Big Data Collection and Utilization for Operational Support of Smarter Social Infrastructure

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OVERVIEW: Progress is being made on the use of information-control platforms for the collection of social infrastructure data and its utilization in fields such as electric power and EV operation. In addition to the collection of social infrastructure data, information-control platforms also have a role in large-scale data analysis (big data) and as analytical databases that span different applications. They can provide a means for optimizing the operation of social infrastructure through their use as a platform for big data analysis involving the collection and analysis of information on electric power, EV use, and equipment operation. Hitachi is currently working on the use of information-control platforms for data collection in projects in Japan and elsewhere, and has plans to add additional functions for utilizing this data.

INTRODUCTION

RECENT years have seen the rise of an approach to urban development that is associated with terms such as "smart cities" or "smart communities"[1]. In addition to enhancing the convenience of existing social infrastructure for services like electric power, water, and transportation, this also includes the introduction of new social infrastructure that helps reduce greenhouse gas emissions and other loads on the environment, such as photovoltaic and wind power generation or electric vehicles (EVs). The combination of new and old infrastructure is seen as a way of making society more comfortable as well as safe and secure. It involves understanding patterns of use or consumption and making appropriate operational decisions to ensure that the many different types of social infrastructure function efficiently. To achieve this, there is a need to identify trends by using information technology (IT) to collect and analyze information on the operation and use of social infrastructure. Because of the nature of this data, its frequency of collection, and the size of activity records, its quantity is expected to be large enough to justify the term "big data."

This article describes how big data is used on an information-control platform[2, 3] (referred to below as the smart city platform) for the efficient operation of social infrastructure, with a particular emphasis on its use in power system management, transportation, and especially EV operation.

OPERATION OF SOCIAL INFRASTRUCTURE USING SMART CITY PLATFORM

The smart city platform plays an important role in understanding the changing patterns of use or consumption, and in taking account of this knowledge in the operation of the many different types of social infrastructure to ensure efficiency (see Fig. 1).

Role of Smart City Platform

The roles of the smart city platform are (1) data collection, (2) data analysis, and (3) coordination of the systems (applications) that operate social infrastructure (see Fig. 2). Given the interrelationships between different social infrastructure systems, this supports the implementation of new operational applications that take account of these interrelationships by supplying data that has been collected from these systems and analyzed.

The following sections describe data collection, data analysis, and application coordination.

Data Collection

The smart city platform includes a database function. In addition to data on equipment performance and configuration data such as the topology of links between equipment (network information), it also handles the collection and management of large quantities of other data, including data on the supply of a diverse range of social infrastructure along with details of consumption or use, and records of

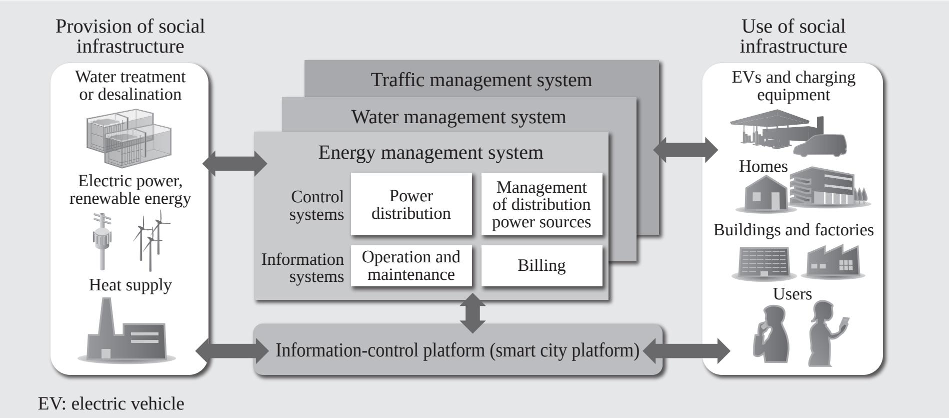


Fig. 1—Functions and Roles of Smart City Platform.
In addition to collecting data from different types of social infrastructure, the smart city platform is also used for analysis and to improve the efficiency of social infrastructure operation.

equipment operation, malfunctions, and other journal data. For example, data on the supply of electric power is collected from sensors fitted to power plants, transformers, and other equipment. Similarly, details of consumption are collected from sources such as smart meters installed in buildings, home energy management systems (HEMSs), building and energy management systems (BEMSs), and EV charging equipment. Over a wide area, this can add up to tens of millions of items of data to be collected. By collecting and managing this information in the form of historical data, it is possible to determine power use over a wide area.

