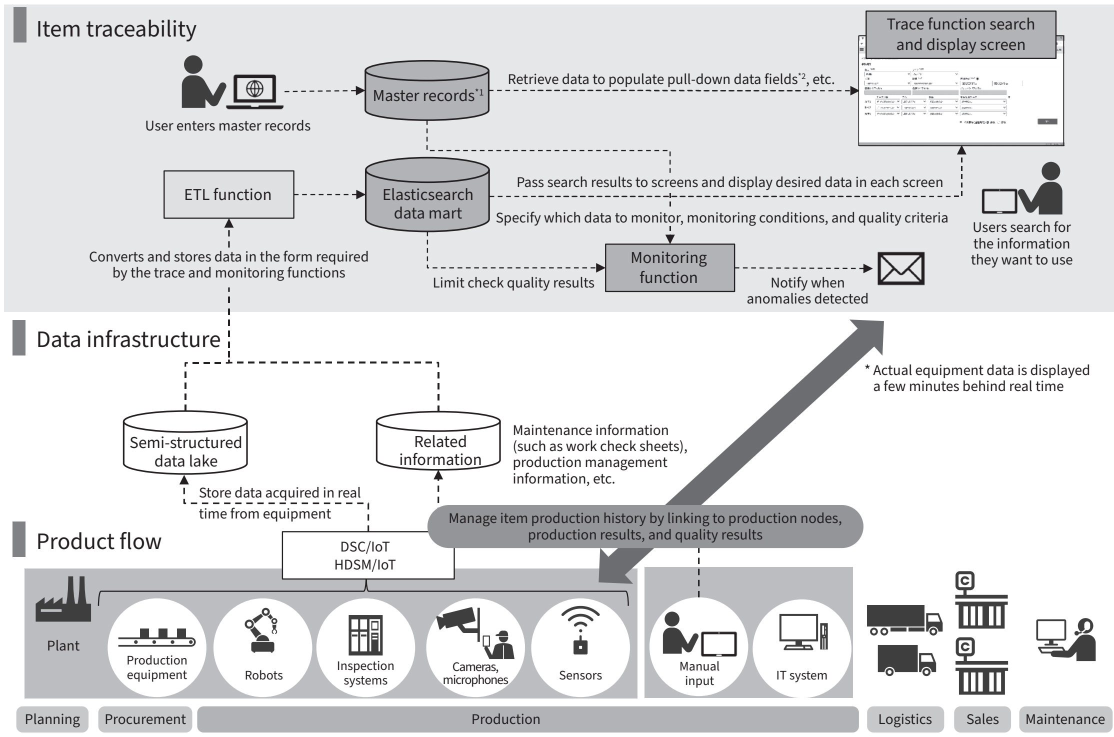
2. 2 Item Traceability Solution Functions

The item traceability solution is made up of an extract, transform, and load (ETL) function, a monitoring function, and a trace function.

The ETL function deals with production and quality management information from the plant that is collected in the primary data mart on the data platform, converting

Figure 1 — Block Diagram of Item Traceability

Item traceability works in tandem with a factory IoT platform for collecting and archiving item-level production and quality information to make production history and quality results available to users.



ETL: extract, transform, load DSC: Hitachi Digital Supply Chain/IoT HDSM: Hitachi Digital Solution for Manufacturing IoT: Internet of Things
*1 Master data for production management held by users
*2 Equipment name, quality management data field, etc.

this information and storing it in the secondary data mart in a form that can be used for item traceability.

The monitoring function monitors production and inspection results collected from the plant in real time and issues alerts if values exceed their thresholds.

The trace function searches the large quantity of item-linked production and inspection results collected from the plant and displays the retrieved data along with the relevant process.

For the real-time collection and archiving of production and quality information at the level of individual items, item traceability uses Elasticsearch[*1] as its data mart. Elasticsearch is a full-text search engine able to index a wide range of content and quickly extract the required data from large datasets. Its application programming interface (API) is based on the fast, scalable, and simple representational state transfer (REST)[*2] architecture and can handle distributed design and both structured and unstructured data.

2. 2. 1 ETL Function

Node-RED[*3] is a visual programming tool (that does not require the writing of code) for defining data processing flows, including data input and output, data operations such as merge and split, and output to the data mart. It is used to create an environment for handling data that is user-led. It can also present large quantities of different types of traceability data that is up-to-date and features extensive expansion capabilities for seamlessly expanding the scope of both horizontal traceability (from individual processes to multiple sites) and vertical traceability (types and quantities of data handled). To help customers reap rapid benefits, Hitachi can augment the solution by supplying templates and other resources for addressing specific customer challenges.

