Featured Articles

Solution for Improving Hospital Management in Denmark

Shigeyuki Tani, Ph.D.
Iris Fermin, Ph.D.
Yukinobu Maruyama
Atsushi Ito

OVERVIEW: Denmark is a world leader in addressing the challenges that face mature societies. Both citizens and the government are working together to bring about social innovation through the early adoption and evaluation of innovative technologies. Hitachi established its Denmark Big Data Laboratory in Copenhagen in November 2014. The laboratory is engaged in the development of new service concepts through participation in joint trials with local institutions. Hitachi is participating in the "super hospital" concept consolidating public hospitals into 16 while also improving the efficiency of hospital management by 25%. To boost efficiency at hospitals that are increasing in scale or experiencing incremental growth, Hitachi is implementing hospital management solutions that utilize autonomous decentralized control technology and techniques for managing the flow of people and devices.

INTRODUCTION

THROUGH the Horizon 2020 program, European nations have identified seven challenges that face mature societies, including welfare, food, and transportation, and are working on ways of overcoming them. Based on a background that includes an integral role for information technology (IT) through the widespread adoption of electronic government, the Kingdom of Denmark in particular has set itself high targets in such areas as reducing the load on the environment and cutting healthcare costs, and is proceeding with the implementation of sophisticated policies aimed at overcoming the challenges it faces. Hitachi has established its Denmark Big Data Laboratory and has embarked on work aimed at implementing solutions to the challenges that face mature societies through "collaborative creation" projects with partners in Denmark.

INNOVATIONS FROM DENMARK

Although many people will likely think of Northern Europe as home to strong welfare states, this is predicated on citizens playing a central role in supporting society and represents a model for a new type of society to which mature societies such as Japan should aspire. However, there is no doubt that the welfare state comes with high costs. In response, Denmark has set out to use innovation to overcome this problem. As a result, the country has succeeded in using innovation to expand employment by 150,000 to 250,000 jobs each year in a total population of 5.6 million.

Features of Denmark

Two key features of Denmark are its international competitiveness and its ability to innovate. Ranked sixth in the world by per capita gross domestic product (GDP) in 2014, Denmark has remained ahead of Japan throughout the last decade[1] (see Fig. 1).

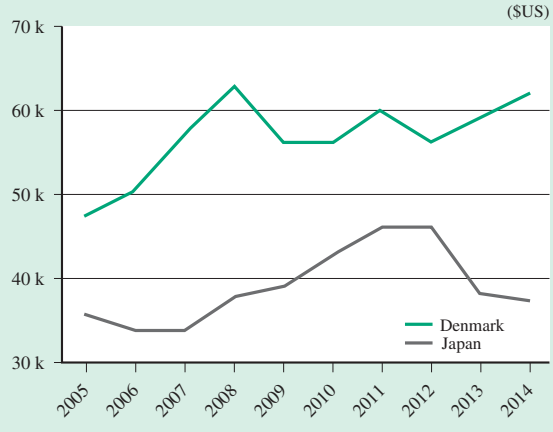

Fig. 1—Comparison of per Capita GDPs of Japan and Denmark. The figures are based on 2005 to 2014 data from the International Monetary Fund. Denmark's per capita GDP was higher than that of Japan throughout this 10-year period.

It ranked ninth in the 2014 world competitiveness rankings of the Swiss-based International Institute for Management Development (IMD), sharing its high ranking with other Northern Europe nations[2].

Having been an early adopter of innovative technologies and practices for addressing the problems faced by society, Denmark is pushing ahead with societal-level innovations. Despite being an oil producer, thanks to its North Sea oil fields, Denmark has actively pursued renewable energy and leads the world in per capita wind power generation capacity. Utilizing wind and biomass power, it already supplies one-third of its electric power needs through renewables, and has set a national target of increasing this to one-half by 2020, and of reducing fossil fuel use to zero to become carbon neutral by 2025[3].

User-driven Innovation

One feature of innovation in Denmark is that it is user-driven, with the tradition at Denmark's companies of proactively involving users in the development process having prepared the ground for this approach[4]. This makes the country one that is quick to adapt to new technologies and other changes, with no hesitancy among citizens about participating in social innovation or trying out new technologies for themselves. With a test bed that provides opportunities for trial and error being essential to the development of innovative solutions, Denmark provides just the sort of environment needed for this.

