Implementation and Future Plans for Global IoT Maintenance System

There is an accelerating global trend, especially in industry, for improving efficiency through AI and big data analysis that utilizes the Internet of Things, and data collected via the Internet of Things, to create new services and revolutionize businesses. As Hitachi continues the global expansion of its elevator and escalator business, it has become an urgent task to rebuild its high-quality maintenance and service infrastructure, which utilizes remote monitoring technology cultivated in Japan since 1985 and the latest Lumada Internet of Things platform. This article introduces a global Internet of Things maintenance system that incorporates a common international system for elevator and escalator remote monitoring, and a system for rapid recovery from faults that utilizes AI technology, and describes the future outlook for these systems.

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1. Introduction: Trends for Adoption of IoT

In industry, the transformation of businesses that combines the collection of a wide range of data via the Internet of Things (IoT) with technologies for utilizing data, such as artificial intelligence (AI) and big data, etc. is progressing rapidly. This transformation began with maintenance in fields such as aircraft and automobiles, and now successful implementations are starting to develop at production sites.

In overseas elevator and escalator maintenance businesses, as safety requirements become stricter, and the standardization and mandating of operations such as maintaining records from the planning stage of maintenance work, and disclosing the operation statuses of equipment, every company is proactively pursuing the adoption of IoT for remote monitoring, and information and communication technology (ICT) for maintenance work. In Europe, the remote monitoring of elevators and escalators has only been adopted by about 5%[1] of operators up to now. However, operators are embracing this IoT trend and this practice is now expected to spread rapidly. The utilization of data in maintenance businesses has enabled a progression from the conventional time based maintenance, to condition based maintenance, and then to predictive maintenance. This has improved safety and improved convenience by minimizing downtime. The level of sophistication in the added value provided has also been improved, such as by enabling rapid recovery using AI in the unlikely event of a failure, and by enabling the use of dashboards to visualize performance contracts (see **Table 1**).

2. Evolution and Internationalization of Elevator and Escalator Maintenance Systems

Hitachi has developed and deployed its remote intelligent diagnostic system for elevators and escalators in Japan faster than its overseas competitors. The initial goal was to improve efficiency, which then evolved

Table 1 — IoT and IT Utilization in the Elevator and Escalator Industry Overseas

Each company is rapidly developing IT and the Internet of Things (IoT) in partnership with IT businesses.

	Company A	Company B	Company C	Company D
Increased efficiency (remote monitoring)	Remote monitoring (IoT devices) • Failure detection • Operational data collection	Remote monitoring (IoT devices) • Failure detection • Operational data collection	Remote monitoring (IoT devices) • Failure detection • Operational data collection • Wearable device applications	Remote monitoring (IoT devices) • Failure detection • Operational data collection
Improved quality (failure recovery)	Work instructions and results management via engineer smartphones	Work instructions and results management via engineer smartphones	Predictive maintenance via machine learning based on remote monitoring data	AI fieldwork support (failure recovery support via AI)
Added value (dashboard)	Information provision service Contracts, invoices, number of calls, number of responses, operational information, etc.	Equipment operational information, etc. Digital signage providing advertisements, news, etc.	–	Traffic reports Provision of public transport schedules

