Information and Control Platform for Smarter Social Infrastructure

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OVERVIEW: The information-control platforms that support efficient operation by coordinating the different types of social infrastructure in smart cities fulfill the following three roles: (1) obtaining an overview of the entire operation by collecting, managing, and sharing large quantities of data from the operation and maintenance of social infrastructure, (2) use of this data to generate new data that can be used in solutions, and (3) providing the foundations for the expansion of services for social infrastructure operation. Hitachi is working on the development of information-control platforms like these for use as core systems for smart cities.

INTRODUCTION

RECENT years have seen progress around the world on the construction of smart cities that can operate electric power, water, transportation, healthcare, and other social infrastructure efficiently, including by cutting waste in the supply and consumption of energy and other resources, and that can reduce emissions of greenhouse gases that place a load on the environment[(1)]. Hitachi has participated in such projects globally, where it has been working on the development of a new generation of social infrastructure to help deliver a comfortable way of life.

Two features differentiate the social infrastructure in a smart city from that of the past. The first is the ability to monitor supply and consumption across all social infrastructure so that it can be operated efficiently based on an understanding of the interrelationships between all its different parts. The second is that safe and reliable operation of social infrastructure can be achieved through the collection of maintenance information about faults and other degradation so that potential problems can be identified in advance and repairs or replacements implemented.

New types of platform systems have an important role in this approach of system-wide operation of social infrastructure, allowing the collection and consolidation of information about the supply and consumption of energy and resources and its use in facilitating the resolution of any problems, including the use of control techniques. Accordingly, Hitachi is working on the development of information-control platforms that can serve as these core systems for smart cities[(2)].

This article describes progress on the development of information-control platforms, examples of their application, and the directions for future development.

INFORMATION-CONTROL PLATFORMS

Features of Smart City Social Infrastructure

Smart cities have the following features.

(1) Wider range of social infrastructure and opportunities for choice

New types of social infrastructure are being constructed and linked together with those that are already in place. In the field of electric power infrastructure, for example, renewable energy sources such as photovoltaic or wind power are being incorporated into the electric power system. Other examples include the growing use of seawater desalination and water recycling (in the water sector), and also the adoption of environmentally conscious electric vehicles (EV) that do not emit any exhaust gas (in the transportation sector). These trends are increasing the number of different forms of infrastructure available in a smart city, and with this come greater opportunities for consumers to choose the options that best suit their lifestyle.

(2) Advanced social infrastructure operation based on information

Information from consumers' electricity or water meters can be read remotely by suppliers via a communication network, and the large quantities of information collected can then be utilized in applications such as the control of electric power or water distribution. In particular, "peak cut" measures can be adopted when the supply of electric power has difficulty keeping up with demand, such as having consumers reduce their consumption or supply electric power they have generated back to the grid. In addition to operational information, the regular collection of status-related maintenance information from social infrastructure can also be used to ensure that equipment is replaced or repaired when problems are identified so that it will continue to operate reliably.

As the number of different types of social infrastructure increases and sophisticated ways of using information become available, these developments make it possible to optimize operations across an entire region. Meanwhile, the concept of a social system coordinator (SSC) has also been proposed as a way of managing operations at a regional level as well as supporting the use of all social infrastructure by consumers[3] (see Fig. 1).

A new type of business entity, an SSC is an organization that provides services to customers. An SSC selects social infrastructure and delivers it to consumers in a way that is tailored to their lifestyle and preferences. It coordinates the operation of social infrastructure in ways that benefit the entire region, such as saving electric power, reducing emissions of greenhouse gases, or achieving zero emissions.

To operate social infrastructure at a regional level, an SSC collects information on its use and maintenance, and then generates the information required for its operation. Information-control platforms provide the core systems for this generation of added-value information.

Requirements for Core Systems

This section describes the key requirements for core systems such as information-control platforms[2].

(1) Interoperability

Because these systems collect data from many different types of social infrastructure, each with different data collection timings, protocols, and security measures, standard methods are used. There is also a need to provide for shared use by using a database to store data that, even if it is of the same type, may have been collected from equipment supplied by different vendors.

(2) Reliability

Reliability is an essential requirement for services such as electric power or urban transportation infrastructure. It is necessary to be able to connect via the telecommunications infrastructure to specific equipment as and when required, both during routine operation and at times of emergency. This requires the ability to connect across various different networks. In the case of data used in control, the ability to connect within a specified time limit must be guaranteed.

