Development of Cutting-edge Technologies for Next-generation Logistics Services

The logistics industry is facing a period of major change as the operational practices of the past approach the limit of their ability to deal with societal changes in purchasing behavior and demographics over recent years. Hitachi is engaged in the implementation of next-generation logistics solutions that satisfy diverse needs in order to enhance the value of its customers' businesses. This article describes five initiatives led by Hitachi's Research & Development Group that it expects to see used in the logistics sector, namely logistics optimization, control of warehouse robots, transportation-environment monitoring, use of sensors to measure worker activities, and co-creation with customers to identify value and create services.

Shuji Soga, Dr. Eng.
Takahiro Ogura
Takashi Watanabe
Akiko Sato
Yusuke Yatabe
Miho Kobayashi

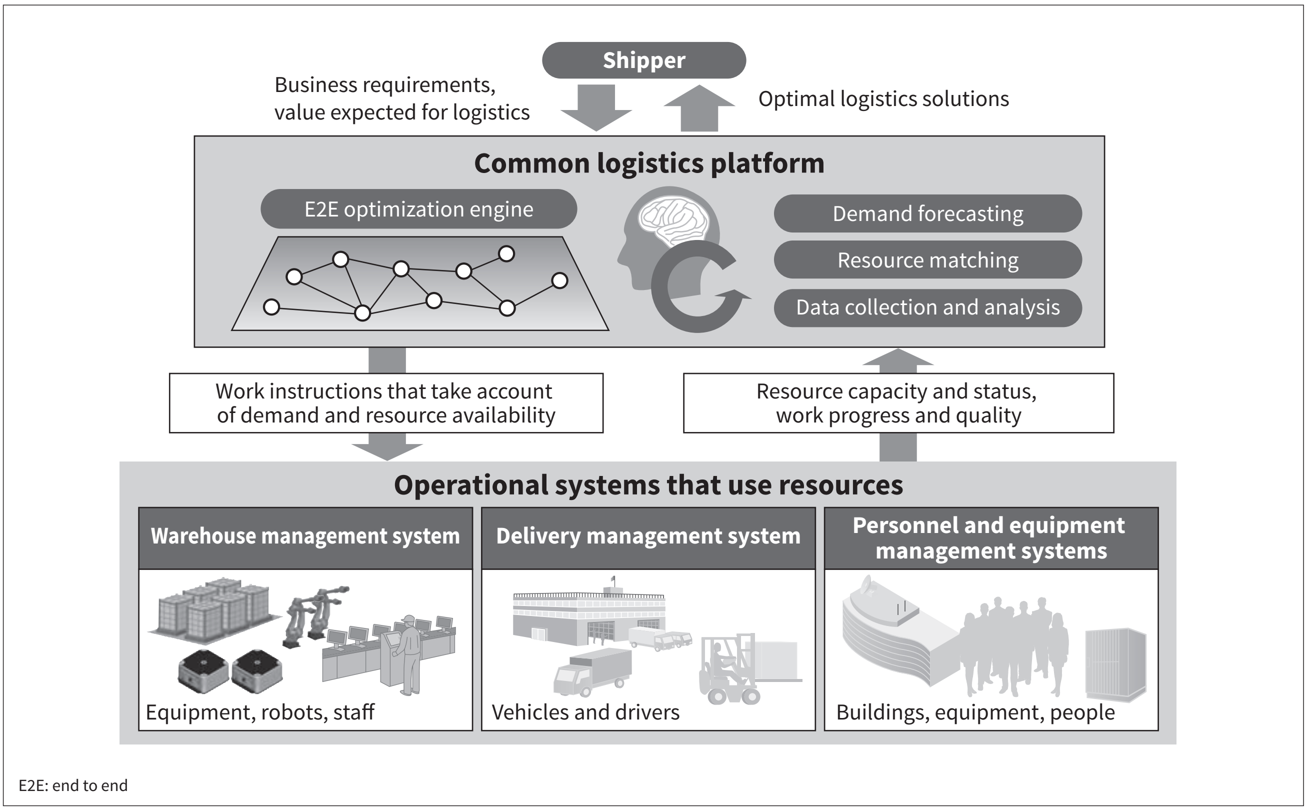
1. Introduction

While factors such as the growth of electronic commerce (e-commerce) have caused the logistics industry to experience increasingly frequent deliveries of small packages, other factors such as labor shortages and the shift to services with higher added value have detracted from the profitability of labor-intensive operations, to the extent that the industry is facing a crisis in its ability to sustain its role in the social infrastructure. In response, rapid progress is being made on new initiatives such as resource sharing or the use of artificial intelligence (AI) and robotics to reduce manual work.