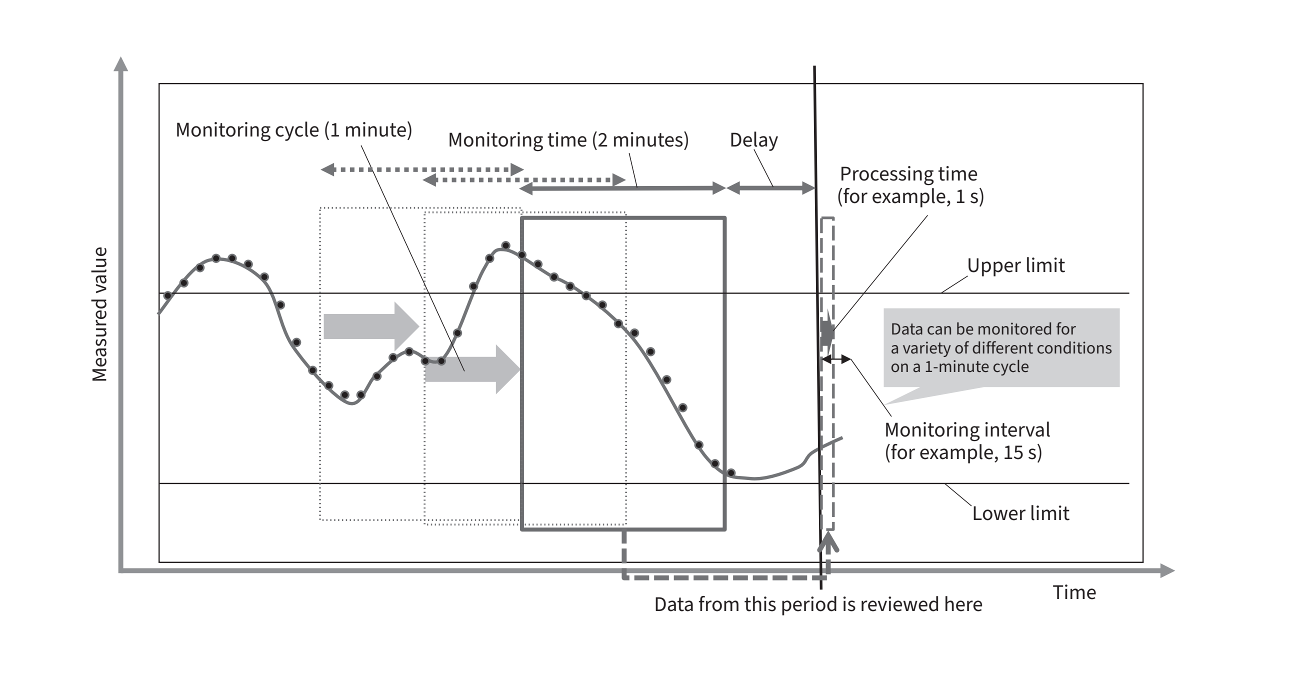
2. 2. 2 Monitoring Function

This function sets the monitoring intervals, monitoring duration, and number of divergences for the upper and lower control values used to monitor for abnormal trends in the production and inspection results from the production process in real time. It also issues alerts when abnormalities are detected.

*1 Elasticsearch is a registered trademark of Elasticsearch BV.
*2 An API developed in accordance with a philosophy and set of design principles for interoperation between different software on distributed systems.
*3 Node-RED is a registered trademark or trademark of JS Foundation in the USA and other countries.

Figure 2 — Overview of How Monitoring Function Works

Monitoring and delay times are specified and the time it takes for data to arrive is taken into consideration ensuring reliable notification when monitoring limits are exceeded.



A monitoring plugin (Watcher) runs in Elasticsearch where it monitors specified indexes. The data loaded into Watcher is compared against the settings stored in the master database and the specified alert action is performed if the required conditions are not satisfied. The function can monitor for abnormal trends as well as anomalies and the alert action can take the form of notifying the relevant people in real time, which is done by using the mail function to send emails to specified addresses. **Figure 2** gives an overview of how this function provides reliable notification of when data exceeds its monitoring limits, taking account of the time it takes for data to arrive.

2. 2. 3 Trace Function

This function searches the production history using product ID and equipment (production node) as keys and presents the results in tabular or graphical form. It retrieves the data from the secondary data mart used to store production and inspection results from the plant, and from master data such as quality management indicators or equipment names and other production management information.

To facilitate use with modification management and quality management, it presents information about modifications or changes that occurred in the production process for a product. One application is for investigating and analyzing the causes of defects, which can be done more quickly by utilizing information about modifications or changes that was acquired automatically from the production process. By doing so, the function can isolate the causes of a problem and accurately determine the extent of the consequences that will arise from it. **Figure 3** shows an example for the item traceability use case where production history