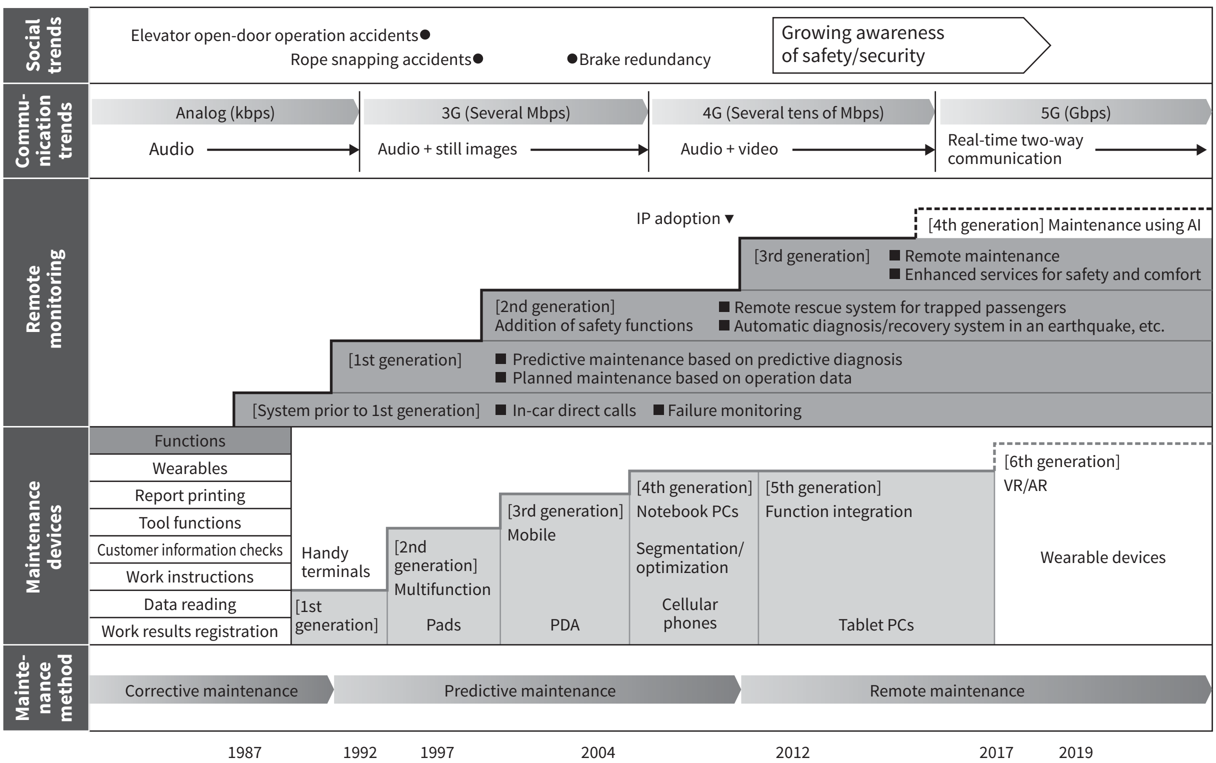
AI: artificial intelligence

into also improving safety, maintaining higher quality, and increasing the appeal of services. Typical functions include a remote rescue system for trapped passengers that enables remote recovery while checking an in-car video, and an automatic diagnosis/recovery system in an earthquake.

Currently, these elevator and escalator maintenance systems are in their third generation of development, where the scope of computerization is being expanded and IoT is being adopted for inspection work previously performed by engineers. In terms of maintenance devices as well, technology has evolved from the initial control panel devices that were only used for reading data, to tablet PCs that also include functions such as work management and customer reports (see **Figure 1**).

Figure 1 — Evolution of Remote Monitoring and Maintenance Device Systems for Elevators and Escalators

Systems have evolved to use Internet Protocols (IP) for remote monitoring (Internet of Things) and to collect data from the results of work via maintenance devices, in order to improve the efficiency, safety, and appeal of systems, as well as deliver high quality.



VR: virtual reality AR: augmented reality PDA: personal digital assistant

Hitachi is confident that the remote monitoring system and maintenance device technologies its has developed in Japan still maintain advantages compared with the level of global companies. However, recent technological innovations by overseas companies have been notable, which means Hitachi must accelerate its overseas expansion based on its technological advantages. At the same time, it has become an urgent task to rebuild the systems to improve services to maintain Hitachi's advantages by using its Lumada IoT platform for more efficient utilization of data obtained from IoT remote monitoring and from maintenance devices.

