The Future Pioneered by Device Technology for a Sustainable Society

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Abstract

The research and development NTT is conducting to create a sustainable society, specifically regarding human health and aging infrastructure, is outlined in the following Feature Articles in this issue. After the trends toward solving social issues in Japan and overseas are briefly described, the direction of smart-healthcare and infrastructure-maintenance technologies—which use device technology cultivated by NTT laboratories—is discussed. Research results and cutting-edge technologies that are about to be put into practical use and be used for prevention and maintenance by grasping and estimating the conditions of people and infrastructure are also introduced.

Keywords: healthcare, infrastructure maintenance, sustainability

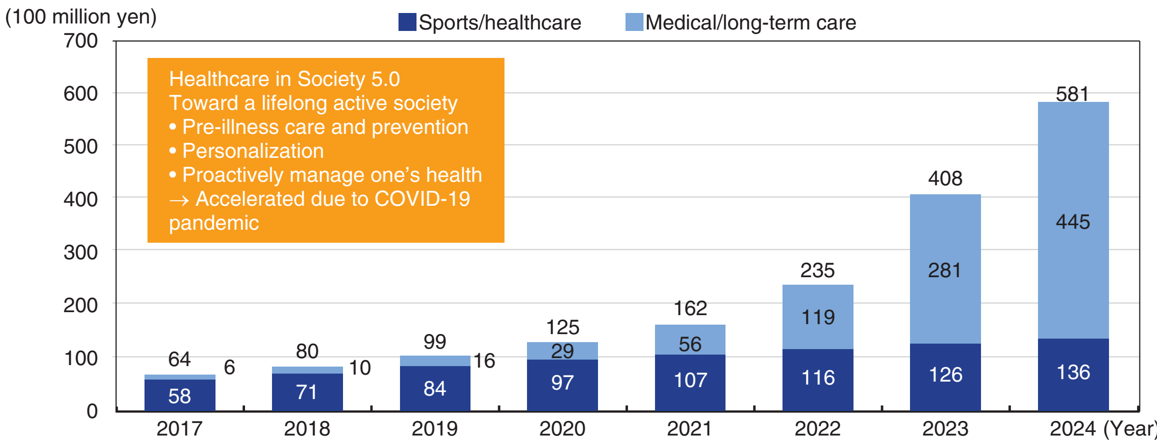
1. Challenges facing creation of a sustainable society

Problems, such as declining birthrates and aging populations, global warming, energy problems, and food crises, are becoming apparent across the world, and it is said that 2030 will be the turning point for the continuous economic growth that humankind has enjoyed as civilizations have developed. The Sustainable Development Goals (SDGs) were established by the United Nations with the aim of creating a sustainable society [1], and in Japan, efforts toward creating a people-centered super-smart society called "Society 5.0" have been positioned as important issues [2]. Under such circumstances, we have entered an era of reorganization of the economic and geopolitical world order, and how to revise the information society has become a major issue. To address such issues, it is necessary to develop technologies to promote continuous business while understanding the needs of society and expanding the horizons of the entire social system. In other words, simultaneously achieving business continuity and solutions to social issues is the key to the creation of a truly sustainable society.

We believe that people-centered efforts will be a major first step when addressing the above issues. If we want to think in a people-centric manner, we should focus on two aspects: (i) the health of individuals and healthcare provided for them and (ii) the environment surrounding them. We believe that developing technology that takes into account people and their environment will significantly contribute to solving social issues while achieving business continuity.

