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HITACHI
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Hitachi's Vision of the Smart City

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Message from the Planner

While the international trend toward urbanization accelerates, the world also faces a number of challenges that are becoming increasingly more serious, including sharp resource depletion driven by population growth and environmental problems on a global scale. This is creating a need for smart cities that can confront these challenges in a comprehensive way and sustain ongoing growth while minimizing carbon emissions.

Hitachi, Ltd. established its Smart City Business Management Division (currently Social Innovation Business Project Division) in April 2010 to develop and coordinate business activities in the smart city sector in collaboration with other parts of Hitachi and with partners inside and outside Japan. What we are aiming to achieve is the creation of a well-balanced relationship between people and the Earth. Hitachi's vision for smart cities involves creating a sustainable society in terms of both economics and how we deal with the environment, with a well-balanced natural harmony between the "eco" value of reducing the impact on the environment, and the human-centered "experience" values of comfort, safety, convenience, and well-being. What establishes this well-balanced relationship between "eco" and "experience" is the numerous public infrastructure systems that manage our cities and our way of life.

Hitachi has been involved in the construction of various different types of infrastructure systems for many years. These infrastructure systems are undergoing major changes that are closely related to the rapid progress currently taking place in the field of IT (information technology). Possibilities that are now being realized include the generation of new value through the utilization of large quantities of information collected within infrastructure systems, and the creation of new services through interoperation between different types of infrastructure. In this way, the creation of smart cities is about more than just the use of new technologies in the development of cities. Rather, Hitachi also believes in the importance of opening up new possibilities for the people, businesses, and other stakeholders who live in these cities.

The Technotalk article in this issue features a discussion on the system technologies that manage public infrastructure between Professor Seiichi Shin of The University of Electro-Communications and Yutaka Saito, President & CEO, Infrastructure Systems Group and Infrastructure Systems Company, Hitachi, Ltd. Meanwhile, in this issue's Special Contribution, Hiromichi Iwasa, Chairman and Chief Executive Officer of Mitsui Fudosan Co., Ltd., has contributed an article about the Kashiwanoha Campus City, which seeks to provide a growth-oriented and fine-tuned Japanese model for smart cities.

Other articles in this issue describe service infrastructure (such as finance, administration, and healthcare), public infrastructure (such as energy, transportation, water, and telecommunications), and the IT platforms and other system technologies that support this public infrastructure, with a focus on Hitachi's capabilities, activities, and philosophies in the field of smart cities.

Through this issue, I hope you will find Hitachi's involvement in the field of smart cities to be both interesting and helpful.

Planner for this special issue on Hitachi's Vision of the Smart City

Katsuya Koda
Senior Director
Smart Business Strategy Planning
Smart Information Systems Division
Information & Telecommunication Systems Company
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Technotalk

21st Century Public Infrastructure Systems that Coexist with People

Seiichi Shin

Professor, Control Systems Program, Department of Mechanical Engineering and Intelligent Systems, Graduate School of Informatics and Engineering, The University of Electro-Communications

Graduated from the masters program of the Graduate School of Engineering at The University of Tokyo and appointed as a research associate to the Faculty of Engineering at The University of Tokyo in 1980. Received doctor of engineering (The University of Tokyo) in 1987. Appointed associate professor of Institute of Information Science and Technology at the University of Tsukuba in 1988. Appointed associate professor in the Faculty of Engineering at The University of Tokyo in 1992. Appointed professor in the Department of Systems Engineering at The University of Electro-Communications in 2006. Appointed to his current position in 2009. Professor Shin is a vice president and fellow of The Society of Instrument and Control Engineers, a trustee of the Manufacturing Science and Technology Center, and chairman of the Control System Security Task Force of the Ministry of Economy, Trade and Industry.

Yutaka Saito

Senior Vice President and Executive Officer President & CEO, Infrastructure Systems Group and Infrastructure Systems Company, Hitachi, Ltd.

Joined Hitachi, Ltd. in 1979. Appointed General Manager of Public & Municipal Systems Division, Industrial Systems Group in 2005. Appointed General Manager of Information & Control Systems Division, Information & Telecommunication Systems Group in 2006. Appointed Chief Strategy Officer, Chief Technology Officer, and General Manager of Strategy Planning & Development Office, Information & Telecommunication Systems Group in 2009. Appointed President & CEO of Information & Control Systems Company in 2009. Appointed Vice President and Executive Officer, President & CEO of Information & Control Systems Company in 2010. Appointed to his current position in 2012.

People are taking a fresh look at what form cities should take in our era of global environmental problems and the growing urbanization in emerging economies. The key to future urban development lies in finding ways of simultaneously achieving conflicting objectives, namely the pursuit of convenience and economic efficiency that are essential to societal progress while also reducing the growing burden that this progress places on the environment. Hitachi believes that the next generation of cities, smart cities, should maintain a relationship of harmony between the global environment and the people who live and work in them. Hitachi combines total engineering capabilities with diverse technologies and extensive experience built up over many years in the public infrastructures sector and the information and telecommunications sector. It is working to utilize these to establish a global capacity for achieving this relationship of harmony based on the information and control systems development technologies that have sustained the reliability of public infrastructures.

Society in which People and Environment are in Harmony

Saito: Views on how to go about urban development and the provision of infrastructures are being rethought with the aim of realizing a sustainable society. Hitachi is working towards creating smart cities, the next generation of sustainable cities, by bringing together our accumulated technologies for public infrastructures, with one field of increasing importance being that of system development technologies for public infrastructures. Today I intend to discuss the future form of system development technologies for public infrastructures with Professor Seiichi Shin, a specialist in system engineering at The University of Electro-Communications.

Shin: In terms of factors such as the duration of power outages or ensuring that the trains run on time, it is clear that the public infrastructure in Japan is extremely reliable by global standards. While I believe that the distinctively high level of quality demanded in Japan is one reason for this, you can also point to the excellence of the control systems as well as fundamentally high product reliability. Technologies that make the parts of a system mesh together and interoperate correctly have kept system quality levels high. While scheduled power outages, restrictions on power use, and other disruptions following the Great East Japan Earthquake have impacted people's daily lives, it is likely that this has also had the effect of making many people realize just how good the infrastructure was prior to the disaster. Nevertheless, this does not mean that more progress is not needed and I feel that we need to work toward new public infrastructures by applying what we have learnt from the earthquake.

Saito: In the past, we have built systems and other products for different parts of public infrastructures with a view to continually raising standards and making improvements. However, I believe there is a sense in which the optimization of individual components has gone too far, with problems emerging in areas such as flexibility and coordination with other systems. Moreover, I believe that coordination with the people who actually use the infrastructure has been inadequate. The Great East Japan Earthquake exposed these issues. In my opinion, their resolution will also lead to the creation of smart cities.

Shin: The coordination with residents will be one of the key concepts in the future of this field.

Saito: For everyone to live happily on our finite planet, it is essential that we find forms of infrastructure that provide a harmonious balance between the global environment and convenience of living. This means we need to consider not only the infrastructures themselves but also to factor in the people who use them. "Considering the situation from the other person's perspective" has been a fundamental philosophy behind Hitachi's business and it will be necessary to construct future infrastructures from a perspective of overall optimization that takes account of everything from corporate activity to the consumers who use the services. When Hitachi thinks about smart cities, we mean the sort of cities that are supported by infrastructure like this.

To achieve this we need to make progress on using IT (information technology) for "transparency" (ways of making the actual situation visible). Transparency includes sharing of the places where interaction with residents takes place and I believe that the next generation of infrastructures will involve using these for the mutual publishing of knowledge as well as an ongoing search for improvements.

Shin: Transparency is certainly an important starting point. It is also needed for the interoperation of the various systems that support infrastructures in optimum ways that go beyond their individual scopes. Also of importance is simulation technology for comparing different scenarios.

The greatest difficulty when building public infrastructure systems that include consumers is that it is impossible to manage all of the different things connected to the system. Building public infrastructures that are capable of dealing with this reality will require advanced architectures with even greater flexibility.

System Development Technology for Public Infrastructures that Realize Symbiosis

Saito: Although they have ceased to be commonly remarked on in recent times, three keywords for system design are philosophy, concept, and architecture. What is needed in the construction of new public infrastructure systems, I believe, is to think about them in terms of philosophies and concepts and then to produce new architectures based on these thoughts. As you know, a Hitachi autonomous decentralized system is used as Japan's railway operation management system. Systems like this, in which the scope of future expansion was not delimited at the beginning and which undergo ongoing change, are difficult to implement using other than an autonomous and decentralized approach. The same applies to smart cities where the infrastructure must work in harmony with other systems and requires a sustainability in which continuing social change is a given. We call this system concept "symbiosis autonomous decentralization."

Here, "symbiosis" means a number of systems with different purposes working together in a mutually beneficial way. One example would be a regional electric power grid and household or building EMSs (energy management systems). To create advanced architectures based on this concept, as well as making the simulation and modeling technologies that are the basis of control more sophisticated, we are also developing technologies for the interoperation of various different systems.

Shin: You mean the balance between component optimization and overall optimization. I think people are also an important factor to consider.

From a system engineering perspective, half of system engineering involves mathematical approaches while the other half deals with how people behave. This is because unforeseen situations can arise in systems that include people and ongoing progress is being made in manufacturing toward adopting system designs that seek to achieve best practice. I believe that taking advantage of philosophies, concepts, and architectures like these in public infrastructure will also be important.

Saito: I agree. While symbiosis has the meaning I gave earlier in the context of system engineering, consideration of symbiosis between systems and the people who use them is also important. From this perspective, we will not be able to create the next generation of public infrastructure systems unless we identify new architectures, by which I mean things like the overall structure of systems and their principles of operation, and use the PDCA (plan, do, check, and action) cycle to achieve growth.

Shin: Accountability is important to making the PDCA cycle work. For example, a major point about a railway operation management system is that it needs not only to ensure that the trains run on time but also to coordinate with mechanisms for disseminating information when delays do occur. In electric power, demand response can be seen as having greater accountability than mandatory rolling blackouts. Symbiosis is only possible by considering the situation from the other person's perspective, and to achieve this it is important that engineers too know more about their customers and about the outside world.

Saito: One of the things that was frequently reiterated when I first started work at one of our sites (what is now the Infrastructure Systems Company's Omika Works) was "always look outside." I was also taught to approach work with a spirit of taking not the easy road but the hard one to see it for myself. Although society is different now to when we were young, what has not changed is that well-balanced system designs cannot be achieved without considering not only the nature of work and processes and people's behavior but also everything up to and including materials and products. Because the global deployment of public infrastructures that coexist with residents requires an understanding of conditions in the field, I hope that young engineers will build up a diversity of experience including spending time working in China, India, or other foreign economies.

Common Ground that Transcends Boundaries such as Nation or Industry

Shin: Because I see Hitachi as having an obligation to take Japanese technology to the world, I look forward to the global deployment of public infrastructures. Although it is often said that an obstacle to Japanese technology is that it is too advanced, does that not mean it can also be applied flexibly?

Saito: Hitachi is already participating in a number of smart city projects overseas, and since the basis of control system design is to produce what is best for the customer, it is possible to build systems to a different standard than would apply in Japan using the same approach, such as when implementing an autonomous decentralized system overseas, for example. Because of the experience and technologies we have built up in Japan, we are able to say "building something to such and such a standard will be enough to satisfy your objectives." I believe this is a major advantage.

I understand you have had a longstanding involvement in international standardization through bodies such as the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC). I see international standardization of system development technology for public infrastructures as an important factor in their global deployment.

Shin: To make global progress on symbiosis, common foundations are required that transcend boundaries such as nation or industry. I see these foundations as being equivalent to the philosophies, concepts, and architectures that you referred to earlier. With a focus on ensuring things like reliability and safety, it is possible to standardize the form that these take, and then have the freedom to build infrastructure systems within these constraints. In other words, I believe that providing venues like the rakuichi rakuza economic policy of Nobunaga Oda (which allowed marketplaces to operate freely in areas under the control of feudal lords during 16th to 18th century Japan) is a factor in the standardization of public infrastructure systems.

Saito: We intend to enhance our technologies so that we can provide good quality infrastructures on top of this foundation.

Shin: Hitachi has been involved in public infrastructures since its formation and has contributed to maintaining quality not only in energy but also in fields such as transportation, telecommunications, water supply, and sewage. Making full use of the depth and breadth of your technical capabilities is needed not only for individual residents but for Japan as a whole. I always tell my students that system engineering is about bringing together the electrical, mechanical, and other technologies and making it all work together, like the conductor of an orchestra. While I recognize that control of smart city infrastructures represents a difficult challenge, because it involves a large number of players, I hope you will continue to approach it in the spirit of "taking the hard road to see it for yourself." From the perspective of an educator, I hope that this will lead to the nurturing of Japan's young people and its engineers.

Saito: Following your example of a conductor, I see system engineers as being like chefs who are able to wield a number of different high-quality knives. The era in which our generation grew up has been talked about as a golden age and if that is so then my view is that there is nothing to stop us making the era to come even better. The fact that the young people of today are living in an era of which we have no experience holds within it the potential for breakthroughs to be made. I see combining this youthful energy with experience and past success while building the society of the future through reconstruction in Japan and urban development overseas as a task for the Hitachi of today. Thank you very much for your time.

Special Contribution

Taking Japan's Smart City Model to the World
—Kashiwanoha Campus City—

Hiromichi Iwasa
Chairman and Chief Executive Officer
Mitsui Fudosan Co., Ltd.

Town Planning's Role in Solving Problems of Both Japan and the World

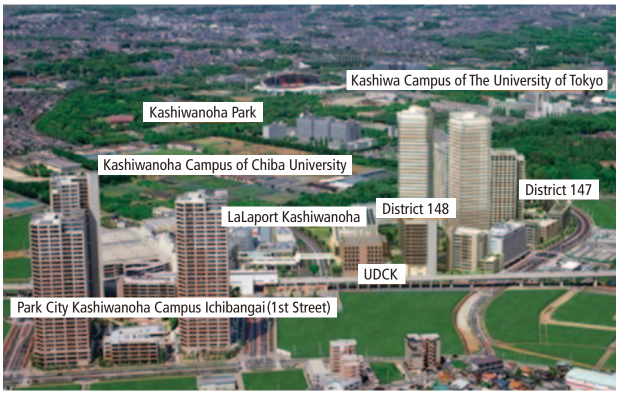
The recent Great East Japan Earthquake has left a sense of sorrow at the extensive loss of precious lives and of the need to be prepared for major disasters lodged deeply in people's hearts. It has also forcibly reminded us of the finite nature of electric power and that modern civilization is built on extremely fragile foundations. Environmental and resource problems and threats to biodiversity represent the negative face of economic progress, and while these continue to intensify on a global scale, rapidly aging populations in advanced economies, particularly Japan, are leading toward social impoverishment and decline. I believe this dangerous situation we now face can be rephrased in terms of the following question: given these conditions of limited resources and energy, declining populations, aging societies, and mature markets and industries, can we recreate the sort of vital and growing societies we once had?

Naturally, my answer is yes. The key, I believe, lies in town planning. Whereas "growth" was the core value of society back in the era of rapid expansion, our core value now is "sustainability." That is, the answer lies in the ability to pass our society on from generation to generation. As the problems we face are complex in structure, being multifaceted and interlinked, we need to take a broad view of the individual challenges and seek out ways of solving these simultaneously in an organic way. This is what the town planning approach is all about and one place where it is being put into practice is in the smart city model at Kashiwanoha Campus City described in this article (see **Fig. 1** and **Fig. 2**). The challenges posed by the environment, energy, and aging populations are shared by all nations, particularly advanced economies, and what is needed most of all at this point in time is a solution model. Ahead of the rest of the world in its need to deal with these issues, Japan's problem solving capabilities are attracting attention from around the world, and it is fair to say that people are looking forward to seeing these solutions achieved.

Town Planning for Kashiwanoha Campus City

A new lifestyle center is starting to take shape at Kashiwa City in Chiba Prefecture, a town of 400,000 people located 30 minutes by the Tsukuba Express from Akihabara in Tokyo. Centered around the Kashiwanoha Campus Station on the Tsukuba Express line, Kashiwanoha Campus City is a model next-generation city that incorporates the latest technologies, services, and systems combined with a participatory social experience for residents. It is being built through a joint public-private-academic project involving Kashiwa City, Chiba Prefecture, The University of Tokyo, and Chiba University. The aim is to construct a smart city for extended healthy living and the creation of new industry.

Kashiwanoha Campus City brings together the latest knowledge from The University of Tokyo, Chiba University, and elsewhere to produce a problem solving model and is



UDCK: Urban Design Center Kashiwa-no-ha

Fig. 1 — Overview of Kashiwanoha Campus City and Surrounds.

Fig. 2 — Image of Completed City.

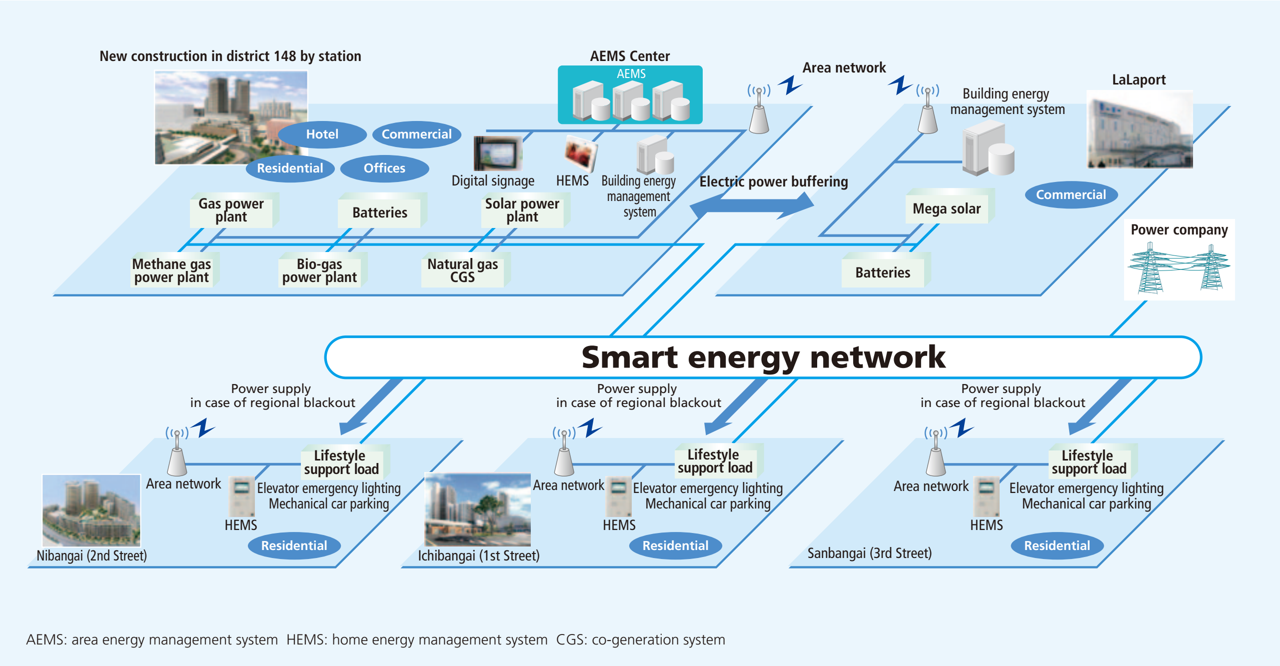


Fig. 3 — Energy Network being Built in Five Blocks around Kashiwanoha Campus Station.

undertaking its realization in a sustained and autonomous way through cooperation between residents, companies, and others. The aim is to build a new social system called the "Co-Create Eco-System" (a joint approach to sustainability), which allows everyone who feels a desire to contribute to their region, from the elderly to the young people who make up the next generation, to participate in the running of the city.

Paradigm Shift after March 2011 Earthquake

The Great East Japan Earthquake has led to a major reappraisal of town planning values. It has shown up the fragility of society relying on large power systems such as nuclear power plants and has brought a lifestyle shift from one in which a reliable supply of electric power was taken for granted to one in which the problem of energy is recognized as a fact of life. What is needed for the future is an optimum mix of centralized grid-based energy sources such as thermal or nuclear power and distributed power supplies that combine elements such as community-based photovoltaic, wind, biomass, and other forms of renewable energy as well as cogeneration and storage batteries. The objective is to perform overall optimization of power, gas, heat, unused energy, and other sources to achieve efficient energy management. It is also recognized that we need to construct robust energy networks that can withstand disasters, including providing alternate lines of energy supply in order to ensure security of supply.

In the past, suppliers and consumers have been separated, with users able to consume without regard for the overall energy supply. The first thing we need to do is to change this approach. As consumers and suppliers will coexist in close proximity in future communities that have succeeded in implementing smart grids that link distributed energy sources, it will become a common practice for them to switch roles flexibly as circumstances require while producing, storing, and conserving energy on a regional basis. Energy generation and consumption will become more transparent with anyone being able to become an energy supplier producing renewable energy and with the use of batteries installed in electric cars, homes, or elsewhere to buffer the energy flows. Such participatory low-carbon communities will lead to the creation of a new lifestyle in which electricity conservation becomes part of daily life (see **Fig. 3**).

Taking Growth-oriented, Fine-tuned Japanese Smart City Model to the World

In addition to building low-carbon cities around the

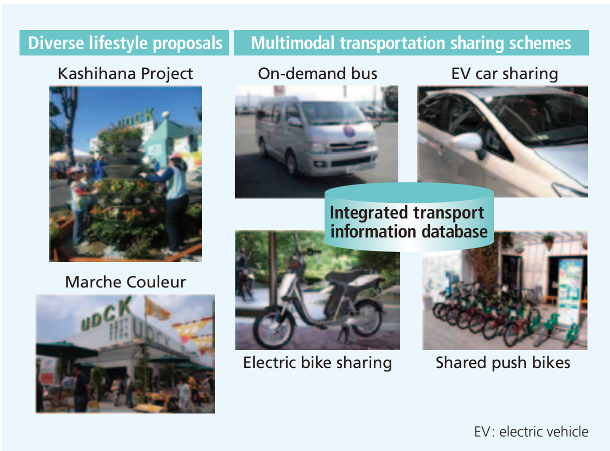


Fig. 4 — Fantastic Outlook for Future Communities.

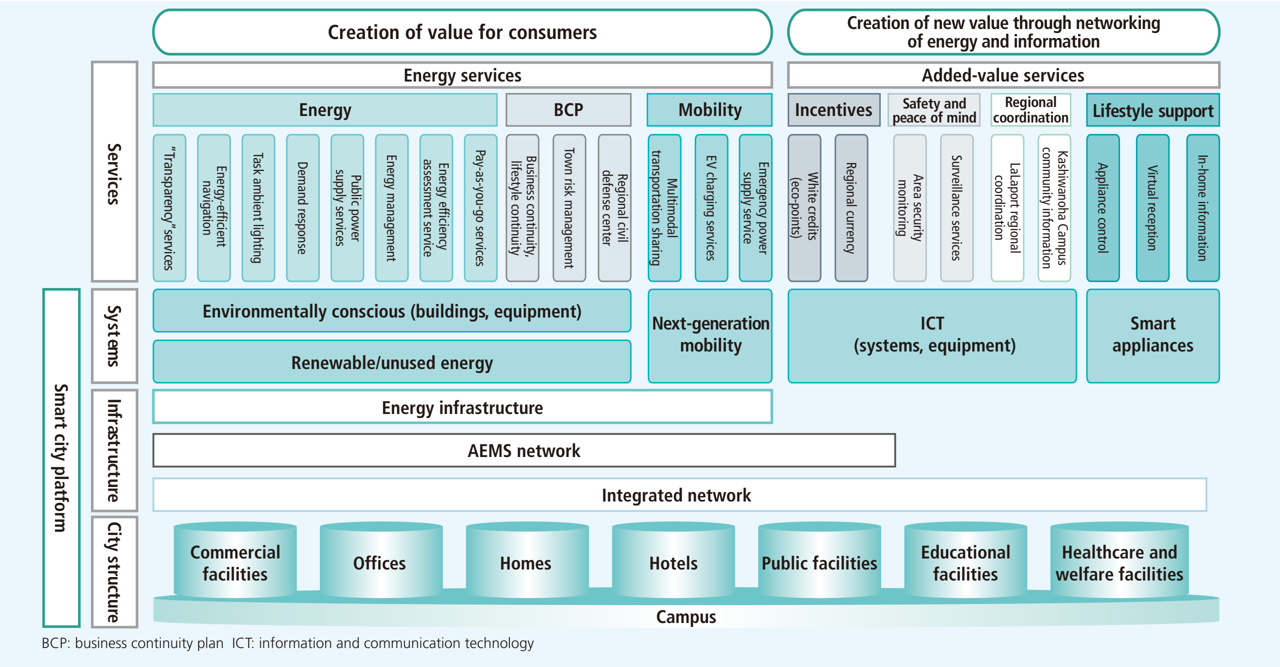


Fig. 5 — Integrated Regional Infrastructure.

world that contribute to reducing the burden on the global environment across entire regions, a true smart city (wise city) is one that is able to sustain ongoing growth so that everyone can experience a healthy lifestyle that provides peace of mind, safety, and fulfillment in a high-quality community. Although lack of space prevents me from discussing community building in this article, I hope to realize the Japanese smart city model, which creates happy and fulfilling living environments while also making broader proposals, not only about advances in technology, but also about people's shift to a new lifestyle (see **Fig. 4**). Realizing this ideal will involve having residents make use of the advanced technologies that have been introduced into the community, and will require regional collaboration based on the PDCA (plan, do, check, and action) cycle aimed at making incremental functional improvements in anticipation of future technological innovation. We intend to build a model for public systems that encompass a wide range of areas, extending from the next generation of ICT (information and communication technology) to fields such as facilities management, mobility management, healthcare services, energy services, and infrastructure control, and which involve growing alongside the wider region (see **Fig. 5**).

Hitachi has for many years been developing and operating the Shinkansen operation management system (a system widely recognized for its continued evolutions for years), and is also a partner in the Future City Model Projects of the Japan Business Federation at Kashiwanoha Campus. For the future, I hope our two organizations can combine their respective capabilities and work together as partners with an integral place in the community to build these knowledge-based public systems at the Kashiwanoha Campus City.

Packaging these management systems for the production, conservation, and storing of energy along with a participatory approach to community building and the establishment of a one-stop service for smart city development will deliver us a business model that is highly competitive in the global market. While building the next generation of energy systems presents a challenge to the entire world, it is anticipated to become an engine for sustained growth that will be in demand all around the world.

The Smart City Project is a joint venture involving leading companies from the environmental sector and has Hitachi playing a central role. It is taking up the challenge of bringing together the diverse know-how and technologies of all the participating companies to establish a Japanese smart city model at Kashiwanoha Campus City, which we seek to make into a de facto international standard. I look forward to your cooperation in the future.

* This article was originally written in December 2011.

Hiromichi Iwasa

Chairman and Chief Executive Officer
Mitsui Fudosan Co., Ltd.

Joined Mitsui Fudosan Co., Ltd. in 1967. Appointed General Manager of Development Planning in 1992. Appointed Managing Director and General Manager of No. 1 Project Planning Department, Project Planning Division in 1995. Appointed Executive Director and General Manager of Project Planning Division in 1996. Appointed Senior Executive Managing Director and General Manager of Project Planning Division in 1997. Appointed Senior Executive Managing Director and General Manager of Asset Management Division in April, 1998. Appointed President in June 1998. Appointed President and Chief Executive Officer in 2001. Appointed to his current position in June 2011.

Mr. Iwasa is the Vice Chairman of the Japan Business Federation, Chairman of The Real Estate Companies Association of Japan, Chairman of The Association for Real Estate Securitization, and Member of The Tokyo Chamber of Commerce and Industry.

Hitachi's Vision of the Smart City

Yoshihito Yoshikawa
Atsutoshi Sato
Shigeki Hirasawa
Masato Takahashi
Mayuko Yamamoto

HITACHI'S SMART CITY THEME

RECENTLY, the growing severity of global-scale environmental and resource problems together with changes in people's views and values have prompting a reevaluation of what form future cities should take. Hitachi approaches smart city development with the aim of creating a well-balanced relationship between people and the Earth. This means cities that remain in harmony with the environment while providing a lifestyle that is comfortable, safe, and convenient, without compromising people's quality of life.

To achieve this well-balanced ideal, Hitachi is seeking to achieve an advanced fusion of infrastructure with information and telecommunications by drawing on its total engineering capabilities and extensive experience built up over many years working in the field of public infrastructure, including the electric power and mobility sectors, and its capacity to deliver superior solutions in the information and telecommunications fields. These capabilities can be thought of as lying at the core of smart city development, and Hitachi plans to supply them globally in conjunction with real estate developers, construction companies, manufacturers, trading companies, and other businesses involved in urban development.

WHY THE CALL FOR SMART CITIES NOW?

Global Environmental Change and Adverse Effects of Urbanization

Behind the need for smart cities are the external factors that influence people's lives, namely the global environment and the society in which they live. Specific examples include climate change, resource depletion, population growth, demographic changes, the concentration of populations in cities, and the associated adverse effects of urbanization.

Changing Lifestyles

Another set of factors behind the need for smart cities are human considerations such as changes in people's views and values.

Specific examples include the change in the mode of consumption from ownership to sharing, such as when people rent products rather than own them, and consumers who are producers as well as users, such as when people publish their own blogs as well as browsing the Internet.

In broad terms, this represents a shift in values from "material goods" to "activities" and it is anticipated that emerging economies too will undergo a similar shift once they have completed their rapid growth in material terms.

HITACHI'S APPROACH TO SMART CITIES

What do Smart Cities Need?