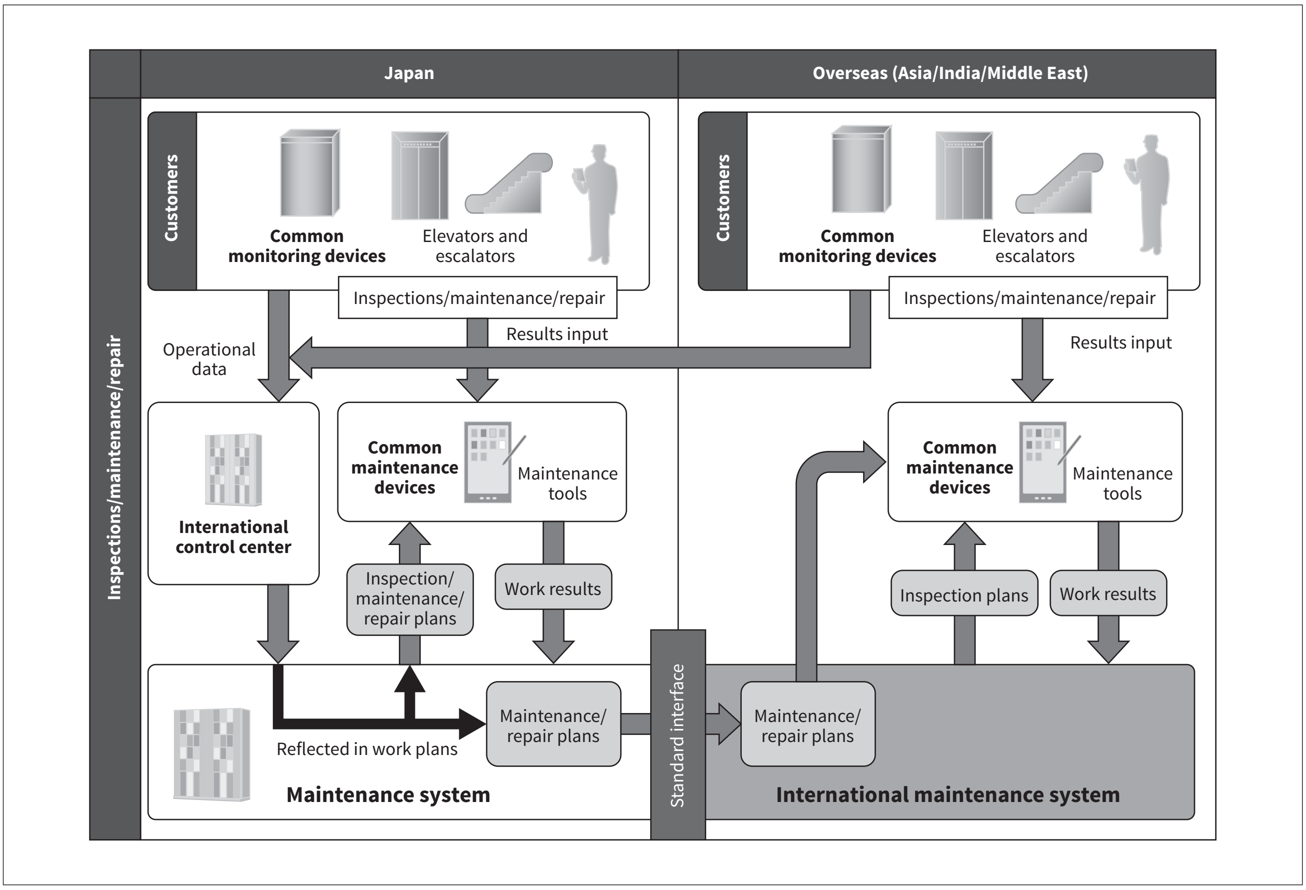
2. 1 Challenges in Global Expansion

In Japan, operational data for elevators and escalators are collected at the control center, and a work plan is created by calculating the proper inspections, maintenance, and repair times based on the operation frequency. This enables work such as inspections, repairs, and maintenance to be performed at the appropriate time for each elevator or escalator. The work plan and work details are displayed on a mobile tablet maintenance device held by each engineer, and the work results are registered in the maintenance system and managed via the maintenance devices.

Currently, maintenance systems overseas, for example in China, use a maintenance system separate from the one in Japan because the market is very large and security policies are different. A future challenge will be to utilize the data collected from elevators and escalators in China based on the remote monitoring know-how that has been cultivated in Japan. In other regions of Asia and the Middle East, IT has been only partially adopted for maintenance tasks. Therefore, building the IT infrastructure itself, such as maintenance systems based on remote monitoring and maintenance devices, will be a challenge.

The sharing of data is essential for deploying know-how from maintenance systems in Japan to overseas markets. For example, it will be necessary to promote a common international system for the data from

Figure 2 — Common Elevator and Escalator Maintenance System (Work Plan/Results Management)
Work plan and results management algorithms from Japan are shared to improve quality.



elevator and escalator remote monitoring devices and the inspection and maintenance work codes used in maintenance devices. To do this, Hitachi is developing an international maintenance system consisting of common global remote monitoring devices and maintenance devices.

