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Case Study

Smart approaches to waste management for post-COVID-19 smart cities in Japan

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Hiroshi Onoda[1] ✉
[1]*Graduate School of Environment and Energy Engineering, Waseda University, Tokyo, Japan*
✉ *E-mail: onoda@waseda.jp*

Abstract: The COVID-19 crisis has had a great impact on Japanese society. The author is rapidly going online and trying to make the transition to a new way of life. This study discusses the topics before and after the COVID-19 pandemic in Japan. Then, smart approaches to waste management for post-COVID-19 smart cities in Japan are described by illustrating the results of the author's research group. Specifically, the author states that virtual reality can be an effective solution for remote education. The work chain management system contributes to the promotion of cashless in addition to the traceability of waste. The multi-benefits mobility system that supports self-driving will contribute to the automatic garbage collection by linking it to smart garbage bins. Besides, remote control of waste incineration facilities and robotic arms in waste treatment and recycling facilities will take on more importance. The author believes that the COVID-19 crisis could be an opportunity to accelerate smart city initiatives in Japan.

1 Introduction

In Japan, before the COVID-19 crisis, the focus of the discussion was on how to deal with frequent natural disasters and global environmental problems, examining such things as the Paris Agreement and the waste plastic waste problem. At the same time, the science and technology policy, also known as Society 5.0 [1], has led to a growing number of initiatives in various fields based on the use of artificial intelligence (AI) and the Internet of Things (IoT).

The pandemic caused by the spread of the COVID-19 has had a significant impact on Japan's life and economy. In particular, it has rapidly encouraged the rapid development of telecommuting and other online activities. In the environmental and energy sectors, the post-COVID-19 approach is essential because of the need for medium- and long-term responses.

This paper presents the situation in Japan both before and after the COVID-19 crisis, focusing on the environmental and energy sectors. Then, we refer to smart approaches to waste management for post-COVID-19 smart cities in Japan with examples of specific solutions.

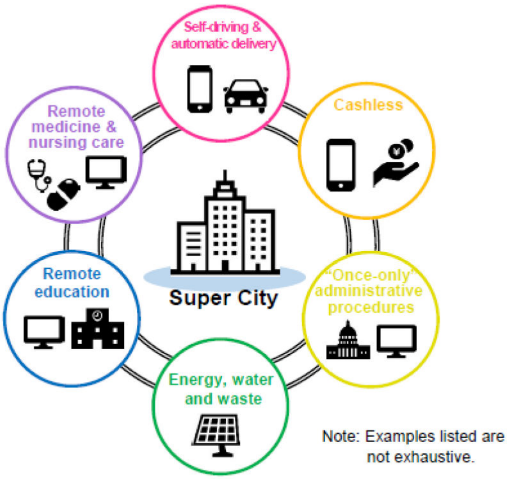


Fig. 1 *Components of the super city (source: https://www.kantei.go.jp/jp/singi/tiiki/kokusentoc/supercity/supercityforum2019/supercityforum2019_EnglishVer.html)*

2 Japan situation before COVID-19 crisis

The topics of interest for the environmental and energy sector in Japan in 2019 and beyond are as follows:

(a) Discussions have been underway on building a sustainable social system for a declining population and an ageing society. Sustainable development goals (SDGs) have become a low keyword [2].
(b) Ensuring resilience to frequent disasters, such as the typhoon that struck in September 2019, has become an urgent issue [3].
(c) At COP 25 [4] in December 2019, Japan was criticised internationally for its response to coal-fired power generation.

Some of the trends related to smart cities include the following:

(a) The Ministry of the Environment (MOE) is promoting a policy called 'Regional Circular Symbiosis Sphere', which aims at a self-sustaining and decentralised social system [5].
(b) Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) has launched a platform for public–private collaboration on smart cities [6].
(c) The Cabinet Office is making progress in its discussions on the super city concept (see Fig. 1) using the framework of National Strategic Special Zones [7]. Although the difference between a super city and a smart city is not clear, it is an advanced smart city that includes institutional reforms.
(d) As for moves by the private sector, Toyota Motor Corporation announced a plan to build a smart city named 'Woven City [8]' on the site of its former factory, which has become a hot topic.