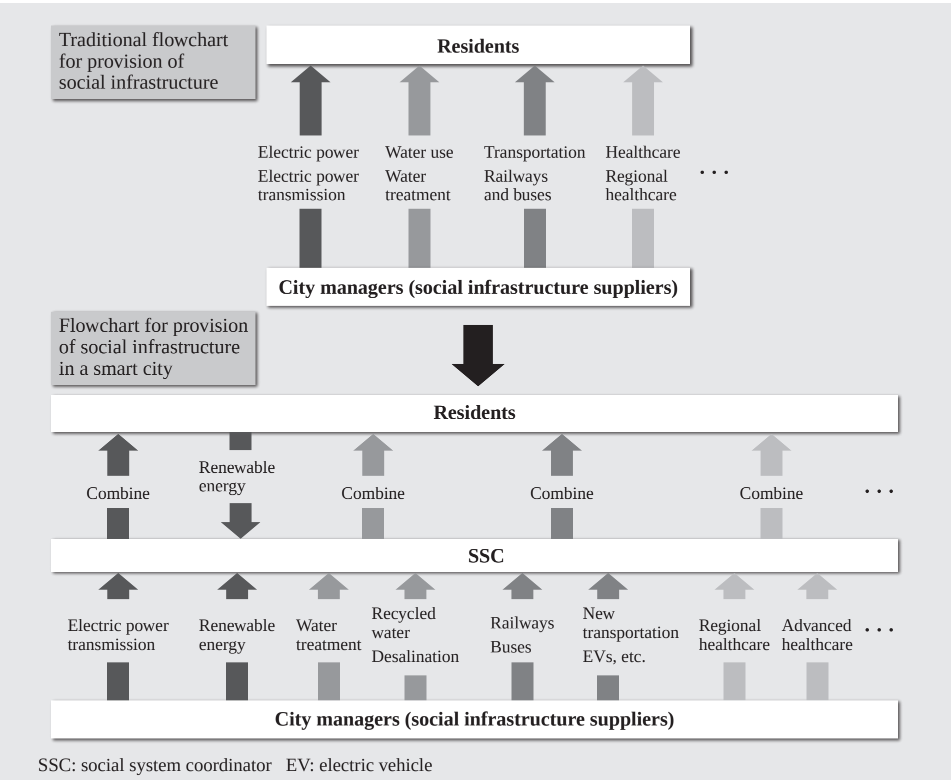

Fig. 1—Expansion in Use of Social Infrastructure in Smart Cities.
Smart cities provide consumers with a choice from an increasing number of different types of social infrastructure. SSCs help consumers to make choices that suit their lifestyle, and support operation at a regional level.

(3) Sustainable urban growth

Providing ongoing support for a growing city requires scalable systems that can keep up with the expansion and enhancement of social infrastructure. To ensure that social infrastructure can operate reliably, there is also a need to collect maintenance data and use it for diagnostic applications to identify potential faults or other degradation.

Roles of Information-control Platforms

To satisfy the above requirements, information-control platforms must fulfill the following roles (see Fig. 2).

(1) Collection of information on social infrastructure

This involves collecting and processing data relating to the problems, maintenance, control, and use of different types of social infrastructure, and then storing it for use as shared data. Sharing can give access to data that was previously unavailable, allowing it to be used to identify correlations or new applications.

In particular, the forwarding of control data for storage allows it to be collated along with control system operation to determine causality. The accumulation of causality information can be used to predict the flow-on effects of different forms of control on the entire region. The collation of information on electricity distribution control and its operation could be used to identify appropriate ways of supplying electric power to regions with high demand due to large numbers of EV chargers, for example.

(2) Contribution to solutions

This involves analyzing collected data and converting it into new forms that are easy for applications to use. It incorporates the following functions that can be applied to different types of data.

(a) Interpolation

The data available for collection will not necessarily be complete and cover the entire region. For example, it may not be possible to collect electric power or water usage from all households. To overcome this problem, interpolation is used to produce estimates for the entire region from incomplete data. Also, large amounts of data may contain abnormal values that are the result of equipment faults. Such data is removed or corrected.