As a common international system develops, the operational data of elevators and escalators and the work data of maintenance devices can be consolidated at a center in Japan, and Hitachi's previously cultivated know-how for creating work plans can be used to create plans. These plans can be distributed to the common maintenance devices of engineers in each country via the international maintenance system to achieve higher quality in overseas operations. In addition, being able to make IT systems more compact will facilitate the deployment of maintenance systems in Asia and the Middle East (see **Figure 2**).

2. 2 Advantages of a Common Elevator and Escalator Maintenance System

Failure response is based on the same concept as maintenance work. Using common data such as failure codes and device codes enables not only the centralization of data management and analysis, but also more efficient know-how utilization and accumulation.

The next section provides an overview of the global IoT maintenance system, including the utilization of data by the Lumada IoT platform.

3. Configuration of a Common Maintenance Platform

3. 1 Core International Control Center and Its Changing Role

Currently, the control center is operating for the market in Japan and is connected to remote monitoring devices, maintenance devices, and task IT systems to provide seamless operations, from maintenance tasks to urgent failure response. However, with the increase in the number of elevators and escalators subject to maintenance and generational change as engineers become older, passing on the know-how of engineers is becoming a challenge in Japan. Hiring and training engineers is also expected to become a serious challenge in overseas markets as Hitachi's footprint expands and the number of elevators and escalators subject to maintenance increases. Therefore, major changes must be made in the role of the international control center. Furthermore, in the elevator and escalator maintenance business in Japan, demand in the new installation market is not expected to grow in the future. Therefore, using the know-how from elevator and escalator maintenance to expand business into other fields is also required.

In this context, it is important that the international control center can handle the expansion into maintenance work for a wide range of devices linked to the IoT, such as with robot services. At the same time, it is important to develop a common system with a unified interface for performing universal and core tasks in the maintenance business, such as failure response. The common maintenance platform has been built by taking such maintenance business expansion into account.

3. 2 Overview of the Common Maintenance Platform

Figure 3 shows an overview of the common maintenance platform.

At the front, information for the devices subject to maintenance such as elevators, escalators, and building equipment is collected from the previously described common remote monitoring devices. All the data is consolidated via the core international control center on the maintenance data server, which manages the maintenance work. Data from maintenance devices, such as work results, etc., are similarly consolidated on the server. The stored operational technology (OT) data is analyzed together with data such as work information and engineer information by using the Lumada IoT platform on the back end.

This analysis produces tools such as high-efficiency work plan algorithms and failure recovery support algorithms. These are implemented on the maintenance database server that creates the maintenance plans and the technical support system that supports failure recovery. By repeating the cycle of data collection, verification, analysis, and implementation, a system is created that produces continuous business innovation.

Furthermore, the collected OT and IT data, including maintenance work history such as contract details, inspections, and maintenance, and work quality such as failure rates, can be visualized and provided to customers as a dashboard. This provides visualizations of maintenance service performance to customers, helping to differentiate the services.