During these discussions, the pandemic caused by COVID-19 was utterly unpredictable.

3 Pandemic situation in Japan and post-COVID-19 smart cities from an environmental engineering perspective

3.1 Process of COVID-19 response in Japan

The background of the COVID-19 response in Japan can be confirmed at the website of the Cabinet Secretariat [9]. The first cases of COVID-19 infection confirmed in Japan were in late

January. In February, the response to the Diamond Princess at the Port of Yokohama was a hot topic of conversation. In March, the number of infected persons, especially those returning from overseas, gradually increased. It was around this time that the federal and local governments began to request that people refrain from going out and doing business, and that all scheduled events be cancelled or postponed.

It was also on 24 March 2020 that the Tokyo Olympics and Paralympics, major events scheduled for 2020, were postponed. The decision was a significant blow to the business community, which had been expecting the economic benefits of inbound tourism. From that time, the topic of conversation in Japan became all about the COVID-19. The Japanese government declared a state of emergency on April 7 and phased it out by May 25. According to the published data, the number of infected people peaked at the beginning of April and has been on a downward trend since then, but the situation remains unpredictable. At the time of this writing, the cumulative number of infected persons was ∼17 000 [9], or 7.2 deaths per million population [10] in Japan. The number of bankruptcies associated with COVID-19 is over 200 [11]. A radical paradigm shift has come upon us.

3.2 Noteworthy trends from the environmental engineering perspective

The Japanese government used the phrase ‘new way of life’. These changes in lifestyle and business style will also have a significant impact on environmental and energy issues.

Japan's measure is not a lockdown, but a request for self-restraint. In order to ‘visualise’ the effect, the once anonymous movement history of smartphones in major cities is now being made public [9].

One of the big changes is the rapid shift to ‘online’, such as telecommuting. In the past, ‘work style reforms’ aimed at reducing overtime and avoiding congestion on crowded trains have been recommended. However, these never became a significant trend due to Japan's unique seal culture and working time constraints. Through working from home, we have been experiencing online meetings. While continuing the current self-restraint needs to balance with an economic perspective, we believe that going online will remain post-COVID-19.

From the environmental engineering perspective, it is essential to determine the extent to which these new lifestyles will become entrenched in society. For example, concerning the Paris Agreement, it will be a challenge for the household, business, and transport sectors to reduce greenhouse gas (GHG) emissions by 2030 and 2050, and this will depend significantly on lifestyle changes. Overseas, there have been preliminary reports that the lockdown has reduced GHG emissions by 17% [12]. International energy agency (IEA) is forecasting that global energy demand in 2020 will be reduced by about 6% through reductions in electricity and fuel use for cars and aircraft [13]. EU is advocating the green recovery, which links recovery from the COVID-19 crisis to climate change response [14]. We expect Japan to step up these post-COVID-19 responses as well.

The COVID-19 crisis has implications not only for GHG and energy but also for waste. The more time we spend at home, the more garbage we emit from our homes. The increase in the number of home deliveries will increase the amount of cardboard and other emissions. On the other hand, business waste from stores and offices will decrease. Cautious handling of infectious waste will also be required. Further increases in demand for disposable masks and testing kits will also increase the number of infectious waste plastics discarded. In Japan, due to a declining population and embargoes on waste plastics in neighbouring countries, the maintenance of waste treatment and recycling infrastructure has become a significant problem. The COVID-19 crisis could be said to have added significant problems to this situation.

Risk communication is also an essential issue for us. In Japan, there has been infodemic [15] due to misinformation sent through social networking service, and masks and rubbing alcohol are still unavailable in the Tokyo metropolitan area. Some have argued that this issue is similar to the rumours surrounding radioactive contamination after the Great East Japan Earthquake of 11 March 2011 [16].