A smart city can be defined as an environmentally conscious city that uses IT (information technology) to utilize energy and other resources efficiently. Furthermore, Hitachi also believes that it is important

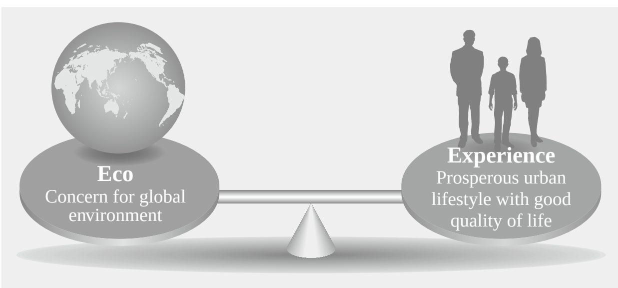


Fig. 1—Well-balanced Relationship between People and the Earth.
This means establishing a well-balanced natural harmony between the "eco" value of reducing the impact on the environment and the human-centered "experience" values of comfort, safety, convenience, and well-being.

for smart cities to be attractive places in which people will want to live. In addition to concern for the global environment, smart cities also need to satisfy the wants and values of their residents.

Well-balanced Relationship between People and the Earth

Hitachi believes that smart cities that suit all stakeholders can be achieved through a well-balanced relationship between the "eco" perspective of the global environment and the "experience" perspective of the consumers who live in the city, where "eco" means environmentally conscious and "experience" means a prosperous urban lifestyle that offers a good quality of life (see Fig. 1).

Seeking to combine convenience with consideration for the environment will be essential if cities are to continue to grow in a sustainable way. It is also very important in terms of economic considerations such as improving cities' international competitiveness and the formulation of urban policy.

The following sections discuss each of these perspectives in turn.

(1) Eco: Environmentally conscious

This perspective is concerned with how to handle a changing global environment and reduce the future impact on the environment. The need to take account of the global environment exists in a variety of fields, including the creation of a low-carbon society in response to climate change, the efficient use of water resources to resolve the imbalances in its supply and demand, and effective use of energy in ways that take account of the depletion of mined resources such as fossil fuels.

(2) Experience: A prosperous urban lifestyle that offers a good quality of life

An extremely important factor when considering the sustainability of cities is how to enhance people's experience values, such as living, working, studying, and traveling. These concern people's way of life and require the creation of a prosperous urban lifestyle that offers a good quality of life in a way that is also balanced in economic terms, with a view to solving problems such as demographic changes as well as those faced by cities directly.

The following section considers what is meant by and what is required for well-balanced relationships in the natural environment, urban lifestyles, and the economy.

(i) Well-balanced relationship between natural environment and economy

The more priority is given to the economy, the more it tends to cause environmental problems. Overcoming this requires initiatives such as the reassembly of public infrastructure and advanced control of the balance between supply and demand.

To obtain an urban structure that can achieve a better balance between the natural environment and the economy at a low cost, it is necessary to consider the city in terms of its component parts using the concept of the smallest unit of urban infrastructure.

(ii) Well-balanced relationship between urban lifestyle and economy

Placing too much emphasis on considerations like economics and efficiency results in a loss of consumer convenience and comfort. To give an extreme example, the most economically efficient way to build a city, in which the distance people need to travel is kept short, thermal efficiency is high, and infrastructure management costs are low, would be to construct a single huge building capable of housing all homes, workplaces, supermarkets, schools, and hospitals along with waste management, entertainment, sports, and other facilities. However, this would not make for an attractive place to live.

If urban consumers do not find a city to be attractive, they will go somewhere else. Being a consumer-oriented city that considers ways of providing attractive lifestyles is also an important factor.

(iii) Well-balanced relationships in urban living

Many people acting to maximize the benefit to themselves will not necessarily maximize overall welfare. For example, traffic congestion occurs when large numbers of people choose to use cars so that they can benefit from getting to where they want to go quickly and efficiently, resulting in longer travel times and the loss of that benefit they hoped to gain. What is needed to resolve this fallacy of composition is sophisticated control of demand and supply, including ways of making information visible.

This involves not only eliminating energy wastage to reduce the impact on the environment, but also improving the utilization of infrastructure and other equipment to reduce overall costs and reduce resource wastage.

(iv) Well-balanced human values

Establishing a well-balanced relationship between ownership and sharing of tools, facilities, and other equipment is essential for responding to changing consumer values. For example, if services were provided that allowed cars or other products to be used by those people who really need them, when they need them, sharing between large numbers of people would bring savings such as in the overheads of ownership and the dead time when the products are not being used. It would also minimize energy use and reduce the impact on the environment by allowing city managers to provide their services without the need to maintain excess resource or equipment capacity.

Smart City Stakeholders

The stakeholders in a city can be broadly divided into the following three groups. Hitachi believes that realizing smart cities will require well-balanced relationships in which the needs of each group of stakeholders are satisfied.

(1) Consumers

This group includes the people who live, work, study, or visit the city. They represent the people who act (live, work, study, or travel) within the city while also seeking their own fulfillment and a better quality of life.

(2) City managers

These are the organizations such as local government, real estate developers, and infrastructure operators who manage and execute the planning, design, construction, operation, and growth of the urban environment that supports consumer activity. They represent those stakeholders who seek to ensure the ongoing growth of the city.

(3) World opinion

This group represents those stakeholders who seek to reduce the impact on the global environment. Their priorities include reducing carbon emissions, making effective use of natural resources, and maintaining biodiversity.

Although they all share the same actual problems, these three groups of stakeholders can come into conflict because of differences in their priorities and the directions in which they seek to move.

For example, railway passengers would each like to travel seated in an uncrowded train, but if a city manager increased the number of trains to satisfy this demand, the result would be higher costs for the railway company as well as rises in fares and energy consumption.

On the other hand, if the number of trains were cut to reduce the impact on the environment, consumers would suffer from longer travel times and the discomfort of traveling in crowded trains.

That is, the comfort, convenience, safety, and security demanded by consumers conflict with the city manager's desire for efficient urban services, industrial vitality, and a symbiotic society, while both conflict with the prevention of global warming, effective use of natural resources, maintenance of biodiversity, and reduced impact on the environment demanded by world opinion. What is required is a sustainable approach that achieves a balance between the many conflicting demands of each group without compelling any of them to endure more than their fair share.

Hierarchical Structure of Smart Cities

Smart cities consist of two infrastructure layers for public services built on top of the national infrastructure, together with urban management infrastructure that uses IT to link these together (see Fig. 2).

(1) National infrastructure

These are infrastructures that cover areas larger than single cities. In addition to providing the foundational layers of energy, water, transportation,

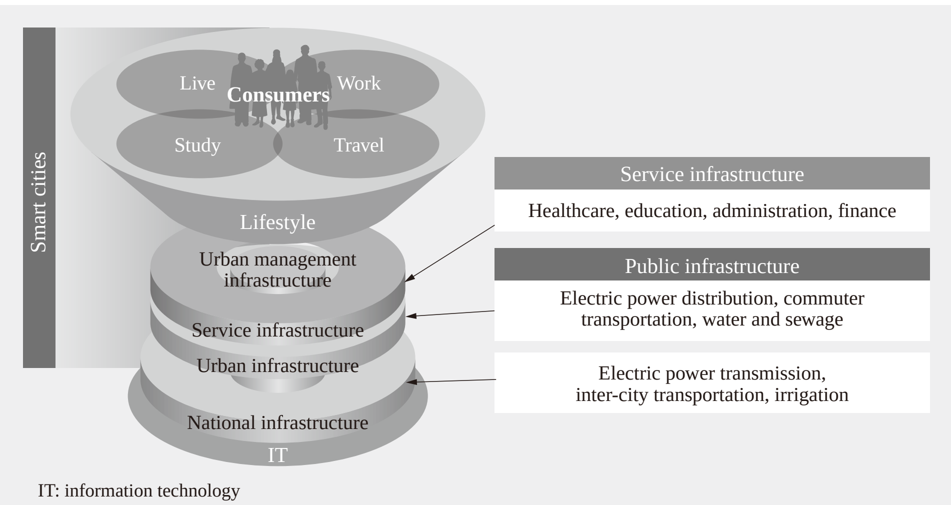


Fig. 2—Hierarchical Structure of Smart Cities.
Smart cities consist of urban management infrastructure and two infrastructure layers for public services built on top of the national infrastructure.

and communications that protect people's lives and support their day-to-day activities at a national or regional level, this is also the level at which coordination between different cities is managed.

(2) Urban infrastructure

The urban infrastructure layer is formed by linking together the smallest units based on the geographical and physical characteristics of individual cities. Most of the sectors handled by the urban infrastructure layer, including energy, water, mobility, communications, and waste, are closely integrated with the national infrastructure layer. It also represents the lowest level at which demand balancing can be considered, and the level at which interoperation, expansion, and reduction are handled in an autonomous and decentralized[(a)] way.

(3) Service infrastructure

This layer contains a city's facilities and other services including medicine and healthcare, education, administration, and finance. Built on top of the urban infrastructure, this layer can be considered from a consumer's perspective as being the layer in which they obtain services, and from a city manager's perspective as being the layer in which services are supplied to consumers.

The aim in this service infrastructure layer is to create a next-generation way of life by dividing the different services of the city into their smallest component parts, such as the ability to receive medical services or the provision of places of study, making the individual functions smarter, and then reassembling them in accordance with consumer needs.

This means making services multi-functional where this is needed or, alternatively, coordinating together under common services those that can be shared so as to eliminate waste and achieve greater efficiency and convenience. This can be thought of as the application to cities of the "object-oriented[(b)]" concept used in fields like software engineering.

(a) Autonomous and decentralized
A system architecture concept in which the overall mechanism and the associated functions are formed by combining a number of component elements from an autonomous system and having them work together.

(b) Object-oriented
A technique used in design, development, and other areas of software engineering whereby the data to be manipulated and the methods (procedures) that perform the manipulation are treated and managed as a single entity (an "object"). An object-oriented approach means putting systems together from the interactions between these objects.

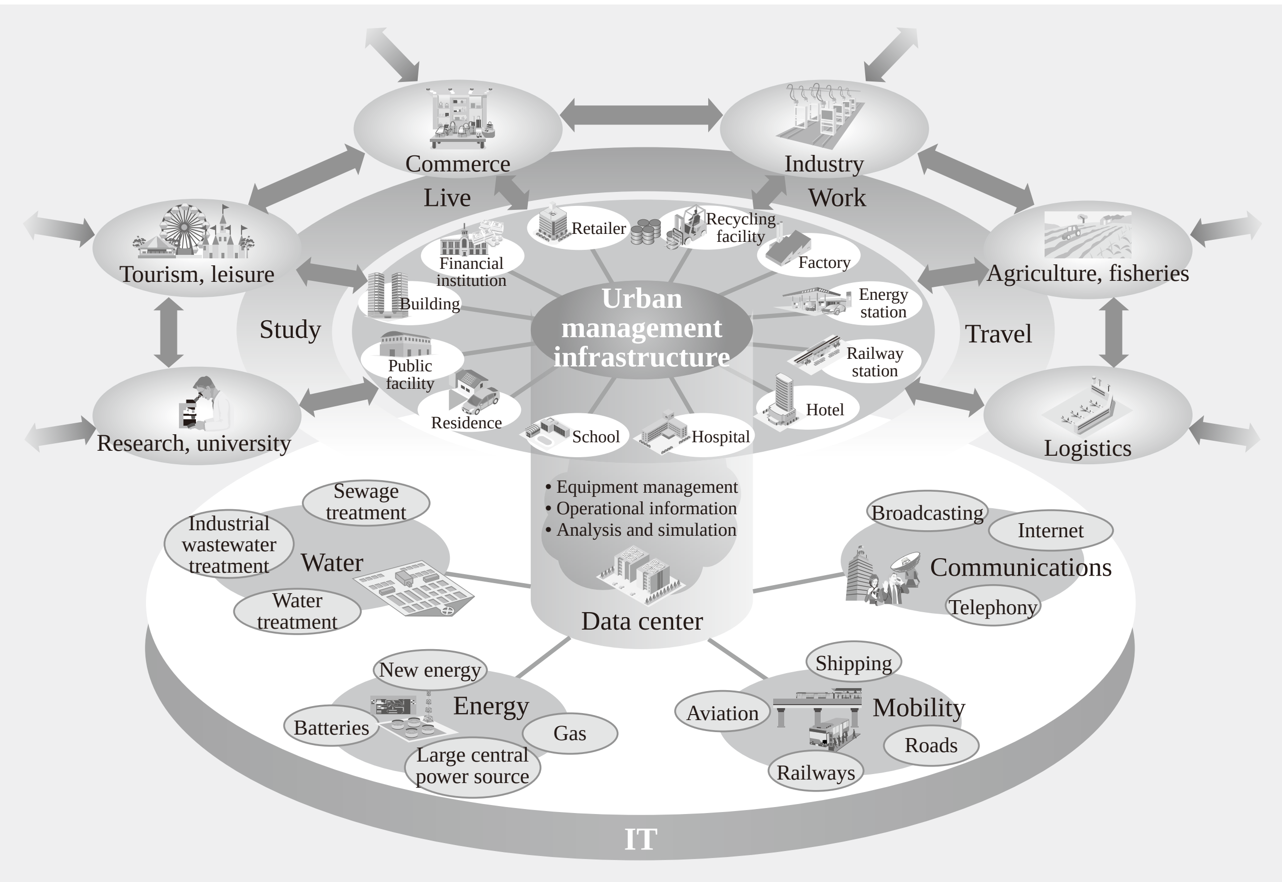


Fig. 3—Relationship between Smart Cities and IT.
IT links together and coordinates the infrastructure, services, and other elements that make up a city.

(4) Urban management infrastructure

This layer provides comfort to consumers and efficiency to city managers by reducing the impact on the environment at the same time as coordinating operations within and between different infrastructure using urban management infrastructure with functions that include using IT to manage city information, administer operations, and operate equipment. In the energy sector, for example, urban management infrastructure will be used to coordinate smart grids (which are currently a subject of interest). In the mobility sector, they will coordinate navigation systems and facilitate green mobility by using EVs (electric vehicles). In the water sector, they will coordinate advanced water management systems using water from rain and recycling.

(5) Lifestyle

This layer represents the "consumer's way of life," which means living, working, studying, and traveling. Hitachi's vision for smart cities seeks to improve QoL by understanding consumers' genuine needs and then disassembling and reassembling the functions of the service infrastructure layer accordingly.

IT SUPPORT FOR SMART CITIES

Hitachi's vision for smart cities involves using IT to combine the various elements of the hierarchy described above so that they work together. Hitachi is aiming to build a platform that can act as a foundation for achieving this coordination by utilizing the information technologies and control technologies it has built up over time (see Fig. 3).

Fusion of Information and Control

There are significant differences between the IT used in information systems and control systems.

Rapid progress is being made on increasing the speed and expanding the capacity of information systems in order to process the explosive growth in information, particularly on the Internet and mobile networks. Also, many information systems work on the "best effort[c]" principle and use horizontally demarcated, open system configurations to handle the steady stream of new services.

Control systems, on the other hand, because they are used for the reliable and safe operation of physical equipment, are designed to prioritize safety, reliability, and real-time performance. They also tend to be designed to remain in operation for decades and most adopt a vertically integrated system configuration.

Many information systems are what are called "mission-critical systems," designed for real-time performance and requiring the reliability for 24-hour non-stop operation, such as financial systems. Even in such systems as these, however, the approach to a system's reliability requirements is significantly different. For example, whereas information systems are often designed with an emphasis on average execution speed, such as throughput under normal conditions, the emphasis in control systems is on what is known as "hard real-time performance," which means that processing is guaranteed to complete within the allowed time with 100% certainty.

Hitachi believes that what will be important in the future will be to aim for overall optimization to deal with the various issues faced by a city in a comprehensive way through the fusion of information and control, whereby the two types of IT (information and control systems) interoperate much more closely than in the past.

Advanced Control for Balancing Supply and Demand

By coordinating the urban infrastructure and service infrastructure layers, urban management infrastructure gives access to more information on supply and demand than was available in the past. They also allow management of the supply and demand balance to be performed instantaneously and with high precision.

(1) Control of demand

It is possible to smooth the utilization ratios of urban infrastructure equipment, without changing total demand, by guiding and controlling demand-side needs. For example, by extending this mechanism, it is possible to reduce traffic congestion by controlling the peak in demand for road use or to guide and control demand in ways that can cope with situations where supply-side control is difficult, such as the output of photovoltaic power generation.

(2) Control of supply

It is possible to take account of demand-side considerations and control the level of supply appropriately in accordance with individual demands, such as supplying electric power based on public

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(c) Best effort

A term used for communication networks and services that do not guarantee communication quality, such as the Internet in its present form. As communication speed depends on factors such as the extent to which lines are being used and the performance and settings of software and hardware, it is possible for communication speeds and other aspects of service quality to fall below designated levels. In contrast, the term "guaranteed" is used for networks and other communication services that guarantee communication quality.

priorities in situations when adequate supply cannot be obtained.

(3) Risk mitigation

When controlling supply and demand during disasters or other emergencies, it is possible to specify and handle these independently based on geographical and physical characteristics. Minimum guidelines can be set for the smallest units of the urban infrastructure layer such as shared energy or other resources so that, by linking and coordinating these with other systems in an autonomous and decentralized way, things like the supply and demand balance and load distribution are controlled appropriately, even during an emergency. This secures service infrastructure appropriately unless they are physically damaged.

Non-stop Autonomous and Decentralized Operation of Urban Infrastructure

Hitachi considers city infrastructure in terms of its smallest units and builds the infrastructure based on an autonomous and decentralized system concept. By designing each system to function autonomously, service outages can be prevented when abnormal situations arise without any local malfunctions spreading to the entire system. These can then be enhanced further to become "symbiosis autonomous decentralized systems" that are more easily able to interoperate, even between different communities and different systems, and can adapt to a dynamically changing city for long into the future without interruptions to 365-day, 24-hour functions.

Adapting to Geographical Characteristics

By dividing infrastructure and other city functions into small units and combining only those that are needed by the community, it is possible to satisfy the requirements of islands or other small or geographically isolated areas by providing autonomous infrastructure consisting of only those elements that are required by the community. Meanwhile, to satisfy the requirements of arid areas where catchment management is a priority, it is possible to provide, in a limited way, some of the functions available in cities, such as Hitachi's intelligent water system[d].

By separating non-location-dependent services from their locations, it is possible to respond in a fine-tuned way to the requirements perceived by the administrators who formulate city policies, including improving both convenience and efficiency, reducing operating costs by sharing those services that are best shared, and cutting energy use by eliminating unnecessary functions.

Adapting to Changes that Come with Different City Life Stages

Cities can be differentiated on the basis of the series of life stages they go through over time, such as the rapid progress in emerging economies, the renewal taking place in the mature cities of developed nations, and the renewal stage when the national infrastructure layer and service infrastructure layer become separated. The smart cities envisaged by Hitachi will be able to adapt to these changes in an extremely flexible way.

In the stage of rapid progress, for example, the national infrastructure layer and urban infrastructure layer are developed in an integrated way, with the service infrastructure layer and lifestyle provision added as they become needed.

The situation in the renewal stage is that the national infrastructure layer remains in good condition but there is a loss of urban infrastructure layer and service infrastructure layer, with provision of these undertaken rapidly, starting with those parts that are needed.

In the mature cities of developed economies, it is possible to operate cities in a sustainable way that suits even societies such as Japan's, with a diminishing population, by allowing the conversion of facilities, for example, such as taking schooling functions that are no longer necessary due to a falling birth rate and redeploying them in rest homes for the elderly.

HITACHI'S CAPABILITIES

Hitachi boasts extensive experience and total engineering capabilities built up over many years of involvement in public infrastructure sectors such as electric power, mobility, water and sewage, and industrial systems. It also has the capabilities to achieve an advanced fusion of infrastructure with information and telecommunications, being equipped with excellent solution capabilities in the information and telecommunication sectors along

(d) Intelligent water system
Hitachi's proposal for a water infrastructure that integrates water treatment systems with information and control systems. The system uses information on water use (collected from sensors and other sources and then stored) to predict water demand and coordinates the operation of the water supply, recycled water, and industrial wastewater treatment systems in an optimum way to maximize energy efficiency and make effective use of water resources. The system also supports the coordination of water infrastructure over a wide area using an integrated management system.

with advanced technologies and know-how, including autonomous decentralized technology. By utilizing these capabilities, which are seen as essential for the development of smart cities, and undertaking projects in partnership with real estate developers, construction companies, manufacturers, trading companies, and others involved in urban development, Hitachi believes that it can design smart cities that exhibit a higher degree of completeness.

Hitachi is currently involved in many smart city projects being undertaken around the world where it is verifying specific practices and building experience. Not just in three or five years' time, but 30 years from now and beyond, Hitachi intends to be involved in supporting smart city development and will continue supplying solutions for a wide range of areas as one of the essential participants in the industry.

Current and Future Activities

Hitachi, Ltd. established its Smart City Business Management Division (currently Social Innovation Business Project Division) on April 1, 2010 to serve as a coordinating organization that spans a range of sectors involved with smart cities, including electric power, mobility, public and industrial infrastructure, urban development, telecommunications, information, and control. The mission of the new division is to participate in smart cities from the concept stage, offering a one-stop service that acts as a powerful driver for the business while also adding new value.

Currently, Hitachi is engaged in the following three major initiatives associated with smart city development.

(1) Packaging of Japan's advanced infrastructure

Japan is an environmental leader and this initiative involves packaging the strengths of its advanced infrastructures so that they can be deployed globally through collaboration with local partners. Rather than acting on its own, Hitachi is working with corporations and other entities with strengths in the various components that make up the package in order to cover all aspects of infrastructure construction, from planning to operation and maintenance services.

(2) Participation through collaboration between public and private sectors from the concept stage, and participation as a primary contractor

This initiative involves expanding Hitachi's business into services such as operation and maintenance, and taking part in activities such as central and local government policies and the consulting and planning work undertaken at the concept stage of projects by expanding its PPP (public-private partnership) business. This will sometimes mean Hitachi acts as the primary contractor. In such cases, if adequate capital cannot be raised for smart city development, Hitachi will support urban progress by having a comprehensive involvement in everything from investment in the infrastructure to its operation and maintenance.

(3) Technology and system development

This involves utilizing the strengths of Hitachi, with its extensive experience and success in the public infrastructure sector, to develop and supply the new technologies and other systems required by smart cities. Examples include plans for energy management systems that can reduce the impact on the environment while maintaining security of supply through the flexible adjustment of the balance of regional energy demand and supply, charging management, vehicle information management, and other systems that allow EVs to play their part in a city's mobility infrastructure.

APPLYING JAPANESE INGENUITY TO URBAN DEVELOPMENT

The ingenuity of the Japanese people that gave rise to the term "mottainai," which has now spread around the world, has expanded to encompass every aspect of urban infrastructure and lifestyles, and Hitachi wants to use the term "smart city" to refer to such cities when creating a well-balanced relationship between people and the Earth through advanced technology and other know-how.

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Service Infrastructure for Next-generation Smart Cities

Yoshihito Yoshikawa
Yoshiaki Hanafusa
Takumi Matsuda
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OVERVIEW: The disassemble and reassemble approach has an important role to play in realizing smart cities. This approach involves disassembling service infrastructure, making it smarter, and then putting the required parts back together again. Hitachi believes that, when applied to smart cities, this approach will provide not only the consumers who live in them, but also others such as the businesses involved in town planning and the public and other operators of urban facilities with benefits that have not previously existed. We are currently entering an era in which overall optimization will solve social issues such as urban and environmental problems. Given these circumstances, Hitachi intends to achieve genuine coordination across different public infrastructures and contribute to realizing the various different smart city concepts in use around the world. In addition to making further enhancements to its public infrastructure systems and telecommunication technologies, Hitachi will do this not just by combining different elements of service infrastructure, but also by enhancing these in such a way that the services become fused.

INTRODUCTION

WHEN humans first started living in communities, the major factors in establishing those community living spaces were geographical. Examples include whether river flows were reliable, whether the water was clean, and whether the site was in the mountains or on a plain or island. Also, the risk of natural disasters such as earthquakes, tsunamis, storms, or tornados; the nature of the climate; and the availability of resources. People have built the infrastructure they require within the constraints of these geographical and physical conditions and gone about communal living with a degree of control over some aspects of the natural environment, but also at the mercy of others.

Cities have expanded over time, with the consequent evolution of urban functions being directed by the demands or desires that have emerged from people's ways of life. For example, taking on board the demands of different people, cities have evolved in response to factors such as religion, culture, customs, and other values inherited from the past; the needs of politics and economics driven by factors such as the spread of infrastructure, policies and systems, and the industrial structure; and the need to respond to change, such as changing demographics and employment conditions.

In modern times, however, the things that people want from cities have become more diverse and extensive, resulting in a rapidly worsening imbalance with the global environment. Recognizing this situation, Hitachi has put forward the idea of a well-balanced relationship between people and the Earth and has embarked on measures aimed at building smart cities that take account of the global environment without compromising the convenience of people's way of life.

This article describes Hitachi's approach to service infrastructure for next-generation smart cities.

HITACHI'S CONCEPT OF WELL-BALANCED IN SMART CITIES

In Hitachi's view, a well-balanced relationship between people and the Earth begins with the idea of a well-balanced relationship being maintained between eco (meaning environmentally conscious) and experience (meaning a prosperous urban lifestyle that offers peace of mind and convenience).

The concept of "well-balanced" in smart cities is not limited to thinking in terms of the balance between the global environment and urban lifestyles. Taking the achievement of both of these as a starting point, this issue of Hitachi Review shows examples of such well-balanced relationships in a range of different contexts so that the sort of smart city that is desired by all of the city's stakeholders can be realized in a sustainable way (see the "Hitachi's Vision of the Smart City" article).

In Hitachi's vision, it is possible to maintain a well-balanced situation even in large and complex cities by having the flexibility to change with the times, which is to say, continuing to accept rather than reject change and maintaining structures that continue to evolve, while these well-balanced relationships remain in harmony. This section describes the specific mechanisms by which smart cities come about.

Disassembly and Reassembly of Service Infrastructure

Service infrastructure includes city facilities and services such as medicine and healthcare, education, administration, and finance. By disassembling and reassembling this service infrastructure, Hitachi believes it is possible to satisfy consumers' genuine needs and build cities in which service providers and other operators can deliver the services that the community demands in an optimum form.

Paradigm shift brought about by disassembly and reassembly of service infrastructure

Under the conventional view of cities, a hospital, for example, is thought of as a place at which functions are performed such as consultation, admission, the serving of meals, surgery, and the issuing of prescriptions. In other words, a place at which consultations, admission, the serving of meals, surgery, the issuing of prescriptions, and other such functions take place was called a hospital.

If hospital functions like admission and the serving of hospital meals were performed in a hotel instead, we would think of them as being equivalent to functions performed in a hotel like the provision of rooms or meals.

Also, the fundamental requirement of consumers who enter a hospital is to have their illness cured. Thus, actions like visiting the hospital, being admitted, or surgery are only steps toward this end. If the hospital management updates their check-in system to shorten waiting times, this represents an improvement in one of those steps and does not satisfy the fundamental requirement of curing the illness.

Hitachi believes that considering the locations and functions of service infrastructure separately and reassembling them based on specific fundamental requirements provides completely different insights and allows the services to be made smarter. That is, it is possible to usher in a paradigm shift in our approach to cities by separating the service delivery functions that make up the city from the conventional idea of their being places and reassembling them based on actual requirements.

Continuing with the hospital example, it is possible to satisfy medical needs in a more responsive way by providing completely new multi-function facilities that combine different types of conventional service infrastructure, such as allowing children who have been admitted to hospital to continue remotely receiving the same lessons as their classmates at school, or allowing patients to receive medical counseling at a neighborhood police or fire stations.

This approach achieves well-balanced results through a combination of services, places, and other factors.

It also allows service management and operators to deliver different types of services at a reasonable cost so that consumers are able to access various services at the same place and at an appropriate price.

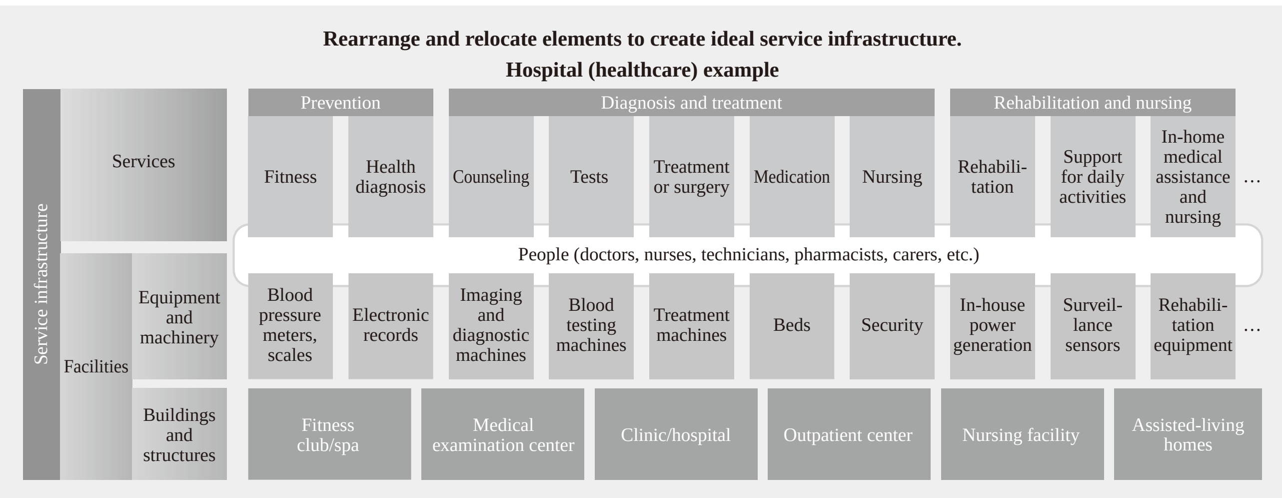

Fig. 1—Example Disassembly of Service Infrastructure.
Infrastructure is divided into buildings and structures, equipment and machinery, and services.