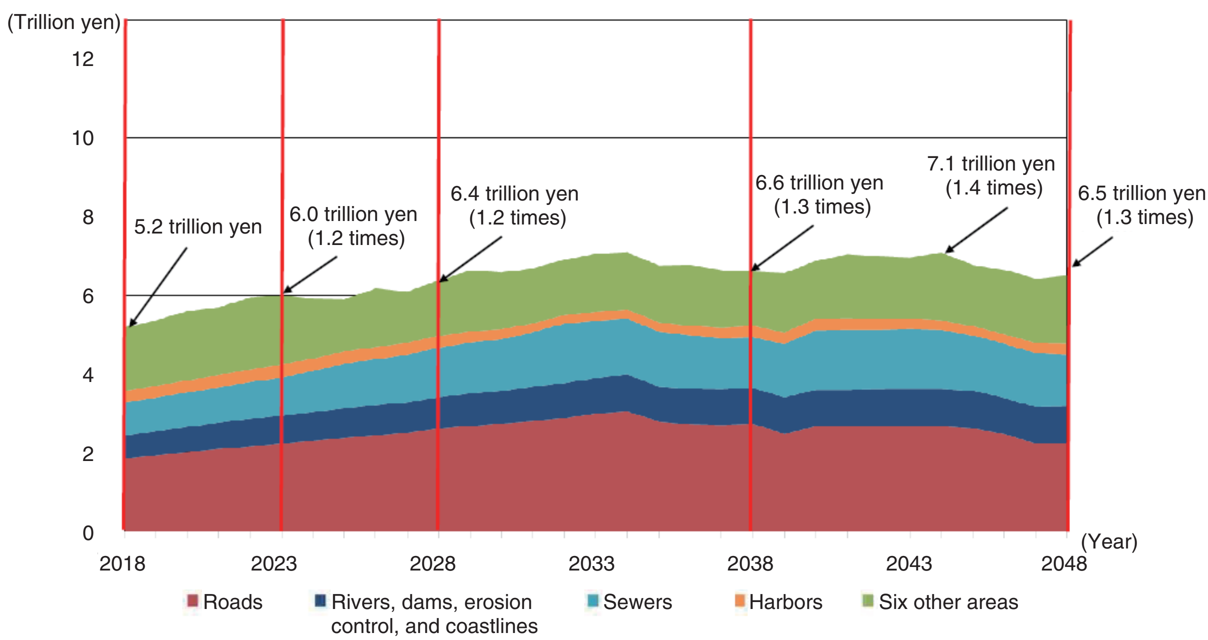
Regarding human health, the economic effect of achieving a lifelong active society is 33 trillion yen, and the health-technology market is worth over 50 billion yen [3] (**Fig. 1**). It is thought that the time will come when we will take the initiative in managing our own health, such as early intervention through daily monitoring and pre-illness care and prevention through personalized guidance. The above awareness of issues has been pointed out for some time; however, the need for digital transformation (DX) of health is increasing at a rapid pace due to the recent spread of infectious diseases.

Regarding environment-friendly technology, how to efficiently maintain infrastructure equipment, the most-basic element of the information society, needs to be addressed. The cost of infrastructure maintenance and renewal in Japan is estimated to be enormous, 5 to 7 trillion yen per year [4] (**Fig. 2**). Infrastructure maintenance is an extremely difficult technical area because infrastructure is used for a long



Source: Nomura Research Institute, materials for the 273rd NRI Media Forum (issued on December 6, 2018). The graph is created by NTT utilizing data from Nomura Research Institute.

Fig. 1. Trends in domestic market size of healthcare technology.



*Since the estimated value is a value with a width, the graph is created using the maximum value.

Source: Ministry of Land, Infrastructure, Transport and Tourism, "Estimation of Future Maintenance and Renewal Costs of Social Capital in Fields under the Jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism," 2018 (in Japanese).

Fig. 2. Changes in infrastructure maintenance and renewal costs.

time in various environments, and it is necessary to evaluate and elucidate physical phenomena in units of ten-years. Infrastructure maintenance currently involves a large amount of manual work; therefore, DX conversion including automation of inspection is required by using the power of technology. Against this background and to create a sustainable society, NTT is focusing on research and development (R&D)