The smart city platform also has a bus function[2] that is used to collect control information. The bus buffers equipment control information sent from control applications in memory before forwarding it to the destination device. The buffered data is also saved in the database. This provides a latency guarantee, meaning that the control information is forwarded on within the allocated time, without having to wait for processing by the smart city platform.

The smart city platform also collects journal data at intervals of between several seconds and several minutes, including data on equipment operation or alarms (notification of malfunction). This provides timely updates on whether equipment is operating normally or malfunctioning, and allows the extent of the flow-on effects of any malfunction to be determined with reference to the network configuration. As this journal data can also be collected and managed in the form of historical data, it can be used to detect or infer potential malfunctions.

Data Analysis

Analysis can add value to collected data. The analysis data is used for high level decisions in control and prediction applications. Accordingly, the analytics functions on the smart city platform fall into the following two categories.

(1) Functions able to prepare data required by applications

(2) Functions able to be used by a number of different applications

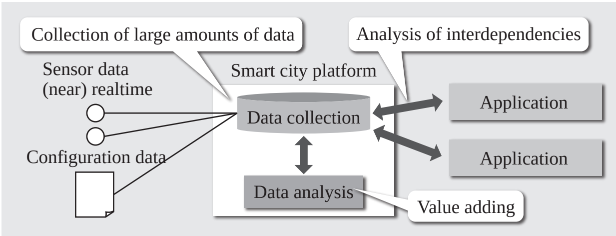


Fig. 2—Roles of Smart City Platform.
Smart city platforms enhance the value of social infrastructure data through data collection, data analysis, and application coordination.

The following three functions are important for data analyses used by a number of different applications.

(1) Data interpolation

This means interpolating the overall situation from collected sampling data.

Electric power data, for example, may not be able to be collected from all buildings. Instead, statistical analysis or other techniques are used to estimate power use for the entire district.

(2) Prediction

Collected data is time-stamped and stored in the database. Changes in historical data can be analyzed to identify trends. Because prediction accuracy improves as more data is collected, potential applications include situations that are continuously changing, such as determining trends in electric power or water use, or assessing conditions such as traffic congestion.

(3) Knowledge acquisition

The analysis of historical data can identify trends and extract knowledge. Information on things like electric power, water, or traffic congestion depend on the time of day, date (whether it is summer or winter, weekday, weekend or long holiday, etc.), and location (residential or commercial district, etc.). These categories can be used to determine the applicable parameters for prediction.

Application Coordination

Data collected from social infrastructure and data obtained from analysis is made available to applications and used in ways that take account of the interdependencies between different parts of the infrastructure, including control and predicting usage. Because of this interdependency between different types of social infrastructure, the smart city platform helps coordinate applications by exchanging data between them.

One example is the way in which greater use of EVs increases demand for electric power (for charging vehicle batteries). Accordingly, by collecting all information on EV use, it will be possible to determine factors such as which areas (sites at which charging equipment is located) and which times will have a high demand for electric power. Similarly, interrelationships also exist between existing grid power and renewable energy. If power use information such as times of peak demand can be obtained, it is possible to determine the times when renewable energy will be used. Also, predictions about the deterioration of facilities can be made by coordinating information about the provision and use of electric power or EVs with enterprise asset management (EAM) systems.

EXAMPLE DEPLOYMENTS OF DATA COLLECTION USING SMART CITY PLATFORM

Hitachi is currently seeking to implement data collection functions on smart city platforms and deploy them in projects involving smart cities or smart grids in Japan and elsewhere. In the future, Hitachi also plans to implement them as an analytical database by developing and deploying functions for the analysis of collected data. The system configurations used in the projects are described below.

Example projects for making social infrastructure smarter include initiatives that involve electric power management and the wider use of EVs. The system characteristics are listed below (see Fig. 3).

(1) Collection of electric power data by micro demand management system (μDMS)

Information on power use is collected from smart meters installed at buildings or other sites by systems called μDMSs that manage energy use for a district. The smart city platform collects power use data from the μDMSs and sends back control data specifying adjustments to power use that it has received from the applications.

(2) Coordination of renewable energy and existing grid power

Hitachi is building systems that manage not only existing sources of electric power such as thermal power generation, but also combine it with electric power from renewable sources such as photovoltaic and wind power. Because of its weather-dependence, use of renewable energy involves storing it in storage batteries. The storage batteries are also used to store electric power at times when tariffs are low. The smart city platform collects data on the storage and discharge of renewable energy.