4. Improved Maintenance Quality Using IoT Platform Lumada

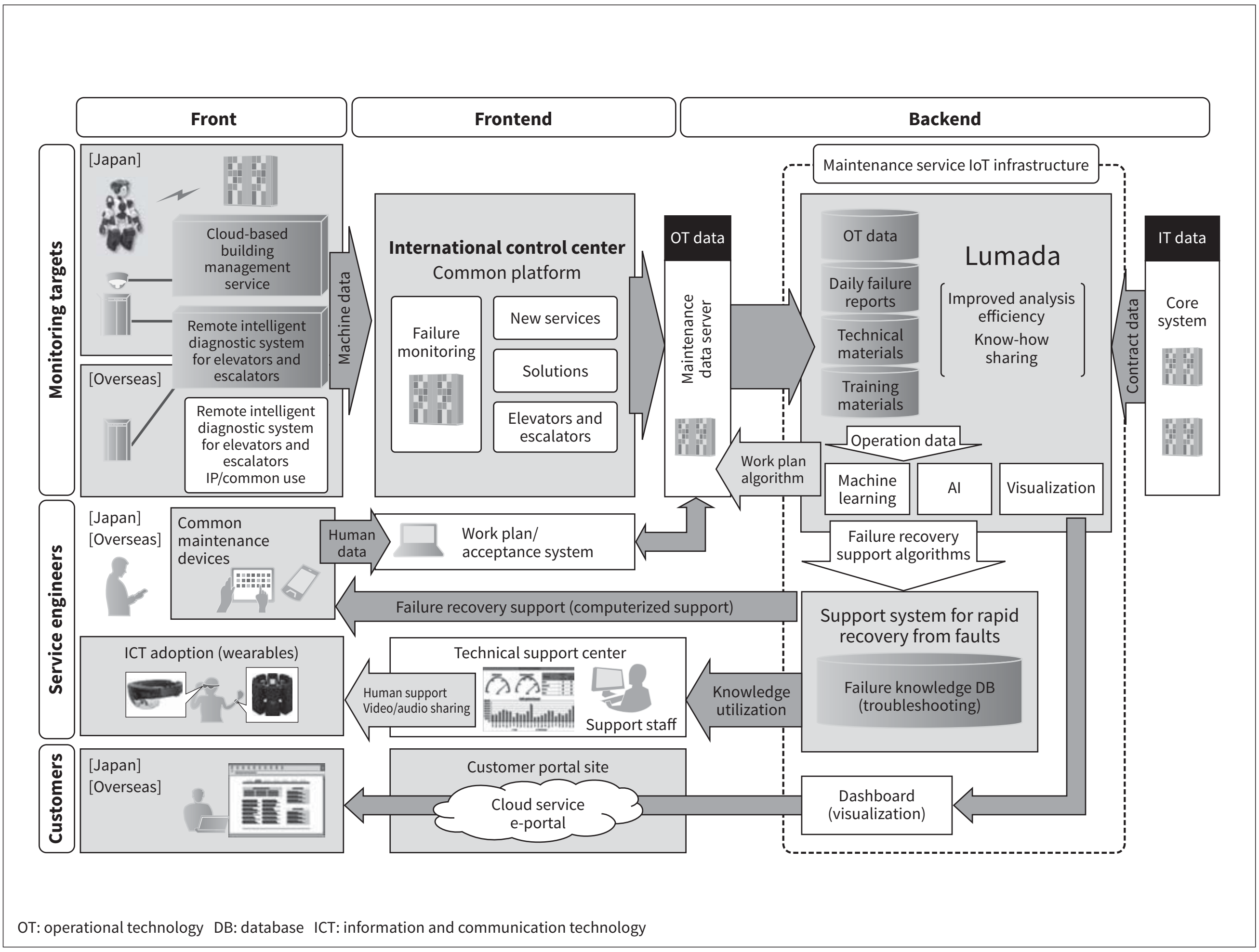
4. 1 Failure Recovery Support Challenges

Failure recovery for elevators and escalators in Japan are subject to factors such as the increasing numbers and models of equipment that require maintenance and the aging and decreasing number of experienced engineers. The existence of these factors means that, when complex failures or failures in older models occur, it takes time to find the cause of the failure and to perform the recovery work. This increases the risk of equipment being out of operation for a long time. There is also the risk of repeated failures due to the misidentification of the causes. Adequate time and cost are also required for training a large number of highly skilled engineers to deal with the increased number of elevators and escalators subject to maintenance due to global expansion.

To solve these problems, Hitachi has started to develop computerized failure recovery support technologies that utilize digital data from elevator and escalator remote monitoring systems that have adopted IoT, and operational data such as maintenance work histories and failure response records. This also is another effective use of the data collected by the common maintenance platform.

Figure 3 — Overview of the Common Maintenance Platform

This shows the structure of a common maintenance platform that can deal not only with elevators, escalators, and building equipment, but also with future expansion into new business, such as robot services.



4. 2 Development of Support System for Rapid Recovery from Faults that Uses AI

The AI support system for recovery from faults is based on the concept of computerized failure recovery support, and consists of the following four phases (see **Figure 4**).