3.3 Post-COVID-19 smart cities in Japan

In Japan, urban areas as well as regional cities are interested in smart cities. However, due to technical and economic issues and the lack of capability of local governments, we do not believe that Japan's smart cities have produced any tangible results. As the ‘online’ lifestyle takes root, the concentration of the population in Tokyo will ease, the population will disperse to regional cities, and we can expect to see smart cities in regional areas.

We also expect the progress of the effective use of personal information. While other countries have attempted to use applications on smartphones to identify how COVID-19 is transmitted, Japan has not accepted this approach from the perspective of protecting personal information. During the recent COVID-19 response, it became clear that the exchange of information was inefficient in some areas, so we hope that this will develop in a positive sense. In response to this situation, the Japanese government has begun discussing regulatory reforms across multiple areas. For example, the ‘Super City Act [17]’ was enacted on 27 May, which allows for the collection and organisation of data among multiple advanced services. It also enables business entities to request data from the national and local governments.

Online medical treatment and administrative procedures are also being discussed, and we expect to see a linkage between these trends and smart cities.

4 Discussion on smart approaches to waste management for post-COVID-19 smart cities in Japan

We consider smart approaches to waste management in post-COVID-19 smart cities, focusing on the results of the research in the author's group offering examples.

4.1 Virtual reality (VR) as a tool for remote education

Although there has been a significant shift to remote education, we have not established an effective methodology on how to conduct experimental and practical education. VR has the potential to be an effective solution. The authors have created the content utilising a 3D-VR in the field of occupational safety and have confirmed its effectiveness (see Fig. 2). We are now attempting to apply these techniques to the field of education and the transmission of people's skills.

4.2 Work chain management system (WCMS) as a new traceability system

As mentioned earlier, one of the critical issues is the traceability of infection routes. The authors are developing a traceability system for the waste produced by small medical institutions. Similar systems do exist, but they are just systems that digitise slips. Miyaki Ishii has developed the WCMS [18] that automatically records a worker's activity history as a timeline (evidence) by providing information on the waste itself using smartphones and quick response codes (see Fig. 3). Robotic process automation can significantly improve the efficiency of operations, such as the preparation of legal documents by utilising the accumulated information. WCMS will simplify the workload of creating slips required for waste management, and we are considering its application to other fields. The WCMS can contribute to the realisation of contactless and cashless systems that are not well established in Japan.

4.3 Multi-benefits mobility system

This ‘new way of life’ will lead to an increase in the workload of logistic companies due to the increased number of in-home deliveries and an increase in the amount of waste generated by households. We thus introduce the concept of the multi-benefits

Fig. 2 *Example of occupational safety education content using 3D-VR for recycling plants*