(3) Coordination with EVs

EVs have a shorter range than vehicles that use an internal combustion engine. Accordingly information is collected from EVs on location, speed, steering, and remaining battery level. Information about power consumption and usage is also collected from charging equipment and used for applications such as advising drivers on where to go for charging.

DEPLOYMENT FOR BIG DATA UTILIZATION

The smart city platform delivers added value to providers and users of social infrastructure by collecting and analyzing big data, such as equipment

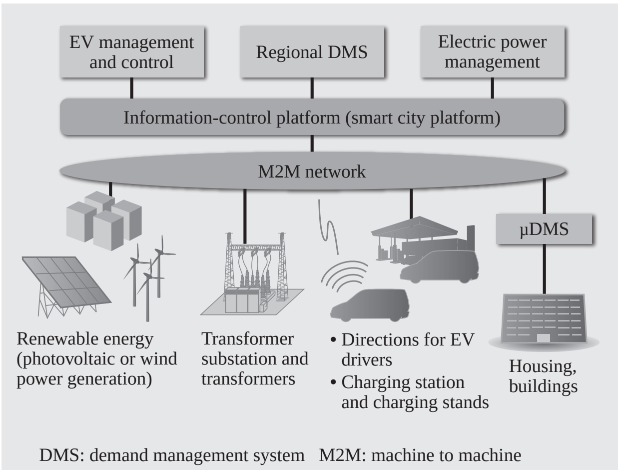


Fig. 3—Deployment of Smart City Platform for Collection of Electric Power and EV Data.
Smart city platforms are adopted and evaluated for the collection of data on electric power operation and use.

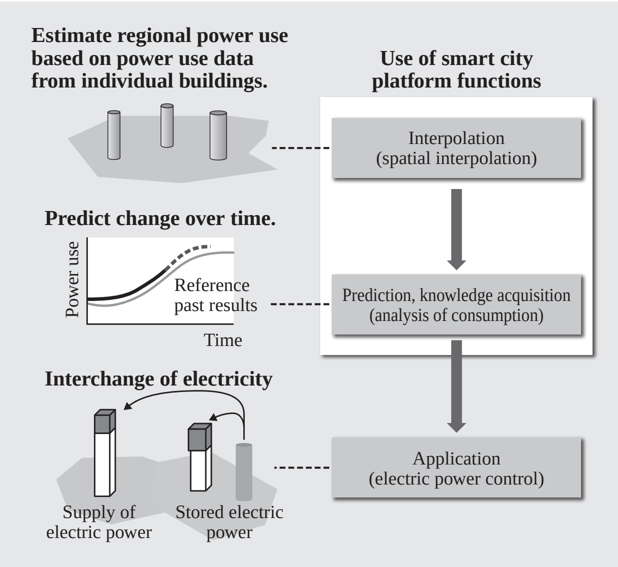


Fig. 4—Analysis of Big Data on Electric Power.
The smart city platform provides functions for prediction and the analysis of electric power data, and supports its use by applications such as electric power distribution.

journal data or information on EVs or supply and demand for electric power, and by coordinating this with applications (see Fig. 2). The following sections give an overview of future applications for big data processing(4).

Deployment in Smart Grids

Smart grids are a way supplying electric power in the best way possible and combining it with the discharging of storage batteries to shift the timing of peak demand. They are being built in conjunction with renewable energy from photovoltaic or wind power generation. Because the operation of smart grids is based on the analysis of information such as the balance of supply and demand, or supply and demand including the discharging of storage batteries, it is seen as a field with potential applications for big data processing (see Fig. 4).

(1) Identification of trends in use of electric power by district or building cluster

Residential, commercial, and industrial districts are each likely to have different patterns of power use. This means that precise assessments of trends in power use can be made by using statistical processing to detect changes in power use in specific districts or in clusters of similar buildings.

(2) Support for electric power supply decisions

The storage of electric power in storage batteries not only helps supply power to the district, interchange arrangements can also be established to supply power to other areas. The best times to discharge the batteries can be determined by analyzing how power use fluctuates. The system also works out how to discharge the batteries in situations such as when there is a risk of damage to equipment due to reverse power flows caused by voltage differences becoming reversed. When a number of households are generating photovoltaic power, this information can be used to determine the order in which batteries should be discharged and to operate the system so as to minimize equipment deterioration caused by discharging.