The CPH 2025 Climate Plan is a plan published by the city of Copenhagen, the capital of Denmark, for taking on environmental challenges in the period up to 2025[5] (see Fig. 2). Among its objectives, Copenhagen is aiming to increase the proportion of citizens commuting by bicycle, with active involvement by citizens having already seen this figure rise to 35%.

Utilizing Collaborative Creation with Customers for Solution Development

Hitachi established its Denmark Big Data Laboratory in Copenhagen in November 2014. Through involvement in industry-government-academia initiatives in Denmark's major cities and in collaborative trials featuring user participation, the laboratory is working on the development of new service concepts and the formulation of business models. Its work covers the fields of energy and the environment, transportation, and healthcare, each of which has been identified as a key area by the government of Denmark. In addition to contributing to national development through the collaborative creation of solutions with customers and other partners who are grappling with these future challenges in Denmark, the plan is also to deploy the solutions in other countries and areas that face the same issues.

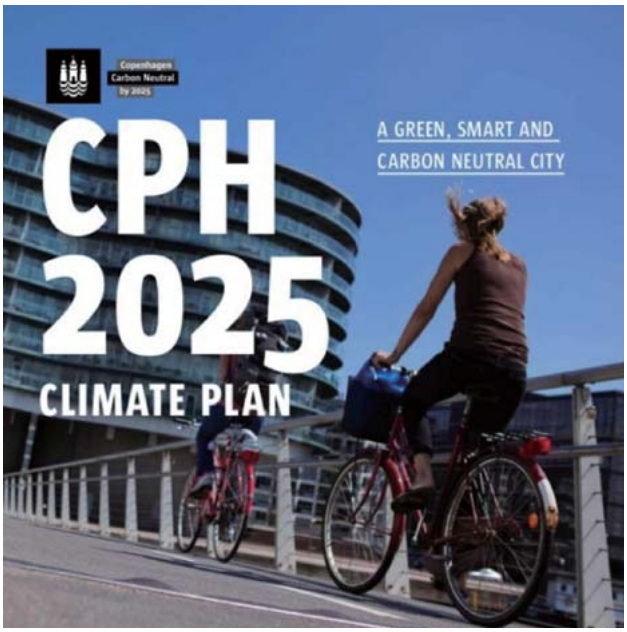

Fig. 2—CPH 2025.
The CPH 2025 Climate Plan published by the city of Copenhagen, the capital of Denmark, runs until 2025 and is aimed at reducing the load on the environment.

SUPER HOSPITAL

Super Hospital Concept

In the healthcare field, Denmark is working on a "super hospital" concept. Against a background of rising social security costs due to increases in the cost of healthcare, the concept involves investing a total of 40 billion kroner over 10 years with the aim of consolidating 40 existing public hospitals into 16 "super hospitals" (advanced medical facilities) (see Fig. 3) while also improving the efficiency of hospital management by 25%. A distinctive feature of the plan is the choice of three particular indicators to help achieve these goals[6] (see Fig. 4).

Because of Denmark's implicit adoption of a quality-first philosophy, as exemplified by its user-driven innovation, it is looking to technologies that can provide highly efficient healthcare services without compromising the quality of medical care. In the city of Aarhus, construction of a planned huge super hospital is already underway on an expansive 4 km × 4 km site. Furthermore, because each region will