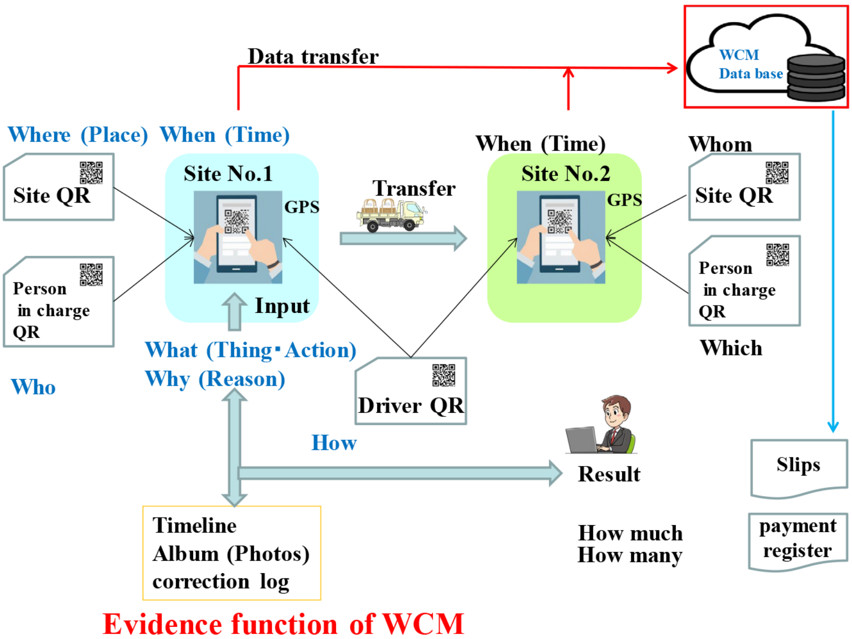


Fig. 3 *Overview of the WCMS as a new traceability system*

Table 1 Specification of a prototype of the multi-benefits mobility

Items	Specification
length, mm	1310
width, mm	1680
height, mm	1650
chassis weight, kg	103.25
method of presumption of own position	LIDAR, stereo camera and GPS
power sources	lithium ion batteries 129.96 Wh (5 sets)
wheel diameter, mm	390
minimum rotary radius, m	1.23
load bearing, kg	190
maximum speed, km/h	10.5
one-charge cruising range, km	9.0

mobility system, which the authors have started to develop as a solution to these problems.

The approach of replacing the traditional hardware does not lead to a fundamental solution. In order to improve the mobility system availability, we proposed the mobility system based on the concept of 'one-service and multi-benefits' and built a prototype (see Table 1 and Fig. 4). The mobility system has only a shared chassis that can be used for different purposes, such as riding or transporting goods. Besides, the vehicle is capable of self-driving or remote control in the following three modes: (a) self-driving by drone GPS location information, (b) self-driving by image recognition of a stereo camera, and (c) remote control by the controller.

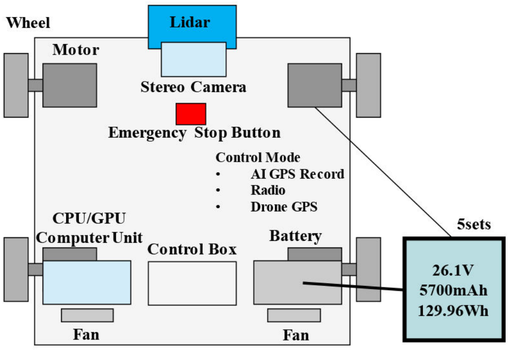
Fig. 5 shows how we demonstrated this mobility as a 'moving trash bin' at one event, and we are now working on applying it to the automatic garbage collection. We combine this mobility with a smart garbage bin that has sensors, compression functions and a robotic arm, which we will discuss later, to achieve automation and contactless.

We are currently in the process of having discussions with various stakeholders. For example, the automation of transportation in factories and shopping malls could be considered, or a logistics and home delivery system linked to drones. It is still in the early stages of development, but the aim is to conduct social experiments in post-COVID-19 smart cities.

4.4 Remote control and automatic operation

The remote operation of the plants contributes to the avoidance of non-migration and contactless as a result. In the field of energy management, the BEMS/HEMS and smart meters are the fields that are advancing. Here, we introduce examples of waste treatment and recycling plants that depend heavily on operators.

a



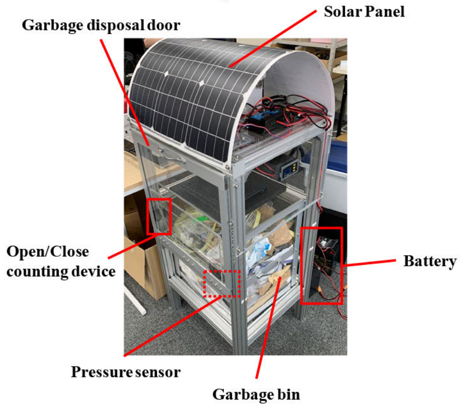
b

Fig. 4 *Overview of the prototype of multi-benefits mobility system*
(a) Appearance,
(b) System architecture

4.4.1 Remote control and automatic operation at municipal solid waste (MSW) incineration plant: Japanese plant manufacturers are stepping up efforts to monitor plants remotely and automate their operations with AI (focusing on image diagnosis and speech recognition). JFE Engineering has announced that it achieved a fully automated operation of the MSW incineration plant in July 2019 [19] (see Fig. 6). The author visited this plant in February 2020 and confirmed that the plant achieves smooth automatic operation by accumulating combustion images from the skilled workers' operation data, using it as teacher data. As a result, it has led to a reduction in life cycle costs and will become the mainstream in the future.