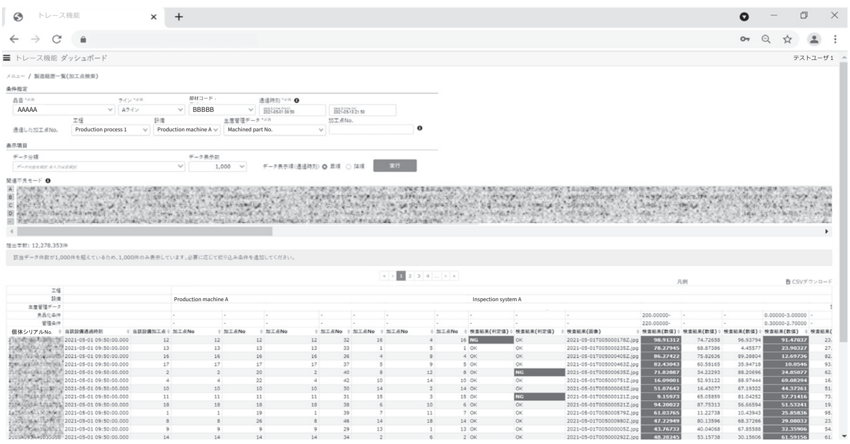


Figure 3 — Example Production History List Displayed by Trace Function

The function makes it easy to identify when abnormal situations occur by tabulating production history based on the production and quality results for products that match the specified search condition specified by parameters such as product ID or production node.

data is tabulated based on the production and quality results for a product that was identified by specifying search keys such as the product ID or production node.

The trace function enables remedial action to be implemented quickly, with products or equipment of concern, such as those associated with alerts from the monitoring function, able to serve as prompts for an investigation into which products were affected by a problem and which items of equipment were responsible, which can be determined using the various functions for searching the production history. The trace function provides the following five functions.

(1) Screen for displaying results distribution by node

Presents statistics for a specified combination of production node and production or quality results.

(2) Product serial number list

Lists the product IDs, case IDs, and other such data that satisfy the specified conditions.

(3) Production history (search by product ID)

For products that match the entered criteria, such as product ID or case ID, this displays production history sorted by production node, production results, or quality results.

(4) Production history (search by production node)

For selected equipment or time periods, this displays the production history for matching products sorted by production node, production results, or quality results.

(5) Time-based production and inspection results

Displays trend graphs of the specified production results or quality results for a specified time period.

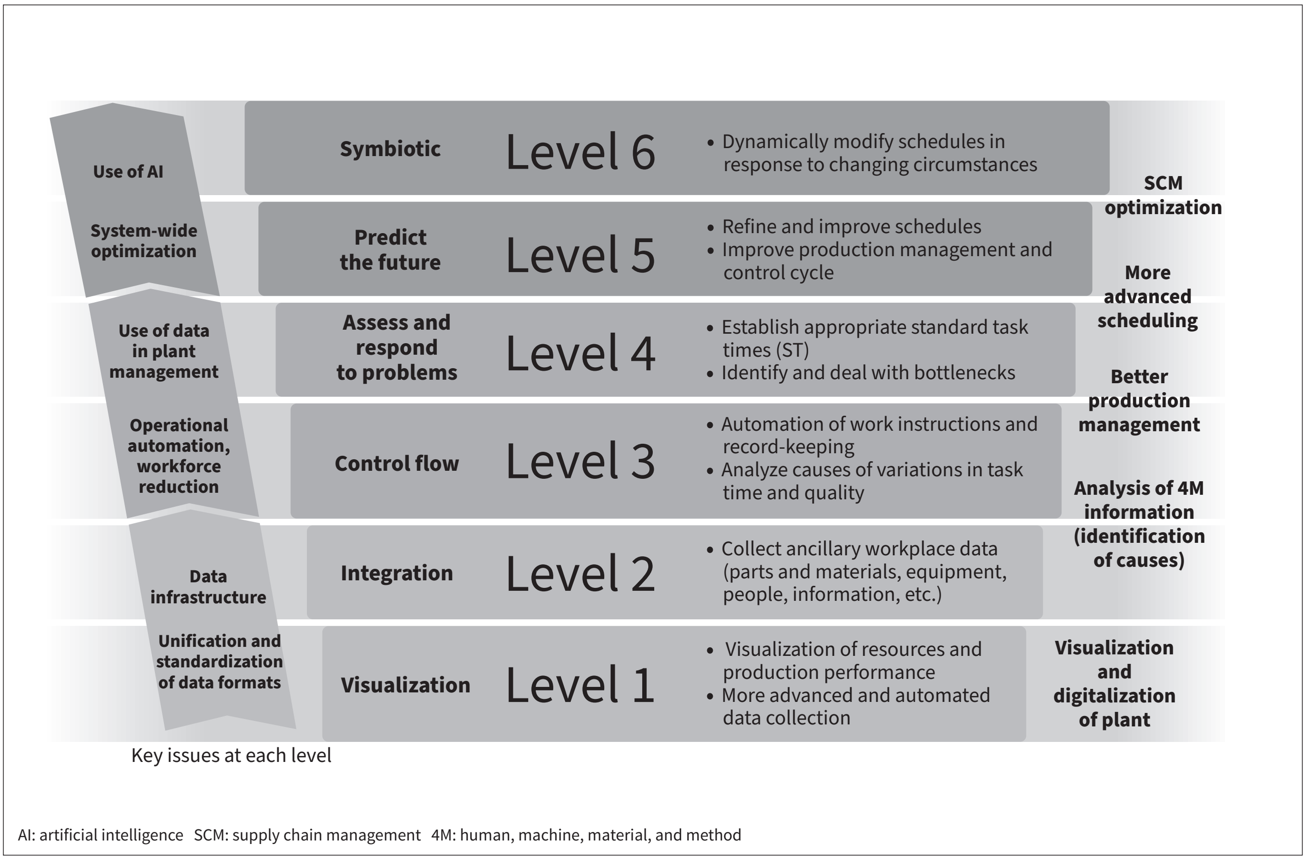
2. 3 Benefits of Item Traceability Solution