It is anticipated that logistics in the future will establish and operate optimal practices whereby a wide variety of resources are connected together on a common logistics platform, as shown in **Figure 1**, and the platform's optimization engine is used to harmonize the use of designated resources based on the shippers' requirements. Once this is achieved, it will be possible to optimize operations so as to maximize the value of the logistics requirements of organizations that dispatch goods ("shippers"), including quality and speed, by determining the capabilities, status, work progress, and quality of a wide variety of resources and using an end-to-end (E2E) optimization engine to handle task allocation and work instructions based on demand and resource availability.

This article describes five technologies being developed by Hitachi's Research & Development Group that are either now or expected to be deployed for logistics, the aim being to create next-generation logistics solutions.

Figure 1 — Next-generation Logistics Solutions
Hitachi collects a variety of relevant data on a common logistics platform and combines available resources to adaptively configure and deliver logistics solutions in response to the requirements of the shipper.



2. Techniques for Logistics Optimization

The following three requirements apply to the efficient delivery of goods when and where customers want them.
(1) Optimization of logistics networks, including warehouse location and modes of transportation
(2) Optimization of resource allocation, including the quantities of stocks held in warehouses, receiving and shipping staff, and trucks
(3) Optimization of delivery instructions that specify efficient routing and sequencing based on the size and number of trucks available and driver constraints.

Hitachi is developing these technologies for supporting and automating optimal decision making about these requirements over long, medium, and short ranges (see **Figure 2**).

For the optimization of logistics networks (1), Hitachi is developing and supplying solutions for techniques that use mathematical programming to automatically determine warehouse locations and modes of transportation to minimize total cost while still meeting the deadline set by the customer, taking account of factors such as customs procedures that have been complicated by free trade agreements (FTAs); currency exchange; labor costs that vary by location; the time required for delivery, which varies depending on the means of transportation used; and the cost of building and reorganizing warehouses[1].

For the optimization of resource allocation (2), Hitachi has developed automated solutions for optimal inventory operations that integrate with E2E supply chains made up of tens of thousands of stock keeping units (SKUs) and thousands of sites, and that handle inventory management through links to the warehouse management systems (WMS) and handle enterprise resource planning (ERP) at the various warehouses that form part of the supply chain. This inventory management has become more difficult due to changes in consumer purchasing behavior. To implement these, Hitachi has developed a technique that represents actual objects, caches, and the inventory operations logic that controls their flow in cyberspace, and uses simulation, parallel processing, and AI to perform high-speed automatic learning for the

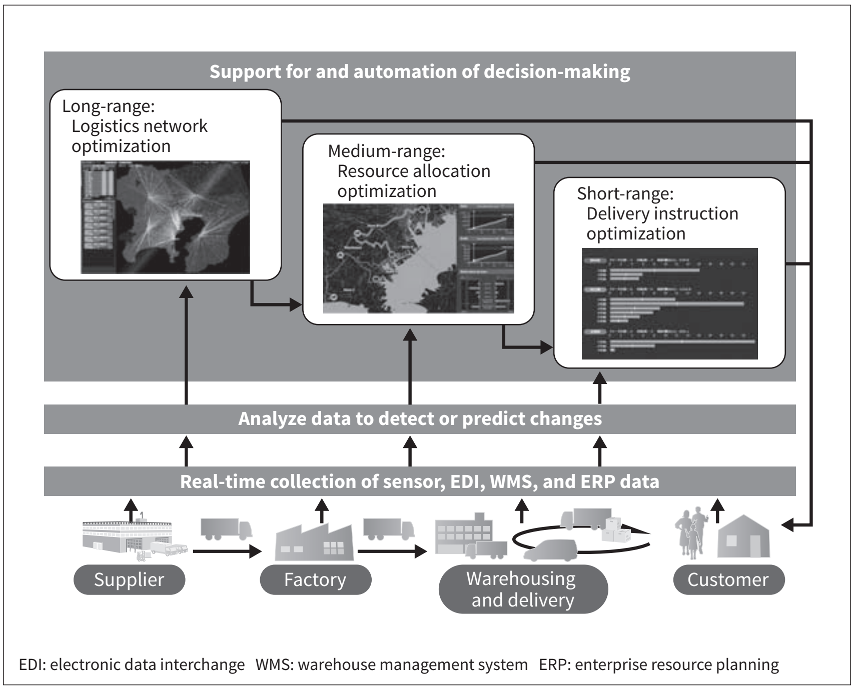


Figure 2 — Different Approaches to Logistics Optimization for Different Timespans