(b) Regional property extraction

The large amounts of collected data represent the properties (characteristics) of the region. Accordingly, changes in the data can be analyzed to identify these properties. Specific examples include analyzing trends based on consumption data for electric power, water,

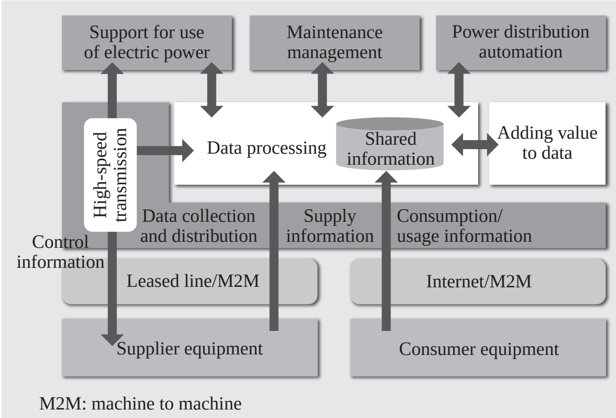

Fig. 2—Structure of Information-control Platforms.
Information-control platforms not only collect and distribute information from various types of social infrastructure, they also help expand services by adding value to data.

or other services, or data on congestion or crowding of vehicles or people. Using this sort of data analysis to generate data for specific purposes can make it easier for applications to use.

(3) Service platforms

These are platforms for running the applications associated with new social infrastructure services that use the collected and synthesized data. For example, integration between information-control platforms and service applications that support the use of electric power can provide easy access to the power consumption data needed for formulating power saving plans. Similarly, if service applications for maintenance management are also integrated, the ability to collect data on the operation of electric power distribution equipment means that the data can be used for predictive diagnosis of degradation or faults.

FUNCTIONAL CONFIGURATION

System Functions

Fig. 3 shows the configuration of an information-control platform, comprising core functions for the collection, distribution, and processing of data and also business interfaces. The following sections describe each of these functions in detail.

(1) Data collection and distribution

(a) Data collection, distribution, and integration

This function performs the periodic or on-demand collection and distribution of information. For example, data is collected periodically from smart meters for electric power or water. Similarly, facility monitoring data (journal data) containing information about equipment faults is collected at short intervals, whereas data collection for equipment maintenance