Use of the item traceability solution can reduce the workload associated with collecting information and investigating the causes of rejects or equipment issues, tasks that in the past have consumed a large number of work hours. It can also eliminate the need for skills held by specific individuals able to keep track of the overall condition of the production line, reduce the workload for large-scale sampling of items with suspected quality issues, and reduce rejects. Companies that have adopted the solution have achieved significant reductions in rejects and time spent dealing with production problems. The lower level of rejects also delivers environmental value by reducing the amount of product that goes to waste.

Another benefit is that, by detecting abnormal trends, the automatic monitoring function can prevent problems before they occur. In terms of quality assurance, by providing integrated management and archiving of traceability information from the production process, the solution also improves accountability when dealing with quality inquiries from the marketplace or distribution system.

Figure 4 — Hitachi's Smart Factory Maturity Model

Using this model to make the smart factory transition on the basis of scenarios in which the factory moves through progressively higher levels of maturity is important for putting initiatives into practice and generating business benefits.



3. Conclusions

Quality management and quality assurance are among the issues that value chains must address. This article has focused on these in the context of the manufacturing workplace and described an item traceability solution that delivers a high level of traceability.

This solution is a real-world example of the cyber-physical system (CPS) approach to overcoming challenges using cyberspace representations of manufacturing plants, and in which the comprehensive and timely collection, integrated management, and presentation of human, machine, material, and method (4M) data from manufacturing processes is used to provide feedback to the factory floor. It corresponds to level 4 in the smart factory maturity model: "Assess and respond to problems" (see **Figure 4**).

A wide variety of different uses for item-level traceability data can be anticipated in the future. Examples relevant to factories include predictive applications such as simulations for quality prediction, system-wide optimization covering multiple sites or processes, and extending traceability throughout the value chain by linking traceability and supply chain management (SCM) information.

The item traceability solution is but one example from a wide range of manufacturing solutions that combine operational and information technology (OT and IT) built up by Hitachi over many years in its own operations. Along with supplying these solutions to the manufacturing industry, Hitachi also intends to help customers overcome challenges and enhance business value by expanding its product range and accelerating the deployment of total seamless solutions.

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Hitachi's Current Progress and Future Plans for Recycling Industrial Products

As it strives to play its part in creating a circular economy, Hitachi is taking action on overcoming resource problems by seeking to use recycled materials and pursue resource-efficiency and longer product life in its "arteries" (the outbound processes of production and sales), and to utilize reuse, remanufacturing, and other ways of turning used goods back into useful materials in its "veins" (the inbound processes of recovery and recycling). The importance of recycling resources is being brought into increasingly sharp focus by factors such as the acquisition of raw materials becoming more difficult than ever over recent years amid rising geopolitical risks. Recycling represents one way to address resource problems and this article reports on what is being done in this area in terms of both "arteries" and "veins." As Hitachi is looking at the use of digital technology to improve the efficiency of how this recycling is done, the article also presents a vision for the future that forms part of this work.

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1. Introduction

Marine plastics are one of the environmental problems that have attracted attention in recent years. Reports have described how plastic waste such as disposable shopping bags or packaging that has washed into the ocean is causing marine pollution and impacting plants and marine organisms. The problem is recognized as serious enough for it to be raised at forums such as the G7 and G20. While plastic is a vital material for modern society, action needs to be taken to enable coexistence with nature. Moves to address the problem of plastic pollution in Japan include the Osaka Blue Ocean Vision that seeks to reduce new marine pollution to zero and action by government in the form of the enactment of the Plastic Resource Circulation Act. Major changes are also taking place in the area of resources, with materials procurement becoming increasingly difficult for reasons that include the recent rise in geopolitical risk and commodity price inflation along with increased consumption driven by global economic development and population growth (see **Figure 1**)[1]. With the passing in 2022 of the Economic Security Promotion Act, which incorporates measures for securing the supply chain for key materials such as rare earth metals and semiconductors that are essential to manufacturing, resource recycling is becoming increasingly important.