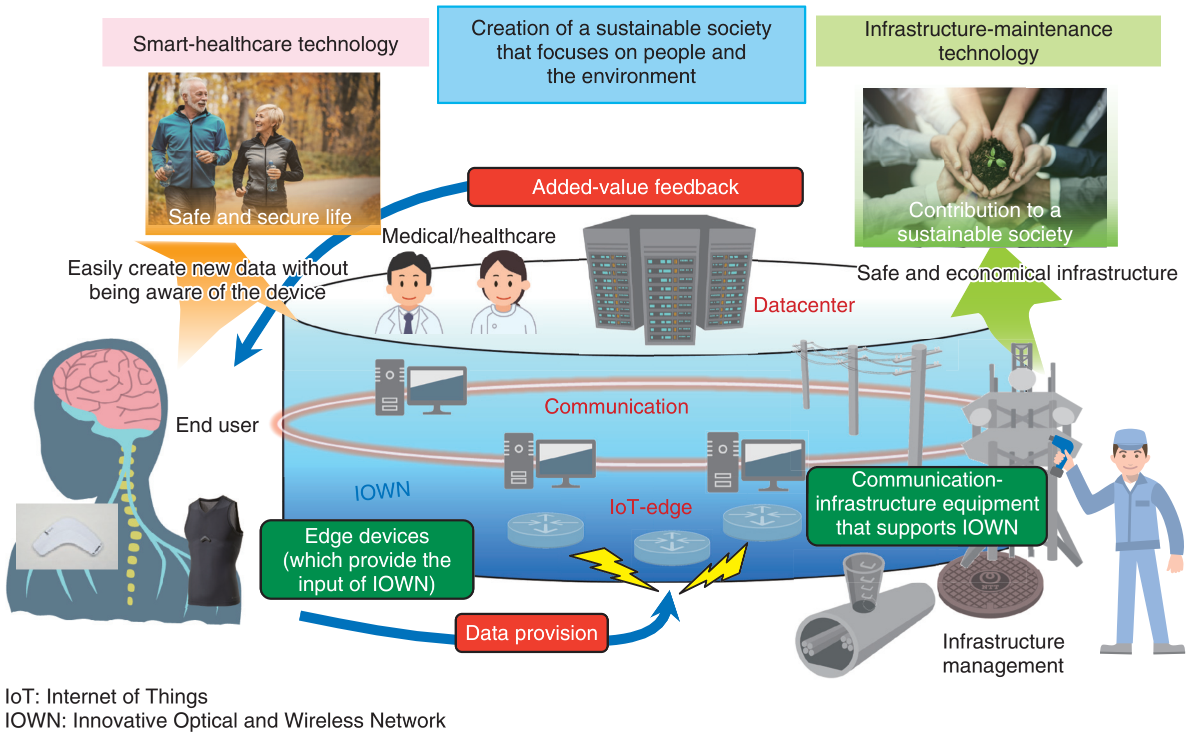


Fig. 3. Smart-healthcare and infrastructure-maintenance technologies for a sustainable society.

of smart-healthcare and infrastructure-maintenance technologies (**Fig. 3**).

2. Direction of smart-healthcare and infrastructure-maintenance technologies

2.1 Smart-healthcare technology

To support people's health and provide healthcare to them on a daily basis, it is necessary to (i) acquire the information necessary of their daily lives without them being aware the devices being used to collect such information and (ii) present the appropriate information in accordance with the circumstances concerning each person. Accordingly, it is necessary to develop devices that naturally blend into as well as enrich our lives. Portable devices and smartwatches for measuring heartbeats and pulse have been commercialized, and their usefulness in various situations is beginning to be recognized. From the perspective of addressing social issues and creating a market, the situation is on the verge of great change. Such devices have begun to evolve from their utilization at the personal-fitness level to true healthcare in the form of medical applications. NTT has developed low-power multi-sensor data-processing and high-precision sensing technologies. In addition to conventional electrocardiographic measurement and acceleration sensors, we have put into practical use a wearable, compact low-power transmitter with a built-in temperature and humidity sensor as our first wearable device [5]. By using this device, it is possible to estimate fluctuations in body temperature and body load, and that information will make it possible to develop high-value-added services by obtaining body information that was previously unknown in real time. We are also researching and developing photoacoustic-sensing and molecular-labeling technologies that enable non-invasive, highly selective, and highly sensitive monitoring. Targeting previously unmeasurable vital-sign information and biomarkers in relation to lifestyle-related and chronic diseases, for which the number of patients is increasing yearly, we are aiming for a simpler biosensor device that does not require the collection of samples such as saliva and blood.