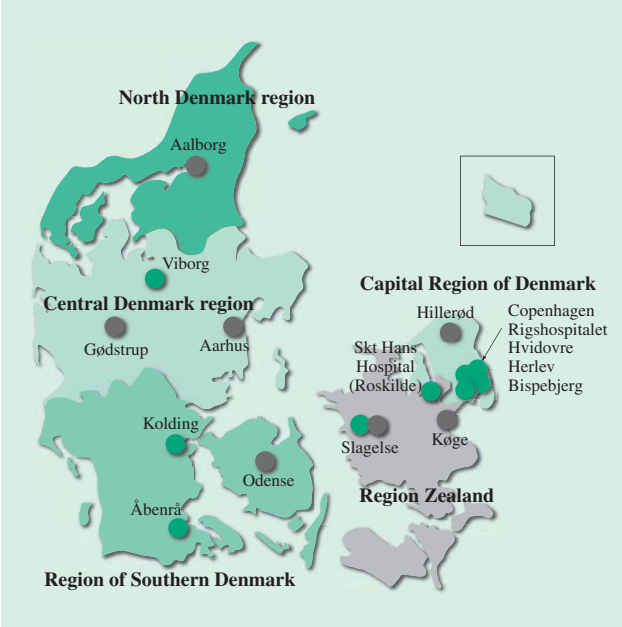

Fig. 3—Super Hospitals in Denmark's Five Regions.
Denmark will consolidate 40 existing public hospitals into 16 super hospitals. The grey dots indicate new construction and the green dots indicate expansion or refurbishment.

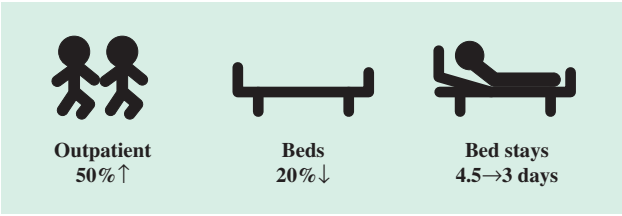

Fig. 4—Three Target Indicators of Super Hospital Concept.
Denmark has defined three targets for achieving a 25% improvement in operational efficiency: a 50% increase in outpatients, a 20% reduction in beds, and a reduction from 4.5 to 3 days in the mean length of a hospital stay.

be served by only three or four hospitals (see Fig. 3), meaning each super hospital will need to cover a wide range of services, information communication technologies (ICT) are anticipated to play a major role in supporting community healthcare.

Collaboration with Bispebjerg and Frederiksberg University Hospital

To participate in the super hospital concept and develop new healthcare solutions, Hitachi reached an agreement with the Bispebjerg and Frederiksberg University Hospital in November 2014 to work jointly on solution development[7]. This joint development will combine the extensive medical and other data resources held by the hospital and its experience in hospital operation and management with Hitachi's

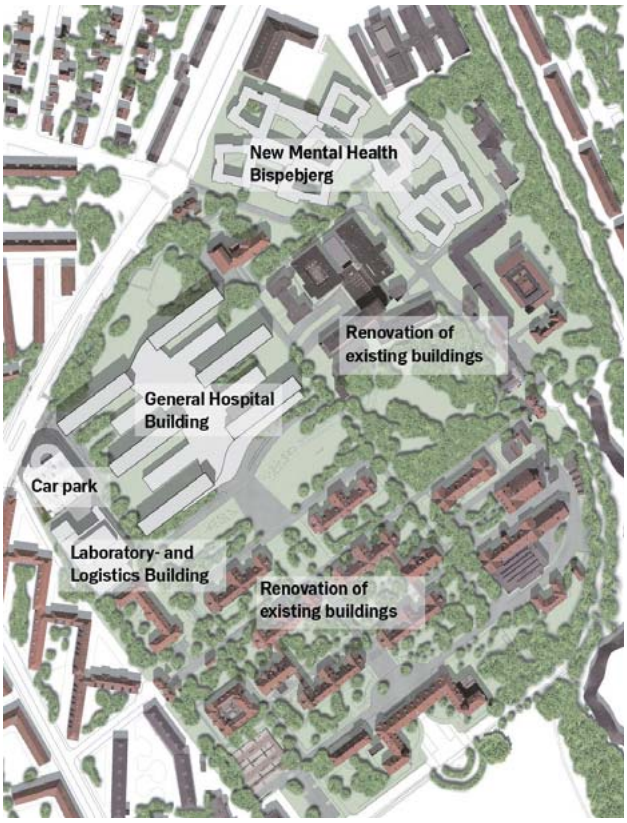

Fig. 5—Future Plan for Bispebjerg and Frederiksberg University Hospital.
The plan includes the construction of a new hospital on the north side of the site and, along with the merger of Bispebjerg Hospital and Frederiksberg Hospital, the new facility is to function as a super hospital.

experience and know-how in the supply of medical devices and systems and in the use of ICT for big data.