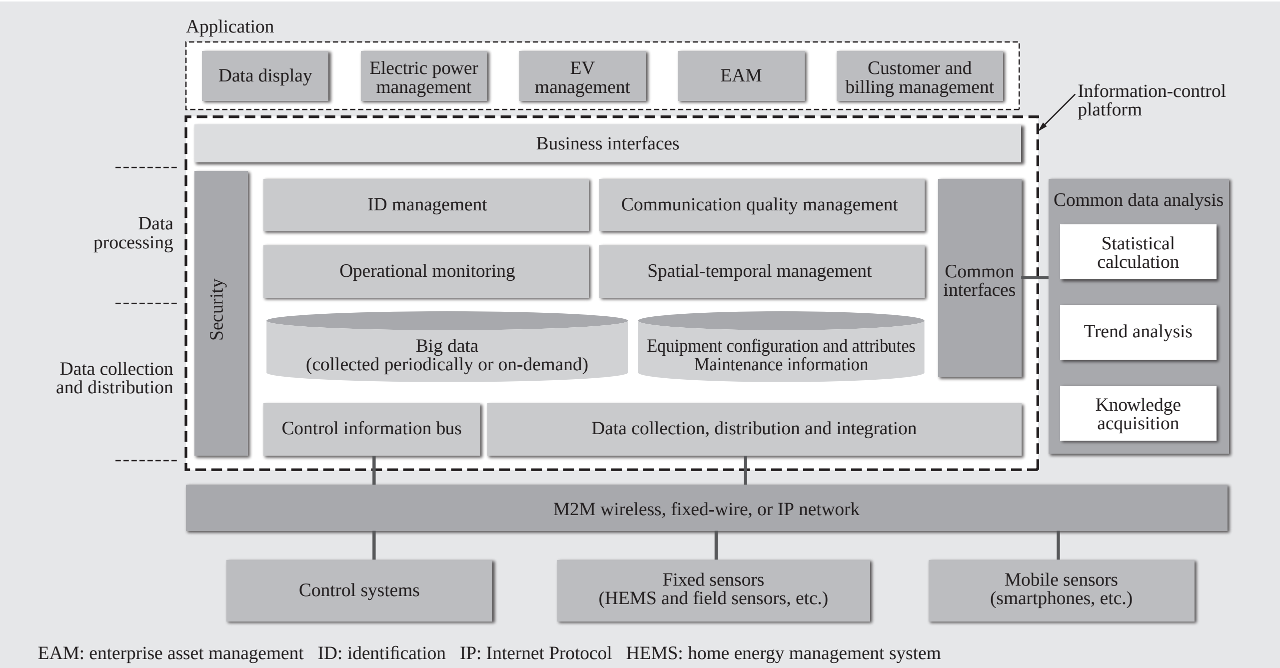

Fig. 3—Functional Configuration of Information-control Platforms.
The main functions of an information-control platform are the collection, distribution, and processing of data; business interfaces; and security. These functions are used in conjunction with common data analysis functions that create data required for coordination of applications.

data is only performed when a change occurs. The collected information is converted and then stored in a database in the form of general-purpose data items suitable for sharing. The correspondences between converted data items and their associated shared data items are pre-defined for each operator in the form of relationships between operator-defined data and general-purpose data items.

(b) Control information bus

A bus-based configuration is used for the transfer of control data. This ensures that control data reaches the intended equipment within a predefined time (latency guarantee), while also passing through the information-control platform.

(2) Data processing

(a) Identification (ID) management

Interconnections between equipment and the network are managed based on a unique number assigned to each device. This function keeps track of the devices connected to the network and their operational status, and this allows it to identify devices for control or maintenance purposes.

(b) Communication quality management

This function ensures that reliable communication routes are available and guarantees that data reaches the systems to which it is sent (accessibility guarantee). For control equipment, this guarantees that control data will arrive within the requested time. Also, use of an information-control platform enhances reliability across all the systems that support a smart city. Hitachi has also proposed machine-to-machine (M2M) techniques for interconnecting between devices and is taking steps toward their international standardization.

(c) Operational monitoring

This function manages the collection of journals (logs of equipment operation), including whether or not equipment is in service (working/suspending). It also uses the journal data to look for indicators of potential equipment faults.

(d) Spatial-temporal management

This function provides integration with geographic information systems (GISs). It can be used to identify the location of equipment and other social infrastructure. It can also manage time-series and archived data to specify links to data that changes over time.

(3) Business interfaces

These provide application programming interfaces (APIs) for integration with other applications, such as enterprise asset management (EAM) systems or applications that manage electric power or EVs. By abstracting these interfaces in the form of APIs, functions can continue to operate even if the operating system (OS) or other standard applications are changed. It also provides for compliance with international standard regulations, including those set by the International Electrotechnical Commission (IEC) for managing electric power.

(4) Security

These are certification and encryption functions that comply with relevant national standards. In addition to preventing impersonation, falsification, and other security breaches, these functions also ensure that information-control platform users are provided with trustworthy data.

Common Data Analysis

The following common data analysis functions are used in conjunction with information-control platforms to facilitate the use by applications of the large amounts of collected data.

(1) Statistical calculation

These are techniques of spatial statistics that take account of regional characteristics to estimate data from an entire region based on a representative sample.

(2) Trend analysis

This uses historic data to predict variations (such as rate of change) in collected data, and then predicts variations in future data. This can be used to predict things like electric power consumption, water use, how congestion will vary over the course of a day, or equipment problems.

(3) Knowledge acquisition

This identifies patterns in the variation of characteristic values for a region. For example, the consumption of electric power or water is likely to follow particular patterns depending on the place, time, or period. Knowledge acquisition extracts these patterns from historic data on consumption.

New Features of Information-control Platforms

The following new features are made possible by adopting a functional configuration unlike that of past core systems (see Fig. 3).

(1) Fusion of data saving and creation

The sharing of collected data not only allows the overall status of social infrastructure to be determined, it also allows the use of data analysis to create new added-value data from accumulated data in ways that go beyond what can be done with databases. For example, an analysis of historic data to determine the operating characteristics of social infrastructure based on how it is used (factors such as city center or suburbs, time of year, weekday or holiday, and the time of day) can provide the basis for proposing ways of using the social infrastructure in these various different circumstances.

(2) Coordination of applications

It is possible to help optimize operation by supporting interoperation through access to data available for sharing between applications, and by using the results of executing one application as feedback for execution of a different application. For example, equipment load data for electric power distribution can be utilized for equipment maintenance.