4.4.2 Robotic arms in industrial waste treatment and recycling facilities: Also, there is a growing movement towards the introduction of robots in waste treatment and recycling processes. Fig. 7 shows an example of the practical introduction of the system in the author's collaborators [20, 21]. A stereo camera recognises images and distances, and the robotic arm sorts them. In this photo, the operators are remotely controlling the robotic arm with the tablet. In the field of waste treatment and recycling, such robotic arms have not performed adequately due to the wide variety of input types and shapes. However, at waste treatment and recycling sites, hygiene issues such as the manual handling of infectious waste containers by operators have been pointed out for a long time. We look forward to furthering technological development and maturity in the future.

a



b

Fig. 5 *Consideration for automatic garbage collection*
(a) Demonstration test of the moving garbage can at an event,
(b) Prototype of smart garbage bin

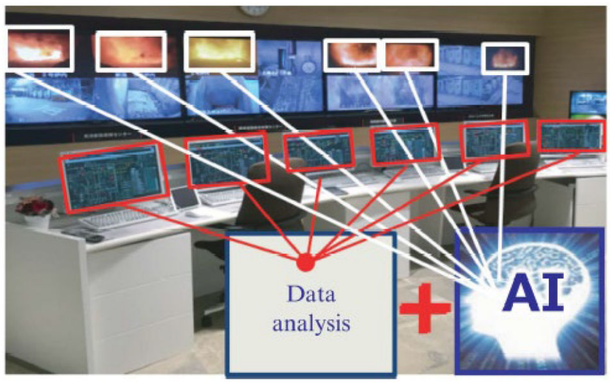


Fig. 6 *Remote control and automatic operation at MSW Incineration Plan (source: https://www.jfesteel.co.jp/research/giho/045/pdf/045-13.pdf)*

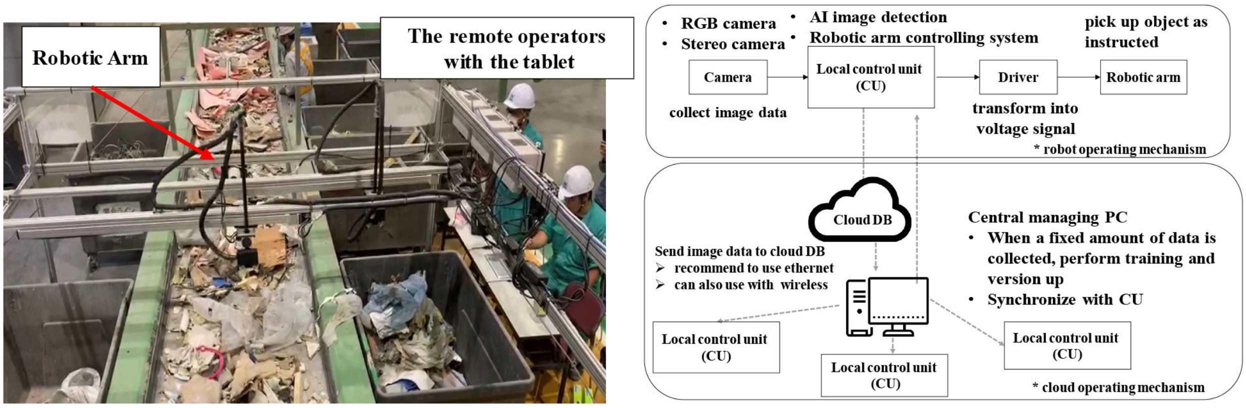
4.5 Positioning of each solution in smart cities

Fig. 8 summarises the relationships between the solutions introduced and smart cities. They are elemental technologies that constitute smart cities, and we need to integrate them with the entire smart cities. The technologies discussed here have been planned for the development since before the COVID-19 crisis, but the 'new way of life' must urgently address their development and social implementation.