Hitachi has developed technologies for automating operations that support long-, medium-, and short-range decision-making by collecting and using supply chain data. The logistics network optimization and delivery instruction optimization examples shown in the figure are tools that were developed through joint research with Hitachi Transport System, Ltd.

optimal logic and combination of parameters for each set of potential future supply and demand conditions. Moreover, for daily inventory operations, a technique has been developed that uses an AI to identify which of the supply and demand conditions is the closest match for which learning has been performed. Then, it updates the restocking and allocation logic for the systems at each site, and executes it automatically. This solution is scheduled to be rolled out during FY2018.

For the optimization of delivery instructions (3), it has developed a technique that uses mathematical programming to automatically determine the delivery route and sequence that minimizes driver working time and transportation costs, considering factors such as truck capacity, when the destination can receive the goods, traffic congestion, and driving constraints such as one-way roads. Work is also progressing on the development of a technique for optimal real-time delivery instructions that can adapt to ever-changing levels of congestion as well as requests for same-day delivery or re-delivery, requirements that are increasing rapidly due to e-commerce.

3. Autonomous Robots for Handling Individual Stock Items

Automation at logistics centers in recent years has involved automated warehouse systems connected by conveyors or box-level automation using sorters. Unfortunately, the rapid increase in the handling of individual stock items that has come with the growth of e-commerce has led to a significant increase in workload. While attempts are currently being made to automate this labor-intensive handling of individual stock items, both the item recognition and handling needed for automation pose a problem because of the diversity in the shape and appearance of individual items compared to boxes.

In the case of recognition, greater use is being made of red/green/blue/depth (RGBD) cameras that provide depth as well as the conventional color information. The use of RGBD cameras makes it possible to determine the shape as well as the appearance of an item from a particular direction. Comparing this information with three-dimensional (3D) data stored for items in the system can both identify if an item is the correct one and determine its relative position in the space in which it has been placed.

Once an item is recognized, the next steps are to use the above 3D data to calculate the contact points that a robot can use to pick the item up, and to use the relative position to pick up the item without colliding with any nearby obstacles. These contact points vary depending on factors such as whether the robot hand uses suction or a finger-grip mechanism. Moreover, now that it has become possible for a robot

Figure 3 — Use of Two-armed Robot for Picking of Oblong Objects
The robot uses two arms to pick up an oblong object, with the right arm supporting the box from below while the left arm attaches itself by suction to the side of the box. Picking techniques like these for distribution centers are being developed through joint research with Hitachi Transport System, Ltd.

to learn this for itself using techniques such as AI reinforcement learning, it is anticipated that there will no longer be any need to provide the robot with the correct information by manual instruction.

As no robot hand currently exists that is able to pick up an arbitrarily shaped object on its own, it is necessary to use many different types of hands, or else wait for new hands to be developed. It is possible, however, to handle diverse objects by using a two-armed robot that can coordinate the operation of its left and right arms in a way that mimics the action of a human being (see **Figure 3**). This means that robots can already be used in a wide variety of situations. One example is the work at the Center for Technology Innovation – Systems Engineering on developing a two-armed picking robot for use in distribution centers that works in tandem with the Racrew automatic guided vehicle[(2)].

4. Transportation Environment Monitoring

Southeast Asian nations are experiencing growth in logistics volumes due to increasing populations and rising living standards resulting from economic growth. This includes attention being focused on the distribution of frozen and chilled foods due to the spread of modern grocery and convenience stores and an emerging food service industry. Unfortunately, this has also been accompanied by issues with delivery delays and the spoilage or degradation of cargo caused by problems such as traffic congestion, poor road infrastructure, and a lack of low-temperature and temperature-controlled facilities.

With the aim of overcoming these challenges, Hitachi Asia Ltd. is working on the research and development of technology for transportation environment monitoring and identifying the factors that influence quality. In Southeast Asian nations, not only do urban areas routinely experience heavy traffic congestion, a cause of late deliveries, but also the roads outside cities are in a poor state, a cause of damage to goods due to vehicle vibration. This makes it necessary to consider how to maintain freight quality when seeking to shorten delivery times. In response, Hitachi Asia Ltd. has developed a technique for collecting and analyzing information about the transportation environment from sensors fitted to delivery trucks. This technique can use global positioning system (GPS) information to determine the truck location and speed, and accelerometers to determine the condition of the freight in the truck. Through the highly accurate prediction of bottlenecks that cause delivery delays, damage to freight, or quality degradation, the technique can also identify the best scheduling and routing that does not compromise quality.