Deployment in EV Management and Control

When driving an EV, it is essential to monitor power consumption and take care not to run out of battery power. However, it is not ideal for the driver to be continuously having to deal with all this monitoring on their own. Instead, to ensure safety for EV users, it would be better to provide a service that notifies the driver of available charging equipment, taking account of waiting and charging times. Achieving this will likely involve management and control of EVs together with monitoring and notification functions. This means that big data processing will be an effective tool for providing information to drivers based on information on EV use (see Fig. 5).

(1) Providing directions to charging equipment

If the location of an EV is known, suitable charging equipment can be identified. Together with the collection of information from charging equipment, including its future schedule, this means that drivers can be directed to the charging equipment with the shortest waiting time when the level of charge in their EV is running low. The directions in this case are provided by the car navigation system. By applying statistical analysis and prediction functions

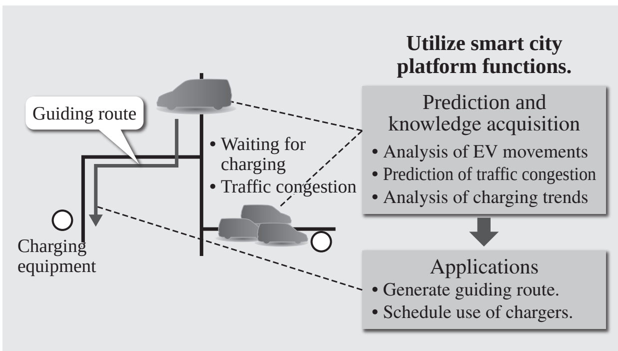


Fig. 5—Analysis of EV Big Data.
The smart city platform analyses things like traffic congestion prediction and possible guiding routes based on information from EVs such as location or remaining battery power.

to location and speed information from a large number of vehicles, it is possible to identify which roads are congested (road sections in a traffic jam) or estimate how long it will take to reach the charging equipment. Furthermore, the availability of accurate arrival time predictions improves the convenience of EV use because it allows the use of charging equipment to be scheduled and drivers to be informed of how long they will need to wait before their vehicle can start charging.

(2) Redirecting EVs in accordance with predicted charging power use

Frequent use of the charging equipment in a particular area will increase power use in that area and potentially affect other consumers. Accordingly, if the system predicts heavy use of a particular set of charging equipment, drivers will be directed elsewhere to avoid the excessive concentration of load.

Deployment in Equipment Monitoring

Collection of journal data includes data on the operational status of control, production, or communication equipment, and on faults or malfunctions. Equipment that operates autonomously requires continuous monitoring. In the case of production equipment in particular, in which malfunctions have serious consequences, large quantities of machinery big data is collected at intervals ranging from microseconds to seconds (see Fig. 6).

(1) Identify warning signs of potential malfunctions

Journal data is used for the following types of monitoring, for example.

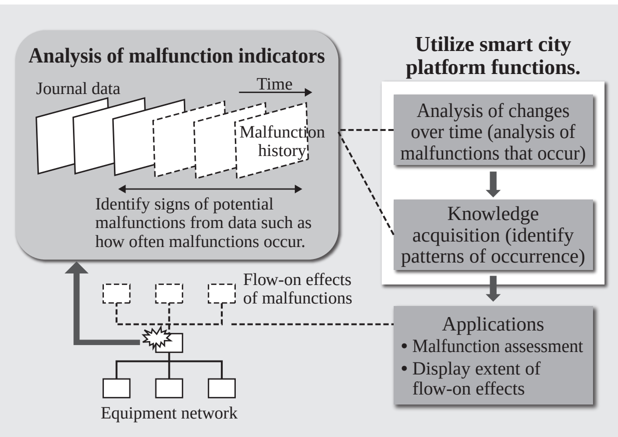


Fig. 6—Big Data Analysis of Journal Data.
The smart city platform collects and analyzes journal data comprising information on equipment operation or alarms to help respond quickly when warning signs such as malfunctions occur.

(a) Problems in equipment operation
(b) Interruptions to communications
(c) Rises in internal temperature of equipment

The following two types of monitoring can be used.

(a) Determine how often and for how long data is not received

(b) Determine how often data values exceed a threshold

When a malfunction is detected, it is not necessarily clear whether it is an equipment fault or simply a temporary malfunction. Because the smart city platform manages a large volume of historical journal data, knowledge acquisition functions can be used to analyze variations in the frequency of malfunctions and past assessment results so as to identify potential malfunctions and pass them on to an assessment application.

(2) Analysis of flow-on effects

By holding configuration information about communication networks and other systems on the smart city platform, it is possible to determine which areas will be affected by the failure of a particular communication relay device, for example.