STEPS FOR IMPLEMENTING INFORMATION-CONTROL PLATFORMS, AND EXAMPLE APPLICATIONS

Smart cities are currently being built in Japan and other countries, and these projects include the deployment of information-control platforms. The following sections describe the steps involved in implementing these platforms, and give an example of their use in coordinating infrastructure for electric power and EVs.

Implementation

The functions of information-control platforms are implemented in stages in accordance with the level of social infrastructure provision. The following sections describe the steps involved in their implementation.

Step 1: collection of data for sharing

This function uses techniques such as M2M communications to collect status data from both social infrastructure and consumer equipment over communication networks. The collected data is stored in a shared database.

Step 2: application coordination

This seeks to use data sharing as the basis for coordinating the operation of application systems. One example might be the implementation of an operation support application for coordinating charging of EVs with the electricity supply in cases where EV charging may be concentrated in particular areas or at particular times.

Step 3: acquisition and use of operational knowledge

When the amount of data collected has become large enough, the data can be analyzed to identify knowledge about trends. For example, it can provide information about changes over time in congestion or the consumption of electric power and other services. The knowledge obtained can then be used for purposes such as optimization of the electricity supply across entire regions or the mitigation of traffic jams.

Electric Power Supply and Demand Management for Coordination of EVs and Electricity Supply

This section describes an electric power supply and demand management application that coordinates EV management with the electricity supply (see Fig. 4).

The features of the overall system are as follows.

(1) The grid power plants that provide the base-load power are augmented by renewable photovoltaic and wind power.

(2) The system supports not only conventional uses of electric power, but also new forms of electric power consumption that incorporate the charging of EVs.

(3) A micro distribution management system (μDMS) is used to achieve household power savings. The information-control platform collects information about electric power consumption for the entire region, and also location and level of battery charge information from EVs. It then uses interoperation between applications to help optimize electric power consumption for the region and to advise EVs on which charging stations to use.

(4) The business interfaces of the information-control platform are utilized to add or expand applications and services, such as EV management and regional distribution management systems (DMS).

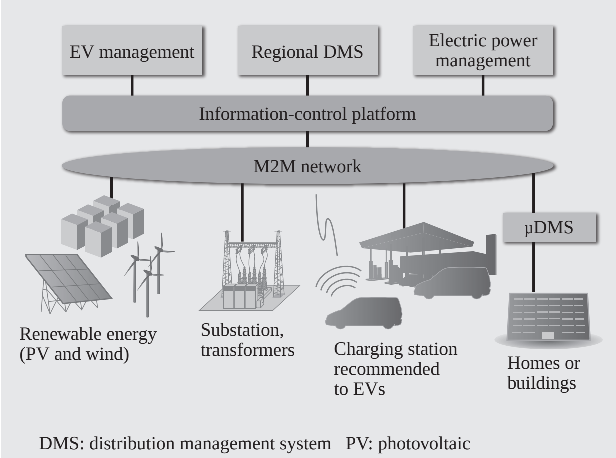

Fig. 4—Application of Information-control Platforms to Electric Power Supply and Demand Management.
The information-control platform collects information on electric power consumption for an electricity supply that includes renewable energy, and on electricity supply and consumption by homes, buildings, EV charging, and other loads. It also coordinates interoperation between applications such as EV management and consumer management.

FUTURE DEVELOPMENTS

The use of information-control platforms in actual projects results in the collection of large amounts of data. While this corresponds to steps 1 and 2 above, making use of this data (step 3) is also important. The following sections describe potential ways of utilizing or deploying this data, namely integration with GIS, EAM, and meter data management (MDM), and use of the data in big data processing and in applying cloud computing systems, two fields that are experiencing rapid growth throughout the world.

Integration with GIS, EAM, and MDM

(1) Integration with GIS

GISs are used both as platforms for managing position-related information using an electronic map as a base, and as display systems for data visualization. As social infrastructure such as roads, railway lines, and pipelines that extend over long distances may be constructed on contoured land, they sometimes need to be considered in three-dimensional terms. Also, because infrastructure is subject to change, systems must be able to cope with data that has planar, three-dimensional, and time axes. Implementing the techniques used for managing this data[4] in the form of spatial-temporal management functions allows the system not only to keep track of information such as equipment locations and changes over time, but also to perform tasks to which existing GISs are not well suited, such as the analysis of large amounts of data.