Methods of disassembly and reassembly

To explain how to go about the disassembly and reassembly of service infrastructure, the following section describes an example of the steps in this process.

The following describes the disassembly and reassembly of service infrastructure.

(1) Divide the service infrastructure into services and facilities.

(2) Divide the facilities into buildings or structures and equipment or machinery.

(3) Split into the fundamental needs of consumers.

(4) Sort based on whether the particular item is a procedure or objective. Sort based on factors such as whether the particular item is location-dependent or not.

(5) Make the split up functions smarter.

(6) Using the results of steps (1) to (5), reassemble the service infrastructure by bringing together the equipment and machines one by one.

In following this process, the following considerations are needed for disassembly, improvement, and reassembly.

(i) Disassembly

Divide the service infrastructure into services and facilities and then further divide the facilities into buildings or structures and equipment or machinery. Perform this disassembly based on the smallest units of urban living. As a consequence, the elements into which the infrastructure is divided become general-purpose components that can be used anywhere in the world (see Fig. 1).

(ii) Improvement

Map the functions of the individual elements to the fundamental needs and make them smarter so that they can work more reliably and efficiently. Specifically, in addition to identifying their fundamental purpose and whether they are location-dependent or not, also consider advances in technology when making them smarter, such as any technical innovations or the potential to apply technologies from other fields.

(iii) Reassembly

While the disassembled and improved parts were divided based on the smallest units of urban living, when put back together again, they are combined in such a way as to satisfy the individual elements required in a smart city. For example, it is possible to select only those functions that are required for the needs of the consumers who live there based on considerations such as the topography, culture, religion, nationality, and level of infrastructure at the place where the smart city is located. This allows the reassembly of smart service infrastructure, which only provides the functions required and which dispenses with unneeded functions.

Also, by considering the lifecycle of different facilities and equipment (planning, design and development, operation, and maintenance and repair cycle) when reassembling the various elements, the service infrastructure itself can go through cycles of growth, development, and renewal.

Smart cities have a diversity of regional needs specific to the country, region, or city and also due to ongoing changes. Similarly, the conflicts that arise among the three stakeholders, namely consumers (including both the resident and working populations), city managers (public service providers, government, real estate developers, and others), and world opinion (global-scale environmental problems), are different in different places, as are things like how to go about balancing these and where they impact. Even when these regional needs are very tightly intertwined, disassembling and reassembling the functions of service infrastructure will result in smart cities that are well-balanced in terms of their distinctive local characteristics or needs.

Anticipated Benefits of Disassembly and Reassembly

Disassembling and reassembling means dividing the service infrastructure into its component parts, making them smarter, and then putting the required parts back together again. Smart cities built based on this concept will provide not only the consumers who live in them, but also the businesses involved in town planning and the public and other operators of urban services, with benefits that have not previously existed.

(1) Smoothing workloads

By turning functions that were previously performed separately into common functions, and by taking services that were not necessarily tied to particular places and supplying them in a non-location-dependent way over a wide area, it is possible to smooth over periods of high and low demand resulting from the particular circumstances of the community and make full use of limited resources.

In particular, in the case of emergency response by hospitals that are short of doctors, rather than handling calls separately at each hospital, it is possible to use centralized coordination to make effective use of limited medical resources and smooth workloads through measures such as first taking calls at a central call center and then directing and referring the patients who need it to the suitable emergency medical center based on factors such as whether spaces are available and whether the appropriate specialists are on hand.

(2) Efficient sharing

Sharing of equipment and machinery improves its utilization, reduces investment costs, and reduces the amount of resource usage and disposal. Because it makes it possible to select only as much machinery or other resources as is required for a particular purpose, it also contributes to reducing operation energy. In the case of car sharing, for example, if someone who only wants to make a trip in one direction shares a vehicle with someone who wants to make the same trip in the opposite direction, the vehicle's utilization increases and it only travels the distance that is really needed. Because this improved utilization allows greater expenditure on looking after and servicing the vehicle, it also leads to higher service levels.

(3) Improved efficiency by reviewing division of responsibilities

By reviewing individual roles as part of the disassemble and reassemble process, it is possible to make fundamental improvements in response to issues such as concern over long waiting times prior to being seen at a hospital or the fact that, even if you feel ill, medicine cannot be dispensed from a pharmacy without your first visiting the hospital and receiving a prescription. If greater use is made of IT (information technology) to allow things like making inquiries or payments over the network from home, or other locations away from the hospital, it will be possible to make processes like consultation and dispensing more efficient and provide a one-stop service.

(4) Energy efficiency and low carbon emissions

While there is no question of the need to encourage improvements in areas like energy efficiency and lower carbon emissions, greater benefits can be achieved by reviewing components and individual functions. As reassembly results in services that are independent of time or place and are provided in a one-stop format, it reduces carbon emissions by saving energy in areas like transportation.

NEW WAYS OF LIFE MADE POSSIBLE BY DISASSEMBLY AND REASSEMBLY

Disassembly and Reassembly Focused on Services

By disassembling healthcare in terms of the services of a hospital (considered as a type of facility) and reassembling at a different location or facility, it becomes possible to receive various healthcare services without restrictions like time or place.

For example, it would also be possible to receive remote treatment, advice, or other assistance in an emergency at locations outside a hospital, such as a police station, school, supermarket, or in-service train. Further, through collaboration with educational institutions, it would be possible for children who have been admitted to hospital to continue receiving the same lessons as their classmates at school while remaining in their ward or have doctors provide counseling to children in their homes or school without leaving the hospital (see Fig. 2).

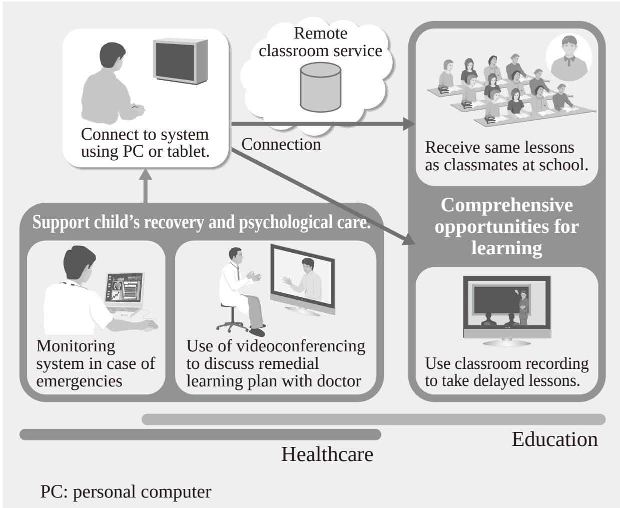

Fig. 2—How Disassembly and Reassembly Might be Used at Facilities Like Hospitals or Schools.
Coordination between medical, educational, and other services provides new services that transcend time and place.

In the field of public facilities, it is possible to review and reassemble the functions of the meeting places in each community to transform them into smart meeting places where people can receive more multi-purpose services.

These new smart meeting places would provide one-stop services for some educational, administrative, medical, and other functions, based on the nature of the town and its way of life, in a way that goes beyond those offered by conventional sites that are tied to a particular function.

Moreover, because the reassembly of functions allows a wider range of services to be provided than in the past, it strengthens the original objective of being a place where people meet and as a result can be expected to revitalize the real communication in each community.

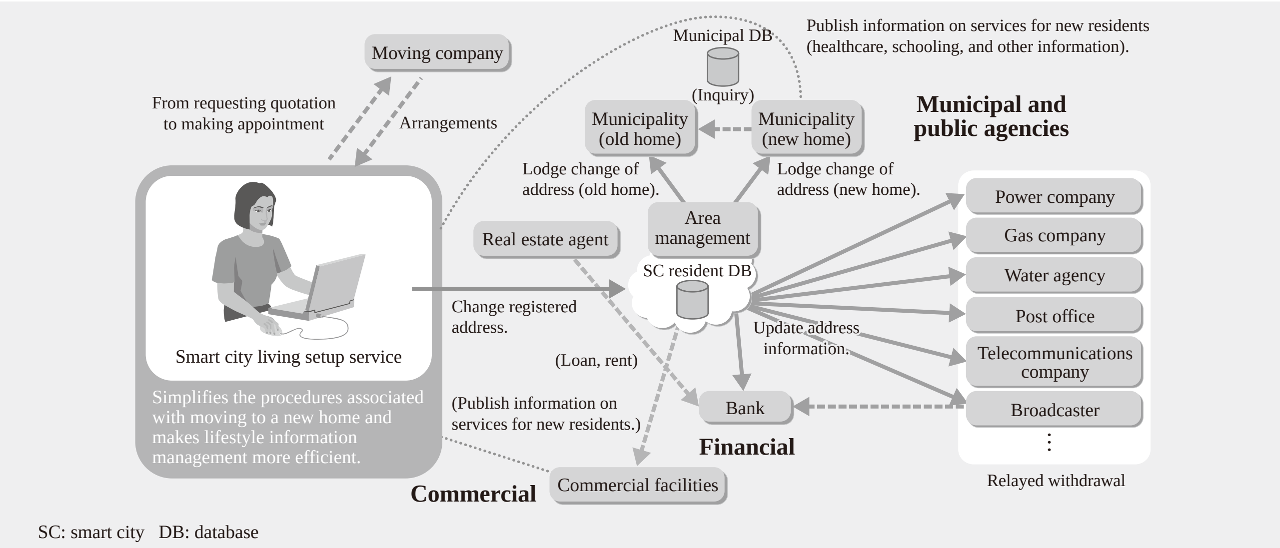

Fig. 3—How Disassembly and Reassembly Might be Used for Moving and Public Administration Services.
The area management function provides smooth updating of usage information for service infrastructure services.

Disassembly and Reassembly Focused on Consumer Objectives and Actions

Reassembling city functions based around the objectives and actions of service consumers can also create a more convenient and comfortable way of life.

The following section considers the example of moving to a new home. Currently, moving requires you to undertake various separate procedures and submit forms such as a certificate of residence. It should be possible to eliminate the complex and troublesome procedures of the past by disassembling the actions required when moving to a new home in terms of services, and then reassembling them with a focus on objectives and actions so that the various services provided by different agencies work in coordination.

Specifically, having changes to personal details such as your address or telephone numbers managed by area management functions will smooth the process of keeping your information up to date, such as updating your details with public agencies and financial institutions or updating your usage information with infrastructural services such as electricity, gas, water, and telecommunications. This also allows local service providers, commercial facilities, and others to offer services to new residents that have a high level of added value (see Fig. 3).

Disassembly and Reassembly Focused on Location

By considering a railway station and reassembling its disassembled functions, it is possible to imagine what form an advanced railway station might take.

If digital signage were installed at various locations around a new railway station, it would be possible for commuters to make use of even the short time they spend waiting for a train. Examples might include three-minute English lessons with an on-line teacher, stretching exercises with an on-screen instructor, or viewing an etiquette lesson prior to visiting a customer. In this way, it is possible to construct functions that suit different needs, not just using the trains.

Moreover, the objectives for the service infrastructure in a railway station are not limited to service improvements aimed at users. In the case of power generation, for example, in addition to installing solar panels, it might also be possible to use the ground under the station to generate geothermal power. This would allow the installation of charging stands for EVs (electric vehicles) that use this power. In the event of a power shortage, it might also be possible to draw a temporary power supply from the batteries in a number of EVs.

ACHIEVING HIGH-QUALITY SERVICE INFRASTRUCTURE

One aspect of a smart city is very different to traditional urban development. Hitachi is working to achieve the following objectives while interlinking service infrastructure with this aspect of smart cities, namely their urban infrastructure like energy, transportation, water, and telecommunications (see Fig. 4). Specifically, they intend to:

(1) Generate new value through the disassembly and reassembly of service infrastructure.

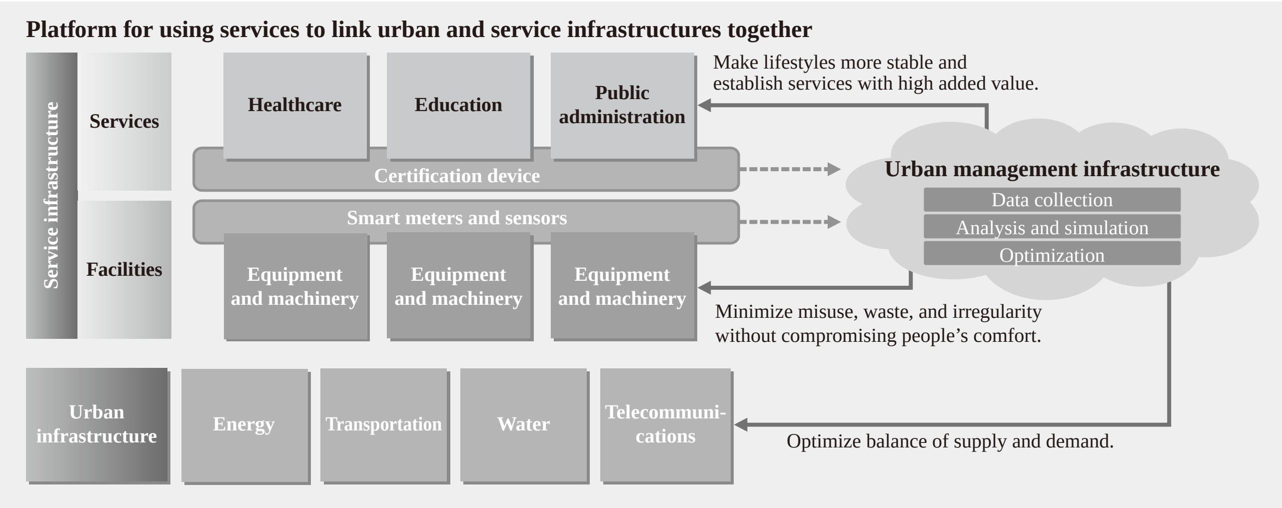

Fig. 4—Urban and Service Infrastructures Linked Together by Urban Management Infrastructure.
Hitachi contributes to various forms of value creation in smart cities by linking urban and service infrastructures together.

(2) Minimize misuse, waste, and irregularity in equipment and machinery without compromising people's comfort.
(3) Establish various services that provide consumers with a high level of added value.
(4) Optimize the balance of supply and demand in urban infrastructure.
(5) Achieve an efficient allocation of functions and coordination between national infrastructure and urban infrastructure.
(6) Development of an urban management infrastructure that supports these objectives and the development of the integrated information and control systems for data collection, analysis, simulation, and optimization that lie at their core

Specifically, in addition to making ongoing improvements to existing products and technologies, Hitachi is undertaking development of technology for new elements, validating technologies and models by conducting tests and trials in Japan and other countries or regions, and planning new products and solutions and learning about needs by being involved in urban development from the concept stage.

Hitachi has been involved for many years in the development of Japan's public infrastructure systems, which support the country's society and way of life, including power, water, transportation, and telecommunications. "Contributing to society through the development of superior, original technology and products" has been Hitachi's corporate credo since its formation, and Hitachi believes that putting this vision into action globally is its raison d'etre and its mission in the field of smart cities.

We live in an era in which overall optimization is used to solve urban and environmental problems and other challenges for society. In addition to enhancing its public infrastructure systems and information and telecommunications technologies, Hitachi believes that, by going so far as to fuse service infrastructure together rather than just combining separate parts, not only can it provide solutions in which different types of public and service infrastructure are truly integrated, but also that it can contribute to the realization of smart city concepts from around the world.

CONCLUSIONS

This article has described Hitachi's approach to the service infrastructure that supports next-generation lifestyles.

Urban development involves huge projects in which many different organizations and companies participate over a long period, from planning through to development and operation. Hitachi intends to continue working together with its partners, local businesses, and others as it seeks to achieve a well-balanced relationship between people and the Earth by contributing to smart city development globally in ways that suit local needs based on a smart city vision design.

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Coordination of Urban and Service Infrastructures for Smart Cities

Kazuaki Iwamura
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OVERVIEW: While various urban and service infrastructures are available for use in smart cities, their mutual interdependence means that attempting to optimize each one independently may result in their being used inefficiently. Therefore, a new type of urban service provider called Social System Coordinator provides urban and service infrastructures that suit consumers' lifestyles and consumption needs, as well as coordinating infrastructures to improve the overall efficiency of their use in the community. Hitachi promotes the coordination of infrastructures for smart cities by providing the associated equipment and IT platforms.

INTRODUCTION

MEASURES aimed at creating smart cities through the introduction of the latest information and control technologies[1] have been adopted in various countries in recent years. Smart cities are expected to improve the convenience of urban and service infrastructures and make people's lives more comfortable, with the aim of achieving sustainable development while also taking account of the environment. What has become essential is the creation of new usage value by operating urban infrastructure (such as electric power and water use) and service infrastructure (such as healthcare) in a coordinated way, rather than just improving their efficiency independently.

This article describes the need for the coordination of urban and service infrastructures in smart cities, the merits of coordination from a consumer's perspective, and examples of how this coordination might work along with the methods for achieving it.

NEED FOR COORDINATION OF URBAN AND SERVICE INFRASTRUCTURES

Coordination of infrastructures is needed as a way of solving the issues that arise from changes in the operation and use of urban and service infrastructures.

Changes in Operation and Use of Urban and Service Infrastructures

The operation and use of urban and service infrastructures such as electric power, water, mobility, and healthcare are undergoing the following changes:

(1) Increasing diversity of infrastructure

In the past, the urban and service infrastructures available for use were determined in advance. However, the improving efficiencies of photovoltaic power generation, use of recycled water, and EVs (electric vehicles) are increasing the number of urban and service infrastructures that can be used.

(2) Greater use of information

The spread of the Internet and the rapid proliferation of sites providing information have made a wide variety of information available. While this provides valuable information to consumers, it also makes it required to be able to filter unnecessary information from the necessary one.

(3) Advanced infrastructure operation

Advances in IoT (Internet of things) technology for connecting large numbers of objects together has made it possible to monitor the status of urban and service infrastructures. The impact of faults can be minimized by being quick to replace or repair equipment when this information indicates a potential problem.

Challenges for the Operation and Use of Urban and Service Infrastructures and Need for Coordination

Challenges for operation and use

It is anticipated that the following challenges will arise for the operation and use of urban and service infrastructures as they become more diverse.

(1) Challenges for operations

The advent of technologies such as photovoltaic power generation and EVs mean that those who, until now, have only ever been power consumers now have the potential to become power producers. However, because the power from such sources cannot be indiscriminately connected to the grid, it is necessary to monitor electric power consumption and only connect to the grid when appropriate.

(2) Challenges for use

Although EVs and other similar technologies can be described as an environmentally conscious form of mobility because they do not emit CO_2 (carbon dioxide), their range is shorter than conventional vehicles. This makes it necessary to pay close attention to charging as the vehicle may run out of power before reaching its destination if the charge is insufficient.

Need for coordination

It is difficult to solve the challenges faced in the operation and use of urban and service infrastructures within their own respective operational scopes because it is impossible to know what impact changes will have on other infrastructure. Accordingly, it is necessary to improve convenience by coordinating the various urban and service infrastructures and optimizing operation by assessing their interrelationships.

In the case of recycled water production or seawater desalination, for example, some of the power requirements can be met by photovoltaic power generation, wind power generation, and power supplied from EVs. Also, trouble-free use of EVs can be achieved without the vehicles running out of power by providing appropriate guidance based on location information. The following sections give examples of this sort of coordination of urban and service infrastructures.

MERITS OF COORDINATION OF URBAN AND SERVICE INFRASTRUCTURES FROM CONSUMER’S VIEWPOINT

The coordination of urban and service infrastructures can be thought of both in terms of coordination within particular fields and in terms of coordination across different fields such as electric power and water use.

Although the coordination of urban and service infrastructures in itself is not something visible to consumers, it can lead to the creation of new value, provide a way to reduce usage costs, and improve things like convenience and comfort. In this case, the key word for use is “lifestyle.” Hitachi recognizes that the benefits of coordination of infrastructures result from their use in ways that suit consumers’ lifestyles made possible by the coordination of urban and service infrastructures.

(1) Reduction of usage costs

Consumers are billed for their use of urban and service infrastructures and can reduce this cost by producing electric power or other utilities for themselves. For example, generating electric power and selling it can provide an income. The resulting electric power can then be taken and used to produce recycled water, thereby reducing the charges for water use.

(2) Improvement of comfort

The increase in the number of urban and service infrastructures that are available must lead to improved comfort. For example, a shortage of water can be avoided if electric power generated in the home is diverted to purify water. Also, a comfortable lifestyle can be facilitated by using the recycled water for district cooling.

(3) Improvement of convenience

While the spread of the Internet has improved convenience by making it easier to obtain information, it is common for consumers to want information to be aggregated. For example, if the choice of hospital appointment and means of transportation is combined, convenience is improved by also informing the consumer about how they can get to the hospital when they specify the date on which they want to make the appointment. Coordination of urban and service infrastructures can identify interrelationships and complementarity between infrastructure information, which can then be provided to consumers.

COORDINATION OF URBAN AND SERVICE INFRASTRUCTURES BY SSC

Coordination of different urban and service infrastructures is performed by operational organizations that use an IT (information technology) platform (a system that supports coordination). An operational organization that uses an IT platform for coordination of urban and service infrastructures

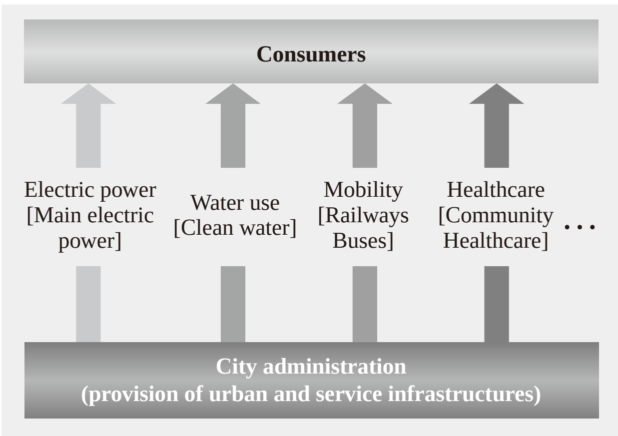

Fig. 1—Conventional Approach to Use of Urban and Service Infrastructures.
In the past, the urban and service infrastructures used by consumers were determined in advance.

is called a Social System Coordinator (SSC), a new business category.

SSCs are community managers and manage communities that use urban and service infrastructures. The position and role of SSCs are described below.

Position of SSCs

Past urban and service infrastructures have been predetermined, which meant changes in the way they were used were not possible. That is, the number of available urban and service infrastructures was small and consumers had no choice but to use them (see Fig. 1).

On the other hand, when the number of available urban and service infrastructures increases, consumers become able to choose which they will use (see Fig. 2). As a result, SSCs act as intermediaries for the operation and use of the many different urban and service infrastructures. The following are specific examples of urban and service infrastructures available for use:

(1) Electric power: Possibilities include use of electric power from renewable energy such as photovoltaic or wind power generation and from thermal storage using city gas. In homes and buildings, consumers are able to generate their own power using photovoltaic power generation or by supplying power from EVs.

(2) Water use: In addition to clean water, use of recycled water is also possible. At locations such as islands or deserts, new water produced by seawater desalination can be used.

(3) Mobility: Vehicles such as EVs and PHVs (plug-in hybrid vehicles) can be used. Also, environmentally conscious forms of mobility such as electric trams can provide the public with a way of getting around.

(4) Healthcare: Performing diagnosis in the home or elsewhere (remote diagnosis) becomes possible as an alternative to having patients visit a hospital for diagnosis and treatment. Meanwhile, the growing use of PBT (proton beam therapy) machines and other medical technology makes it easier for patients to receive highly advanced forms of treatment.

Role of SSCs

In acting as intermediaries for the operation and use of urban and service infrastructures, SSCs have the following three roles (see Fig. 2):

(1) Monitoring of urban and service infrastructures

SSCs monitor the operational status and other aspects of urban and service infrastructures using tools such as sensors and the Internet. Advances in IoT technology accelerate the use of sensing in urban and service infrastructures.

(2) Provision of information on available urban and service infrastructures

Numerous different urban and service infrastructures can be used in each field. However, it is anticipated that consumers will find it difficult to decide the best combination to use. Accordingly, SSCs suggest which options suit a consumer’s lifestyle. In the case of a household in which both partners work, for example, they may want to operate photovoltaic power generation in the daytime and consume the power at night. They may also want to earn some income by selling the electric power if they are away from home for an extended period due to travel or some other reason. SSCs seek to suggest ways of combining urban and service infrastructures so as to satisfy consumer requests such as these.

(3) Operation of urban and service infrastructures

In addition to providing consumers with information about urban and service infrastructures, SSCs also respond to public needs by operating this infrastructure, including providing control (see Fig. 3).

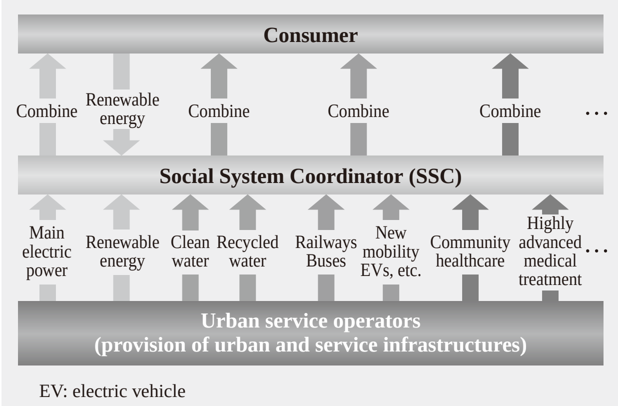

Fig. 2—Future Ways of Using Urban and Service Infrastructures.
SSCs can advise consumers on how to combine use of urban and service infrastructures.

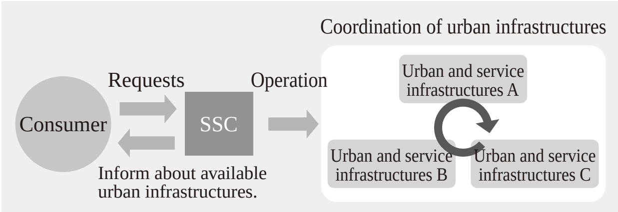

Fig. 3—Role of SSCs (1).
In addition to providing information about what urban and service infrastructures are available to suit consumers’ wants, SSCs also handle their operation.

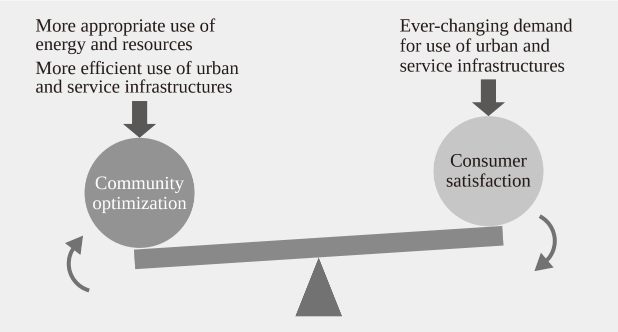

Fig. 4—Role of SSCs (2).
SSCs operate urban and service infrastructures in a way that balances the wants of consumers with what is best for the community.

For example, they execute energy saving and resource saving, the appropriate combination of energy and resources, and the provision of ways of accessing mobility instead of consumers. On the other hand, when viewed from the perspective of the overall community, operating urban and service infrastructures in accordance with consumer lifestyles has the potential to result in under- or over-supply of energy and other resources. For this reason, SSCs coordinate operation across the entire community (see Fig. 4).

Also, when it is not possible to satisfy demands from within the community, an SSC can negotiate with SSCs that manage other communities to acquire energy or other resources, or to reserve use of the other community's means of mobility, healthcare, or other services.

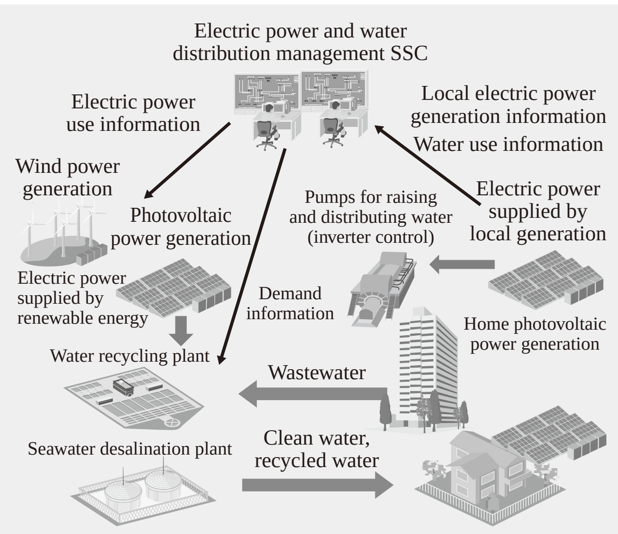

Fig. 5—Coordination of Electric Power and Water Use.
Renewable and other forms of energy are used for purposes such as treatment of recycled water and seawater desalination.

In this way, SSCs operate urban and service infrastructures in a way that balances the requests of consumers with what is best for the community.