(1) Accurate identification of device status
(2) Highly accurate estimation of failure causes
(3) Instructions for recovery procedures
(4) Status sharing (linked to engineers and the technical support center as necessary)

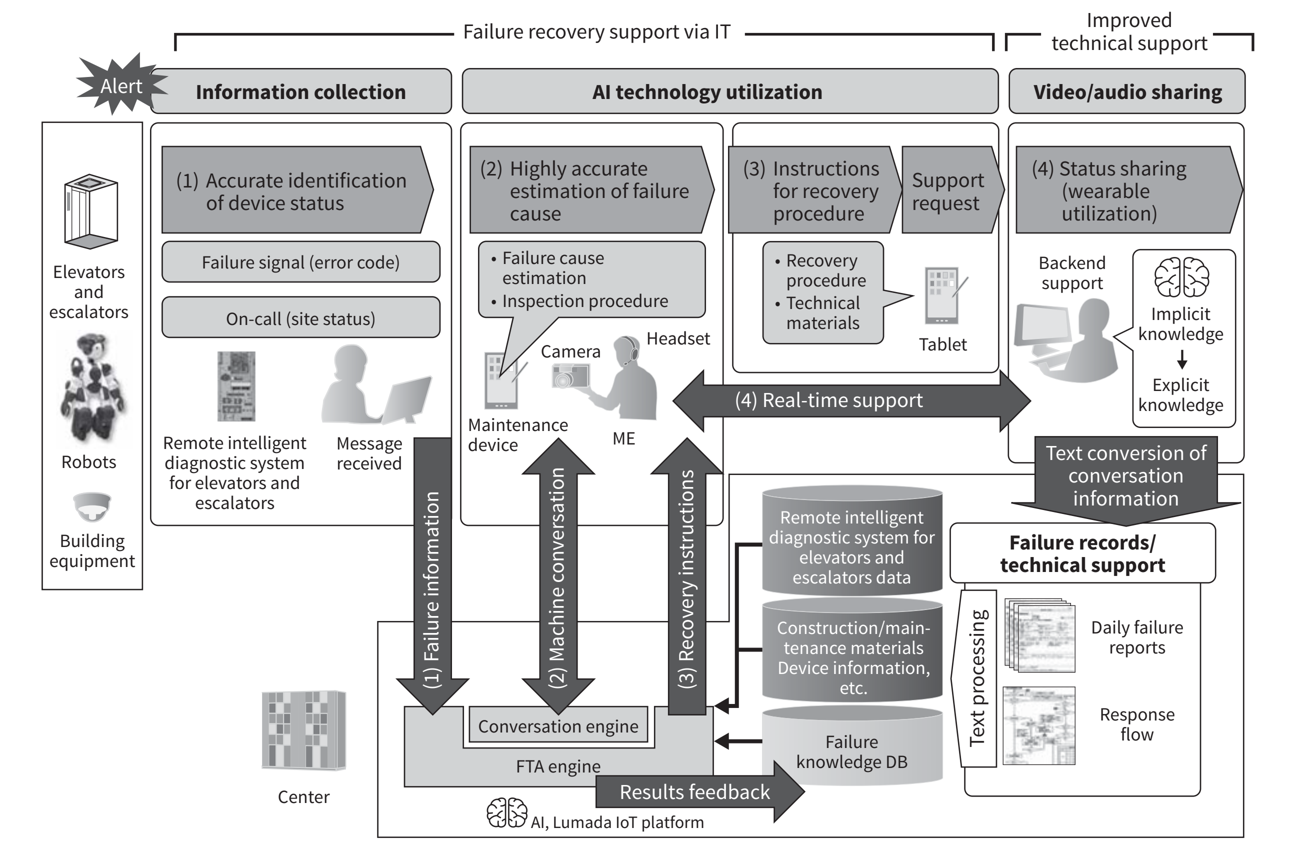
The following describes "(2) Highly accurate estimation of failure causes," which is a particularly important function. Failure cause estimation is accomplished by combining two methods.

The first method uses the device status data (trouble monitor) collected by the remote monitoring devices when failures occur. The trouble monitor is data that records the elevator error codes and the various device information from when errors occur. Machine learning is applied to find the correlation between this trouble monitor and devices that have caused failures identified in past failure response records. This makes it possible to immediately estimate the device that caused the failure, based on the data collected automatically when the failure occurred (see **Figure 5**).