The Bispebjerg and Frederiksberg University Hospital was formed from a merger of Bispebjerg Hospital and Frederiksberg Hospital. It provides medical services to approximately 450,000 citizens in the Frederiksberg and Copenhagen municipalities. It has a staff of approximately 5,000, with major expansions[8] planned that will turn it into a super hospital covering 200,000 m^2 by 2025. Design and construction of a new hospital building commenced in 2014 (see Fig. 5). The work includes active measures aimed at making operational improvements through the use of ICT, such as sensors installed in temperature-controlled facilities at roughly 800 locations, including freezers and medical cabinets, for example.

Another objective is to look at the movement of people at the site to achieve an efficient flow of people and devices through the enlarged facility that will result from the super hospital concept.

USE OF COLLABORATIVE CREATION WITH HOSPITAL TO IDENTIFY CHALLENGES

Big Data Analytics

A feature of big data analytics that has come about through advances in computer technology is the ability to measure and assess specific circumstances to identify and classify particular features within the wider context, and to use these features as a basis for performing control in accordance with these specific circumstances. This does not mean control functions are restricted to the particular device on which they are running, as with past systems, nor does it mean only attempting to control overall trends, as in mass-marketing. Instead, less wasteful control is achieved by considering both specific circumstances and overall trends.

As noted above, Bispebjerg and Frederiksberg University Hospital has installed monitoring sensors in temperature-controlled facilities such as freezers and medical cabinets at roughly 800 locations. Hitachi conducted an analysis of roughly one year of temperature data from these sensors that identified and classified a number of features from within the wider situation (see Fig. 6). Based on these features and the specific circumstances at each of the locations, Hitachi found potential savings of more than 5% in the hospital's total cooling cost that could be achieved by performing control in ways that minimize waste. In the future, Hitachi will work with the hospital to investigate what forms of dynamic control to perform for the existing monitoring systems and the various temperature-controlled facilities spread across the site.

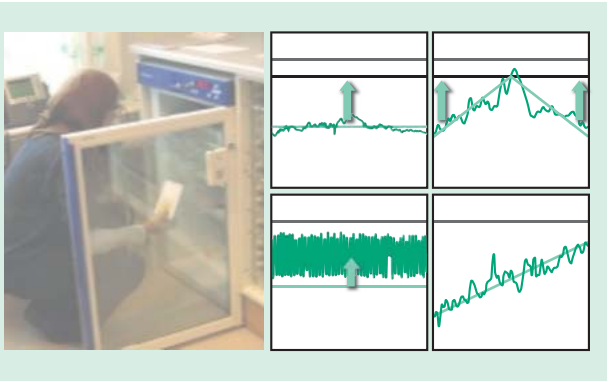

Fig. 6—Temperature-controlled Facilities at Hospital (Freezer) and Example of Feature Classification of Temperature Data.
Data from each temperature-controlled facility is collected via a wireless network. The data is classified based on usage and dynamic characteristics that vary from day to day.

Ethnographic Analysis

Ethnographic analysis is a technique for identifying the structures and processes at a workplace through close observation of actual behavior at the site. By identifying patterns associated with workplace problems and enabling them to be understood at a conceptual level, this uncovers the underlying issues that will improve the "experience" of the solution being developed. Furthermore, because it uses observational methods, it can help discover latent needs by identifying tacitly assumed attitudes[9]. An ethnographic analysis of doctors, nurses, pharmacists, and other hospital staff is already underway in collaboration with Bispebjerg and Frederiksberg University Hospital (see Fig. 7).

The greatest benefit of ethnographic analysis is its identification of issues that are not apparent from the measurement data alone. In the case of the temperature data described above, the measurement data may be adequate on its own if the only objective is to detect faults in the temperature-controlled facilities. If an ethnographic analysis of the workplace is conducted, on the other hand, it will identify that the important issue for the organization and staff is to manage the quality of medicine or food stored in these facilities. This then becomes a question of hospital logistics concerning how, when, and where this medicine and food are distributed (allocation).