EXAMPLES OF COORDINATION OF URBAN AND SERVICE INFRASTRUCTURES

The following two key points relate to the coordination of urban and service infrastructures:

(1) Greater choice of urban and service infrastructures

(2) Support for use of urban and service infrastructures from SSCs

Bearing these in mind, the following sections use coordination of electric power and water use, coordination of mobility and electric power, and coordination of mobility and healthcare as examples to present a specific and representative image of how coordination of urban and service infrastructures might work in practice.

Coordination of Electric Power and Water Use

This section describes the coordination of power supplies with seawater desalination, use of recycled water, improvements to pumping efficiency for raising and distributing water, and district cooling (see Fig. 5).

Although electric power is required for water treatment and cooling, power use can be made more efficient by incorporating renewable energy. SSCs assess the demand for recycled and clean water and ensure that adequate electric power is available for its supply.

(1) Recycled water

It is accepted that recycled water that can be purified with less power consumption is appropriate for uses such as flushing toilets or cooling buildings. Meanwhile, the spread of facilities for treating recycled as well as clean water means that electric power is required for their operation. Use of recycled water can be encouraged if electric power stored in batteries during the night or other times when electricity is cheap is used to provide the power for water treatment. It is also possible to reduce the cost of energy and resource use for both electric power and water use by incorporating other sources, such as electric power from consumers who want to sell the power they have generated in their home or elsewhere, or from large-scale photovoltaic or wind power generation. SSCs promote the use of cheap recycled water by distributing it for use by consumers.

(2) Seawater desalination

Seawater desalination systems are recognized for their potential to provide a reliable supply of water in locations concerned about water shortages, such as islands or deserts. However, seawater desalination requires large amounts of electric power. If the power is supplied by conventional forms of power generation, generation can become very expensive in the event of sudden oil price rises, for example, and this would likely lead to a jump in the price of water. Consequently, the installation of practical photovoltaic, wind, or other such forms of power generation at the island or desert location should help eliminate worries about electric power shortages.

(3) Inverter control of pumps for raising and distributing water

Water usage varies with the time of day. This means that the flow rate must be regulated to match user demand. While this has typically been executed by opening or closing valves, this does not change the power consumption. In contrast, power can be saved by using inverter control to vary the pump speed based on the amount of electric power. Also, if electric power supplied from photovoltaic or wind power generation is introduced, water use can also be reduced along with providing the required amount of electric power.

Coordination of Electric Power and Mobility

Initiatives aimed at encouraging greater use of EVs are evident around the world and progress is being made on establishing the infrastructure for supplying the electric power.

EVs have attracted attention as an environmentally conscious form of transportation that does not emit any exhaust gas. Although progress is being made on installing charge stations along with the standardization of things like fast charging and connectors, the distance current EVs are able to travel on a single charge is still only a few hundred kilometers. This means that EVs require frequent charging and careful use to avoid having them run out of power before reaching their destination.

Solving these problems requires management of the EV's electric power and driving the vehicle to a charge station or other charging site when the remaining battery power is low. However, having consumers monitor the remaining charge on their EVs and make their own decisions about when to stop at a charge station will be an obstacle to wider use of EVs as it is dependent on traffic conditions such as congestion and is likely to pose problems in situations such as when the charge stands are busy. Accordingly, the SSC responsible for the management station handles things like charge stand usage and ensuring convenience (see Fig. 6).

At the management station, information is collected on the location of all EVs, their power consumption, and the number of charge stands available at charge stations. The management station then directs EVs that are running low on charge to a charge station with an available slot. It can also reserve the charge stand to cut down on waiting time by avoiding having it taken by another EV. The supply of electric power can be made more efficient by increasing the number of available charge stands and the amount of electric power supplied to heavily used charge stations while decreasing the number of available charge stands and the power supply to infrequently used charge stations.

Coordination of Mobility and Healthcare

It is now possible to use the Internet for tasks such as making healthcare appointments or getting updates on the status of public mobility, and combining these

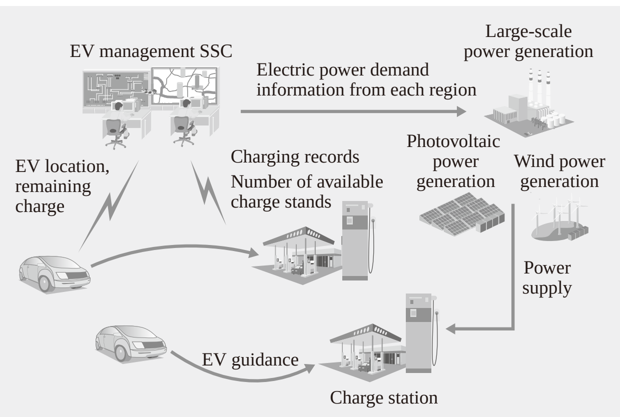

Fig. 6—Examples of Coordination of Electric Power and Mobility.
Coordinating the management of EV use with the supply of electric power to charge stations facilitates safe EV motoring.

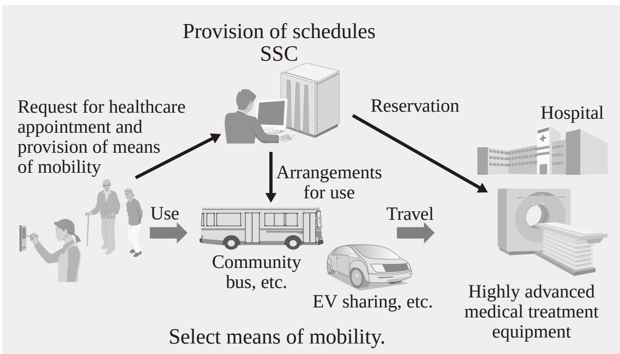

Fig. 7—Examples of Coordination of Mobility and Healthcare.
Convenience can be improved by coordinating reservations for highly advanced medical treatment equipment with arrangements for travel to the hospital.

enables a one-stop service to be offered for healthcare appointments and mobility scheduling (see Fig. 7).

The realization of smart cities will also encourage progress in healthcare. Increasing populations of elderly are forecast in developed countries in particular. This creates a need for greater use of IT and more advanced healthcare for the elderly in some communities.

While progress is being made in remote diagnosis technology, a visit to the hospital is still needed for things like face-to-face consultations with a doctor, treatment, and use of highly advanced medical treatment equipment such as PBT and MRI (magnetic resonance imaging). In this case, the consumer makes an appointment for a consultation and finds a way of getting to the hospital. While the spread of the Internet means it can be used to obtain information, such as about healthcare institutions and forms of mobility, or to make an appointment if necessary, this can be a time consuming process of trial and error involving repeated adjustments to appointments and transportation schedules. Therefore, convenience can be improved by making the necessary appointments and healthcare equipment bookings, and providing a means of mobility for getting to the hospital, in response to the consumer entering their reason for visiting the hospital.

The SSC acts as an agent, providing information like this about healthcare and mobility as well as arranging a means of mobility if needed. The SSC makes appointments for consultation or treatment instead of the consumer based on what they want, and coordinates or arranges a travel schedule.

Inter-community Coordination of Urban and Service Infrastructures

SSCs handle the coordination of electric power, water use, mobility, and healthcare on consumers' behalf. The consumers are able to reap the convenience, comfort, and other benefits of the coordination of infrastructures that is taking place behind the scenes. However, the quantity of resources such as electric power and water may in some cases be insufficient to satisfy the demands of all consumers. Similarly, it is not always possible to satisfy all consumers when making reservations for healthcare equipment or forms of mobility. To deal with this, SSCs responsible for other communities are contacted to see if some accommodation can be reached regarding the required resources. Similarly, an SSC will consider such arrangements with other SSCs. It is anticipated that mutual arrangements among communities will allow the maximization of community satisfaction (see Fig. 8).

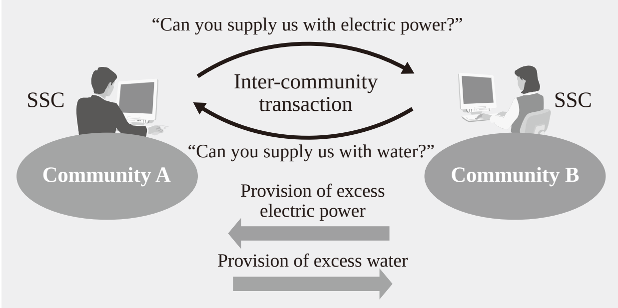

Fig. 8—Use of Inter-community Transactions to Secure Energy and Resources.
By reaching accommodations between communities on the use of electric power, water, and other resources, the wants of the consumers in each community can be realized.

METHODS FOR COORDINATION OF URBAN AND SERVICE INFRASTRUCTURES

SSCs collect information on urban and service infrastructures and devise ways of making them work together based on the results of analysis. This information collection is performed by an IT platform and the urban and service infrastructures are operated based on the results of analysis. As the IT platform adopts autonomous decentralized technology, it can easily accommodate the addition and upgrading of equipment needed for services and has a structure that allows a different server computer to take over if the service system goes offline.

The overall system has a three-layer structure consisting of a sensing layer for collecting information about the urban and service infrastructures, a network layer for carrying the information to the SSC, and a service layer that produces services by consolidating the collected information and conducting analysis. Of these, the SSC corresponds to the service layer (see Fig. 9).

(1) Sensing layer

Sensing is used to determine the status of the urban and service infrastructures. As the size of sensors and other hardware becomes smaller and the infrastructure for wireless communications more widespread, it becomes possible to more closely monitor the status of the urban and service infrastructures. This use of networks for sensing objects is made possible by the progress of IoT technology.

(2) Network layer

This corresponds to existing carrier networks and IP (Internet protocol) networks.

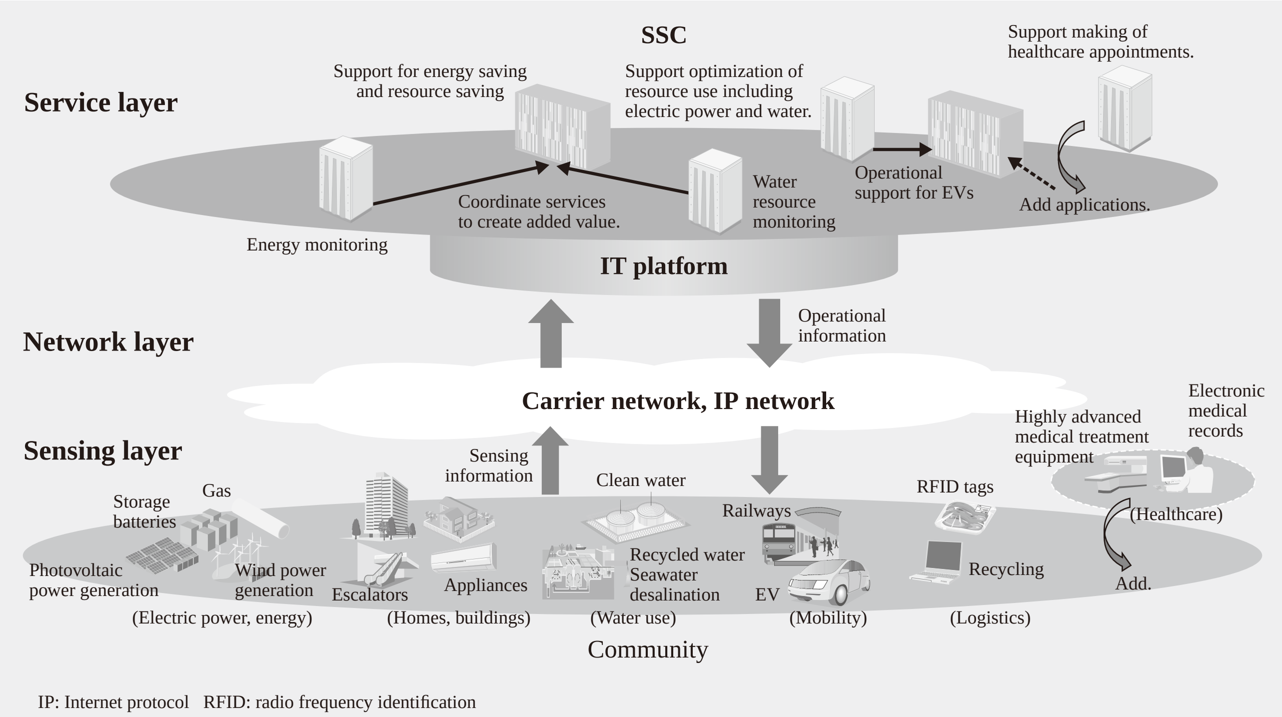

Fig. 9—Overall System Configuration.
The overall system has a three-tier structure consisting of a sensing layer for monitoring the urban and service infrastructures, a network layer for transmitting information, and a service layer that operates services for coordination of urban and service infrastructures.

(3) Service layer

Acquired information is collected on an IT platform and analyzed by a system called an application to determine the status of the urban and service infrastructures. This also facilitates coordination because it provides a view of the statuses of the different parts of the urban and service infrastructures, as well as the relationships between city functions such as logistics and payments. Simulation and other techniques are used to analyze the status information. The results of this analysis are used to provide consumers with services such as a one-stop payment service that consolidates payments of charges for different infrastructural services with income from electric power generation, and including infrastructure information presentation services that inform consumers about infrastructure that suits their lifestyle. Services for city managers include operating infrastructure under contract and infrastructure diagnosis services, which monitor and diagnose infrastructure to ensure that it operates continuously. In particular, use of urban and service infrastructures varies with the time of day and fluctuates with the seasons. Accordingly, operational records are stored and utilized as knowledge to help with operation.

CONCLUSIONS

This article has described the need for the coordination of urban and service infrastructures in smart cities, the merits of coordination from a consumer's viewpoint, and examples of how this coordination might work along with the methods for achieving it.

It is recognized that the number of urban and service infrastructures (such as electric power, water use, mobility, and healthcare) will increase in the future and that consumers will be able to select those that best suit their own lifestyles. Also, SSCs will become more active in their role of operating infrastructure and providing information based on consumer needs. It is also anticipated that coordination of urban and service infrastructures will reduce the burden on consumers and allow for electricity saving and other frugality without compromising things like the comfort and convenience of the overall community.

Hitachi intends to continue contributing to the ongoing progress of society by promoting coordination of infrastructures through the supply of IT platforms and other equipment for urban and service infrastructures.

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Hitachi's Smart Grid Technologies for Smart Cities

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OVERVIEW: Prompted by the problem of global warming together with factors such as the power outages resulting from the Great East Japan Earthquake, the growing momentum behind the worldwide adoption of renewable energy is intensifying the need for smart grids. Hitachi is involved in the development and supply of systems for smart grids, including solutions for improving electric power quality and reliability. Different economies and regions around the world have a variety of different needs, and Hitachi is contributing to the building of a greener, smarter, and more robust grid in order to realize a smart grid that can satisfy these needs by converging its extensive know-how in information, telecommunications, monitoring, and control technologies for electricity systems.

INTRODUCTION

A smart city can be defined as an environmentally conscious city that uses IT (information technology) to utilize energy and other resources efficiently[1].

In the context of the electric power industry, Hitachi's smart city concept of a well-balanced relationship between people and the Earth can be interpreted as meaning the construction of power systems that place less of an impact on the environment. In terms of energy, the smart city concept involves consolidating a number of supply and use systems for electricity, gas, water, transportation and so on within an area to increase energy efficiency and maximize the use of renewable energy, such as roof-top photovoltaic generation. The concept is an extension of the smart grid concept for electricity systems and this article describes the technologies used in smart grids.

SMART GRIDS

Smart grids are advanced electric transmission and distribution infrastructures constructed by applying electric power technologies and information technologies. The importance of making electric power grids smarter is growing, with particular background factors including the ongoing increase in energy consumption around the world, the problem of energy resource depletion, the aging of electric power transmission and distribution equipment, the large-scale power outages that have occurred in both advanced and emerging economies and their associated economic losses, the problem of global warming, and the issue of how to maintain local energy supplies during a disaster.

The requirements for smart grids differ significantly in different economies and regions.

The USA faced the problem of diminishing security of supply due to the aging of transmission and distribution equipment and a shortage of generation capacity. In addition to equipment modernization, there are also demands for making improvements through the use of information and telecommunication technologies, including better energy efficiency, lower costs, and greater reliability. As electric power demand is anticipated to continue growing in the future, use of demand response techniques to reduce peak-hour power consumption has advantages for the global environment as well as for consumers and utilities.

Europe adopted the 20-20-20 targets in December 2008 (an environmental policy with three targets: A reduction in greenhouse gas emissions of at least 20% below 1990 levels by 2020, a 20% reduction below 1990 levels in primary energy achieved by improving energy efficiency, and 20% of energy consumption to come from renewable resources). The region has also been making rapid progress on the adoption of renewable energy, assisted by individual country policies such as feed-in tariffs, which offer a guaranteed price for purchase of renewable energy. As a result, the installation of numerous distributed energy sources such as wind and photovoltaic power generation has led to the emergence of power system issues, such as grid operation and the management of supply and demand. Resolving these has become a matter of urgency.

In emerging economies, demand for electric power has been growing rapidly and there is considerable activity in the construction of large conventional and renewable energy plants and new transmission and distribution networks. The aim, when establishing new transmission and distribution networks, is to use the latest smart, low-carbon equipment from the very beginning. The field of urban construction also has examples of projects involving the building of large new smart cities from scratch. Here too, the demand is for the use of smart, low-carbon technology in the electric power system and its associated control.

In terms of both interruption frequency and duration, the extent of power outages in Japan is among the lowest in the world. The country has also achieved world-leading levels of power quality measured by parameters such as electric power frequency and voltage. One of the challenges anticipated for transmission and distribution systems in the future is finding ways to introduce greater use of renewable energy while maintaining and improving on this excellent level of power quality. The government of Japan has announced a plan to increase photovoltaic power generation to 28 GW in 2020 (a roughly 20 times increase on 2005), the majority of which is expected to come from household photovoltaic power generation. This corresponds to more than 15% of peak summer power demand and, at times when demand is particularly low, such as during the daytime in the New Year period, the presence of this capacity will make maintaining the supply and demand balance difficult because the sum of base generation capacity and photovoltaic power generation will exceed total demand. In addition to supply and demand balancing, numerous other issues also need to be solved. These include problems with the distribution grid voltage and the threat of simultaneous drop-out of photovoltaic power generation during grid faults.

Although electric power is predominately supplied from electric power companies, in the future, distributed generation systems such as wind and photovoltaic power generation will also supply electricity. Energy consumers will adopt a wide range of energy efficiency measures and these are likely to have a major influence on the power supply system. For this reason, it is anticipated that mechanisms will be established to allow participation in the power supply system to extend beyond power suppliers in the future, and to include power users as well.

In this way, Japan’s electric power system would become more complex and undergo significant changes, including readjustments to the relationships between consumers and suppliers and the associated legal framework and operations, as well as the connection of new supplies and loads. Maintaining and improving power quality in the face of these changes will require more advanced and smarter grid stability equipment, control systems, and information systems, as well as new mechanisms, system configurations, and other innovations.

Hitachi has been involved in a wide range of products over many years, ranging from electric power generation, transmission, and distribution equipment to control systems such as EMS (energy management system), SCADA (supervisory control and data acquisition system), DMS (distribution management system), and AMI (advanced metering infrastructure) systems, as well as utility business systems such as billing systems and call center systems. By drawing on its strengths in equipment, control systems, and information systems, Hitachi believes its integrated solutions can contribute to the creation of the advanced smart grids of the future.

SMART GRID TECHNOLOGIES

This section describes how power grid analysis technology can be used to identify problems and solutions in order to maintain grid quality and reliability in situations where a large amount of renewable energy capacity is installed in a smart grid, along with the technologies for solving these problems.

FACTS (Flexible AC Transmission System) Devices

Advanced power electronics improve the quality of power supply and energy efficiency because they allow the rapid and continuous variable-speed control of generators and motors. They can be applied to reactive power control and HVDC (high-voltage direct current).

A STATCOM (static synchronous compensator) is a voltage regulator based on a voltage-sourced converter that uses power electronics.

Maintaining a suitable transmission voltage is important not only to ensure that users’ electrical devices function properly but also for reasons of transmission capacity, transmission efficiency, and the stability of the power system.

The STATCOM is a solution for increasing the power transmission capacity of existing equipment as well as minimizing and keeping to an appropriate level the voltage fluctuations in the grid caused by variations in the output of renewable energy (see Fig. 1 and Fig. 2).

Fig. 1—STATCOM Unit.
An installed STATCOM (static synchronous compensator) unit is shown.

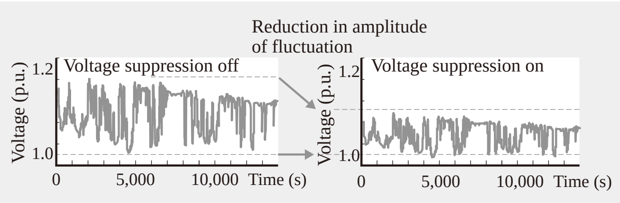


Fig. 2—Suppression of Voltage Fluctuations Resulting from Installation of STATCOM Unit.
This simulation models use of a STATCOM to minimize voltage fluctuations from renewable energy.

The need for STATCOMs, with their fast response, will grow in the future as use of power sources with fluctuating outputs, such as photovoltaic power generation and wind power, increases.

D-STATCOM is the STATCOM for distribution networks.

The connection of large numbers of distributed power sources, such as household photovoltaic power generation, to the grid has the potential to cause instability in the distribution network voltage. Causes include voltage rises due to reverse power flows or voltage drops below the stipulated range due to a rapid drop in the output of photovoltaic power generation following a sudden change in the weather.

While possible measures for dealing with this voltage problem include splitting pole-top transformers, adopting low-impedance conductors, or shifting to higher distribution voltages, the D-STATCOM offers an effective solution in terms of cost and its ability to ensure power quality over a wide area through integration with distribution management systems and its rapid response to sudden changes.

HVDC transmission systems including FCs (frequency converters) and BTB (back to back) HVDC use DC (direct current) to interconnect between bulk power network systems.

To reduce electricity costs, electric utilities (power companies) are obliged to operate their electric power systems over a wide area. However, connecting an electric power grid across a wide area carries the risk that a local failure will affect the entire grid. Technologies that can help to prevent this and achieve trouble-free interoperation over a large grid include HVDC. Also, because the transmission distance possible using AC (alternating current) transmission is limited by stability issues, DC transmission is being adopted around the world for use in long-distance transmission systems that carry power to consumers from large remote power sources.

Hitachi has been working on all of the DC projects in Japan, and has also embarked on the development of a new HVDC system based on voltage-sourced converter technology that helps achieve better grid stability.

Advanced Network Technology

Power grid analysis technologies that analyze grid behavior are essential for predicting and resolving the many complex problems that arise in power grids. A variety of different phenomena are likely to accompany the connection of significant amounts of photovoltaic power or wind power and the analysis techniques used range across a variety of methods, from steady analysis to instantaneous value analysis, depending on the time constant of the phenomena concerned. In particular, the behavior of the power system in the event of a grid fault is expected to be made more complex by the presence of large amounts of photovoltaic power generation or wind, and a variety of research about this topic is already underway.

Hitachi provides an analysis service to suit different needs depending on the nature of the project, and is working on the development of actual systems based on the results of this analysis.

A grid stabilization system is a solution that applies grid analysis techniques to make effective use of existing equipment and prevent wide-area outages. For example, a grid fault caused by lightning strike has the potential to result in a major outage if it leads to a chain reaction of generators dropping out. Preventing this requires limiting output in line with the amount of power that can no longer be transmitted as a result of the grid fault, but the choice of which generators to govern depends on factors such as the location of the original grid fault and how it propagates across the grid.

The grid stabilization system runs an online stability calculation continuously based on grid information and prevents an outage from spreading over a wide area by pre-loading the on-site equipment at substations with information on the appropriate measures to take in the event of a grid fault, such as generation shedding.

In the future, increased use of distributed power sources will require grid stabilization systems that monitor the output of these power sources or produce estimates based on factors such as the weather, and that incorporate models of how the distributed power sources will behave in the event of a grid fault.

Energy Storage

It is assumed that greater energy storage capacity at various levels will be needed as more renewable energy capacity is added to power systems. Batteries are one form of energy storage and it is expected that they will play a major role.

The ideal capacity and power output for an electrical storage system differ depending on factors such as its intended purpose and how it will be used. Peak shifting, for example, requires large storage and discharge capacities but can get by without an instantaneous response. In contrast, an instantaneous response is needed to suppress fluctuations in renewable energy output, whereas the storage capacity and discharge power output can be small. By utilizing the characteristics of fixed lead-acid batteries, lithium-ion batteries, and lithium-ion capacitors in accordance with these diverse needs, it is possible to supply highly reliable optimum systems that can maintain long-term operation for a range of different applications.

Information Communication Technology

Wide deployment of communication networks and new energy management systems are indispensable to enable grid automation, online services, and DSM (demand side management) including active demand control.

The distribution network has been designed and constructed to deliver electricity at safe voltages to customers supplied from high voltage substations in a passive manner.

The connection of many active devices such as photovoltaic generation and EVs (electric vehicles), however, will transform the distribution network from a passive to an active network.

In active distribution grids, the voltage situation in the MV (medium voltage) and LV (low voltage) networks becomes more complex and changes dynamically. In some cases, it is not possible to keep the voltage within the stipulated range using conventional tap control of transformers and SVRs (step voltage regulators) alone.

Active distribution networks require advanced distribution management systems with VVC (voltage var control) voltage optimization control.

This function can work with new power distribution system equipment such as D-STATCOMs, PCSs (power conditioning systems) for photovoltaics, and battery systems, as well as the traditional transformer taps and SVRs.

These devices differ in terms of characteristics such as control response and control range. Therefore, sudden fluctuations might be handled by the high-speed local voltage control provided by a D-STATCOM whereas phenomena with a longer time constant are handled in advance using measures such as D-STATCOM set points, changes to SVR taps, and control of battery charging and discharging through a FAN (field area network). By coordinating the control of these devices and the communication network, it is possible to maintain appropriate voltage levels throughout the active distribution network (see Fig. 3).

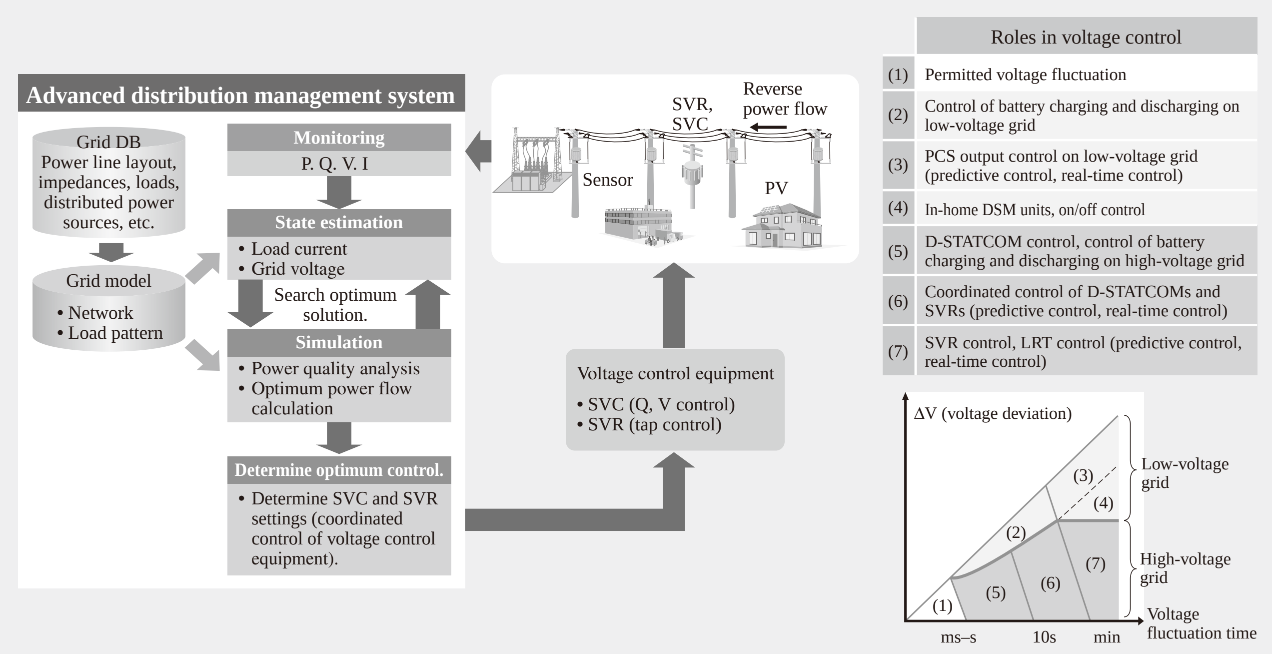
SMART CITY/COMMUNITY

A smart city integrates several energy supply and use systems within a given region in an attempt to optimize operation and allow for maximum integration of renewable energy resources—from large-scale wind farm deployments to micro-scale rooftop photovoltaics and residential energy management systems. Smart cities are a logical extension of the smart grid concept used in electricity systems to other types of infrastructure systems(2).

In the future, smart cities will have a micro grid function known as “islanding.” The islanding function supplies power generated by distributed energy resources within the city to customers for several hours when power from the bulk grid is absent. The grid in a smart city is connected to a high-voltage bulk network and power is usually supplied from the bulk network. If the connection is lost, however, the grid can continue to operate autonomously using the islanding function.

In addition to an advanced distribution management system incorporating FACTS devices and IT infrastructure, islanding also requires a DR (demand response) function and energy storage in the form of “spinning reserve.”