The second method is used when device status data cannot be obtained by remote monitoring. The device causing the failure is estimated using document structure analysis and case-based inference technology, based on the onsite conditions entered by the engineer, and by searching the failure knowledge database created from past failure cases.

Both of these methods record a history of the engineers' operations and judgments regarding estimates made for new failure cases, which are then utilized as new learning materials, automatically increasing diagnosis accuracy.

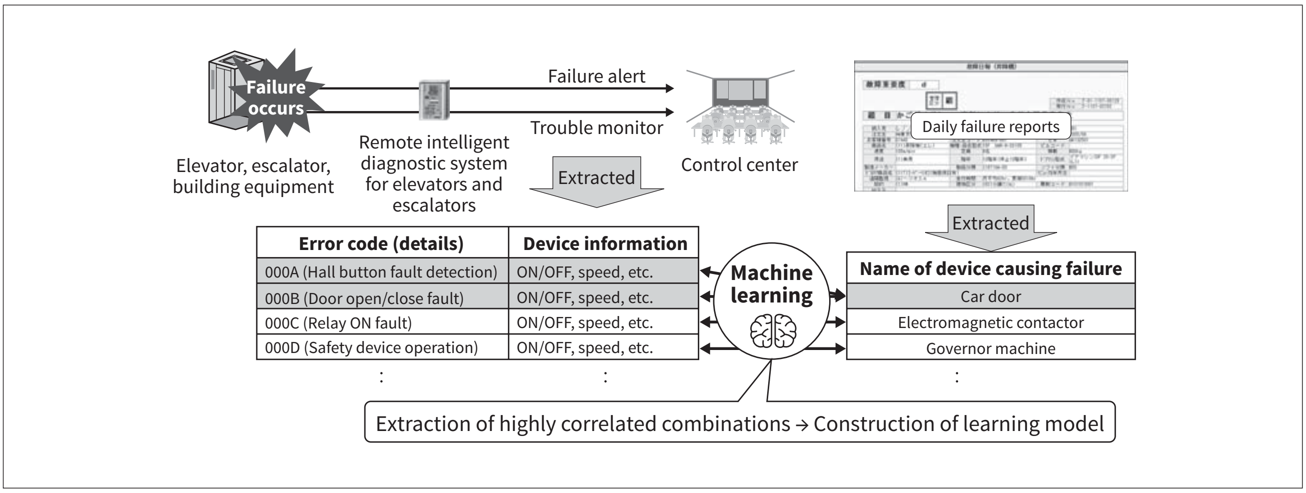
Figure 4 — Overview of Support System for Rapid Recovery from Faults
Work is made more efficient and downtime is minimized by adopting IT for all processes, from information collection and estimating the device causing the failure, to recovery procedure guidance and backend support.



ME: maintenance engineer FTA: fault tree analysis

Figure 5 — Estimation of Device Causing Failure Using Machine Learning

Machine learning is applied to find the correlation between this trouble monitor and the device causing the failure from past failure cases to automatically identify the device causing the failure when a failure occurs.



The AI support system for recovery from faults is expected to be used by onsite engineers via smartphones or tablets. The aim is for engineers to perform audio input and audio replies to enable a speedy response to failures. In addition, the system can be used by the technical support center that performs backend support to understand details such as how failure causes were identified onsite and whether the engineer has performed cause isolation work. Consequently, if it is judged that recovery will take time, the technical support center can become proactively involved to help address the issue.

5. Conclusions

Most work in the maintenance business depends on technology and the know-how and experience of engineers, and further digitalization using IT and efficiency improvements are expected.

The development of technologies such as head-mounted display devices and augmented reality (AR) that overlays computer graphics on real images will transform maintenance systems in the future by giving appropriate work instructions and guidance for replacements on a parts basis, and by achieving seamless automation of records and reports for maintenance and parts replacement. Because all competitors in the market are moving in the same direction, it is vital to launch these services quickly.

In addition to making work more efficient, it is also imperative to be the first in improving the added value of services that can be provided to customers. Hitachi will continue to enhance its services that deepen the connections between the users of a building, not only for elevators, escalators, and building equipment, but also for all devices that are subject to maintenance.

Reference

1) Elevator World, Inc.: Elevator World (Oct. 2016)

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