DYNAMIC RESOURCE ALLOCATION

As these hospitals grow in size, the factors important to improving efficiency extend beyond just the medicine

Fig. 7—Ethnographic Analysis in Progress at Bispebjerg and Frederiksberg University Hospital.
Hitachi undertook an ethnographic analysis of doctors, nurses, and other staff in collaboration with Bispebjerg and Frederiksberg University Hospital.

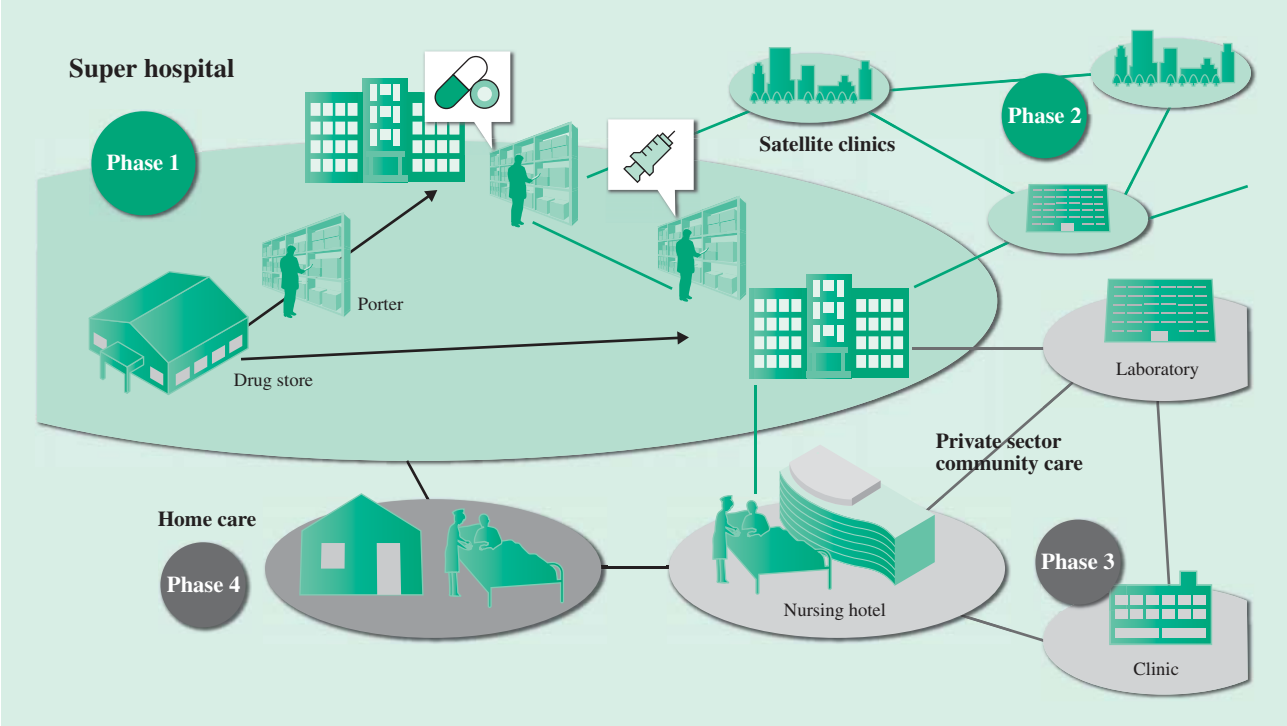

Fig. 8—Dynamic Resource Allocation.
The diagram shows how the dynamic distribution and disposition of resources is used to improve efficiency as these hospitals grow in size. To allow for future enhancements, consideration is also given to extending the practices outside the hospital.

or food stored in temperature-controlled facilities. They also encompass the dynamic distribution and disposition of resources that include staff, medical devices, and other medical supplies. As human resources are of the utmost importance, particularly in hospitals, the challenge is to maintain an awareness of the location and movement of people and to ensure that these movements are appropriate given changing circumstances. Furthermore, when a hospital plays a central role in community healthcare, there is a need to consider how to handle the sharing of resources with the private sector, including general practitioners (GPs). In this case, the methods adopted need to be able to work with the different systems already in place at external organizations (see Fig. 8).