The DR function contributes not only to balancing supply and demand during islanding, in normal operation it also helps reduce energy consumption



DB: database SVC: static var compensator SVR: step voltage regulator PV: photovoltaic PCS: power conditioning system DSM: demand-side management D-STATCOM: STATCOM for distribution network LRT: load ratio transformer

Fig. 3—Advanced Distribution Management System.
This example shows how an advanced distribution management system divides up distribution voltage control between its different parts.

and obtain resources for ancillary services such as voltage control.

The energy management system that has advanced distribution functions, islanding function and DR function is called CEMS (community energy management system).

CEMS performs functions such as peak shifting and using control of consumer equipment (such as heat pump water heaters and EV chargers) for load balancing.

For example, demand can be induced at times of excess supply by automatically starting washing machines and dryers or by having heat pump water heaters operate during times when the output from photovoltaic power generation is high. Peak shifting can be achieved by measures such as shifting the EV charging times within the community so that they do not start charging at the same time at night. This sort of control of consumer equipment is handled via the HEMSs (home energy management systems) described below and is done in a way that works in with people's lifestyles without compromising their comfort. HEMSs, building energy management systems, and FEMSs (factory energy management systems) are all types of consumer EMSs (energy management systems).

In addition to making energy use in the home visible, HEMSs have functions for controlling the electric equipment in the home to optimize energy consumption while maintaining comfortable living. They also provide a range of services through interoperation with information systems.

Similarly, building energy management systems and FEMSs make visible the energy use in buildings and factories respectively while also providing optimization (energy efficiency) and other energy services. In some cases, they handle gas as well as electric power.

In addition to these functions such as energy efficiency and visualization of energy use, it is anticipated that consumer EMSs will also interoperate with the DSM function of CEMSs (described above) to assist with the optimization of electric power consumption through operations such as load balancing and peak shifting (see Fig. 4).

Also, the practice of having consumers contribute to grid stabilization through active steps such as minimizing demand is called DR. Through interoperation with AMI and other information systems, consumer EMSs prompt consumers to optimize their power consumption in a range of different situations, such as taking advantage of times when electricity tariffs are lower or when incentives are offered for participating in demand minimization.

Another potential benefit is the provision of a range of different information distribution services,

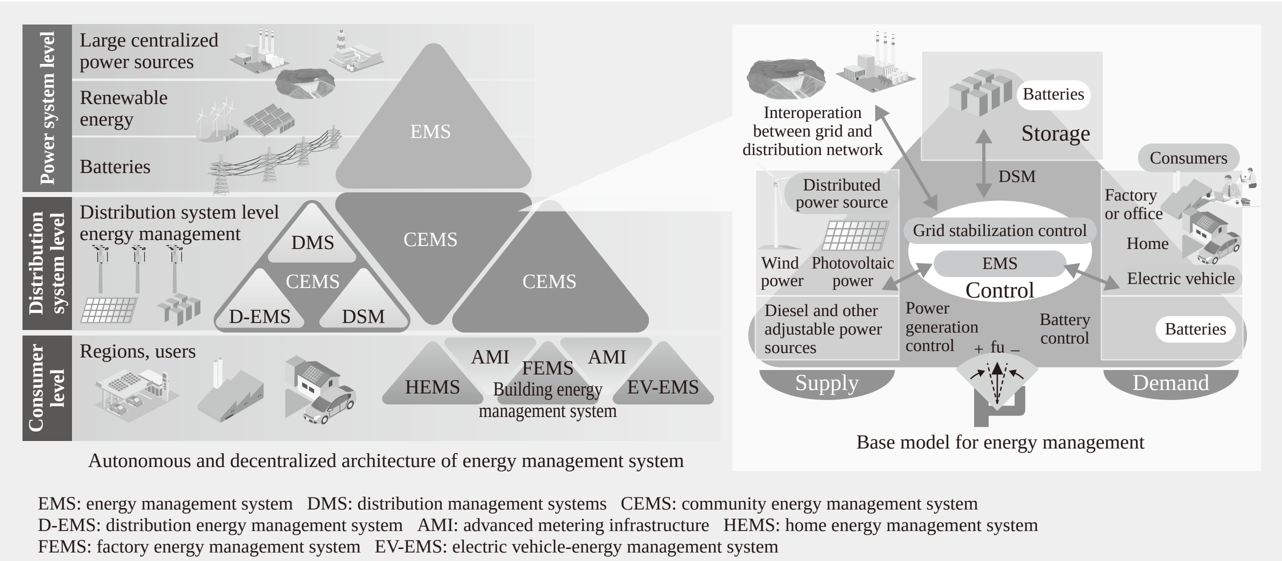


Fig. 4—Base Model for Energy Management.
Having the energy management systems for each level control each segment in an autonomous and decentralized way contributes to the stability of the power system while also providing an expandable configuration.

maintenance management services, or lifestyle support services for the elderly by using this mechanism to link together consumers and information systems (see Fig. 5).

CONCLUSIONS

This article has described the use of energy management systems to help realize smart cities.

Hitachi will continue to contribute to further enhancements to power systems and the building of smart grids through its participation in a variety of smart grid demonstration projects and other research in Japan and overseas, and by developing and supplying total systems that combine the equipment, control technology, and information technology described in this article.

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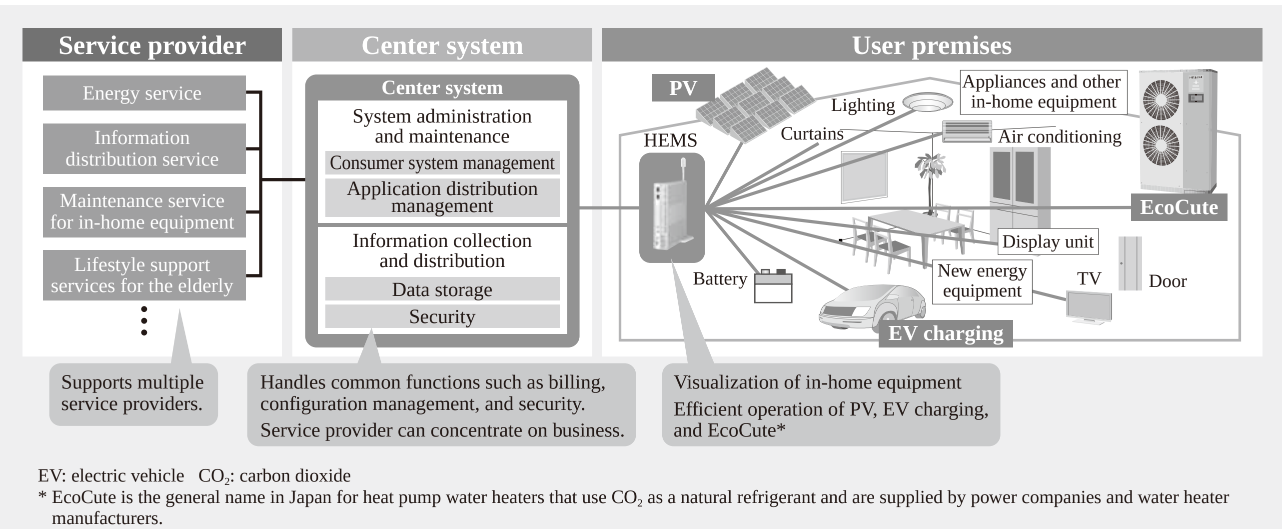

Fig. 5—HEMS System Configuration.
In addition to giving access to information on in-home equipment (visualization), the HEMS operates photovoltaic power generation, EcoCute, and EV charging in a way that best suits the residents’ lifestyle. The center system handles common functions such as billing, system configuration management, and security and provides a range of services to consumers.

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Smart Mobility for Smart Cities

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OVERVIEW: Hitachi sees a need for smart mobility that can achieve a harmonious balance taking account of the sustainability of society while providing the means for the smooth transportation of people and goods. The concept of smart mobility seeks to achieve a smooth and sustainable society by "optimizing transportation services" for the people who use them through "optimization of coordination between transportation companies" and "intra-company optimization," with these being considered in terms of a mobility architecture comprising five layers of transportation functions. To achieve this, Hitachi is using three types of control, namely "control of demand," "control of supply," and "control of actions," to contribute to innovation in both public and private transportation infrastructures by supplying urban management infrastructure, information and control platforms, and transportation applications.

INTRODUCTION

GIVEN the urbanization of the population, particularly in emerging economies, and the consequent problems including traffic congestion and the impact on the environment, attention has been directed in recent years toward the concept of "modal shifts," which means using modes of transportation such as railways and coastal shipping that place less of an impact on the environment. In developed economies, meanwhile, there is growing concern about how to maintain transportation and other services as the existing infrastructure ages.

In terms of mobility, while people place a priority on comfort and want their transportation to run smoothly, there is also the perspective of society as a whole, which needs transportation to operate sustainably for reasons of safety, practicality, and continuity. Unfortunately, these objectives often conflict, creating situations in which a means of transportation chosen by someone for their own reasons is not necessarily the best choice for society. What is desired for the smart cities of the future is the ability to take full account of both of these points of view and create a balanced transportation infrastructure. The divisions of Hitachi that deal with transportation have experience in transportation infrastructure that goes back many years. Solving this problem of balance represents a major challenge for them and is part of what defines their identity.

This article describes Hitachi's concept of mobility in smart cities along with a mobility architecture for translating this concept into reality and example solutions.

MOBILITY CONCEPT AND ARCHITECTURE

Mobility Concept

The negative implications of our modern car-centric world include environmental problems and the congestion that results when large numbers of people give priority to their own comfort when getting from place to place.

On the other hand, placing too much importance on the environment would impose excessive restrictions on mobility. For example, placing simplistic restrictions

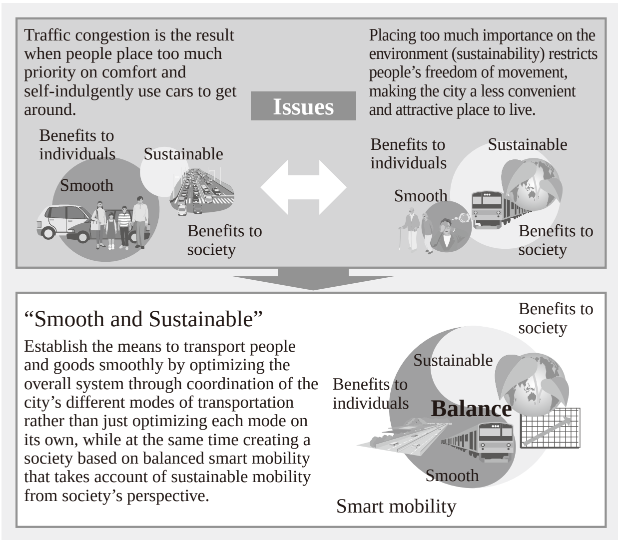

Fig. 1—Overview of Mobility Concept.
Transportation problems cannot be solved by solutions that merely deliver smoothness on its own or sustainability on its own. Rather than optimizing the various different modes of transportation independently, a balanced smooth and sustainable approach is possible by optimizing the overall system.

on entry by vehicles into a city would likely restrict its growth prospects by being a hindrance to motorists and making it a less convenient and attractive place to live.

To solve this dilemma, Hitachi is not only seeking to optimize specific forms of transportation such as trains and cars, it is also working toward a society based on smart mobility, which optimizes all transportation services by coordinating the different means of transportation within the city.

This will eliminate frustrations related to traffic and smooth the process of getting from place to place while helping create harmony in the form of a sustainable society with a reduced impact on the planet.

Hitachi uses the concepts of “smooth and sustainable” to represent this idea of aiming for a win-win society that balances benefits to individuals (providing the comfort sought by people) with benefits to society (providing the practicality, safety, and continuity sought by government) (see Fig. 1).

Mobility Architecture for Realizing Smart Mobility Concept

Currently, each transportation company provides its own services. The provision of transportation in a way that realizes the smart mobility concept requires building a network for the coordination of transportation companies, which collects and analyzes information from the various companies that operate in the city and supplies each company with information they can use to optimize the overall system.

Hitachi believes that building such a network will require an architecture that allows three specific types of optimization to be performed and that spans the five layers of transportation functions that make up a city.

Five layers of transportation functions

Hitachi’s approach is to consider the elements that make up a society based on smart mobility in terms of the five separate layers listed below, which it calls the “five layers of transportation functions” (see Fig. 2).

(1) Transportation user experience layer (domain of transportation service users): Layer in which users receive transportation, information, and other services from transportation companies as they travel from place to place

(2) Transportation services layer (domain of transportation companies): Layer in which transportation companies supply services to users

(3) Information collection layer (domain of transportation companies): Layer in which usage information is collected, such as on how users use the services supplied by transportation companies

(4) Information management and control layer (domain of transportation companies): Layer in which information management and control is performed to ensure that transportation companies supply their services smoothly

(5) Transportation company coordination layer (domain of transportation companies): Layer in which information from all the transportation companies is collected and analyzed, and information is provided to

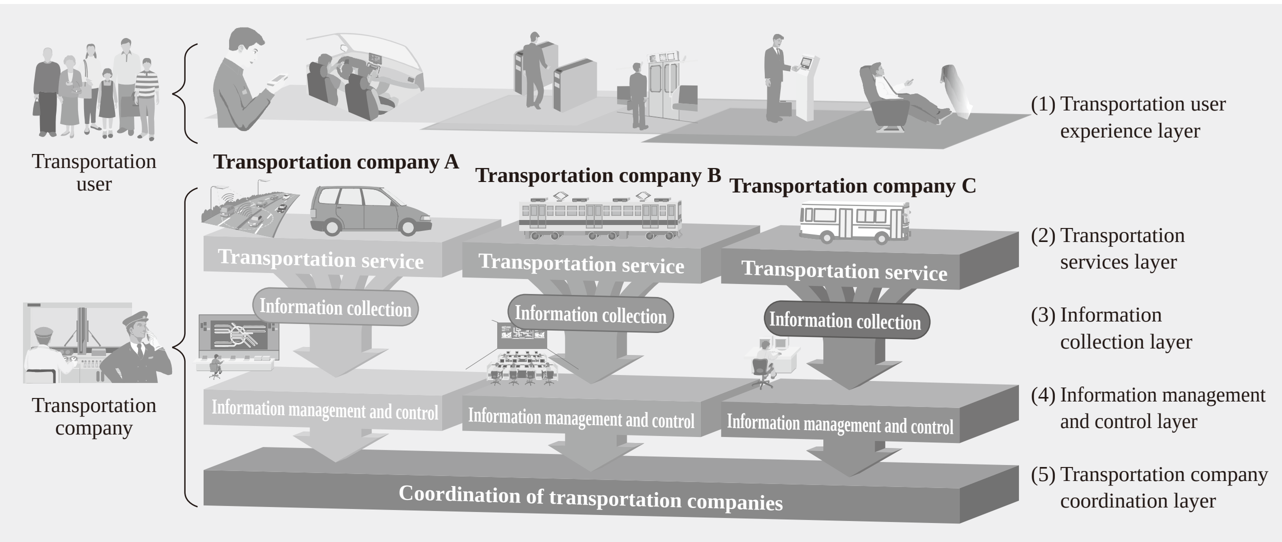

Fig. 2—Five Layers of Transportation Functions.
The five elements involved in creating a society based on smart mobility are the transportation user experience layer, transportation services layer, information collection layer, information management and control layer, and transportation company coordination layer. Hitachi calls these the five layers of transportation functions.

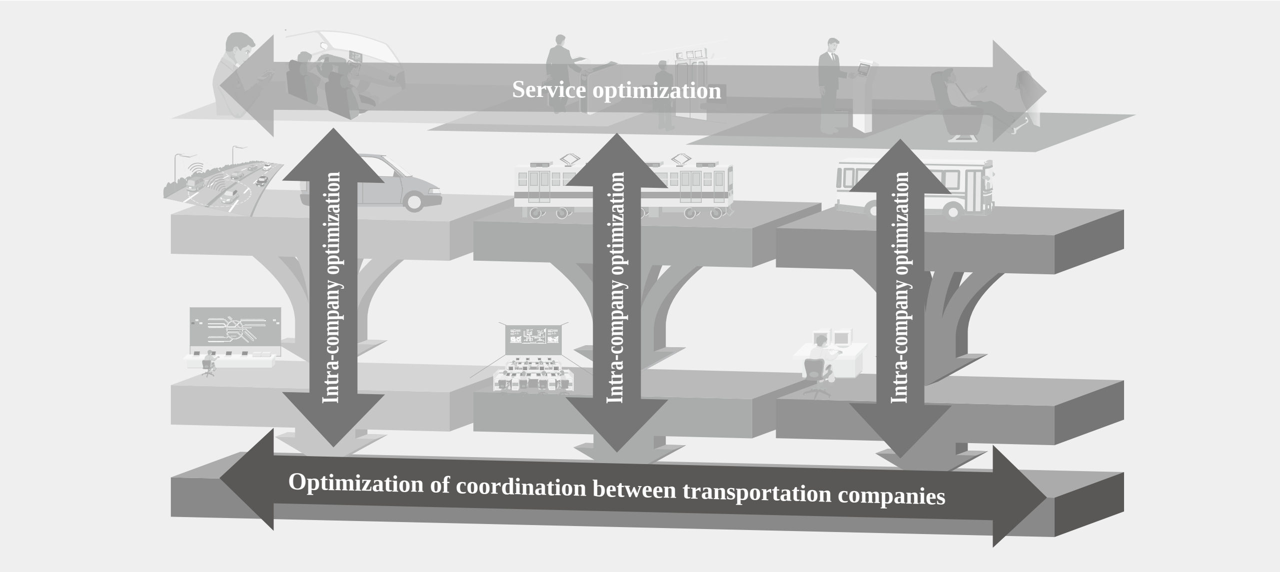

Fig. 3—Three Types of Optimization.
Three different types of optimization are needed to realize the smart mobility concept, namely "optimization of coordination between transportation companies," "intra-company optimization," and "service optimization.

guide the operation, control, and other functions of the transportation companies with the aim of optimizing the city's overall transportation system.

Three types of optimization

The three types of optimization are "optimization of coordination between transportation companies," "intra-company optimization," and "service optimization." Fig. 3 shows the relationships among these.

To realize the smart mobility concept, "optimization of coordination between transportation companies" and "intra-company optimization" (which means optimizing the respective transportation companies' services) are performed by using the urban management infrastructure described in the section "Solutions" to collect and analyze actual operational data and provide guidance on what is best for the overall system.

In this way, "service optimization" (which means optimizing the services supplied to users) is achieved along with seamless interoperation between the services supplied by the transportation companies. This allows transportation users to move about in a smooth and sustainable way without being conscious of the boundaries between transportation companies.

Relationship between "service optimization" and five transportation function layers

"Service optimization" consists of the following processes. First, "intra-company optimization" is performed for the services within the domain of a particular company's business via the transportation company coordination layer and through the information management and control layer. Furthermore, "optimization of coordination between transportation companies" provides smooth and sustainable trips in which the continuity of all travel through the transportation system is guaranteed up until the users reach their destination, without their having to pay undue attention to junctions in the transportation system, such as locations where users can transfer from one company's service to another (through the transportation services layer to the transportation user experience layer).

In practice, "service optimization" for users involves the three types of control: (1) "Control of demand," meaning the control of the total volume of the flow of people and goods from point of departure to destination, (2) "Control of supply," meaning control of transportation capacity provided by transportation companies from point of departure to destination, and (3) "Control of actions," meaning guiding people's actions by supplying information at the point of departure and up until the destination (see Fig. 4).

In this way, the smart mobility concept means approaching "service optimization" in terms of a mobility architecture consisting of five layers of transportation functions and seeking to create a smooth and sustainable society achieved through three different types of control.

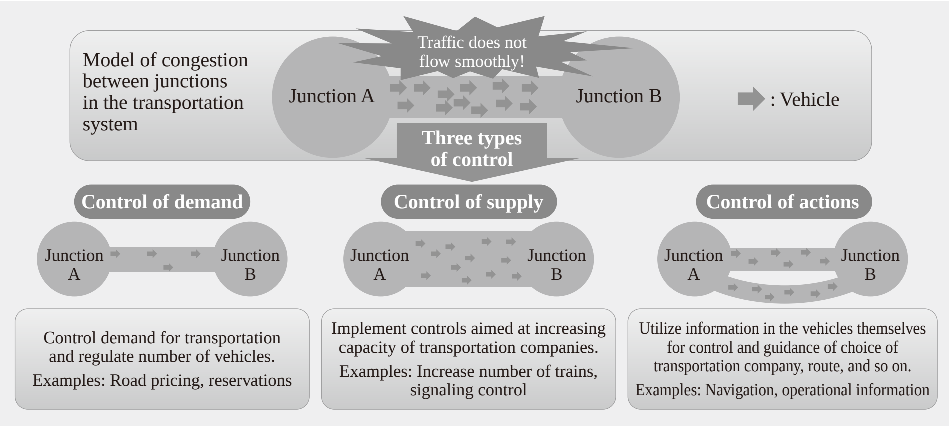

Fig. 4—Three Types of Control.
For travel from A to B, optimization of transportation services is performed using three types of control, namely "control of demand," "control of supply," and "control of actions."

EXAMPLE SOLUTION BASED ON TRANSPORTATION SCENARIO

Transportation Service

This section considers a specific scenario to give a more detailed image of the smart mobility architecture and describe the sorts of transportation services that will be offered to users and the solutions available for use by those services.

A key feature of the scenario is that, by having different transportation companies work together through the urban management infrastructure, multi-dimensional services can be provided of a nature that could not be achieved in the past by transportation companies acting independently.

Fig. 5 shows a scenario in which a company employee is able to commute from home to work in an energy efficient (sustainable) way and arrive on time (smooth) without any sense of having wasted time and effort on changing between different transportation services, nor any economic cost.

The following describes the commuter's experience and the operation of the systems run by the transportation companies, which are invisible to the commuter. This scenario includes products that are not currently supplied by Hitachi.

(1) Multi-modal navigation service

In response to the user entering his desired destination and indicating that his priority is to travel cheaply and quickly, his mobile handset displays a route comprising the optimum mix of transportation companies that will deliver him there quickly and cheaply, and in an energy-efficient way. Meanwhile, smooth optimization of the city is performed by the analysis functions of the urban management infrastructure, which distribute information such as congestion forecasts to guide people and spread them out to avoid congestion or crowding.

(2) Integrated fare collection service

If getting the commuter to his destination involves travel by different bus and train companies, this service allows him to use a smartcard to pay a single fare calculated based on departure and destination instead of paying each company separately at each change of vehicle. This makes commuting cheaper and makes use of public transportation more convenient. Smooth optimization of the city, such as handling changes in fares or regulation of traffic inflows, is performed through control of things like fares, toll roads, car parking, area entry fees, road pricing, eco-points, and local money.

(3) Service to smooth transfers between bus and train

This service coordinates the arrival times of buses at the railway station to connect with the train schedule. This eliminates waiting time when changing from bus to train. Having used multi-modal navigation to find the route, the commuter uses his smartcard to confirm his seat on the bus and the service coordinates the timing of traffic signal green lights to get the bus to the station in the time estimated by simulation. In this process, the bus operation management system invokes the bus priority signal system from the ITS (intelligent transportation system) management system via the analysis functions of the urban management infrastructure. This results ultimately in the smooth optimization of the city, which is achieved by controlling infrastructure such as the traffic signals and the trains or buses that provide (supply) the transportation service.

(4) EV bus charging management system

In this system, the EV (electric vehicle) bus power management system provides information to the bus operation management system via the analysis functions of the urban management infrastructure indicating where, on what route, and when it

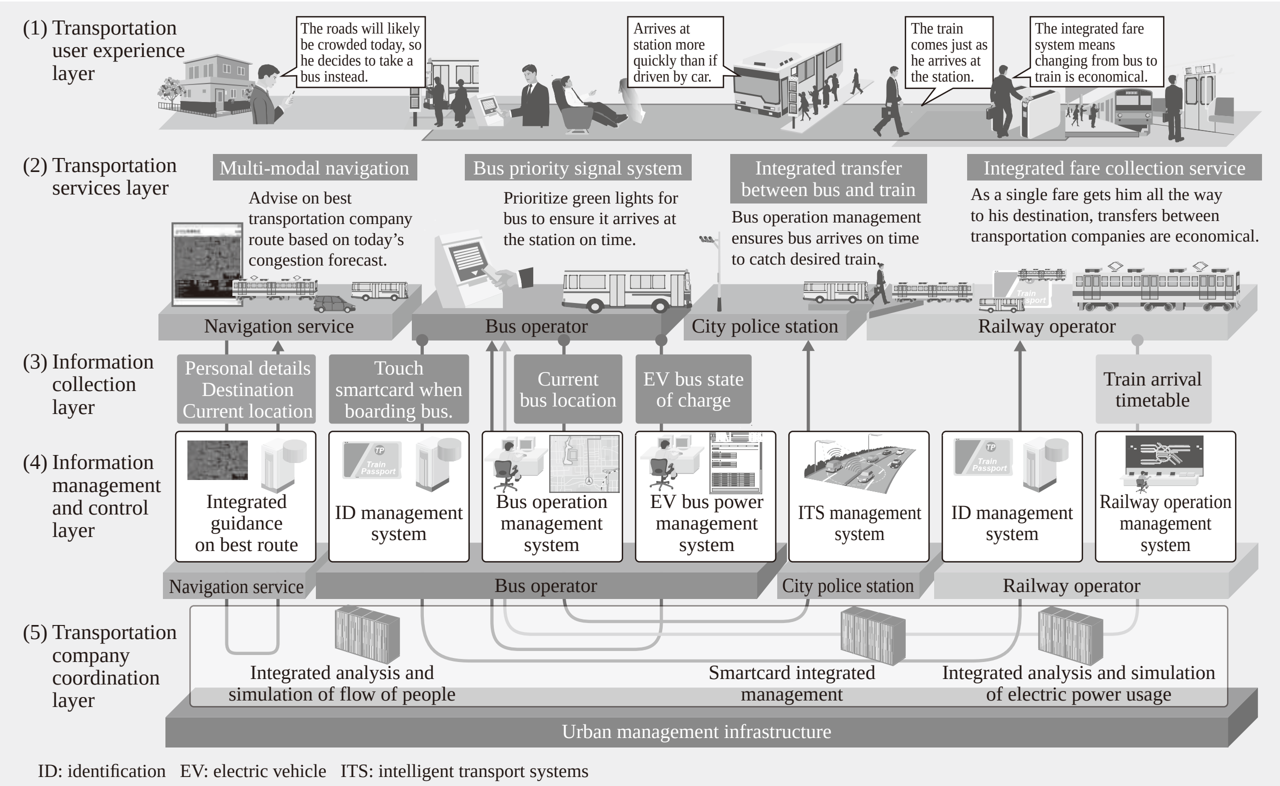

Fig. 5—Relationship between Commuting Scenario and Solution.
Having different transportation companies work together through the urban management infrastructure allows for the provision of multi-dimensional services that could not have been achieved in the past by the companies acting independently.

should be recharged based on its current state of charge. As a result, the solution contributes to sustainability (another of the values of smart mobility) by encouraging efficient use of the EV buses and helping reduce CO_2 (carbon dioxide) emissions.

Based on this management and control, Hitachi, through the supply of this solution, is providing users with smooth and comfortable trips and supporting innovation in transportation infrastructure by transportation companies and government agencies so as to provide users with comfortable trips while ensuring that transportation companies, government, and other agencies can achieve safety, practicality, and continuity in a sustainable way.

Solutions

Hitachi has formed a consortium of companies from inside and outside the Hitachi group to supply the solutions described below (see Fig. 6).

(1) Supply of urban management infrastructure

This performs system-wide optimization by linking transportation companies together and analyzing actual operational data in order to "optimize coordination between transportation companies." The solution is supplied through the information collection, analysis, and distribution functions of the urban management infrastructure. The urban management infrastructure achieves an optimum overall result by supplying timely information to transportation companies to guide their operations. This urban management infrastructure is intended to exchange information between transportation companies about their services so that users can experience smooth trips that have the appearance of a single service; it does not act as an impediment to each transportation company's independent operations.

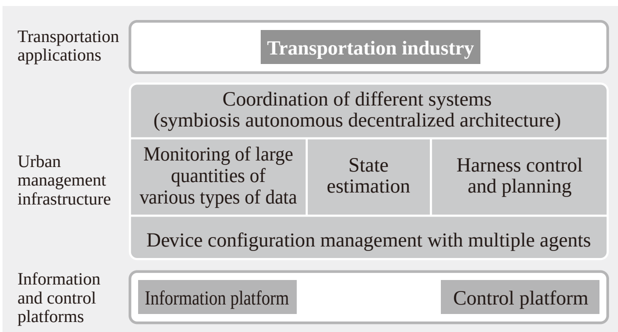

Fig. 6—Hitachi's Solutions.
Hitachi has formed a consortium to supply three solutions: transportation applications, urban management infrastructure, and information and control platforms.

(2) Supply of information and control platforms for transportation companies

The efficient operation of control and services is important for performing “intra-company optimization.” To achieve this, what is needed first of all is to put in place the control and information platforms that act as the foundations. A control platform comprises products such as a transportation company’s operation management system and an information platform makes particular use of cloud services and virtualization.

(3) Supply of transportation applications

The following three services (which embody user needs while also providing the infrastructure and platforms referred to above) are supplied in order to “optimize transportation services.” The general name for these services is “transportation applications.”

(a) Vehicle services: The actual operational services that provide the transportation, consisting of services for vehicles such as rolling stock management

(b) Junction services: Services for junctions in the transportation network such as park-and-ride or ticket gates including smartcard functionality

(c) Information services: Information services such as digital signage or navigation systems

These solutions correspond to elements in the commuting scenario (Fig. 5). The integrated analysis and simulation system for the flow of people and goods, integrated analysis and simulation system for electric power usage, and smartcard integrated management system are examples of urban management infrastructure (1). The bus operation management system, EV bus power management system, ITS management system, and railway operation management system are examples of information and control platforms (2). The multi-modal navigation system is an example of supply of a transportation application (3).