As the main use of plastics at Hitachi is in home appliances, efforts to close the loop through existing home appliance recycling schemes are gradually getting underway. For other products, Hitachi has also started looking at a circular economy model for economically viable resource recycling that is compatible with the nature of the products and how they are used, coming at this from the perspectives of recycling, remanufacturing, rebuilding, and repairing or extending product life (see **Figure 2**).

This article looks at how Hitachi has been developing technologies for recycling since the early days of its involvement in recycling (early 1990s), describing what has been happening in this area right through to its more recent recycling business operations.

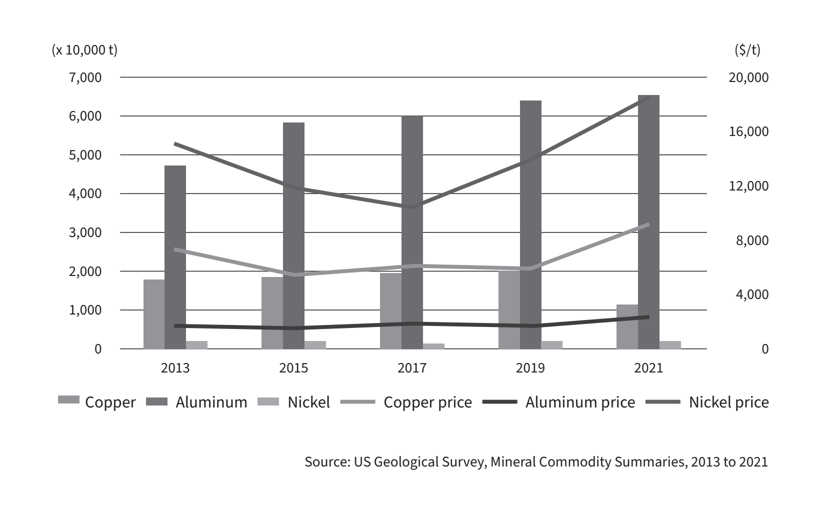


Figure 1 — Production Volume and Price Trends for Key Minerals

The price of copper and aluminum is at historic highs, while that of nickel is at its highest since 2007. While a short-term drop in production happened across the board in 2020 and 2021 due to COVID-19 among other things, this was against a backdrop of years of ongoing increases in the production of mined resources.

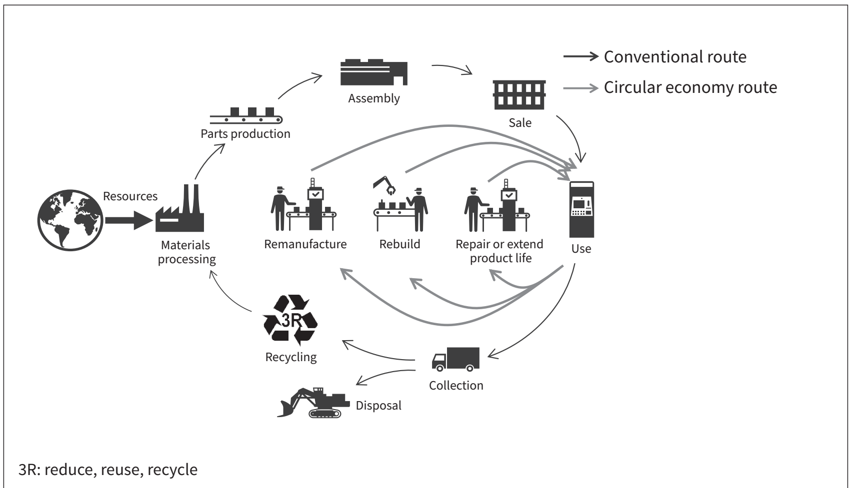


Figure 2 — Circular Economy

The diagram shows other ways in which resource circularity can be achieved in addition to conventional recycling routes.

2. Development of Technology for Home Appliance Recycling

2. 1 Hitachi Process for Fluorocarbon Recovery

The high efficiency with which it can recover fluorocarbon from refrigerator insulation is a feature of the process developed by Hitachi(2). Before applying this process, the coolant fluorocarbon is first extracted and the compressor and other metal parts detached before the remains of the refrigerator are crushed. Crushing efficiently separates the urethane foam stuck to the steel sheet that makes up the outer wall of the refrigerator. A special-purpose wind force separator then selectively sucks up the pieces of urethane from among the crushed fragments and transports them to a pulverizing mill where they are ground down into porous foams (0.3 mm). The gaseous fluorocarbon that degasses from the foams is drawn in from the crusher and pulverizing mill along with air and supplied to an activated carbon adsorption system where the fluorocarbon is recovered by adsorption and desorption. The basic process was patented and it went on to become a de facto standard for home appliance recycling in Japan, including washing machines and air conditioners.

Hitachi subsequently drew on the knowledge it had built up through this work to establish home appliance recycling businesses in Tochigi Prefecture, Hokkaido, and Tokyo in 1999. These companies are described below.

2. 1. 1 Kanto Eco Recycle Co., Ltd.