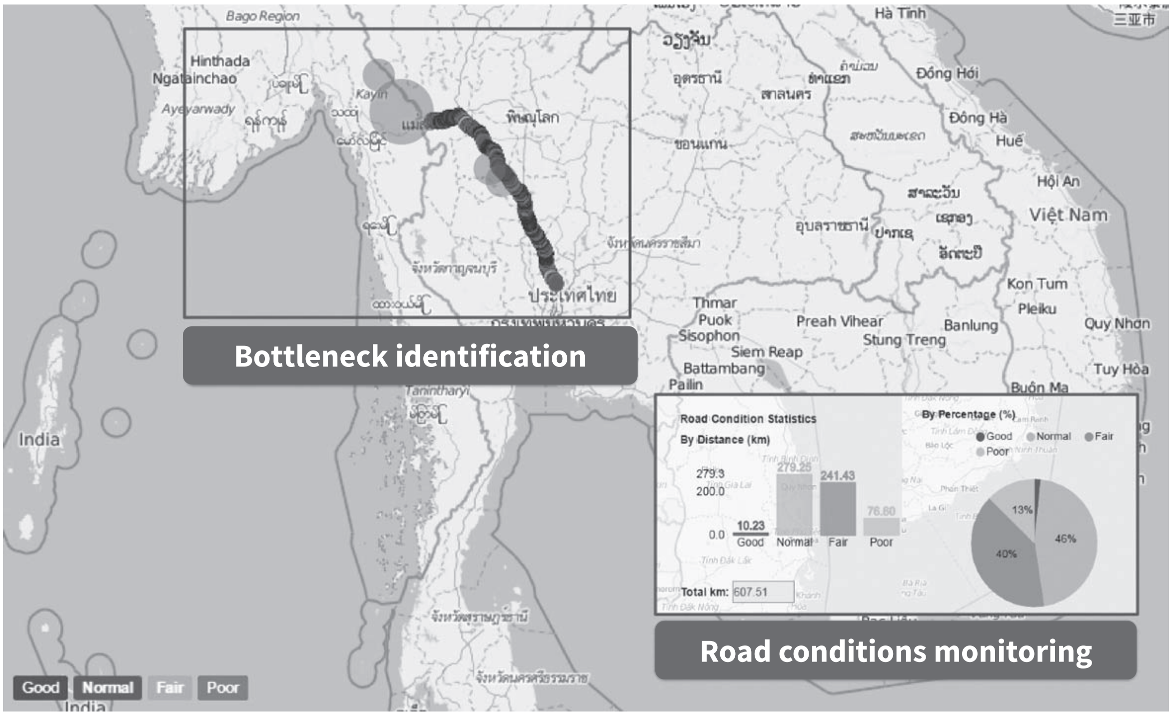
Hitachi Asia Ltd. conducted a demonstration experiment that involved fitting GPS and vibration sensors to actual delivery trucks and using a transportation environment monitoring system to monitor road conditions and identify bottlenecks (see **Figure 4**). Using these results, it was possible to formulate delivery plans that reduced late deliveries and quality degradation. In the future, Hitachi Asia Ltd. intends to continue with the research and development of transportation environment monitoring for frozen and chilled food, including temperature management, in order to prevent quality degradation and reduce the amount of food that goes to waste.

5. Technologies for Sensing and Analyzing Worker Activities

While logistics centers are increasingly using automation, many tasks continue to be performed manually, as in the past. To optimize warehouse work through a flexible mix of different resources (both people and equipment), the future is expected to require

Figure 4 — Transportation Environment Monitoring System

The system monitors the transportation environment by analyzing data collected from sensors on delivery trucks to identify bottlenecks that cause delivery delays or damage to products.



techniques for the efficient acquisition of digital data on worker activities and capabilities, things that were managed using analog techniques in the past. The following describes two examples from other sectors of related research into such techniques for the sensing and analysis of worker activities. The first is a technique for analyzing working practices in detail by having workers wear sensors. The second is a technique for using cameras mounted in the workplace to analyze worker activities.