CONCLUSIONS

This article has described Hitachi’s concept of mobility in smart cities along with a mobility architecture for translating this concept into reality and example solutions.

For transportation in the future, Hitachi believes that the seamless coordination of different transportation companies has an important role to play in balancing people’s desire to be able to move about smoothly with an emphasis on comfort against the desire of society as a whole for transportation to operate sustainably for reasons of safety, practicality, and continuity.

Hitachi is not taking up this challenge on its own. Instead, it sees this task as one to be confronted jointly with partners from around the world.

Hitachi intends to contribute to the progress of society by deploying this smart mobility globally and by realizing the smooth and sustainable approach through win-win collaborations with partners throughout the world who share a belief in this concept.

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Intelligent Water System for Smart Cities

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OVERVIEW: Japan is rich in water resources with little experience of water shortages. Internationally, however, examples can be seen both of locations where lack of water is a physical phenomenon and where it is an economic one, and it is predicted that water shortages will become more severe as populations rise and become more concentrated in the urban areas. Effective ways of supplying water to afflicted cities include production of water by seawater desalination and use of recycled water, and there is a need to manage the overall circulation of water around the city efficiently. To provide smart cities with water infrastructure systems, Hitachi is promoting its intelligent water system concept for integrating water treatment systems with information and control systems for the efficient utilization of recycled water.

INTRODUCTION

MANY countries and regions around the world are confronting severe water shortage problems. Countries with low rainfall include Central Asia, India, the Middle East, North Africa, and North America while countries that are rich in water resources but are unable to provide access to clean water for economic reasons include Southeast Asia, South America, and Africa (see Fig. 1).

Factors such as population increase and especially urbanization mean that the world is forecast to use about 30% more water in 2025 than it did in 2000, with further water shortages expected.

Hitachi has been involved in numerous water-related projects over its 100-year history, including approximately 2,800 sewage treatment plants and 550 water treatment plants, mainly in Japan. Outside Japan, it has participated in nearly 250 projects in about 40 different countries.

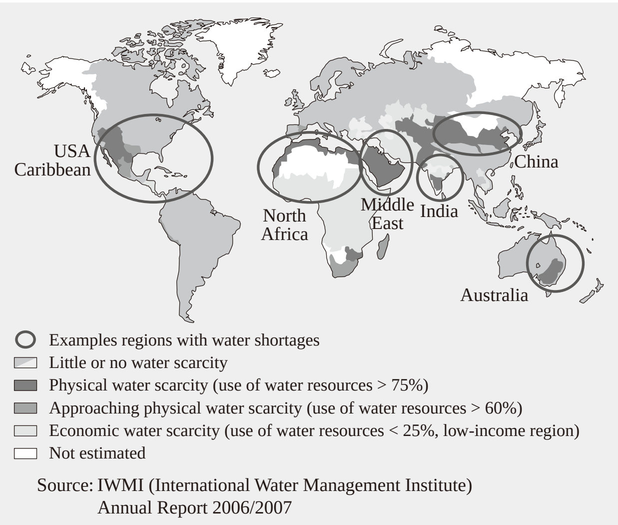

Fig. 1—Global Distribution of Water Shortage.
Water shortages are a physical phenomenon in some locations; an economic one in others.

Based on the technology and experience it has built up along with its customers and its activities over many years in manufacturing, technology development, and ensuring product reliability, Hitachi intends to create smart cities by making effective use of water resources and providing an efficient water infrastructure.

This article describes the intelligent water system concept for smart cities and Hitachi's water infrastructure solutions for achieving this.

INTELLIGENT WATER SYSTEM

Circulation of Water Resources

Drinking water is typically supplied by collecting rainwater or snowmelt in a lake or behind a dam and taking water off for treatment from the outflowing river. The water is used for various purposes, after which it is collected again as wastewater or sewage for treatment before being returned to the river for ultimate discharge into the ocean. The water resource cycle completes when evaporation of the water produces clouds from which the water falls to earth again as rain (see Fig. 2).

However, this circulation of water resources does not work effectively for the countries and regions suffering from water shortages. Also, it is anticipated that new means and technologies for producing water will be needed in those places where this water resource cycle does currently work, albeit only barely. This is because the cycle will be insufficient on its own due to water shortages caused by growing urbanization

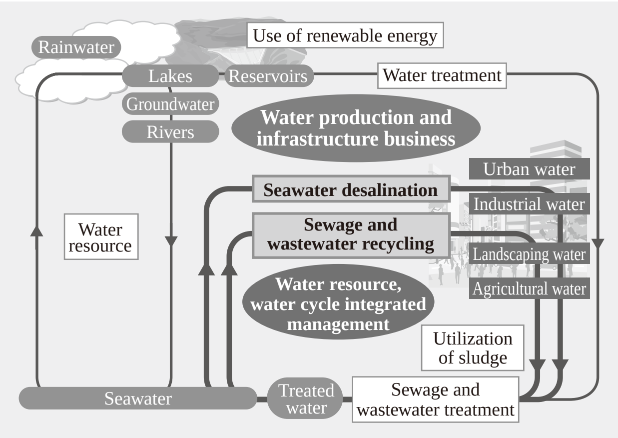

Fig. 2—Overview of Water Resource Cycle.
Whereas Japan can obtain enough water from the outermost cycle, elsewhere many places exist where this is not sufficient or where the cycle is not feasible at all.

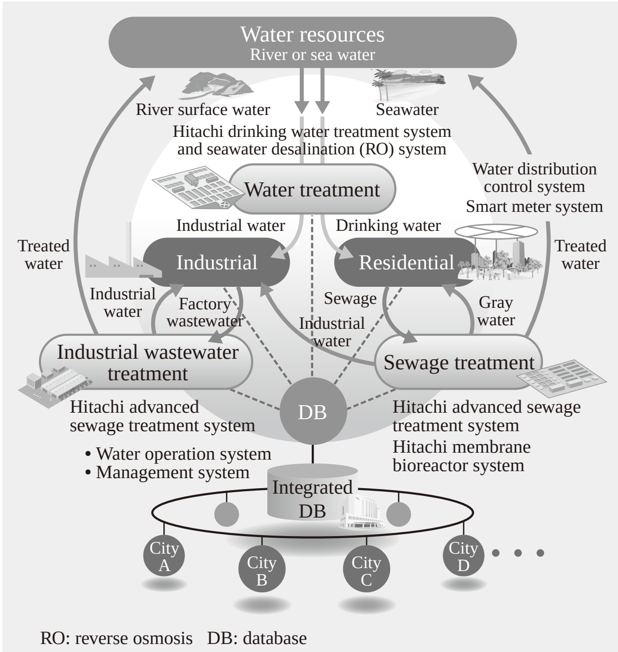

Fig. 3—Intelligent Water System.
The intelligent water system provides a water resource cycle for smart cities by combining IT (information technology) with technology for supplying high-quality recycled water.

and the concentration of population that are predicted for the future.

One potential approach is the use of seawater desalination technology to produce clean water from the ocean. Another is to use water recycling technology to make effective use of treated sewage and wastewater.

The intelligent water system is made up of technologies and systems that make effective use of water resources by increasing the number of pathways for water circulation. It will be an essential element in the realization of smart cities.

Intelligent Water System Concept

Fig. 3 shows the intelligent water system concept proposed by Hitachi.

The figure shows the water cycle for an example region. More efficient operation of treatment plants and improved business efficiency across the entire region is achieved by taking a proactive approach to using treated effluent (which in the past would have been discharged into a river) as recycled water, returning it for use in residential districts, factories, or other sites, and by collecting information (such as operational data from these plants or water usage in the distribution system) in a single location where it can be managed centrally. Hitachi believes that this is precisely the sort of approach that a smart city should aim to achieve.

Technologies for implementing an intelligent water system include conventional treatment technologies for water supply and sewage, industrial wastewater treatment technology, monitoring and control system technology, seawater desalination using RO (reverse osmosis) membranes, technology for the reliable supply of drinking water using water distribution control systems to reduce the rate of leakage, customer information management technology using smart meter systems, and advanced sewage treatment technology using methods like membrane bioreactor systems. Hitachi believes it is possible to improve the business efficiency of the water cycle across an entire region by collecting information such as water usage in the distribution system and operational data from water treatment plants in a single database where it can be managed centrally and used interactively.

HITACHI WATER INFRASTRUCTURE SOLUTIONS

(1) Water treatment systems

Water distribution plant supplied by Hitachi includes a wide range of solutions extending from intake to transportation, purification, distribution, and supply equipment as well as various types of chemical dosing and sterilization machinery and also electrical equipment, instrumentation systems, and monitoring and control systems. Also, membrane-based purification systems such as UF (ultrafiltration) membrane systems and RO membrane systems can be used to supply high-quality tap water by eliminating problems such as turbidity, bacteria, and salinity.

(2) Sewage advanced processing system: Immobilized Microorganism Treatment System

The water treatment process at a sewage treatment plant consists of "first treatment" that covers the processes of separating and removing solid matter and other physical material up until the first sedimentation tank, and "secondary treatment" that involves the use of microorganisms and other mechanisms for eliminating organic matter up until the final sedimentation tank.

The treated water is disinfected and is discharged into public waterways. However, "advanced processing" to remove nitrogen, phosphorous, organic substances, and other contaminants that cannot be removed by the above two processes is needed in cases when action is required to prevent eutrophication of public waterways, or when the treated water is to be reutilized.

Immobilized Microorganism Treatment System is a processing system for retrofitting advanced processing into existing sewage treatment plants. It is a nitrification reaction and denitrification process that uses nitrifying pellets and was developed by Hitachi Plant Technologies, Ltd. through joint research with the Japan Sewage Works Agency. The conventional biological reactor is split into anaerobic and aerobic tanks and the slow growth of the nitrification reaction bacteria is countered by adding nitrifying pellets containing immobilized microorganisms into the aerobic tank. This halves the time taken for treatment (see Fig. 4).

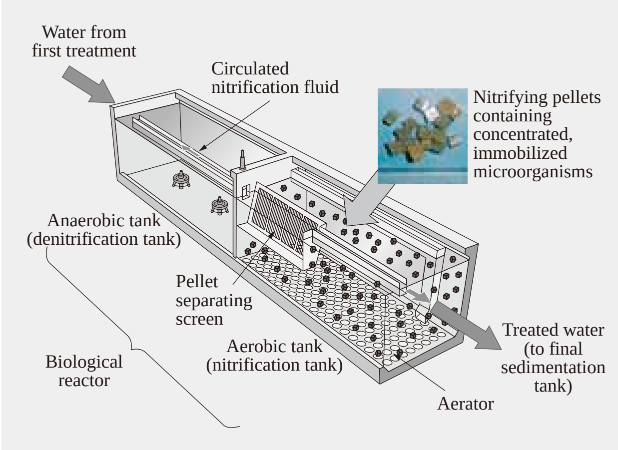

Fig. 4—Immobilized Microorganism Treatment System.
Processing time can be halved by using nitrifying pellets that contain nitrification reaction bacteria.

(3) Membrane bioreactor system: Biological processing and membrane

Membrane bioreactor technology combines a membrane and biological reactor and is known as the membrane bioreactor.

A feature of a membrane bioreactor is that, using a membrane, it can completely remove suspended solids called "activated sludge," which multiply by a biological reaction. As the membrane pores are smaller than bacteria, it can also remove bacteria and other larger microbes to produce high-quality treated water. Hitachi's membrane bioreactor consists of a membrane module with a flat membrane. The sedimentation required in the previous activated sludge method is eliminated by immersing it in the biological reactor. Accordingly, the system takes up less space and is simpler to maintain than previous methods. It produces good-quality treated water suitable for irrigation and other forms of reuse. As a result, it can be seen as an important form of water treatment in the intelligent water system (see Fig. 5).

Fig. 5—Hitachi Flat Membrane Bioreactor Unit.
The unit features small size and ease of maintenance.

(4) Monitoring and control systems

Hitachi has delivered approximately 900 monitoring and control systems for water and sewage infrastructure to date in Japan, supplying its information and control know-how built up over many years in the form of solutions such as water treatment processes, water operation systems, water distribution control systems, and water quality control systems that run on monitoring and control system platforms. In addition to being equipped with user-friendly human-machine interfaces, these systems have a client/server architecture with a distributed server configuration that allows for progressive upgrades. Their design also supports seamless interconnection with wide-area systems.

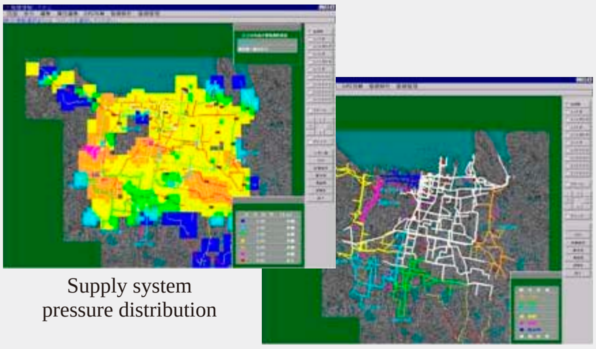

Fig. 6—Example Screen from Water Distribution Control System.
The system manages the pipe network in the district being supplied and predicts the pressure distribution.

Fig. 7—Recycling System at Recycled Water Business in Emirate of Dubai.
The business supplies good-quality recycled water using a membrane bioreactor and RO system.

(5) Water distribution control systems

The distribution of drinking water produced at water treatment plants requires separate reservoirs and other distribution infrastructure for each region being supplied. Because the pumping of water is a key part of this infrastructure, it consumes a large amount of electric power.

Water distribution control systems seek to reduce power consumption and regulate the pressure distribution within each section of the water supply network to achieve a reliable water supply with fewer leaks (see Fig. 6).

HITACHI'S WATER INFRASTRUCTURE BUSINESS OBJECTIVES

To realize its intelligent water system, Hitachi recognizes that it needs to participate actively in the operational side of the water business. Its aim is to help improve regional water infrastructures by working more closely with local operators and supplying better solutions. The following sections describe examples of participation by Hitachi in the recycled water business and water distribution business along with its future plans for the large-scale seawater desalination business.

Water Recycling Business in Dubai in UAE

In August 2008, Hitachi Plant Technologies, Ltd. established Hi-Star Water Solutions LLC. as a joint-venture company with Al Ghurair Group, a notable local conglomerate, to collect and treat domestic wastewater for sale as recycled water in the Emirate of Dubai in the United Arab Emirates (UAE).

The company established a water recycling business based on Hitachi's membrane bioreactor technology in response to the problem of treating the domestic wastewater resulting from the rapid increase in the number of workers associated with the urban development rush in Dubai. The business model involves collecting domestic wastewater from the workers in return for a processing fee, and installing treatment equipment close to the domestic wastewater outlet and selling the treated water to nearby factories for industrial use at a cheaper price than tap water.

The treatment equipment uses a system that combines membrane bioreactor and RO. The treatment equipment for the initial plant is installed in a cement works where it treats domestic wastewater from the neighborhood and supplies the recycled water for industrial use on site (see Fig. 7).

Water and Sewage Business in Republic of Maldives

In January 2010, Hitachi Plant Technologies, Ltd. acquired a 20% stake in Male' Water & Sewerage Company Pvt. Ltd. (MWSC) from the government of the Republic of Maldives. MWSC operates the country's water and sewage systems.

Established in 1995 in the capital, Male', MWSC operates water and sewage systems on seven islands including Male' itself, serving approximately 40% of the country's population. It also has licenses for water and sewage operations on a further six islands. Hitachi group company Hitachi Aqua-Tech Engineering Pte. Ltd. has already supplied approximately 200 RO seawater desalination units to the Maldives. Hitachi is involved in the running of MWSC and is using its intelligent water system to contribute to improvements in the country's living standards by delivering reliable water and sewage services and improving operational efficiency.

Large Seawater Desalination Plants

International demand for large seawater desalination plants is growing as a way of coping with water shortages. In addition to accelerating its own research and development, Hitachi is also participating in the Mega-ton Water System, an advanced research and development support program sponsored by the Cabinet Office of the Government of Japan, which aims to develop large seawater desalination plants with capacities in the 1,000,000-m^3/day class that significantly reduce both CAPEX (capital expenditure) and OPEX (operational expenditure).

CONCLUSIONS

This article has described Hitachi’s intelligent water system concept for smart cities.

A feature of the intelligent water system is that it can improve the efficiency of water resources in a region by combining IT with various different water treatment systems to make effective use of recycled water.

The intelligent water system has an essential role in coping with water shortages throughout the world and the development of the ideal smart cities of the future. Hitachi intends to draw on its past experience to make further improvements in regional water cycles.

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Telecommunication Systems in Smart Cities

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OVERVIEW: Telecommunication systems play a very important role in the infrastructure of smart cities. A plethora of networked devices interact to provide safe, convenient and environmentally conscious new services. Residents in smart cities can enjoy their lives using these services, seamlessly and without being aware of the existence of the networks. To make such telecommunication systems possible, Hitachi is accelerating research into new network technologies, including gateways, highly reliable wireless communications, and network virtualization. Products and solutions under development include home gateways, wireless sensor networks, and M2M solutions.

INTRODUCTION

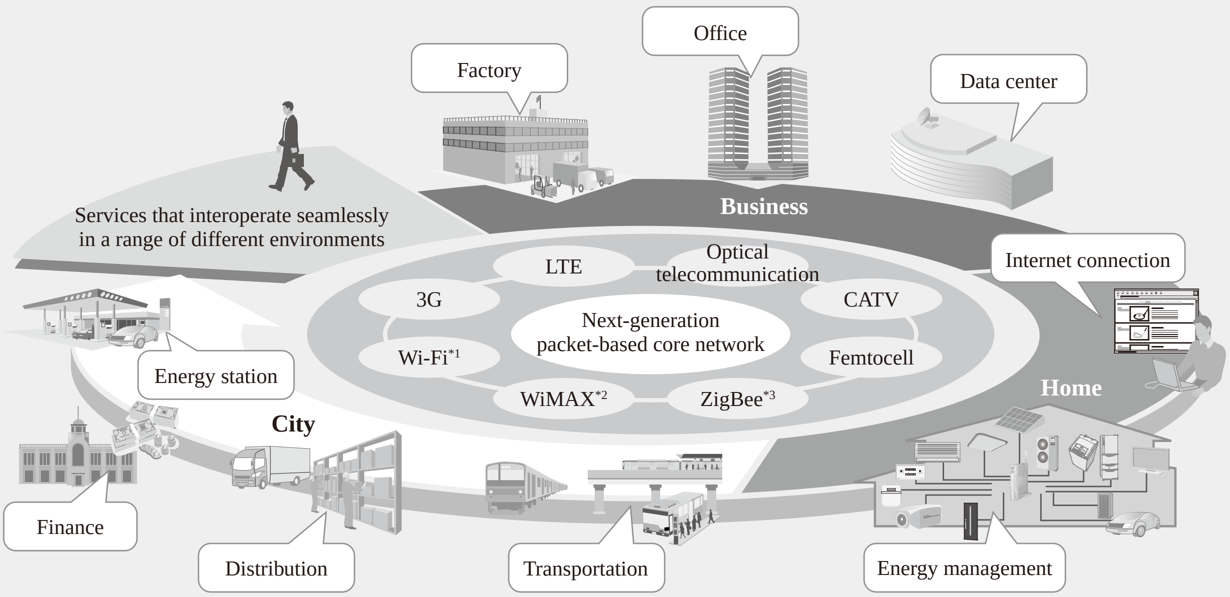
IF people are to enjoy comfortable lives in smart cities, telecommunication systems must be able to connect all manner of things, including human-to-human, human-to-machine, and machine-to-machine connections.

These connections and interactions between things make it possible for people to use energy efficiently while still enjoying comfortable lives. Examples include checking up remotely on what other people are doing, getting the information you need from a portable device as and when you need it, and communication between vehicles and traffic signals to avoid congestion.

This article describes the telecommunication systems necessary for smart cities.

TELECOMMUNICATION SYSTEMS NECESSARY FOR SMART CITIES

Adoption of the most appropriate communication technologies should make possible the seamless provision of a wide variety of services in smart cities (see Fig. 1).



3G: 3rd generation LTE: long term evolution CATV: cable television Wi-Fi: wireless fidelity WiMAX: worldwide interoperability for microwave access
*1 Wi-Fi is a registered trademark of the Wi-Fi Alliance.
*2 WiMAX and WiMAX Forum are trademarks of the WiMAX Forum.
*3 ZigBee is a registered trademark of the ZigBee Alliance.

Fig. 1—Telecommunication Systems in Smart Cities.
Telecommunication systems connect together all the elements that make up a smart city to provide services seamlessly using most appropriate telecommunication technologies.

Greater use of cloud services and visual communication tools using high speed broadband communication networks in the corporate and local government sectors is improving business efficiency and convenience while also being a source of new value creation. Meanwhile, sensor networks utilizing a variety of wireless technologies give access to information on the flow of goods and the status of equipment and the environment. They also facilitate the use of remote control. This makes possible the implementation of systems that are safe, secure, and environmentally conscious.

In the home, network connections for products such as home appliances and cars, as well as telephones and PCs (personal computers), will make life more enjoyable, secure, and comfortable.

In cities, transportation, distribution, finance, and energy services are connected to networks and interact to provide more reliable, convenient, and environmentally conscious new services.

Residents in smart cities will have seamless access to these services without needing to know about the networks on which they are based.

TECHNICAL ISSUES AND R&D

Technical Issues

In smart cities, everything will be connected to the network. This means that networks will not only require the high speed, high reliability, high availability, and other features demanded of today's networks, they must also satisfy new requirements, including the connection of various types of device, effective use of carrier networks, the flexibility to support new devices and services, the economics to provide services at a reasonable price, and consideration for the environment. To satisfy these difficult requirements, Hitachi is undertaking research and development of IP- (Internet protocol) based gateway technologies, highly reliable wireless communication technologies, and network virtualization technologies.

Gateway Technologies

To establish an environment in which objects of all types can link together, gateways for connecting devices to the network play an important role in ensuring support for a wide variety of devices so that they can deliver reliable services (see Fig. 2). Such gateways face the following issues.

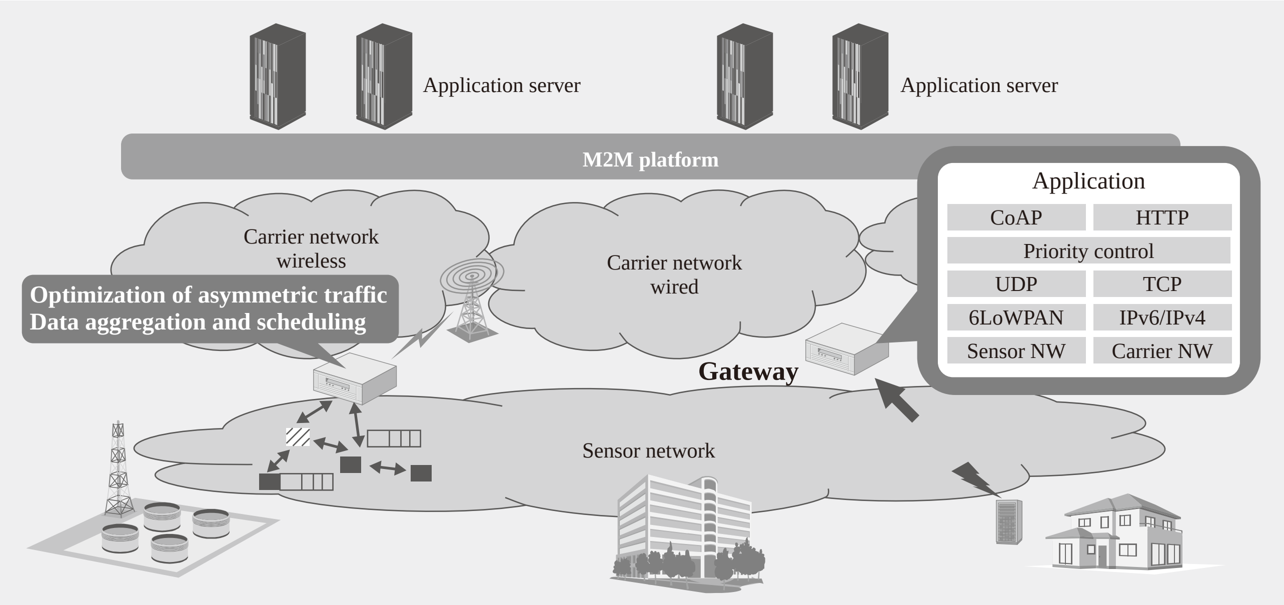
(1) Need to ensure interconnectivity with IP networks

(2) Application communications environment for resource-constrained devices

(3) Traffic optimization for effective use of carrier networks

In order to solve these issues, Hitachi is currently carrying out research on protocol conversion, data aggregation, and scheduling technology.

The huge address space of IPv6 (Internet protocol version 6) is needed if large numbers of sensors are to



M2M: machine to machine CoAP: constrained application protocol HTTP: hyper text transfer protocol UDP: user datagram protocol
TCP: transmission control protocol 6LoWPAN: IPv6 over low-power wireless personal area network IPv6: Internet protocol version 6 NW: network

Fig. 2—Gateway Technologies.
Implementing the interconnection environment requires gateways to connect between devices. The Internet also plays an important role.

connect to the network. Because of their constrained resources, if they are to support IPv6, sensor nodes will require a protocol conversion function to convert between standard IPv6 and light-weight 6LoWPAN (IPv6 over low-power wireless personal area network). In addition, support for M2M (machine to machine) applications in an end-to-end web service environment requires mapping between HTTP (hyper text transfer protocol) and CoAP (constrained application protocol). Standardization and prototyping of related protocols are currently in progress at The Internet Engineering Task Force (IETF).

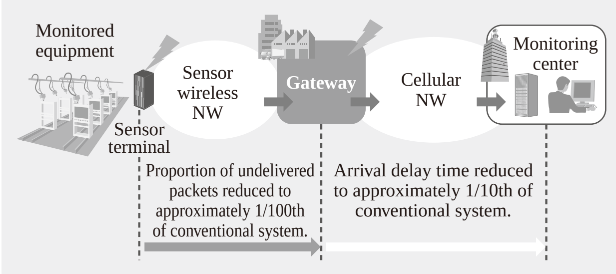


Fig. 3—Configuration of Remote Monitoring System Using Wireless Sensor Network.
Hitachi has developed a remote monitoring system using a wireless sensor network and cellular network. Using a wireless sensor network cuts set-up costs and makes layout changes easier. The advantage of the cellular network is its wide coverage.

Highly Reliable Wireless Communication Technology for Remote Monitoring

The intelligent control of the environment inside smart city facilities will require the use of sensors to measure the equipment power consumption and the temperature and humidity in the facility, as well as the transmission of this data via a communication network to a monitoring center for collection, analysis, and use.

Although most remote monitoring systems currently use reliable wired networks to send data, there is growing interest in the use of wireless networks because of their lower set-up costs and the ease with which layouts can be changed, especially at existing sites where it is difficult to lay new cabling. Furthermore, use of the existing cellular network is likely to be particularly efficient in situations where the factory or building being monitored is a long way from the monitoring center.

However, the use of wireless networks in these remote monitoring systems faces two issues. The first is the potential for radio interference between the signals transmitted by the sensors and those from wireless LANs (local area networks) or other existing equipment when wireless sensor networks are used in factories or buildings. This results in more frequent data communication errors. The second is the risk, when using cellular networks that are experiencing heavy traffic loads, that delays may occur in the arrival of alarm signals from the sensors reporting trouble at a facility being monitored.

Given these concerns, Hitachi has developed wireless communication technologies both for reducing the data communication error rate in wireless sensor networks and for reducing delays in the arrival time of alarm signals carried over cellular networks (see Fig. 3).

The interference avoidance technology for wireless sensor networks monitors the extent of interference and selects a “good” frequency range where communication can proceed smoothly. Combined with time-division multiplexing, which assigns communication time slots to devices, this technology reduces data communication errors without increasing the delay in data arrival time.

Priority control technology was also developed to detect when the cellular network communication speed is slow, in which case the gateway selectively sends only important alarm signals. Use of this technology keeps the arrival time delay for alarm signals within an acceptable threshold.

Network Virtualization Technology

Research and development are underway into a new network concept, called the “New Generation Network” or “Future Internet.” In particular, it is anticipated that network virtualization technology will allow flexible responses to the changing demands of smart city residents in ways that are economically and environmentally efficient. Here, the term “network virtualization” means the operation of multiple networks with different characteristics and functions over the same physical network.

The new communication control technology has two key features: (1) The optimal allocation of virtual network capacity based on communication traffic, and (2) The optimization of virtual network routes (see Fig. 4). This technology will enhance the efficiency of network use in terms of the data communication speed and capacity required for each application, and enable telecommunication operators to provide high-speed communication to a larger number of users. At the same time, it allows end-users to use various types of application at a low cost.