The operations of Kanto Eco Recycle Co., Ltd. are located in a refrigerator factory at Tochigi Works of Hitachi Global Life Solutions, Inc. (Hitachi GLS), a site primarily dedicated to the development and manufacture of these appliances. Recently, the company has been looking at how to recycle refrigerators with glass doors. **Figure 3** shows a machine for disassembling glass-door refrigerators that was jointly developed by Hitachi and Hitachi GLS(3). The machine uses an insert-and-cut mechanism to automatically separate the glass panel from the front of the door in a way that avoids breaking the glass. Separating and recovering the glass this way is safer and more efficient than doing the same task manually. Prompted by the growing popularity of glass-door refrigerators over recent years, this

Figure 3 — System for Disassembling Glass Refrigerator Doors (Principle of Operation)

Inserting the separating tool from where the glass panel is attached and doing so at exactly the right position minimizes cracking of the glass and safely releases it without breaking.

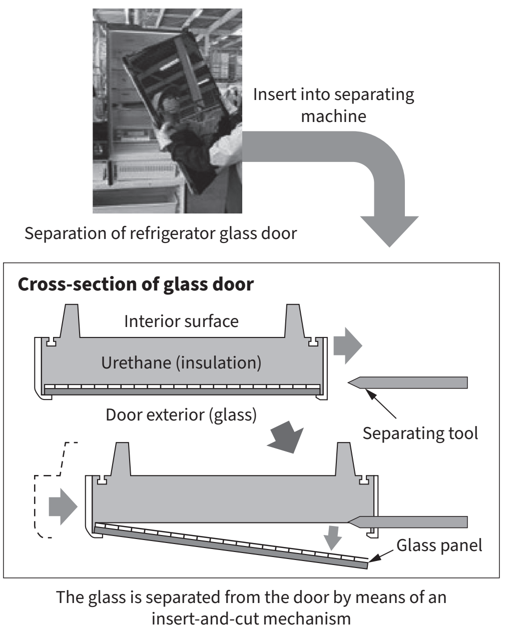
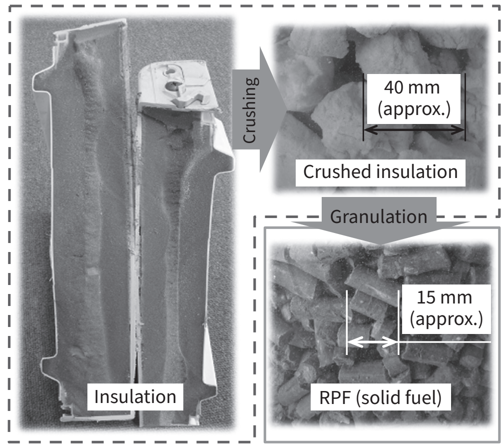


Figure 4 — RPF Made from Refrigerator Insulation (Urethane)

Urethane waste with a density of about 30 kg/m^3 (bulk specific gravity of approximately 0.03 g/cm^3) (indicated by the dotted line in the figure) is turned into valuable solid fuel by compressing it to about 500 kg/m^3 (bulk specific gravity of approximately 0.5 g/cm^3) (indicated by the solid line in the figure).



RPF: refuse-derived paper and plastics densified fuel

work was done in partnership with Hitachi GLS in anticipation of future needs. The machine is currently undergoing further improvements at Kanto Eco Recycle to increase its efficiency.

2. 1. 2 Hokkaido Eco Recycle Systems Co., Ltd.

Hokkaido Eco Recycle Systems Co., Ltd. was established in partnership with Mitsubishi Materials Corporation, a major producer of non-ferrous metals. It is located at an industrial complex in Tomakomai City, Hokkaido. The company was established as part of an eco-town project with support from Hokkaido and the former Ministry of International Trade and Industry. A feature of the operation is that it makes solid fuel by pelletizing urethane that was previously disposed of as waste. This is done in the system for recovering fluorocarbons from insulation by a refuse-derived paper and plastics densified fuel (RPF) machine installed in 2015 that further compresses the urethane fragments (by a factor of more than 20) (see **Figure 4**). As the system also collects the small amounts of freon gas that escape during the compression process, it is among the top performers in the industry in terms of how much fluorocarbon it recovers from the insulation. The site also recycles automated teller machines (ATMs) and other Hitachi IT equipment. The recycling of ATMs covers more than just materials, also including the reuse of parts through an information-sharing arrangement with the manufacturer (Hitachi Channel Solutions, Corporation).

2. 1. 3 Tokyo Eco Recycle Co., Ltd.

Tokyo Eco Recycle Co., Ltd. is located in Koto City, Tokyo. It was established in partnership with Ariake Kougyo Co., Ltd., a company at the forefront of a model project for recycling fluorocarbon coolant from refrigerators being run at the time by the Association for Electric Home Appliances.