The first example involves a system developed to provide work assistance and eliminate human error in the industrial sector that works by giving workers wearable devices to collect data about their activities that is then analyzed using AI[3]. The system tracks worker activity in real time, combining a technique

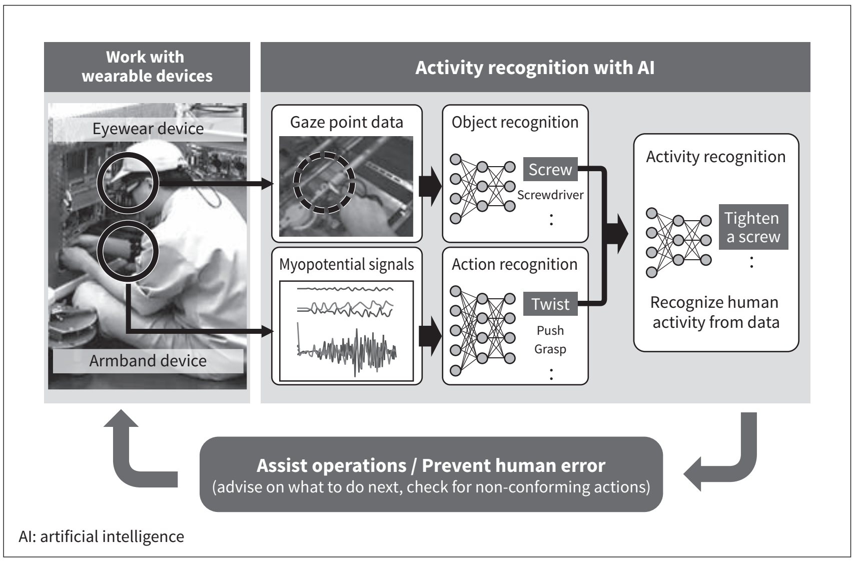


Figure 5 — Example of Analyzing the Activity of a Worker Wearing Sensors

Operation assistance is provided by having workers wear eyewear and armband devices, and having an AI recognize in real time the manual activities being performed. This research is being undertaken jointly with Deutsches Forschungszentrum für Künstliche Intelligenz (DFKI), a German AI research center.

that uses eye-tracking glasses to identify what the worker is looking at, and another that uses arm bands to determine the worker's physical movements (see **Figure 5**). This succeeded in identifying working practices from activity data by first using deep learning to train an AI about the tools and parts used in the workplace and the actions that would be likely to occur.

Figure 6 shows a platform that incorporates an example of the second technique. This integrated physical security platform supports the centralized collection and archiving of data from various sources, including Internet of Things (IoT) sensor data and physical security systems such as surveillance cameras and the access management system, and can analyze it using AI and other analytics software(4). This analytics software includes a technique for recognizing reasonably complex situations using only the live feed from existing surveillance cameras; a high-speed search technique for finding particular individuals in large amounts of surveillance video based on markers such as their face, clothing, items carried, and route traveled; and a technique for detecting particular types of behavior in video (such as running, squatting, or moving erratically)(5).

In the future, Hitachi intends to develop solutions for improving work and resolving management issues by utilizing these techniques in the logistics workplace to analyze the work environment and the movements, actions, and condition of staff or objects (such as equipment or inventory).

6. Co-creation of Next-generation Logistics Services Using NEXPERIENCE

As consumer purchasing behaviors grow more diverse, so too do the forms of value expected for logistics when businesses provide services to consumers, and the means they use to do so. This means that logistics operators require an accurate appreciation of the needs of consumers and service providers, and need to use a variety of technologies and resources to implement logistics in ways that enhance service value.

At its Global Center for Social Innovation, Hitachi has established its NEXPERIENCE(6) methodology for co-creation with customers. The objectives of this methodology are to work with customers to seek out and identify business opportunities, develop new business concepts, and explore business models. Hitachi is utilizing it in a wide variety of business sectors, logistics among them. NEXPERIENCE systematizes the methods and tools for use in each step of the business development process, which it defines as discovering business opportunities, uncovering on-site issues, analyzing management challenges, creating service ideas, defining business processes, and simulating business value. Using these methods and tools enables the strong promotion of a co-creation project from launch to producing a business proposal. Workshops that use the NEXPERIENCE methodology to generate business ideas with customers take a multifaceted approach to encouraging people to come