ADVANTAGES OF SMART CITY PLATFORM USE AND VERIFICATION OF BENEFITS

This section summarizes the advantages to social infrastructure providers and users of using a smart city platform for processing big data, and the visualization techniques that can be used to present these.

Advantages of Using Smart City Platform

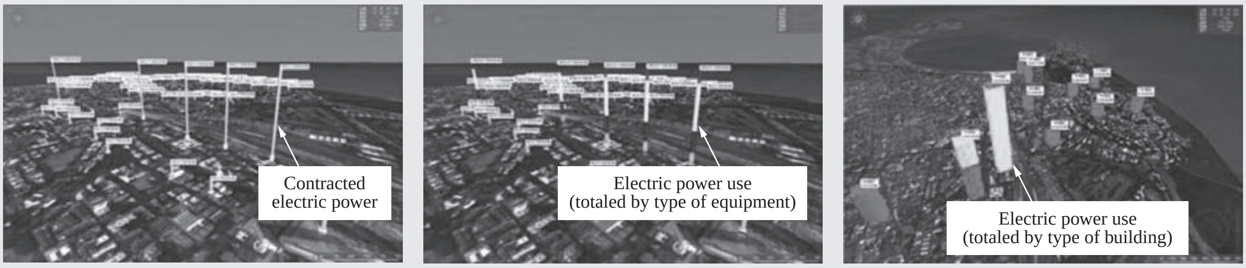
(1) Advantages to providers

(a) Because the smart city platform performs centralized collection and analysis of data from different social infrastructure to generate added-value data, it can be used for predicting demand and how the social infrastructure is used.

(b) Because the smart city platform can provide information on interrelationships between different forms of social infrastructure by supporting the coordination of applications, it can be utilized to operate the infrastructure in a balanced way.

(2) Advantages to users

(a) Because social infrastructure is operated in ways that seek to provide more convenience for users, residential and social activities are easier and more effective. Examples include using regional power generation to reduce user costs and trouble-free use of EVs.



(a) Power use during night **(b) Power use during day** **(c) District totals**

High resolution satellite images: © DigitalGlobe/Hitachi Solutions

Fig. 7—Example Visualization of Electric Power Use.
The effects of control operation can be seen clearly by displaying electric power supply and demand for buildings or districts. Similarly, letting the user shift the viewpoint wherever they want allows them to take in the situation across the entire area. Fig. 7 is created using the flood simulator by Hitachi Power Solutions Co., Ltd.

(b) The smart city platform encourages users to make effective use of their assets. Expected future developments include the use of residential photovoltaic power generation and the earning of income from the sale of excess power, for example.

Visualization

The use of visualization techniques to present the results of big data processing in a geographic information system (GIS) can provide people with a clear representation of the benefits. In particular, this can be used by social infrastructure providers for tasks such as determining the user benefits of electric power supply or identifying the location of a problem that has occurred. Because the collection of control information by the smart city platform facilitates tasks such as reproducing control outputs or predicting the effects of control, it can be used to support decision-making about social infrastructure.

Fig. 7 (a) and (b) show visualization examples from a simulation. They show the changes in electric power use by individual buildings during the night and day, and the power consumption of individual devices. Fig. 7 (c) shows the case when the display has automatically been switched to show electric power use by building type to present the results for a wide area.

Location-based display techniques have the following benefits.

(1) They provide an intuitive appreciation of geographical trends in electric power supply, such as the characteristics of residential, commercial, or other districts.

(2) They show how arrangements for redirecting electric power (interchange of electricity) or the discharge of storage batteries influence the supply and demand of electric power. This also helps determine in advance the timing and benefits of discharging storage batteries based on the time-of-day, date, and location.

(3) They provide effective ways for selecting the best control methods to use in situations such as natural disasters when there is a shortage in the supply of electric power.

By using a global representation of the location of these data points, users can scroll the display to wherever they like.

CONCLUSIONS

This article has described how big data is used on a smart city platform for the efficient operation of social infrastructure, with a particular emphasis on its use in power system management, transportation, and especially EV operation.

The smart city platform acts as an analytical database for big data processing and fulfills the following roles.

(1) Collection and integrated management of data on the operation and use of social infrastructure.

(2) Analysis of collected data to determine the operation of social infrastructure, while also helping improve convenience

(3) Clarification of the relationships between different types of social infrastructure by coordinating applications, and operating social infrastructure in ways that take account of interactions between its different parts

By enhancing analytics functions, these will help identify and resolve the problems faced by social infrastructure operators and other customers in the future.

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