A feature of its plant is that it draws on work done by a demonstration project run by the New Energy and Industrial Technology Development Organization (NEDO) and other agencies from 1992, and by a model project for home appliance recycling run by the Association for Electric Home Appliances and others from 1995(4). The company also uses technology jointly developed by Hitachi to recover the rare earth metals contained in air conditioners, enabling the waste-free supply of these materials to producers such as Hitachi Metals, Ltd.(5) It recycles a range of devices, including medical equipment and smartphones, from other vendors as well as from Hitachi. For smartphones, the company is working with Hitachi on the joint development of equipment for automatically detaching the liquid crystal display (LCD) screen prior to recycling and the subsequent safe and efficient removal of the exposed battery.

While these three companies each have their own distinctive characteristics, the philosophy they all have in common is one of embarking on recycling based on a circular economy model in which materials are recycled from "veins" (used products) to "arteries" (new products). In this case, this involves supplying plastic materials to Hitachi GLS via plastics companies such as Hitachi Appliances Techno Service, Ltd.

3. Method for Rebuilding Air Compressors

Hitachi Industrial Equipment Systems Co., Ltd. is working to implement recycling in the industrial equipment sector. Carrying on the tradition of electric motor manufacturing, the business in which Hitachi got its start, the company manufactures products such as air compressors, pumps, and transformers, also supplying a wide range of machinery, services, and solutions for applications that extend from industry to infrastructure. The rebuilding of air compressors was one such initiative launched as part of the service business. **Figure 5** shows the internal structure of an air compressor.

The heart of an air compressor is the air end (the part where the actual compression takes place). While these are designed for durability to enable 24-hour/365-day operation, friction and other forms of wear on certain parts means that regular maintenance is needed. Proper maintenance of the air end prevents operational problems. The difficulty, however, is that onsite maintenance work can interfere with plant productivity. **Figure 6** shows how this maintenance work is done, including disassembly, cleaning, and the recovery of worn parts.

The plant downtime associated with a rebuild can be significantly reduced by swapping the air end in the plant with another rebuilt air end of the same model and type.

This is an example of rebuilding based on the circular economy model in which parts are recovered to minimize the use of raw materials. This reduction in new material use decreases both costs and carbon dioxide (CO_2) emissions (from 63% to 77% and 60% to 64% respectively, compared to a new compressor).

The air end rebuilding business was launched in 1985. With the recent prominence of environment, social, and governance (ESG) business practices, however, the proportion of domestic air end replacements that use rebuilt units now exceeds 95%.

This work also extends overseas. Hitachi Industrial Equipment Systems operates an integrated business for the manufacture and sale of air compressors, with partnerships for combining information and operational technology (IT and OT) that include Sullair US Purchaser, Inc., a company acquired by Hitachi in 2017. The compressor product range supplied by Sullair US Purchaser is made up of portable models for outdoor use, such as at mines where no electric power supply is available, with most being suitable for remanufacturing under the circular economy model. As these portable compressors are used at outdoor locations with no power supply, they are equipped with an engine. The engine, air end, and other major components are overhauled in a process that includes disassembly and cleaning and the recovered compressors are then sold as remanufactured products. Sales of these remanufactured products exceeded those of new models, accounting for 59% of sales of the company's main product lines in 2020 and 2021. Hitachi Industrial Equipment Systems recognizes the importance of resource circularity both in Japan and overseas and is looking at extending the circular economy model to other products.

Hitachi Industrial Equipment Systems also offers extensive life cycle management (LCM) services targeted at improving the operation and maintenance of the plant and equipment[6]. Utilizing cloud-based management and an extensive range of maintenance options, these services make the maintenance of industrial equipment simpler and more efficient while also reducing labor requirements. These LCM services are now being made available for air compressors, helping to prevent compressor faults by letting customers know when it is best to perform repairs once they are in use. This reduces problems cause by poor maintenance. Cloud monitoring can also significantly reduce downtime by providing early warning of problems so that timely action can be taken.

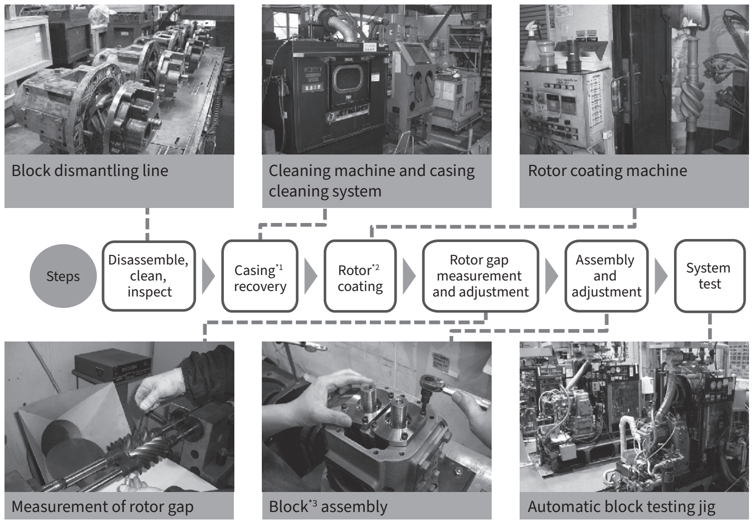
* A device that draws in external air and compresses it by means of a screw

Figure 5 — Internal Structure of Air Compressor (Example)

Compressed air is produced by the main motor and air end working together. Efficiency can be improved by using an inverter to control the motor speed.