Controlling the Flow of People and Devices

Hitachi has engaged in a variety of research and development relating to the measurement and analysis of human behavior over many years. This includes techniques for using sensors to locate people within an area and track their movements, and for measuring people's location and the forms of communication they engage in (time spent in conversation, acceleration data, etc.) to calculate indices for things like activity level, initiative, or time spent concentrating[10].

At the Bispebjerg and Frederiksberg University Hospital, it was estimated that staff wasted 20 steps a day in their movements. Along with using sensor measurements of their movements to identify this waste in more detail, an analysis of the causes is conducted using information about their jobs (whether they are a doctor or nurse) and the work to which they are assigned. The movement characteristics obtained from this analysis are then utilized to optimize the layout of rooms and other facilities at the new hospital construction project currently in progress (see Fig. 9).

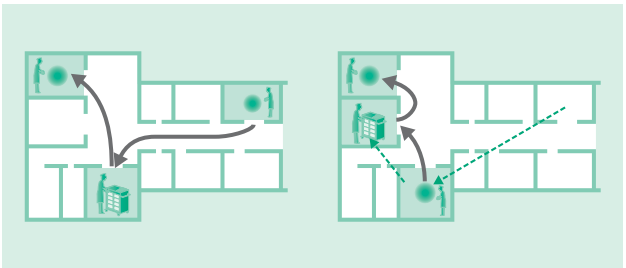

Fig. 9—Analysis of People's Movements at Hospital and Building Layout Optimization.
The layout of rooms and other facilities at the new hospital construction project currently in progress is optimized using movement characteristics identified by an analysis of the flow of people.

By attaching sensors not just to people but also to beds, lifts, and other medical equipment, it is possible to eliminate waste in the use of scarce and expensive equipment and facilitate dynamic resource allocation whereby the ideal location for bringing together staff, equipment, and other medical supplies can be determined on the fly.

Autonomous Decentralized Systems

Based on ideas from living organisms, autonomous decentralized systems are total systems that integrate individual subsystems, analogous to the way a human body is constructed from cells. A feature of autonomous decentralized systems is that, because each subsystem operates autonomously, the overall system can continue to function even if some subsystems fail, or similarly if new subsystems are added. Currently, such systems are being further enhanced to provide the ability to reallocate resources between them, such that even systems intended for different purposes will be able to connect together to the extent that is compatible with their serving their respective purposes[11] (see Fig. 10).

A feature of the super hospital concept is that a number of existing hospitals will merge to form a new expanded and enlarged facility. The Bispebjerg and Frederiksberg University Hospital, for example, is the result of merging Bispebjerg Hospital and Frederiksberg Hospital, and is scheduled to undergo a staged program of new construction, relocation, and refurbishment over the period from 2014 to 2025. This will involve progressive expansion and growth, starting from the base of existing operations and systems. The facility will also be called on to become a hub for community healthcare in the future, expanding the scope of healthcare service coverage by linking together the information and activities of different organizations, including satellite clinics, GPs and other private sector providers, and ultimately families providing care in the home, as shown in Fig. 8.

As this expansion and integration will involve the organizations continuing to use their existing systems, it is an embodiment of the idea of an autonomous decentralized system in which subsystems intended for different purposes are able to share resources between them.

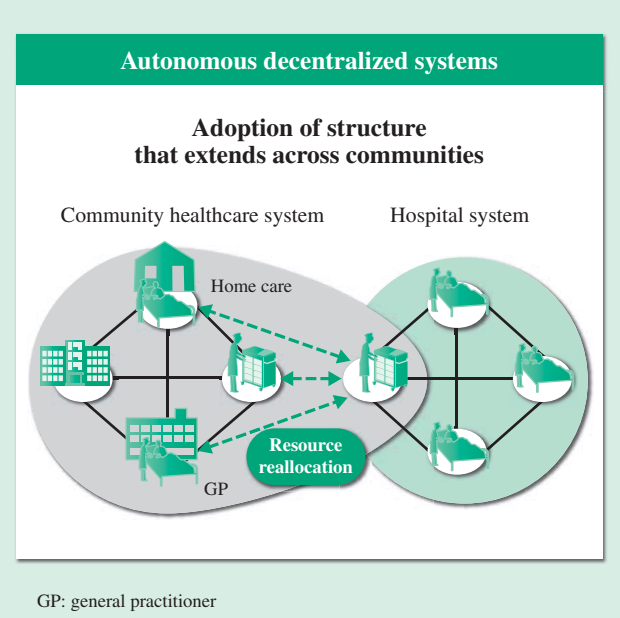

Fig. 10—Use of Autonomous Decentralized Systems for Expansion into Community Healthcare.
By adopting structures that extend across communities, it is possible to connect together even systems intended for different purposes to the extent that is compatible with their serving their purposes, and to reallocate resources between them.