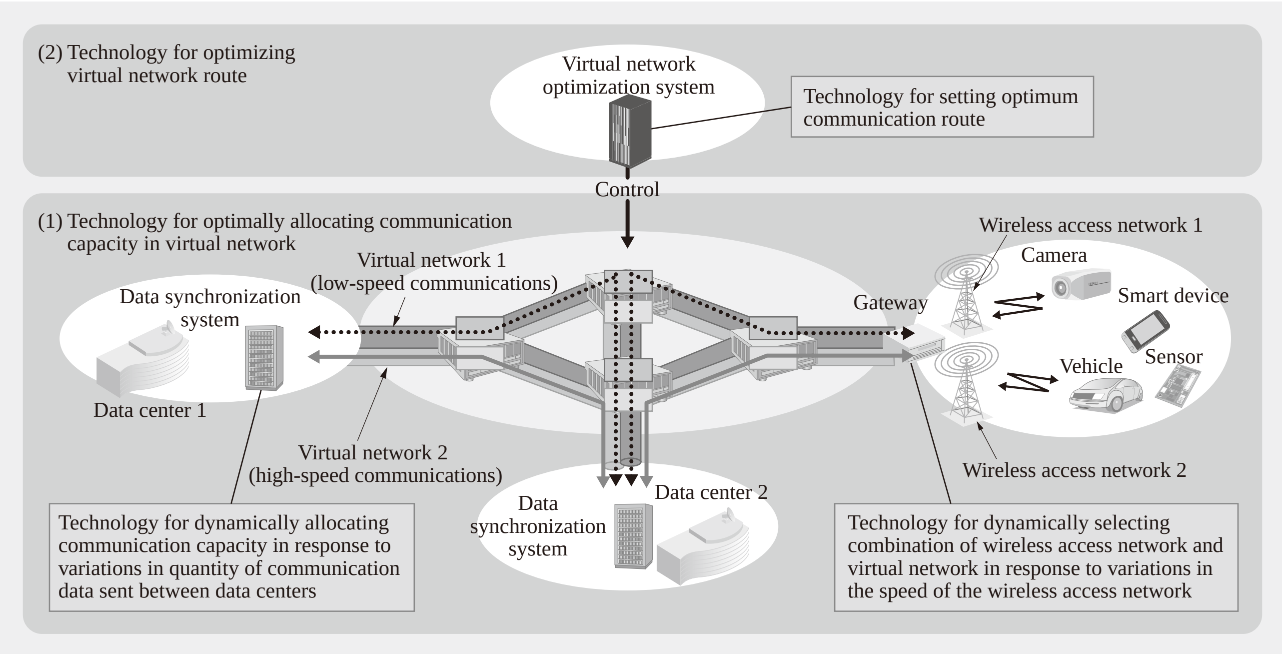


Fig. 4—Network Virtualization Technologies.
Network virtualization allows multiple networks with different characteristics and functions to operate over the same physical network.

The reliable transmission of high-priority data can be achieved by centrally managing the communication quality of multiple wireless and wired networks and by dynamically selecting the appropriate routing. Lower priority data is then transmitted as network resources allow. The virtualization technology copes with network congestion caused by a heavy traffic load in a particular part of network by connecting automatically to other types of network, thereby increasing the potential for services to continue operating.

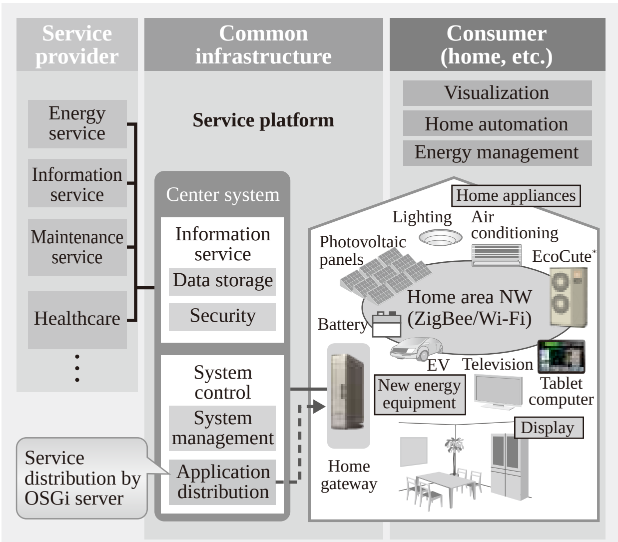
PRODUCT DEVELOPMENT

Home Gateway

Recently, more and more people are becoming aware of the need to save energy. In order to reduce energy consumption and carbon dioxide emissions, it is useful to provide users with information on their usage and to use home automation systems to control home appliances. Meanwhile, greater use of home photovoltaic power generation, electric vehicles, and storage batteries is creating a need for energy management. Hitachi is developing a home gateway system to act as a key component in home energy management.

The home gateway functions as a controller in the energy management system where it performs monitoring and control of home appliances (see Fig. 5). It uses the OSGi*1 framework as a common platform. A variety of service applications are available as OSGi bundles and the system can interoperate with OSGi distribution servers in the center system to add and modify services as required.

*1 OSGi is a trademark or a registered trademark of the OSGi Alliance in the United States, other countries, or both.



OSGi: open services gateway initiative EV: electric vehicle
CO_2: carbon dioxide
* EcoCute is the general name in Japan for heat pump water heaters that use CO_2 as a natural refrigerant and are supplied by power companies and water heater manufacturers.

Fig. 5—Home Gateway.
The home gateway plays an important role in the home network where it controls the energy management system and monitors the status of home appliances and other devices.

Applications suitable for consumer home appliances and services are placed on the OSGi distribution servers and can be added or deleted remotely in accordance with the consumer's service contract. Since an OSGi bundle is a Java[*2] application, development time is relatively short. Furthermore, the open API (application program interface) allows third parties to develop applications, opening up the potential for a variety of new services to be released in the future.

New services planned by Hitachi include information services and support services for the elderly. These use the home gateway to help people enjoy safe, secure, and comfortable lives.

Wireless Sensor Networks

Sensor network systems automatically monitor and detect changes in the status of public infrastructure to ensure the quick and appropriate provision of services. This includes monitoring of people, objects, and equipment.

Sensor network systems are also used for monitoring and control in industry. Typically, sensor network systems have been built using high-performance sensors and highly reliable wired networks. With mobile information technology, however, it is easy to collect large amounts of data at low cost. Wireless sensor network systems provide an efficient way to get data into IT (information technology) systems where it can be coordinated and integrated with a variety of applications, and used to create new services. The visual display and analysis of real-time sensing data, along with use of the results to provide feedback to the field, will help make society safer as well as more secure, comfortable, efficient, and reliable.

The sensor network information system provides powerful solutions for a broad range of areas and operations (see Fig. 6). Use of a wireless sensor network system allows the freedom and flexibility to install and move sensors.

The system provides the following three solutions.
(1) HCCP (hazard analysis and critical control point) and food management
(2) Temperature and humidity control in data centers
(3) Energy management in factories and shops

The sensor network system is also expected to help deal with the aging of public infrastructure, increasing maintenance costs, and the shortage of technicians. While the public infrastructure in Japan was built during a period of rapid economic growth, the country now faces a new problem as this infrastructure deteriorates with age. Solutions are required for issues such as rising maintenance costs and falling numbers of technicians available to work in this field.

*2 Java is a registered trademark of Oracle and/or its affiliates.

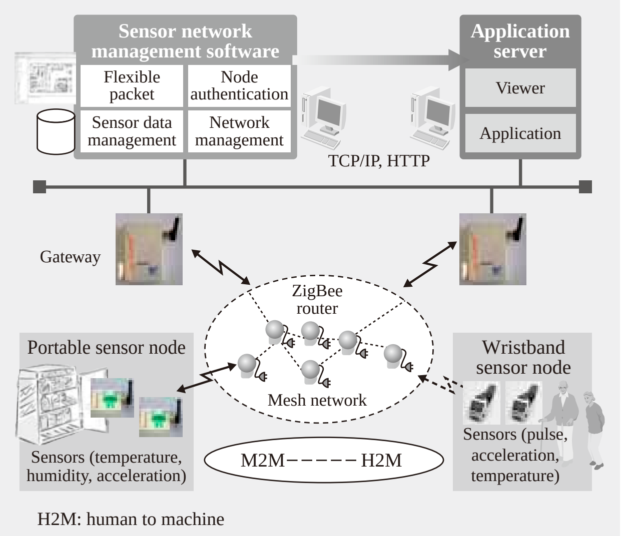


Fig. 6—Configuration of Sensor Network Information System.
Sensor network information system is an information system for collecting sensor information via wireless networks and managing the collected information.

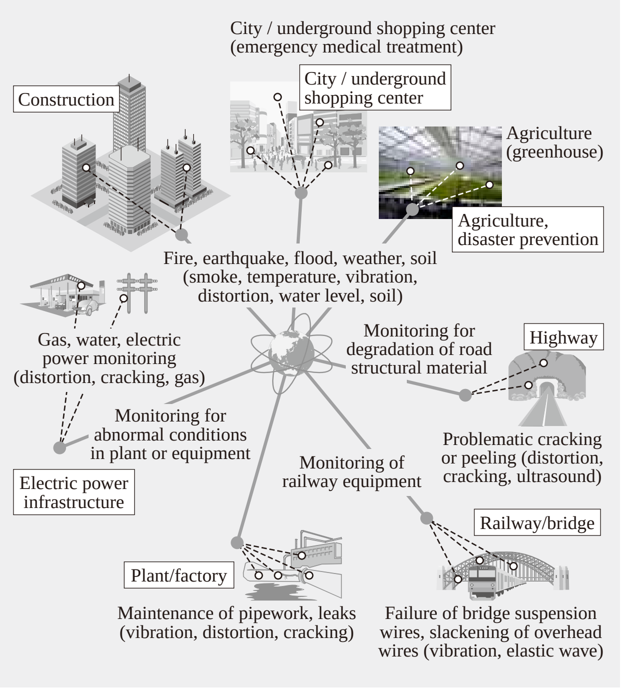


Fig. 7—Wireless Sensor Network System for Public Infrastructure.
The wireless sensor network system will help solve public issues such as the deterioration of public infrastructure over time, rising maintenance costs, and the shortage of technicians.

Sensor network systems offer the possibility of operating and maintaining public infrastructure at a reasonable cost by monitoring the status of equipment and any changes that occur, and by making this information available. To satisfy these requirements, Hitachi is accelerating its research and development of wireless sensor networks with a particular focus on highways, railways, and bridges, electric power infrastructure, plants and factories, construction, cities and underground shopping centers, and agriculture (see Fig. 7).

M2M Solutions

It is anticipated that services and applications in smart cities will continue to evolve over time in response to changes in industrial activity and improvements in lifestyle. This will require service providers and network managers to provide new services and applications in a timely and economical manner. Hitachi is accelerating its research and development of M2M platforms in order to satisfy these requirements.

M2M platforms connect a variety of M2M devices via wired or wireless networks in a way that hides any differences among the networks and devices from the applications. The use of management functions provided by the platform, which include device and line management, network monitoring and operation, activation, billing, and data control, enables service providers to provide reliable and stable services, quickly and easily. Gateway functions are also needed to handle specific protocols, data processing and conversion, and security to allow the connection of a wide variety of devices to the networks, beyond just PCs and mobile phones (see Fig. 8).

CONCLUSIONS

Telecommunication systems play a very important role in smart cities. They must be highly reliable and available as well as flexible, economical, and environmentally conscious. To satisfy these difficult requirements, Hitachi is accelerating its research and development of new telecommunication systems for smart cities.

The network virtualization technology described in this article is part of “Development of Platform Technologies for Data Service Applications Based on Virtualized Networks,” a research project supported by the National Institute of Information and Communications Technology (NICT), Japan. We

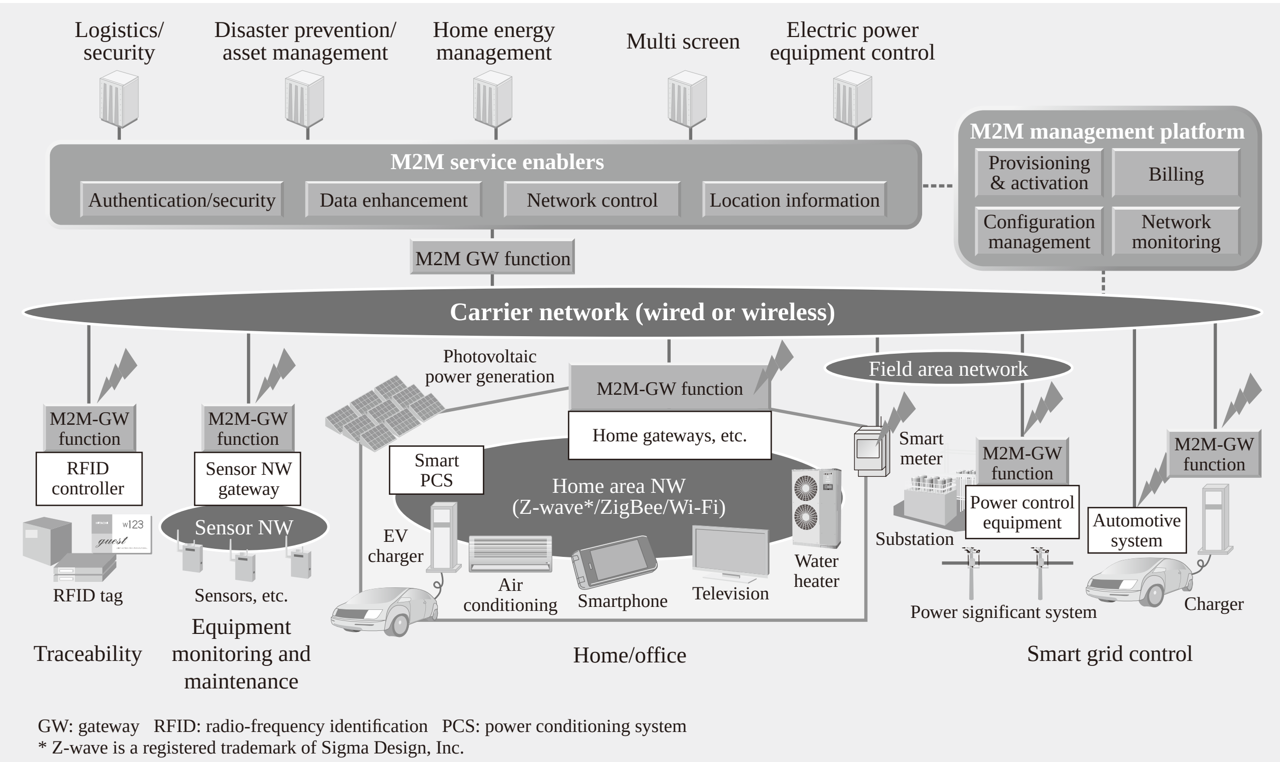


Fig. 8—M2M Solutions.
The M2M platform and gateways are required to provide new services quicker and more economically, handle completely new telecommunication protocols, and connect networks reliably.

would like to acknowledge our appreciation to those involved in this project.

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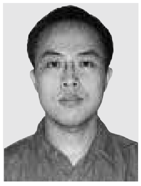

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Systems Development Technology for Public Infrastructure

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OVERVIEW: To supply public infrastructure systems that keep pace with changes in society, Hitachi is promoting the symbiosis autonomous decentralized concept, a system concept for achieving the sustainability of society as a whole while treating change as the norm. To turn this concept into reality, Hitachi is developing system development technologies that satisfy the requirements at the system planning, construction, and operation/evaluation phases. These consist of: (1) Social system modeling and simulation techniques that keep these systems in an optimal and stable condition by controlling the flow of information to stakeholders, (2) System renovation techniques for rebuilding systems without interrupting services by modeling the principles of the physical structures and phenomena that support public infrastructure services, and (3) Heterogeneous system cooperation techniques for achieving optimum operation across the entire system by dynamically linking together the different systems owned by a particular organization.

INTRODUCTION

GIVEN the background of growing urban populations around the world and concern about depletion of energy and other resources, what is desirable is to use IT (information technology) to link consumer services with public infrastructure such as electric power, railways, and water to create the next generation of cities (smart cities) capable of ongoing growth and progress while also combining “conservation of the global environment” with “prosperous urban lifestyles that provide safety, security, and convenience.” This is making public infrastructures increasingly important.

While existing public infrastructure has been built on the basis that it will operate in ways that have been planned in advance, there will be a strong demand in the future for systems that can continue to function autonomously and flexibly even in the event of emergencies such as natural disasters.

This article describes the system development technologies that will be required to support public infrastructure in the future.

TECHNOLOGY CONCEPTS FOR PUBLIC INFRASTRUCTURE

Aims of Technology Development

Consumers possess various ideas and motivations as they go about their lives and many cities have been established and grown quickly to satisfy these diverse needs, resulting in sudden changes in society. Smart cities require the provision of systems and solutions that can respond from a consumer’s perspective, even in the face of these sudden changes in society. With the aim of achieving this, Hitachi is working on the technical development of new system concepts and architectures that extend and generalize the technologies it has built up in collaboration with advanced users of public infrastructure.

The systems with which Hitachi has been involved in the railway, electric power, and other sectors, such as those for railway traffic management or electric power system stabilization, have been designed on the basis that they will operate in pre-planned ways. Because

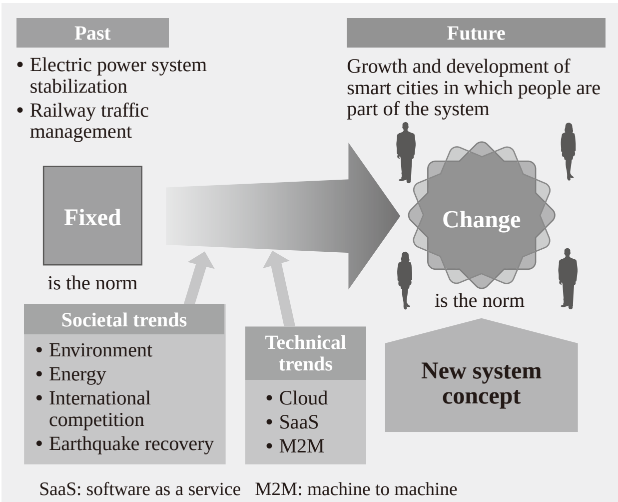

Fig. 1—Aims of Technology Development for Public Infrastructure.
A new system concept needs to be created to supply systems and solutions that can adapt to consumers’ points of view amid a rapidly changing society.

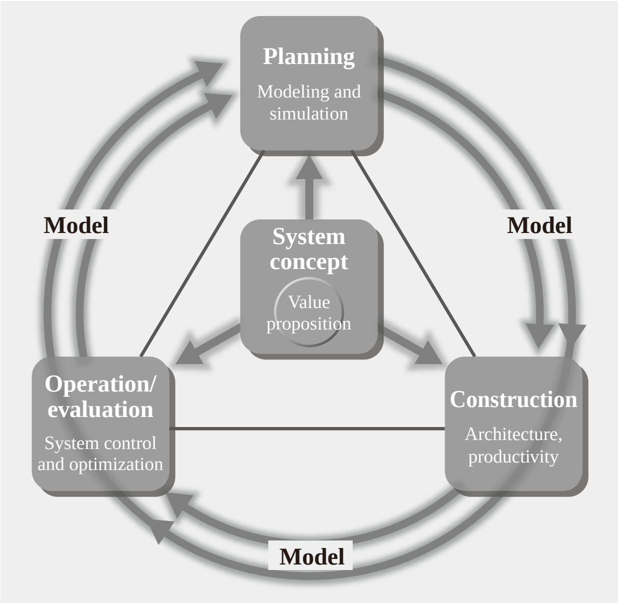

Fig. 2—Framework for System Development Technology.
The framework forms a system of technologies that support each process from planning through to construction and operation/evaluation with "value proposition" as the core system concept at the center of each technology.

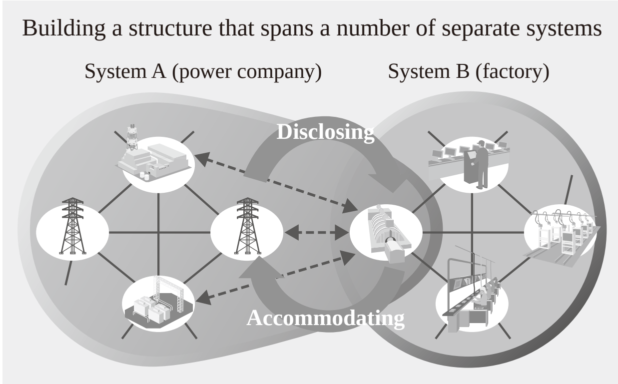

Fig. 3—Symbiosis Autonomous Decentralized Concept.
This involves making effective use of resources by building a structure that spans a number of separate systems.

people with a wide range of different objectives are part of the system, new public infrastructure systems, even while they use these existing systems as a foundation, are defined in terms of "change being the norm," with factors such as the external environment as well as the structure and component elements of the system continually changing in an evolutionary process (see Fig. 1).

Framework for System Development Technology

Fig. 2 shows the framework for system development technology used for public infrastructure systems. The framework forms a system of technologies that support each process from planning through to construction and operation/evaluation with "value proposition" as the core system concept at the center of each technology. This sequence of processes is repeated to move away from partial optimization and closer to the overall optimization of systems designed on the basis that "change is the norm," with models used as the common thread through each step from planning to operation/evaluation.

Symbiosis Autonomous Decentralized Concept

To respond to the type of changes in society referred to above, Hitachi is proposing the symbiosis autonomous decentralized concept in which the idea of "change as the norm" is the basic system concept (see Fig. 3).

In biology, the term "symbiosis" refers to a situation in which two or more organisms coexist in the same habitat in a reciprocal relationship. Unlike the case with parasites, symbiosis means that the organisms are not detrimental to each other. Instead, living in proximity results in a relationship that is mutually beneficial.

To realize infrastructure systems in which the external environment as well as the structure and component elements are continually changing, the symbiosis autonomous decentralized concept takes inspiration from this biological way of thinking. The inclusion of symbiosis in this concept represents the synergy achieved when multiple systems intended for different purposes interoperate to the extent that their respective objectives allow.

The aim of the symbiosis autonomous decentralized concept is to extend existing autonomous decentralized systems[(1)] to ensure the sustainability of the overall system by accommodating finite resources across a number of autonomous systems based on their system objectives and changes in the internal and external environment. Here, resource refers to the functions belonging to each system, including the people, goods, and equipment involved in producing those functions.

To ensure that the accommodation of resources across multiple systems can be maintained in a stable manner, instead of allowing a system that requires resources to acquire those resources from other systems unilaterally, it is desirable that a system that is being requested to supply resources comes to its own autonomous decision on whether to accommodate the request, based on whether it can do so without significantly impacting its ability to achieve its own objectives. This concept is represented by "disclosing" and "accommodating" relationships whereby each system discloses information about what resources it possesses. Systems that receive this information decide to what extent to accept ("accommodate") requests from systems that lack resources based on whether their resources are excess to requirements or their use can be restricted. This can be thought of as a distinctively Japanese concept in which, instead of treating each system as having a fixed role, the systems have flexible roles and collaborative and relative self-configurations while remaining autonomous.

This resource accommodation across multiple systems makes it possible to achieve benefits, such as improving the efficiency of resource use and reducing waste, and to ensure the sustainability of society as a whole.

Necessary System Requirements and Development Technologies

The lifecycle of public infrastructure systems consists of three repeated phases, namely "planning," "construction," and "operation/evaluation." Turning the symbiosis autonomous decentralized concept into reality requires systems development technologies that deal with a variety of different social systems as a single entity in accordance with requirements in each phase along with the IT that supports these technologies (see Fig. 4).

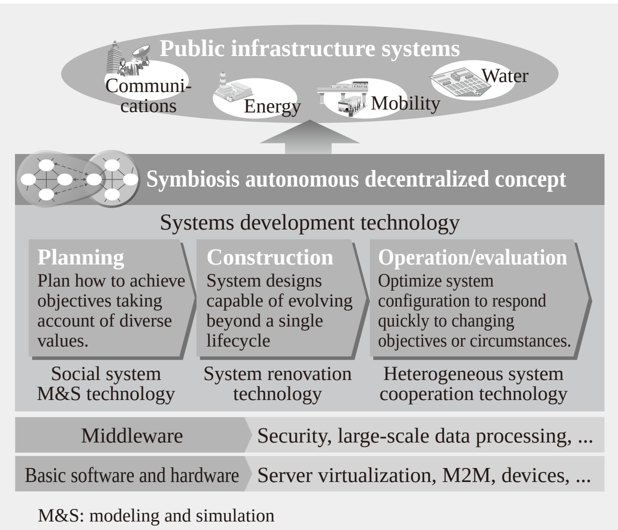

Fig. 4—Systems Development Technologies Supporting Symbiosis Autonomous Decentralization.
Hitachi has developed systems development technologies to satisfy the requirements of the planning, construction, and operation/evaluation phases.

The planning phase involves predicting the actions and needs of a range of different stakeholders with various diverse values (including consumers and urban service operators) when planning aspects of the city such as its structure and functions so that they can be optimized for solving the various issues the stakeholders face. The construction phase involves anticipating changes in society such as urban growth and changes in lifestyles, as well as other changes such as modifications to the functions that systems need to perform, and designing systems that can evolve in ways that transcend lifecycles and generations. The operation phase involves adjusting things like a system's configuration and functional priorities to optimize it quickly in response to changes in objectives and circumstances so that it can make a smooth transition from normal circumstances to an emergency situation and can adapt quickly to a different environment when it is redeployed elsewhere, such as in an emerging economy or a different industry.

Hitachi is developing systems development technologies to meet the requirements of each phase. These consist of social system M&S (modeling and simulation) technologies, system renovation technologies, and heterogeneous system cooperation technologies. These are part of a new trend in systems development technology, corresponding respectively to micro-level simulation techniques such as agent-based simulation, system development methodologies such as SysML (systems modeling language) (a language designed for use in system engineering), and SoS (system-of-systems) and other system configuration techniques[2].

The following sections describe these systems development technologies in detail.

SYSTEMS DEVELOPMENT TECHNOLOGIES SUPPORTING SYMBIOSIS AUTONOMOUS DECENTRALIZATION

Social System M&S Technologies

Simulation is performed in the system planning phase based on models of social systems that express the mutual interactions between stakeholders, defined as the consumers and urban service operators as well as the equipment and facilities they use (such as electric vehicles shared between a number of consumers). The simulation is used to predict the actions and needs of these stakeholders with their diverse values when planning aspects of the city, such as its structure and function, so that they can be optimized for solving the various issues the stakeholders face.

Two points in particular are important considerations when planning the optimum city structure and functions. The first is to consider multi-agent, multi-purpose systems because of the existence of multiple stakeholders. It is likely that many stakeholders will hold one or more different criteria for assessing services based on a diverse range of values. The important factor in this situation is to consider what is meant by “optimum.” The second consideration is to achieve stability of the systems themselves. What we are dealing with is the society in which people reside and go about their lives. This requires not only the optimization of systems, but also that their stability is assured in both social and economic terms. Modeling the behavior of stakeholders such as consumers and urban service operators is important because, unlike that of machines, it appears at first glance to be very indeterminate and complex.

Hitachi has identified the idea of “harnessing” as a technical concept for modeling smart cities of this kind[3].

Deriving from the harnesses (bridles and so on) used on horses, the concept of “harnessing” refers to controlling the flow of information to city stakeholders who act in an autonomous and decentralized manner so that systems are kept in an optimum and stable condition.

The following approaches are adopted to harness smart cities in this way. First, the values of the city’s stakeholders are analyzed to identify KPIs (key performance indicators), and then the ideas of “stability” and “optimization” are formalized in the form of an evaluation function (KPI analysis and identification). Either actual data on stakeholders is analyzed or, if no such data is available, the behaviors of urban service operators, consumers, and others are quantified in the form of expected values and spreads based on hypotheses (stakeholder modeling). Finally, the relationships between stakeholders are analyzed (stakeholder interaction). Based on this modeling, simulations are performed to assess how to implement harnessing in the city (in other words, determining whether systems function effectively when information on “who,” “when,” and “what” is circulated) in terms of stability, optimality, and fairness (see Fig. 5).

Fig. 6 shows an example of social system M&S technologies applied to mobility infrastructure planning. Modeling uses the system dynamics method. Factors like the level of traffic congestion and consumer comfort and safety are used as the KPIs. The stakeholder models include consumer and transportation operator models. The interaction model consists of a model of the exchange of services between stakeholders.

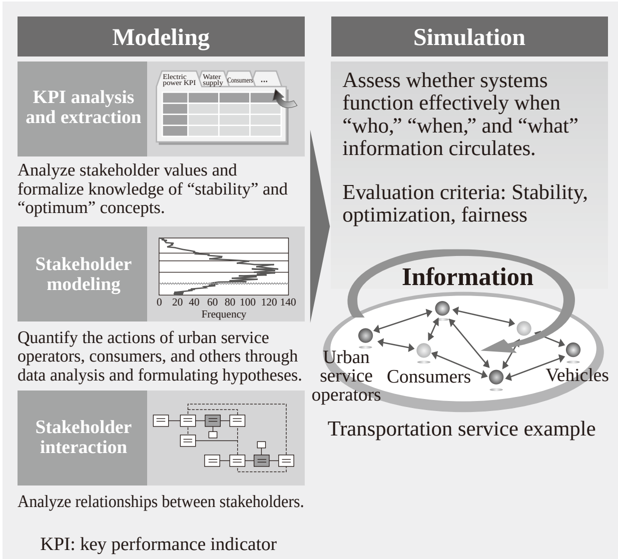

Fig. 5—Social System M&S Technologies.
These technologies are used for modeling and simulation of KPIs, stakeholders, and relationships between stakeholders.

These techniques are an effective way to identify structures that are in conflict with each other in ways that cause activities that would be expected to be beneficial to turn out to be counterproductive.

Simulation highlights trade-offs and can identify factors such as the quantity and timing of guidance information provided to users by quantitatively assessing future changes under different anticipated conditions. It can also be enhanced to better match actual results based on actual measurements from the mobility infrastructure.