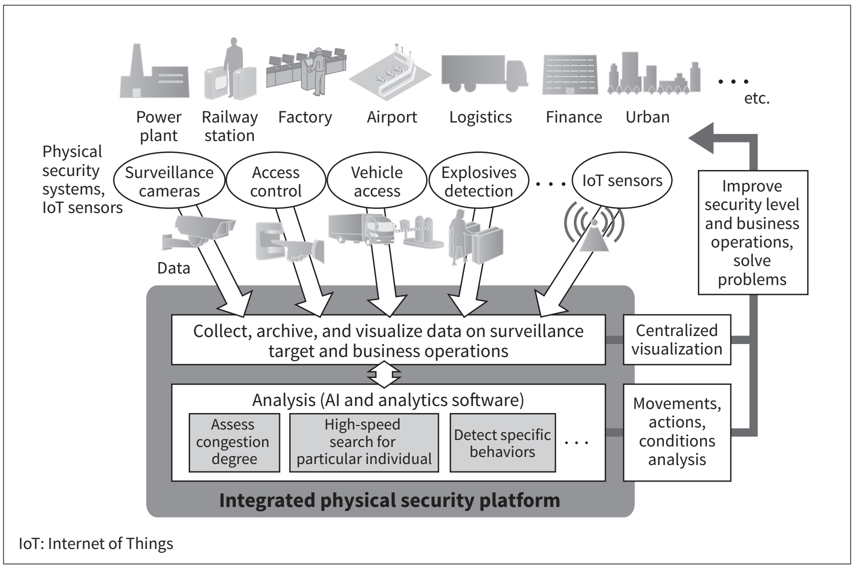


Figure 6 — Example of Using Cameras Mounted in Workplace to Analyze Worker Activity

The aim is to improve work and resolve management issues by collecting video data from surveillance cameras and using analysis software to determine the movements, actions, and conditions of people or equipment. This technology is being developed jointly with Hitachi Industry & Control Solutions, Ltd., Hitachi Kokusai Electric Inc., and Hitachi Systems, Ltd.

up with innovations, with participation by experts, designers, and researchers from a variety of business domains. It also encourages service differentiation and faster rollout by considering the use of Hitachi technologies to implement business ideas.

Past work in the field of logistics has included using workshops to consider how next-generation goods will be purchased and delivered, and simulating the business value of supply chain optimizations. The Global Center for Social Innovation will continue to work with the Center for Technology Innovation and business units to accelerate the co-creation of new services with customers using NEXPERIENCE in a variety of different sectors, including logistics.

7. Conclusions

This article has described technologies from the Research & Development Group that are expected to be deployed in next-generation logistics solutions.

It is anticipated that the logistics domain will give rise to a steady stream of innovative services and operating models in the future. By developing technologies that collect and utilize information in many different forms, Hitachi will continue contributing to the implementation of solutions that maximize logistics value by responding flexibly to changes in society.

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Authors

Shuji Soga, Dr. Eng.
Customer Co-Creation Project, Global Center for Social Innovation – Tokyo, Research & Development Group, Hitachi, Ltd. *Current work and research:* Research of new business creation over the full value chain. *Society memberships*: The Institute of Electrical Engineers of Japan (IEEJ). *Certifications:* Certified Logistics Master and International Logistics Master.

Takahiro Ogura
System Productivity Research Department, Center for Technology Innovation – Production Engineering, Research & Development Group, Hitachi, Ltd. *Current work and research:* Research and development of logistics and supply chain management solutions utilizing mathematical programming and simulation technology. *Society memberships*: The Operations Research Society of Japan (ORSJ) and the Japan Industrial Management Association (JIMA).

Takashi Watanabe
Intelligent Information Research Department, Center for Technology Innovation – Systems Engineering, Research & Development Group, Hitachi, Ltd. *Current work and research:* Development of technologies for logistics warehouse management optimization and automation. *Society memberships*: The Institute of Electronics, Information and Communication Engineers (IEICE) and IEEE.

Akiko Sato
Research & Development Center, Hitachi Asia Ltd. *Current work and research:* Research and development of transportation and logistics systems and cold chain management. *Society memberships*: The Information Processing Society of Japan (IPSJ).

Yusuke Yatabe
Media Systems Research Department, Center for Technology Innovation – Systems Engineering, Research & Development Group, Hitachi, Ltd. *Current work and research:* Research and development of worker support solutions with multi-modal sensing and AI analytics. *Society memberships*: The Institute of Image Information and Television Engineers (ITE) and the IPSJ.

Miho Kobayashi
Customer Co-Creation Project, Global Center for Social Innovation – Tokyo, Research & Development Group, Hitachi, Ltd. *Current work and research:* Development of an interactive system utilizing visualization and user-interface techniques for logistics and supply chain management. *Society memberships*: The Visualization Society of Japan (VSJ).