CONCLUSIONS

To find rapid solutions to the challenges that face mature societies, Denmark has adopted innovation as a key component of its national strategy. Along with its innate national characteristics, Denmark is focusing on initiatives such as education to improve IT literacy to facilitate participatory innovation, and has great potential as a test bed for assessing the value of new technologies and solutions in practical use.

Hitachi is currently participating in the super hospitals initiative and is working to establish new service concepts with the aim of improving the efficiency of management at the new huge hospitals by 25%. In the future, Hitachi also intends to engage in collaborative creation with customers and other partners who are taking the lead in dealing with the challenges of energy and the environment and transportation that have been identified as priorities by the government of Denmark.

Regardless of the field, and unlike in developing economies where social infrastructure can be built from scratch and on a large scale, the provision of social infrastructure in mature societies involves working from a base of existing systems that already have designated functions and that operate in an autonomous and decentralized fashion. Hitachi believes that the technologies it has built up in Japan, such as those for autonomous decentralized systems, will prove effective for this purpose.

REFERENCES

(1) IMF, http://www.imf.org/external/data.htm
(2) International Institute for Management Development (IMD), http://www.imd.org/
(3) Denmark Embassy in Japan, http://japan.um.dk/ja/about-us/press/the-kingdom-of-denmark/ in Japanese.
(4) K. Sunada, "Nordic Innovation Strategy to Lead the Knowledge Economy," Chijo intelplace #118 (Mar. 2013) in Japanese.
(5) City Climate Leadership Awards, http://cityclimateleadershipawards.com/
(6) Ministry of Foreign Affairs of Denmark, "Denmark Invests $7 Billion in Super Hospitals for the Future," http://www.investindk.com/News-and-events/News/2013/Denmark-Invests-$7-billion-in-Super-Hospitals-for-the-Future
(7) Bispebjerg Hospital website, https://www.bispebjerghospital.dk/nythospital/nyt-og-presse/nyheder/2014/Sider/hitachi-finder-mening-i-hospitalets-data.aspx
(8) Bispebjerg Hospital website, https://www.bispebjerghospital.dk/nythospital/english/Pages/project.aspx
(9) T. Kawasaki et al., "Applications and Benefits of Ethnographic Research —Case Study of Management System Upgrade for Power Plant Construction Site—," Hitachi Review **62**, pp. 317–323 (Sep. 2013).
(10) M. Takahashi, M. Nomiya and N. Suzuki, "New Bricks and Mortar Marketing Technique Based on Human Behavior Measurement," Hitachi Review **63**, pp. 30–34 (Feb. 2014).
(11) K. Iijima et al., "Systems Development Technology for Public Infrastructure," Hitachi Review **61**, pp. 159–166 (May 2012).

ABOUT THE AUTHORS

Shigeyuki Tani, Ph.D.
European R&D Centre, Hitachi Europe Ltd. He is currently engaged in big data analysis research in Denmark. Dr. Tani is a member of the Institute of Electrical Engineers of Japan (IEEJ), The Society of Instrument and Control Engineers (SICE), and the Japan Association of Real Options and Strategy (JAROS).

Iris Fermin, Ph.D.
European R&D Centre, Hitachi Europe Ltd. She is currently engaged in healthcare ICT research in Manchester. Dr. Fermin is a member of the British Machine Vision Association (BMVA), the Information Processing Society of Japan (IPSJ), and the UK Public Health Register.

Yukinobu Maruyama
European R&D Centre, Hitachi Europe Ltd. He is currently engaged in energy, railway, and healthcare service design.

Atsushi Ito
Strategy Planning Division, Information & Telecommunication Systems Company, Hitachi, Ltd. He is currently engaged in global business strategy, and service business strategy planning.