2.2 Infrastructure-maintenance technology

Infrastructure facilities, which are used for long periods of time (several decades) in a variety of harsh environments, are supported by a large amount of

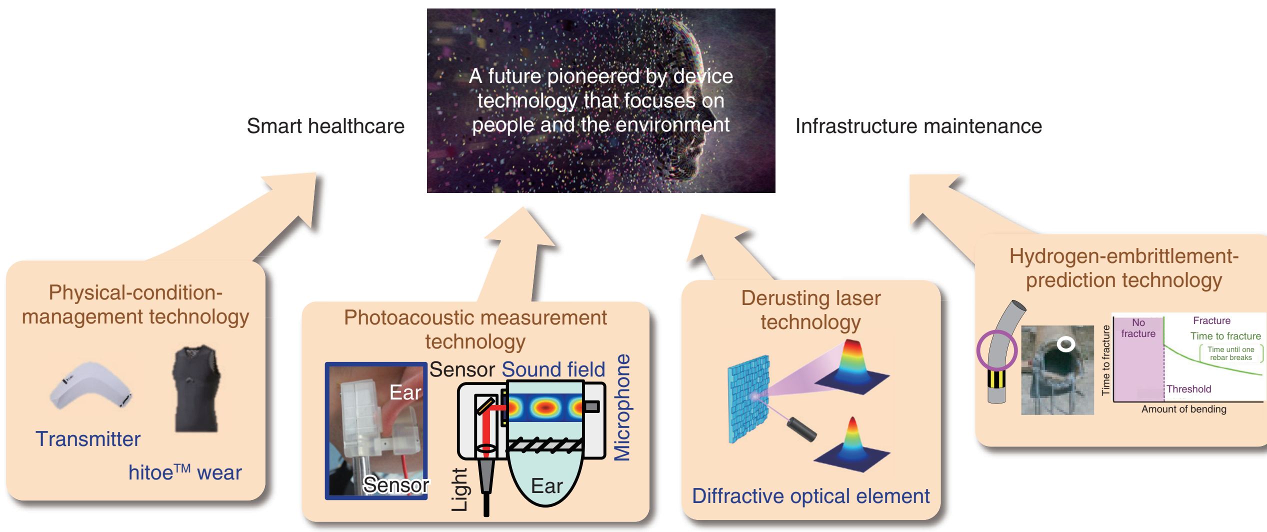


Fig. 4. Technology NTT is developing that is focused on people and the environment.

labor and experience, and the development of technologies that contribute to efficient work is still insufficient. Moreover, many unknowns, such as the degree of deterioration of the materials that make up the infrastructure over a period of ten years, must be considered. It will be paramount to achieve sustainable conservation of infrastructure that is both safe and economical. Infrastructure maintenance mainly consists of four steps: (i) maintenance planning, (ii) inspection, (iii) diagnosis, and (iv) repair and reinforcement. For more efficient and safer infrastructure maintenance, it is important to plan in advance as precisely as possible and streamline manual repair work.

Infrastructure facilities are mainly made of steel and concrete, so it is no exaggeration to say that infrastructure maintenance is the maintenance of steel and concrete. Accordingly, from the viewpoint of preventive maintenance of infrastructure, NTT is focusing on steel and concrete poles and researching and developing technologies that contribute to making rust removal more efficient and estimating deterioration, which are extremely difficult challenges to address with current technologies. It is important to remove rust from telecommunication towers and other steel infrastructure facilities as they age. By using the diffractive-optical-element technology developed by NTT and combining it with a high-power laser, the weight of a rust remover is expected to decrease by several times compared to commercial products, significantly improving work efficiency.

The degradation of reinforcing bars (rebars) in concrete poles is caused by hydrogen embrittlement, but the details of this phenomenon are still unknown. NTT is promoting R&D to establish hydrogen-embrittlement-prediction technology using core technologies such as electrochemistry and materials.

3. Topics and composition of the Feature Articles

The following Feature Articles in this issue focus on smart-healthcare and infrastructure-maintenance technologies that are close to practical application and are medium- to long-term, and the following four technologies are introduced as the latest research results (**Fig. 4**).