Figure 6 — Air End Rebuild Process

The units are refurbished in a process that includes disassembly and cleaning, after which performance testing is performed.



*1 Air end housing
*2 Compressor rotor
*3 Rotor block

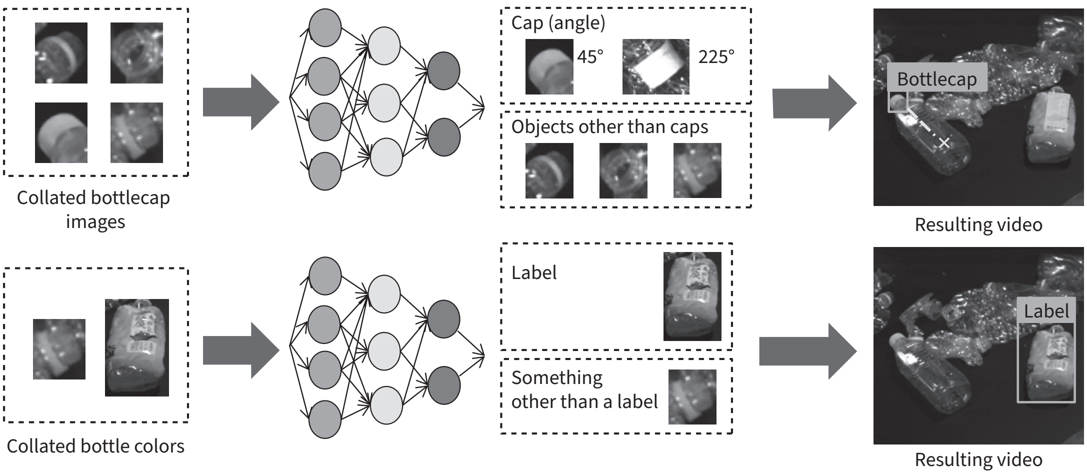
Hitachi believes that expanding these LCM services will play a part in the circular economy model of repairing products and extending their life.

4. Future Outlook

Hitachi is taking action to recycle waste plastic in areas outside home appliances. This includes supplying technologies such as image recognition together with a degree of automation to the sorting lines, often run by local government, that process used polyethylene terephthalate (PET) plastic bottles. While normal practice with PET bottles is to crush them as-is and recycle the materials, the frequent presence of other materials such as polypropylene bottlecaps and polystyrene labels means that recyclers typically separate these beforehand by means of a picking process. The automatic sorting machine for used PET bottles automates this sequence of steps, with the system having been developed by Hitachi Industrial Equipment Systems using image recognition from Hitachi Solutions, Ltd. The latter uses deep learning to recognize bottlecaps and a technique based on the hue saturation value (HSV) color scale to determine whether bottles have a label. The artificial intelligence (AI) models used for bottlecap and label recognition are each implemented as separate processes so as to speed up processing by running them in parallel (see **Figure 7**). Recognition operates in tandem with a picking process,

Figure 7 — Image Recognition Using Deep Learning and HSV Color Scale

The HSV color scale technique represents color in terms of three parameters: hue, saturation, and value (brightness). The HSV color scale is more closely aligned with how humans perceive color.



the automation of which requires special knowhow relating to high-speed object tracking and how to grasp irregular objects. So equipped, the system is able to match the judgement and sorting abilities of a human worker, measuring the total surface area of PET bottles and using this to calculate their area centroid, and then utilizing the pulses output by the encoder (a device for detecting position, direction, and orientation) on the belt conveyor to provide the XY coordinates required for robot movement control.

These techniques are seen as a way to remove foreign material from the continuous stream of crushed fragments and Hitachi is looking at utilizing them in applications such as home appliance recycling facilities struggling with labor shortages.

5. Conclusions

An urgent task for the world is to make the transition away from the era of heavy resource consumption that characterized Society 3.0 and Society 4.0 and toward Society 5.0 and a low-carbon circular economy that makes heavy use of data.

The use of digital technology to track the one-way process whereby products are manufactured from raw materials before being sold, consumed, and ultimately disposed of can shed light on where terrestrial resources (including raw materials and parts) are currently located. While showing where these resources are to be found will bring us closer to a modern circular economy, no single company can overcome this challenge on its own and there is an important role to be played also by the "vein" industries that return those resources to the "arteries."

In the future, Hitachi intends to continue bringing digital and green technologies together as it seeks to achieve "Partnerships for the Goals," Goal 17 of the Sustainable Development Goals (SDGs).

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