Naturally, active collaboration with other technologies should be addressed. For example, the WCMS is expected to be more efficient when linked to an online clinic. Multi-benefits mobility system will also need to be linked to drones and other self-driving systems. Remote control and automatic operation of plants should be integrated with energy management and water treatment systems. Also, it is possible to link with various AI and IoT technologies that are being developed.

5 Conclusion

This paper discussed the prospects of smart cities from an environmental engineering perspective in light of the pandemic in



a b

Fig. 7 *Overview of robotic arms in waste treatment and recycling facilities*
(a) Appearance,
(b) System architecture

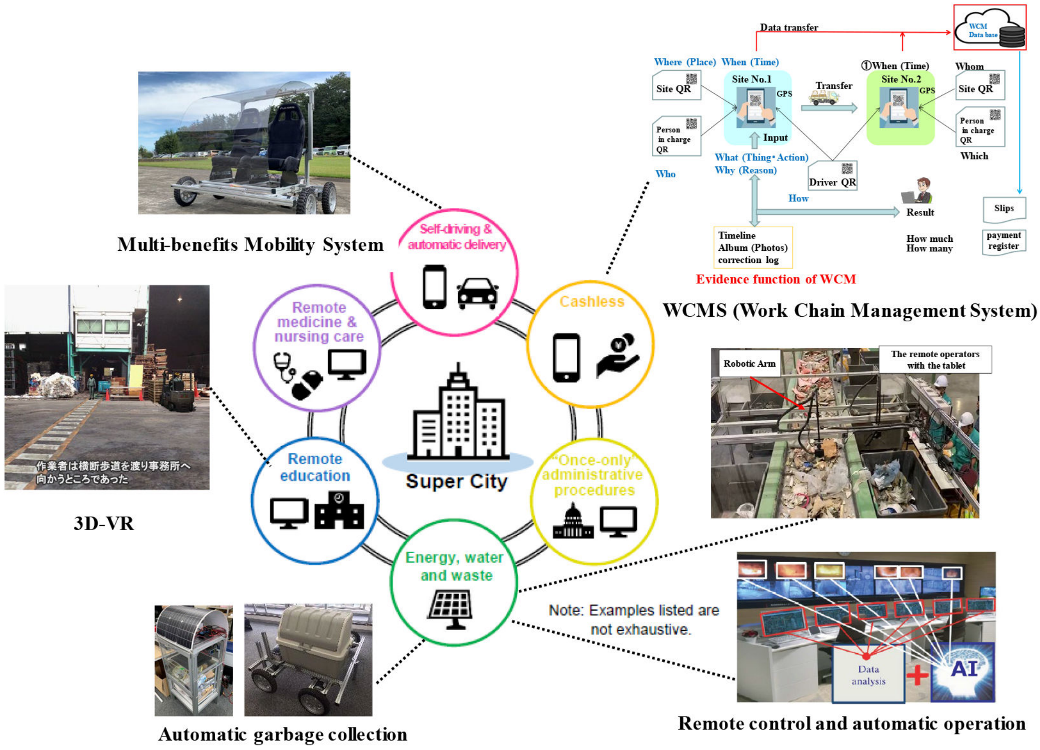


Fig. 8 *Smart approaches to waste management for smart cities*

Japan. This pandemic has caused a lot of confusion and shock throughout the country, but we believe that it will be a catalyst for a significant change in our lives as we move online. In the future, the Japanese government will strengthen its efforts to integrate the COVID-19 responses with the environmental and energy sectors. In particular, solutions focusing on waste management are presented with specific examples. Waste management is an essential social infrastructure that forms a city. Inefficiency, excessive workload of workers and hygiene problems have been pointed out for many years. Contactless and online waste management can solve these problems simultaneously. By strengthening the efforts described in this paper, the author hopes to solve industry-specific problems and contribute to smart cities.

In these circumstances, we hope that active discussions on the handling of personal information will promote positive changes and that smart cities will make progress in their initiatives. This pandemic has highlighted the need for such solutions (VR, traceability systems, self-driving, and remote control) in another way. The challenge is on how to connect the new way of life to innovation.

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