One example made possible through integration with a GIS is the use of diagnostics in the maintenance and management of natural gas trunk pipelines. As a single trunk pipeline may span thousands of kilometers, it can include large amounts of aging plant and numerous cases of corrosion or other forms of deterioration. This means that an information-control platform can collate large amounts of data about the pipeline and use it to perform safety diagnosis for defects on pipes. This data includes information about corrosion and cathodic protection on the pipeline, and also its shape, the material properties of its pipes, and its use for the transportation of natural gas[5] (see Fig. 5).

(2) Integration with EAM

While it is inevitable that social infrastructure will age and degrade, it is not practical to update aging social infrastructure equipment all at once. Instead, measures are put in place for the early detection of abnormalities on equipment, and to resolve the problems without any shutdown in social infrastructure operation. Accordingly, the EAM systems that manage equipment integrate with operational systems via the information-control

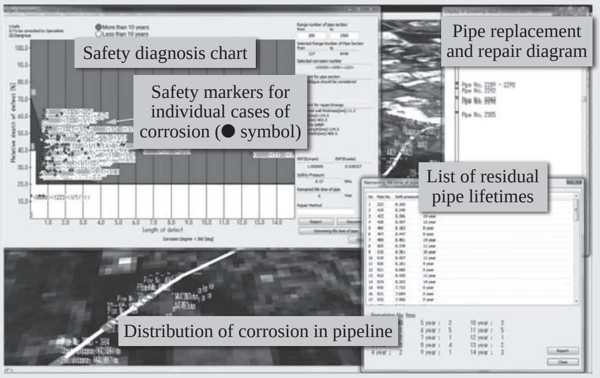

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Fig. 5—Use for Management of Pipeline Maintenance through Integration with GIS.
The appropriate timing for pipe replacement can be determined through management of factors such as corrosion and cathodic protection potentials on large pipelines.

platform. The use of collected operational data (data suitable for uses such as equipment diagnosis) allows changes in the equipment used for social infrastructure to be detected and appropriate maintenance initiated.

(3) Integration with MDM

When the installation of smart meters capable of bidirectional communications makes it possible to see each household’s usage of electric power, water, and gas, this information can be used to assess the use of energy and other resources across the region and the results utilized to make savings. While the number of meters will depend on the size of the region, in the largest cases this will be in the tens of millions. By using information-control platforms to collect this information efficiently, it can be applied in the analysis of regional trends in supply and demand of electric power.

Use with Advanced IT Practices

(1) Use in big data processing

Interest is growing in the processing of big data[(6)] as a way of analyzing the large amounts of data on social infrastructure and putting it to use in operations. When the implementation of information-control platforms provides for the collection of information on the supply and use of electric power and water, equipment status, and traffic and other transportation infrastructure across an entire smart city, the resulting accumulation of terabytes or petabytes worth of historic and other data that can be used to assess the condition of infrastructure and other information about the region. Big data can be divided into the following two categories.

(a) Sources of data that have a static location but changing attributes: electric power, equipment status, etc.

(b) Sources of data that are mobile and have changing attributes: flows of traffic or people, etc.

The analysis of this data can be used to acquire knowledge about the region, such as trends in electric power or water consumption or the locations where traffic congestion occurs.

In-memory processing is a technique for placing data in memory so that it can be processed at high speed. It has an important role for speeding up the analysis of large amounts of data. However, because memory capacities are limited, a way of preventing loss of prediction accuracy is to select only important data that will influence the analysis.

(2) Use in applying cloud computing systems

The advantages to users of applying cloud computing systems to information-control platforms include data management and easier access to added-value services provided through the enhancement of applications. Hitachi intends to make greater use of cloud-based systems in the future to expand services.

CONCLUSIONS

This article has described progress on the development of information-control platforms, examples of their application, and the directions for future development.

Construction is proceeding on smart cities that can deliver a good quality of life and reduce the load on the environment by combining new elements such as renewable energy, EVs, and equipment maintenance with conventional social infrastructure such as electric power and urban transportation to operate new social infrastructure efficiently. Efficient operation of the entire social infrastructure is achieved through the use of information-control platforms to coordinate the operation of both control and information systems. A characteristic of information-control platforms is that they combine: (1) the consolidation and sharing of large amounts of data, (2) integration with data analysis to enhance the operation of social infrastructure, and (3) interfaces for the expansion of new services. By supplying these information-control platforms, Hitachi is contributing to the creation and running of new smart cities.

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