System Renovation Technologies

A consequence of including operations such as stakeholder analysis or social system simulation in the system planning phase is that the results lead to changes in the functions required of the system. What will be required of public infrastructure systems in the future is that they keep up with changes in the required functions and continue to provide reliable services that keep pace with the growth of the city and other lifestyle changes in a way that extends beyond a single lifecycle. Accordingly, Hitachi is developing system renovation technologies in the belief that it is important to pay meticulous attention from the system construction phase to production methodologies that can rebuild systems without interrupting services.

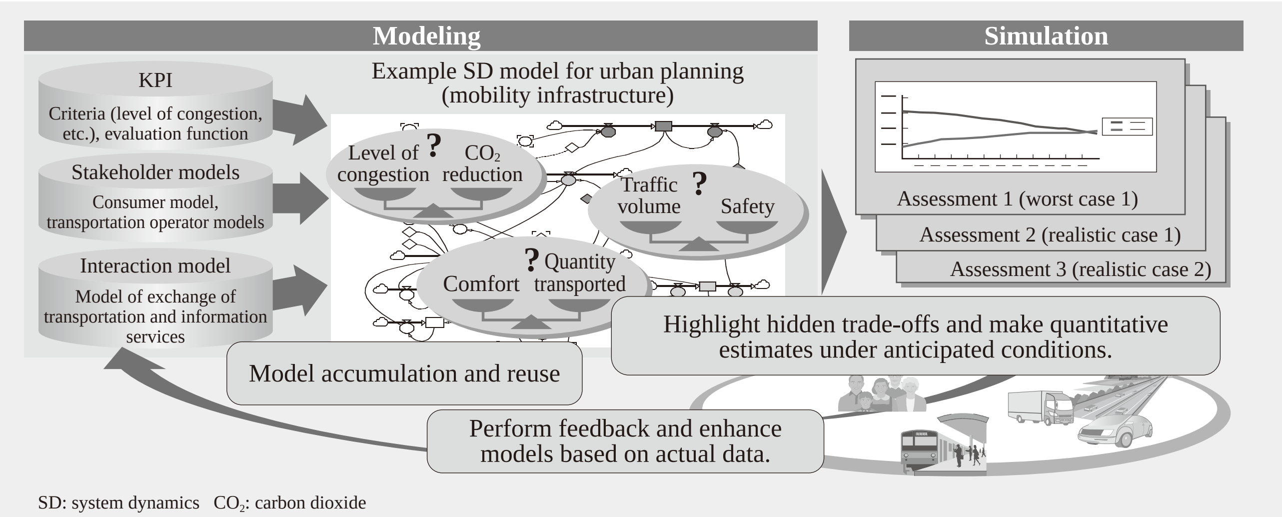

Fig. 6—Example Application in Mobility Infrastructure Planning.
Using outcomes such as the level of congestion as criteria, mobility infrastructure plans are formulated using models of consumers, transportation operators, and the exchange of services between them (representing their interaction).

Public infrastructure systems include services that must remain available in the future as they have been in the past. For example, while the concept of value in railway transportation services has shifted toward things like greater safety and convenience, the physical requirement of using a train running on rails to carry people and freight remains the same as it was in the analog era. In other words, the value that public infrastructure services provide to users has expanded to their physical structures and other physical circumstances through the application of control, information, and other technologies (see Fig. 7).

Hitachi has directed its attention at the physical structures and other physical circumstances that underpin public infrastructure services and believes that it is possible to upgrade these systems without interrupting services by modeling them in terms of the

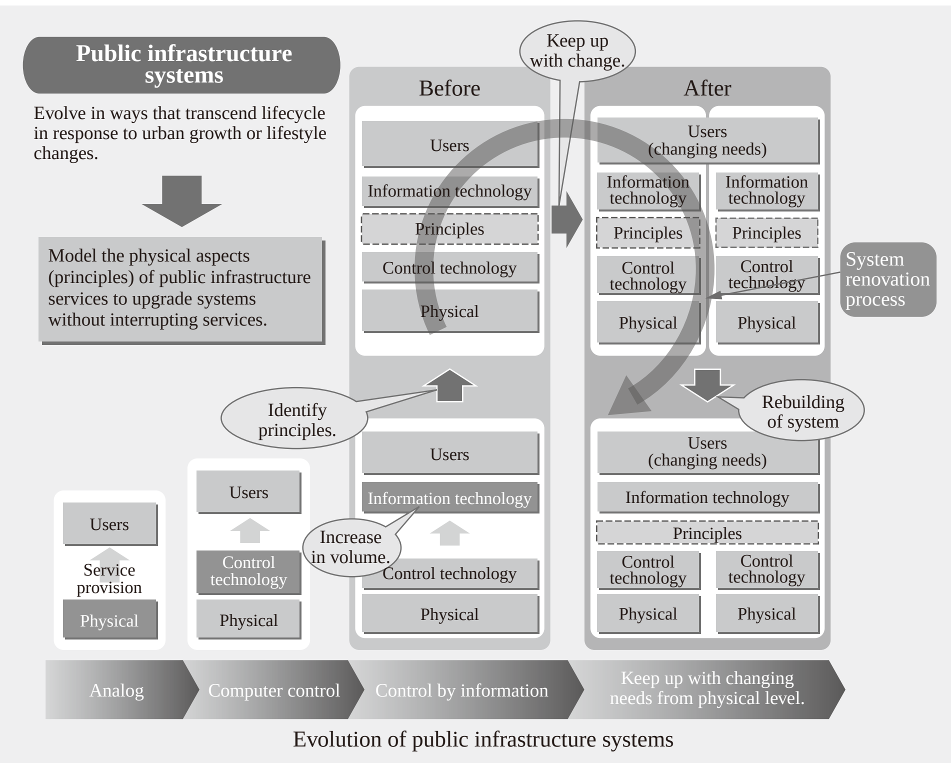

Fig. 7—System Renovation Technologies.
Systems can be upgraded without interrupting services by modeling the principles of public infrastructure services.

principles of their system configurations. Hitachi also believes it is possible to cope with dynamic changes in system configuration that occur in response to stakeholder decisions or circumstances by coordinating the principles of different systems in the case of heterogeneous system cooperation described below.

The system renovation process is called the R3 process as it consists of three steps: "reform (repair)," "refine (rebuild)," and "renovation (upgrading)" (see Fig. 8). The reform step does not extend as far as identifying the system's principles, and instead involves "visualizing" (making visible) a system so that it can be repaired. The refine step involves identifying the principles of the system (the nature of which has been "made visible" by the reform step) so that it can be rebuilt. The renovation step considers what form the system should take given the principles identified in the refine step and upgrades the system accordingly.

In this way, by basing its control systems, monitoring systems, and planning systems on common principles, a railway traffic management system, for example, could be upgraded to a highly flexible system that can handle things such as autonomous routing during emergencies, support for the prompt issuing of instructions based on the actual situation on the ground, and changes to timetables based on feedback from users.

Heterogeneous System Cooperation Technologies

Heterogeneous system cooperation technologies seek to satisfy the requirements for the construction and operation/evaluation phases in particular, with the aim of achieving optimum operation across the entire system by having systems that have their own independent evaluation criteria coordinate the operation of systems dynamically in response to change.

Heterogeneous systems are systems that have different evaluation criteria and judgment autonomy, with systems determining how to operate based on each of these evaluation criteria, and with cooperation between systems being built dynamically based on those decisions.

To implement these functions, systems are made up of the following elements in a heterogeneous system cooperation architecture.

(1) Service layer: Formulates and executes operation plans for the overall system, including the control layer and the various systems.

(2) Control layer: Performs monitoring and control of equipment such as production or transportation machinery.

(3) Control-service cooperation bus: Links the control and service layers and provides a pathway for field data such as sensor measurements from equipment or control targets derived from the operation plans.

(4) Heterogeneous system cooperation bus: Links different types of system and discloses resource information for each system.

To allow different types of system in this arrangement to come to accommodations over use of resources, each system operates in accordance with the following principles.

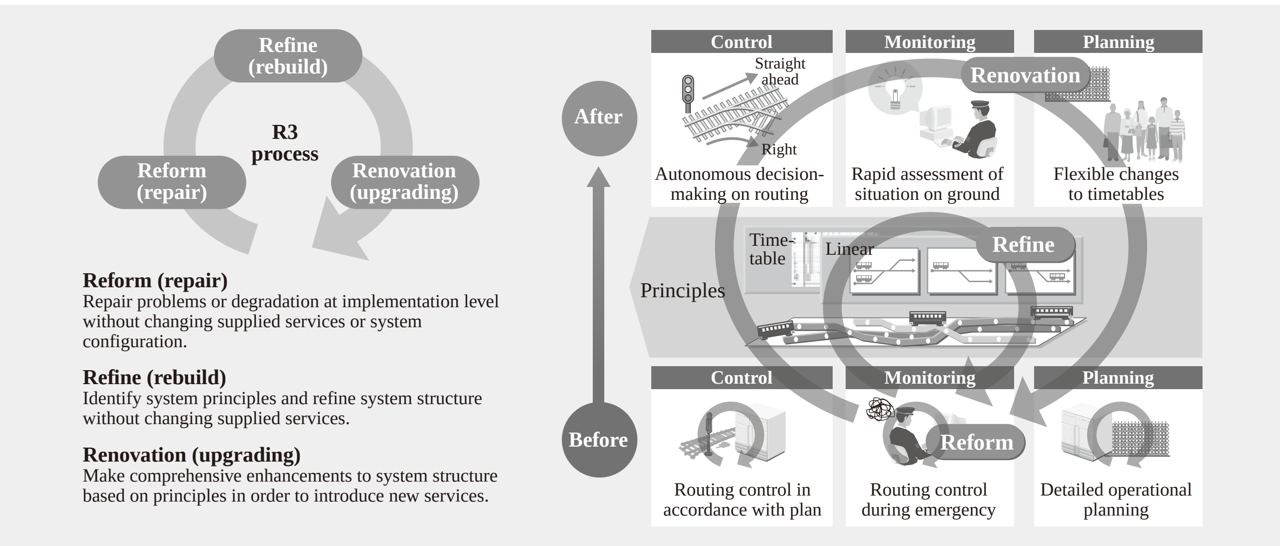

Fig. 8—R3 Process and Example Application to Railway Traffic Management System.
The R3 process uses three steps, "reform (repair)," "refine (rebuild)," and "renovation (upgrading)," to identify the form a system should take (its principles) and upgrades it to be highly flexible.

A system that wants to come to an accommodation over receiving a resource maintains and analyzes a heterogeneous system control model to predict whether each different type of system has an excess or deficit of that resource. Based on this, it discloses the resource that is in short supply and the period of time it is needed to those systems that it predicts will be able to come to an accommodation over the resource.

A system that receives a disclosure uses the received resource information to determine what effect providing the resource will have on its own operation, then decides on whether and how much resource to provide accordingly. To provide the level of resource it decides upon, the system passes control targets to the control layer (taking account of control limitations), and the equipment in the control layer operates autonomously based on these control targets to supply the resources (see Fig. 9).

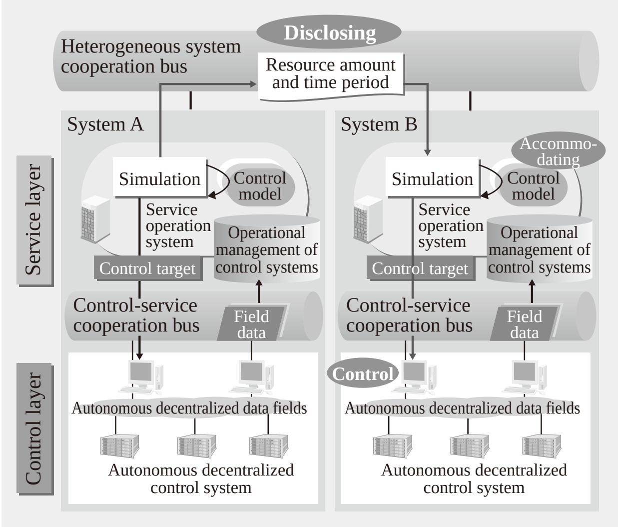

Fig. 9—Heterogeneous System Cooperation Architecture.
Coordinate the overall system by maintaining models of the control layer and various different systems in the service layer.

The heterogeneous system cooperation architecture can be used to balance power supply and demand within a region suffering from a power shortage. This involves the buildings, factories, and consumers in the region working together to make up the power shortage through in-house power generation or power savings (see Fig. 10).

The power company or other organization responsible for regional power supply uses a control model of the buildings, factories, and other consumers of power in the region to analyze regional supply and demand and discloses power information to the region's consumers.

In the event of a power shortage, factories make autonomous decisions on whether to reduce power consumption by adjusting production plans, taking account of the characteristics of the production machinery and the impact that the accommodation would have on things like production and income, and then control their production lines and other equipment accordingly.

CONCLUSIONS

This article has proposed the symbiosis autonomous decentralized concept as a way to cope with changes in society and described the system development technologies required to achieve it. The concept represents a new initiative in the field of system development technologies for supporting public

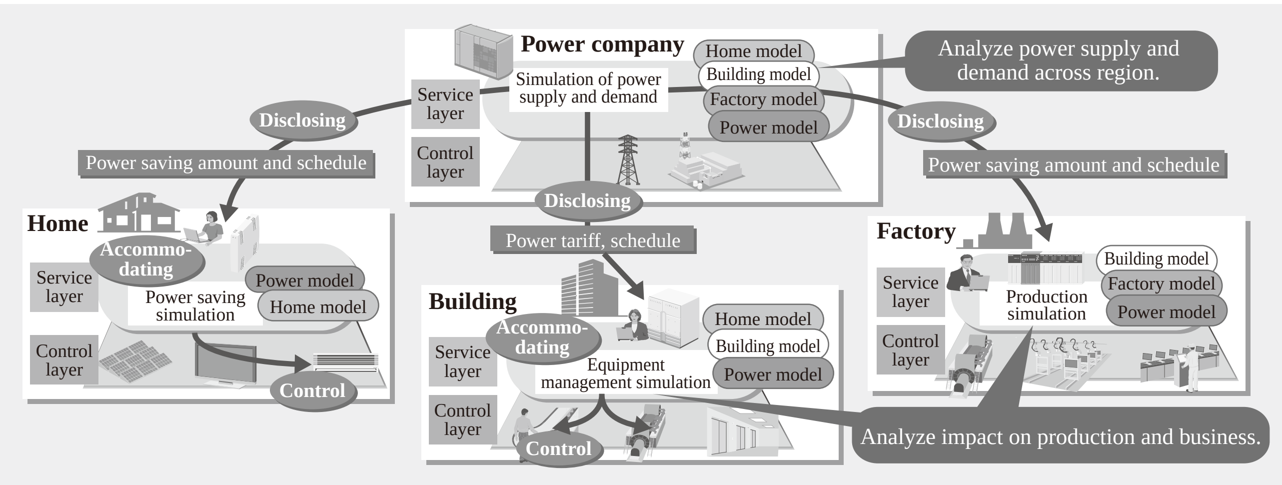

Fig. 10—Application to Regional Power Supply.
In response to the disclosure of electric power information, the region's stakeholders use their control layers autonomously to adjust power supply and demand within the region.

infrastructure and is based on an assumption that change is the norm.

In the future, Hitachi intends to help create flexible and sustainable social systems while also enhancing systems development technology through smart city demonstration projects in Japan and different parts of the world.

Finally, we would like to express our deep thanks to Mr. Yuvraj Agarwal and everyone at the Synergy Lab, the University of California, San Diego for their valuable advice on the content of this article.

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Information & Control Technology Platform for Public Infrastructure

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OVERVIEW: To achieve a well-balanced relationship between people and the Earth that can deliver a comfortable way of life in a low-carbon society, future public infrastructure will need to adapt to changes in the relationships between suppliers and consumers through new business models and by using information in ways it has not been used in the past. This will require new ways of using information; support for devices, applications, and other elements that have proliferated with the growing diversity of service providers; and that the systems underpinning public infrastructure are reliable and able to provide trouble-free operation over the long term. To achieve this, Hitachi is developing the common IT platforms needed by the systems that support the public infrastructure.

INTRODUCTION

RECENT years have seen cities taking on new forms, including new approaches to urban development. Examples include the use of regional energy management to ensure the efficient local production and consumption of energy, including the widespread adoption of technologies such as renewable energy and EVs (electric vehicles) to help realize a low-carbon society, and making trains, buses, and other urban transportation services easier to use from a commuter's perspective in ways that transcend the boundaries between different operators.

Against this background, Hitachi is involved in the development and implementation of smart cities and other forms of public infrastructure based on its vision of a well-balanced relationship between people and the Earth.

This article describes the form taken by the IT (information technology) platforms that underpin public infrastructure systems, along with the functions required for their realization.

REQUIREMENTS FOR PUBLIC INFRASTRUCTURE SUPPORT SYSTEMS

Coping with Diversity

In conventional public infrastructures, energy is supplied by electric or gas companies, and transportation is provided by railway, bus, or taxi companies. With the advent of wind, photovoltaic, and other forms of renewable energy generation in recent years, however, there has also been a move toward consumers generating power for their own consumption or for use within the community. Beyond electric power, moves have also been made toward coordinating regional energy production and making it more efficient by centralizing the supply of heat, such as in the form of district heating and cooling systems. In the mobility sector, meanwhile, some auto manufacturers are entering service businesses such as car sharing as the consumer focus shifts from vehicle ownership to vehicle use. It is anticipated that future cities will see changes in the relationships between supply and demand, with the involvement of a wide

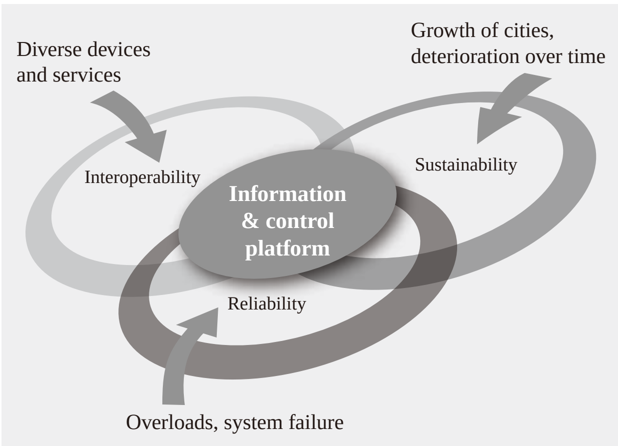

Fig. 1—IT Platform Concept for Public Infrastructure.
The IT (information technology) platform for public infrastructures handles the increasing diversity of devices and services, problems such as processing overloads, and the growth of cities and their deterioration over time.

range of different suppliers and consumers, including service providers entering new businesses and the emergence of new players. It is essential that systems are able to cope with this diversity.

Satisfying Demand for Reliability

Public infrastructure requires stable operation and security of supply. Accordingly, the systems that support public infrastructure must be sufficiently reliable that they can be accessed when and as required. In the past, the reliable and safe provision of public infrastructure services was ensured by keeping the devices and systems (including the networks that linked systems together) isolated from systems with open access. In the future, a wide variety of devices and applications will be incorporated into the public infrastructure via a range of different networks. Given this expectation, systems will need to function in a fashion that ensures that they can be built or extended in ways consistent with the scale of the city or region they serve, including both at the design stage and during operation. For those unforeseen situations when it is difficult to deliver a full range of services, it is necessary to give priority to supplying those functions that are most important to the public infrastructure if no other alternatives are available.

Coping with Growth of Cities and Long-term Sustainability

The growth of cities can take the form of both increases in size and advances in function. Recent years have seen a world-wide tendency for populations to concentrate in urban areas, and for urban consolidation and reorganization. These trends are expected to continue, making it necessary to build systems that match the size of the city and are capable of ongoing expansion. On the other hand, advances in function require advances in the applications, algorithms, and other practices for achieving more comfortable and efficient operation of public infrastructure functions. One possibility would be to measure and predict the changes in the flow of people through a city and then adjust train and bus schedules accordingly. Public infrastructures also need to deliver functions reliably over the long term. This makes it important that public infrastructure has the capacity to regenerate, and it is essential that the provision of public infrastructure functions be maintainable even in the event of an accident or when undertaking partial upgrades of functions that have become obsolete.

CONCEPT BEHIND IT PLATFORM FOR PUBLIC INFRASTRUCTURE

IT has become essential for the provision of public infrastructure. Given the increasing technical innovation and diversification of IT, Hitachi is proposing "smart city platform," which consolidates these technologies and connects together the various devices, networks, applications, and other components involved in public infrastructures (see Fig. 1).

Interoperability

The involvement of a wide range of different service providers means a growing diversity of applications and devices that need to be handled. Requirements such as data formats, data range, timings, communication protocols, and data security policies vary between the interconnecting participants. In such an environment, connectivity is achieved by managing the information collected from applications and equipment under a general-purpose data model, and also by providing standard interfaces.

Meanwhile, there is also a need for security to ensure that the device information handled within the public infrastructure is only visible to those service providers for whom it is appropriate and only to the extent needed. This involves authenticating that the people, applications, or devices that access systems are legitimate, and that they can only access the system in accordance with the authorities they have been granted. Also, data encryption is used for information sent over networks to prevent leaks due to eavesdropping by third parties.

Reliability

Ensuring the reliability of public infrastructure systems requires the prevention of system emergencies or malfunctions due to server or network failures or processing overloads. Here, the role of the platform is to maintain reliability by monitoring the current status of devices, networks, and applications, and by detecting potential emergencies or malfunctions before they happen so that operation can switch over to a different network or to backup servers if necessary.

In the case of a serious emergency, on the other hand, it is essential that the most important public infrastructure functions continue to be supplied. If a malfunction occurs due to a serious processing overload or network failure, making it difficult to continue supplying all functions, the platform selects the most important information from the large and diverse quantity of data exchanged between devices and applications so that it can be prioritized to ensure that supply of the most important public infrastructure functions is not interrupted.

Sustainability

To ensure the long-term support of a growing city, the platform ensures that systems can cope with the size of the city by allowing them to be "scaled out" (expanded) as the city grows in size. The platform also provides common functions for applications such as the visualization and analysis of data from throughout the city as functions become more advanced.

To ensure reliability over the long term, the platform improves the efficiency of things like spare parts management and maintenance staff scheduling by making it possible to monitor the many devices scattered around the city and predict when and where maintenance will be required. Equipment maintenance is also made more efficient by handling version management for the programs, firmware, and other software used in these devices, including distributing updates when programs need to be upgraded. Also, in the normal course of events, devices require replacement over time. To do this for all devices in the city at the same time, however, would be very difficult. The platform supports long-term reliability by allowing maintenance to be performed in stages, by allowing systems to continue operating even when a number of different generations of device coexist in the city at the same time, and by keeping on-site functions to a minimum with all other functions managed centrally.

OVERVIEW OF SMART CITY PLATFORM

System Architecture

Public infrastructure systems consist of devices, applications, and other components connected in a hub and spoke configuration centered on the smart city platform. In this way, the different devices and applications in each system can interoperate as well as undertake modifications or upgrades and establish connections autonomously (see Fig. 2).

The management systems for public infrastructure have a cluster configuration in which each system acts as an autonomous unit. Linking these clusters together allows interoperation between power management and transportation management systems as well as between power management systems from different regions (see Fig. 3). Examples of what this makes possible include the directing of EVs to charge stations with spare capacity based on the electric power supply and demand balance, or advanced management practices such as arranging accommodations between different regions to supply each other with electric power.

Main Functions of Smart City Platform

Applications that run on public infrastructure include some that utilize stored records from devices such as electric power demand forecasting and traffic

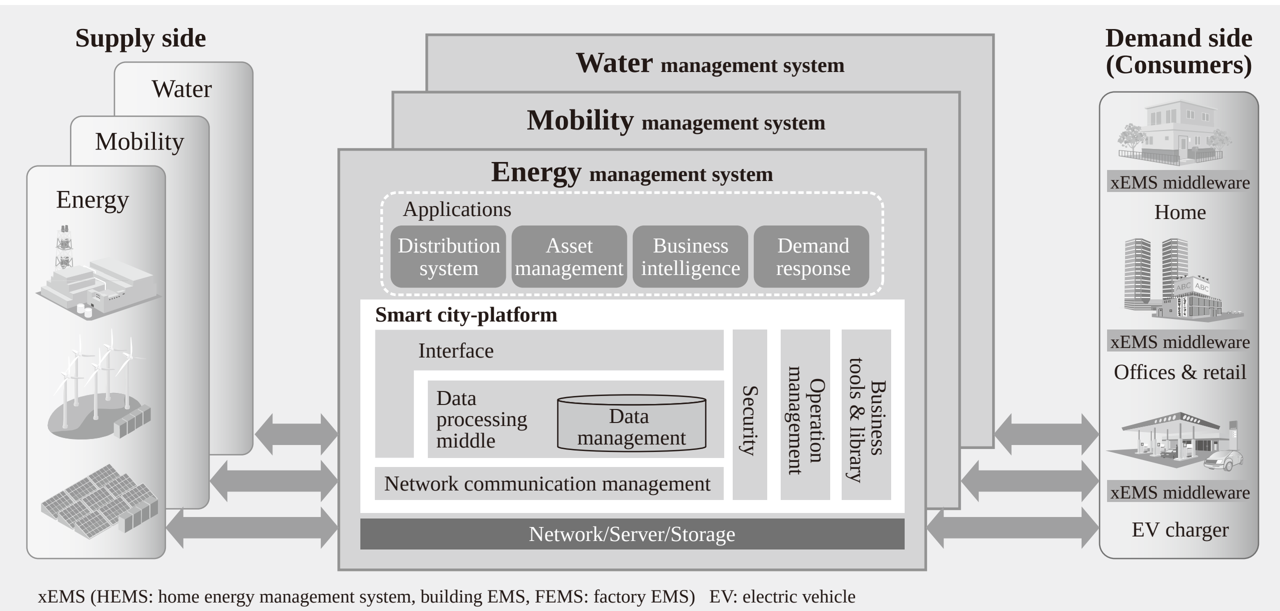

Fig. 2—System Architecture.
Public infrastructure systems connect devices, applications, and other components in a hub and spoke configuration centered on the smart city platform.

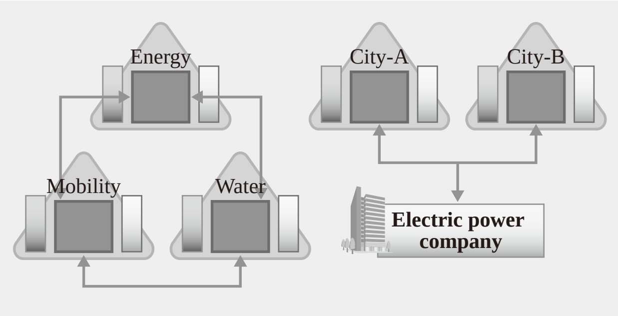

Fig. 3—Model of Links between Clusters.
Interlinking between clusters allows interoperation between different parts of the public infrastructure.

flow prediction, and some that utilize real-time equipment status information such as automation of electric power distribution and traffic management. A key challenge for the former is how to facilitate the collection, storage, and distribution of information from a diverse range of devices, while in the latter case the issue is how to ensure the rapid transmission of information between the devices and applications. The smart city platform uses its data management function to manage information from large numbers of devices and applications of many different types, and its data collection and distribution function to provide rapid delivery of device status information to applications. Table 1 lists the main functions of the smart city platform.

While the role of the smart city platform, as described above, is to provide effective interconnections between the devices, applications, and other components of the public infrastructure, its system architecture, functions, and other features can also be applied outside this realm. For example, it is also suitable for use as an IT platform for service infrastructure such as medical equipment and systems, alarms and home security systems, healthcare, education, administration, and finance. Also possible is its use as an IT platform for the urban management infrastructure that interconnects public and service infrastructure.

CONCLUSIONS

This article has described the form taken by the IT platforms that underpin public infrastructure systems, along with the individual technologies used in such platforms.

IT is making rapid progress and the next generation of public infrastructure will be supported by this advanced technology. Hitachi believes that this next generation of public infrastructure can be realized by undertaking a comprehensive redesign of the electric power, mobility, water, and other public infrastructure that in the past has evolved independently, and by sustaining coordination between each infrastructure while also maintaining autonomous and stable operation.

Hitachi intends to continue contributing to progress in public infrastructure by using the IT capabilities it has built up through its extensive experience to deliver comfort, safety, and peace of mind, without placing a burden on people and others with a stake in the public infrastructure.

TABLE 1. Main Functions of Smart City Platform
These are the main functions of the smart city platform.

Components	Description
Interface	• Collect information from a wide range of devices and supply required information to business applications and other services. • Provide interfaces that comply with IEC and other industrial standards. • Provide high-speed transmission of control information. • Provide xEMS middleware for authentication, communication control, encryption, operational management, and so on.
Data processing	• Convert between data formats used by different devices and applications. • Use stream data processing to handle device data, such as alarms.
Data management	• Use a general-purpose data model suitable for energy, water, mobility, and other public infrastructures to manage device configuration and operational (status and logs) information.
Network communication management	• Measure and monitor communication performance for exchange of information between devices, applications, and other components. • Benchmark communication performance.
Security	• Control authentication of devices, services, and users, and access to information. • Provide encryption techniques that comply with the encryption standards and authentication practices required in different countries in a swappable module configuration.
Operation & maintenance	• Monitor operational status of devices, applications, etc. • Handle version management and upgrades for firmware.
Business tool & library	• Provide unified management of the devices, users, and applications that connect to service systems. • Generate and collect billing logs based on use. • Maintain library for integration with analysis tools, GIS, and other software.

IEC: International Electrotechnical Commission GIS: geometric information system

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