3.1 Physical-condition-management technology using wearable biological and environmental-sensor technology

NTT has commercialized wearable biological and environmental-sensor technology that can acquire and transmit not only biological data (such as heart rate and electrocardiograms) but also environmental data (such as temperature and humidity underneath clothing) by using the functional fabric hitoe™* as electrodes. This technology enables efficient signal processing of data from three sensors (electrocardiogram, acceleration, and temperature/humidity), which result in a low-power, compact wearable device. It will make it possible to comfortably and easily obtain biological information and personal environmental information from various daily activities. For example, it will enable the development of smart-healthcare applications such as those to counter heat stroke. A method based on this technology was developed that involves workers in hot environments wearing sensors to manage their physical conditions. This makes it possible to understand real-time physical information that was previously unavailable. Its effectiveness and practicality were verified at a network-construction site [6].

3.2 Non-invasive biological-information sensing using photoacoustic-measurement technology

A technology for non-invasive sensing of biological information without damaging the body—by using a photoacoustic method for measuring ultrasonic waves generated when a specific light is irradiated onto biological components in the body—is introduced. Compared with other methods such as optical coherence tomography and ultrasonography, photoacoustic technology is superior in measurement depth and spatial resolution as well as the potential in responding to various biological components. It is therefore expected to enable monitoring of various biological components related to lifestyle-related diseases. Since a non-invasive method enables continuous measurement of biological data, it is expected to be used in medical and healthcare applications to monitor biological data that change daily. To establish the technology for such a biological-sensing device, we are constructing a biophysical model of the penetration of a probe into the skin and its effect on biological mechanisms. We are also pursuing R&D on measuring biological components on the basis of the correlation between biological mechanisms and electrical and optical parameters concerning the regions from the surface of the skin to the interior of the body [7].

3.3 Compact and lightweight rust remover incorporating a high-power laser device that uses a diffractive optical element

Infrastructure facilities made of steel, such as communication towers, are subject to aging due to rusting. The first step in maintaining a steel tower is to remove the rust, and the second step is to paint the tower to protect the surface. To maintain the performance of coating and increase the durability of the steel tower, the surface condition of the underlying steel is important, and the key is how to effectively remove the rust. Rust is removed by irradiating a high-power laser beam onto the steel surface. By combining NTT's optical device technology with a compact and lightweight diffractive optical element, it is possible to fabricate a rust remover that is several times lighter than other products on the market for controlling the laser profile and efficiently removing rust. At current work sites, metal brushes are used to remove rust in narrow spaces; however, using the developed technology is expected to reduce work load and shorten work time [8].

3.4 Hydrogen-embrittlement-prediction technology for rebars of concrete poles

A technology for predicting hydrogen embrittlement, which is a degradation phenomenon of steel rebars in concrete poles will enable safer and more economical maintenance and management of concrete poles, which are one of the key infrastructure facilities that support telecommunications services. Concrete is strong in compression but weak in tension; thus, tensile stress is applied to the internal rebars so that compressive stress can be applied to the concrete. However, steel rebars subjected to tension undergo deterioration called hydrogen embrittlement, which can lead to facility failure. However, such rebars cannot be visually checked, so it is difficult to determine the deterioration status of concrete poles, which poses a challenge for maintenance. From the viewpoint of preventive maintenance, by (i) establishing evaluation methods (such as conducting an accelerated hydrogen-embrittlement test and evaluating hydrogen amount), (ii) using analysis methods such as statistical data analysis, and (iii) elucidating and modeling the hydrogen-embrittlement mechanism, we are working on a formula for estimating hydrogen embrittlement [9].

4. Future developments

We will accelerate the practical development of the smart-healthcare and infrastructure-maintenance

* hitoe™: A functional fabric developed by Toray and NTT. It is fabricated by specially coating nanofiber fabric, which is the most-advanced fiber material, with a highly conductive resin. It has excellent durability and can detect biosignals with high sensitivity even though it is a non-metallic material. Having hitoe adhere to the skin surface makes it possible to obtain biological data, such as heart rate, electrocardiograms, and sleep data, estimated from R-wave intervals. Using nanofibers makes it possible to acquire more-sensitive measurements of biological signals in close contact with a person's body (e.g., through clothing and hats) because the nanofibers are durable enough to be washed at home and have an increased degree of adhesion to the skin.

technologies introduced in this article. We will also promote R&D on challenging themes from a medium-to-long-term perspective to contribute to creating a sustainable society that focuses on people and the environment.

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