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Governance of Artificial Intelligence in Water and Wastewater Management: The Case Study of Japan

Tomoko Takeda [1,*], Junko Kato [2], Takashi Matsumura [3], Takeshi Murakami [4] and Amila Abeynayaka [5,*]

[1] Department of Earth and Planetary Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[2] Independent Researcher, 107-6223 Tokyo, Japan; junko.kato@msols.com
[3] Infrastructure Advisory, EY Strategy and Consulting Co., Ltd., Tokyo 100-0006, Japan; Takashi.Matsumura@jp.ey.com
[4] Infrastructure Finance Group, Koei Research & Consulting Inc., Tokyo 102-0083, Japan; murakami-tk@k-rc.co.jp
[5] Graduate School of Environmental and Information Studies, Tokyo City University, Kanagawa 224-0855, Japan
* Correspondence: tomokotakeda@eps.s.u-tokyo.ac.jp (T.T.); g1993101@tcu.ac.jp (A.A.)

Abstract: The integration of artificial intelligence into various aspects of daily life is developing at a rapid pace in Japan. Discussions to govern applications of artificial intelligence to the field of social infrastructure are also critical and need to match the rapid pace of development. However, the legal implications and risks of applying artificial intelligence to the management of lifelines such as drinking water supply and wastewater treatment have not yet been fully explored. This paper reviews the existing legislations and ongoing discussions on governance regarding applications of artificial intelligence to water and wastewater management. Based on the review, we discuss the ability of legislative frameworks in Japan to respond to the applications of artificial intelligence, as well as identifying potential gaps and challenges thereof, including access to accurate data, demarcation of rights and responsibilities, risk hedging and risk management, monitoring and evaluation, and handling of intellectual property rights. This paper concludes with key recommendations to national and local governments to support the application of artificial intelligence in the field of water and wastewater.

Keywords: artificial intelligence; governance; Japan; legislation; machine learning; water supply; wastewater

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1. Introduction

The definition of artificial intelligence (AI) varies depending on the organization and context in which the phrase is used. This paper will adhere to the definition put forward by the Organisation for Economic Co-operation and Development (OECD) in 2019 which stated that an AI system is: "a machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations, or decisions influencing real or virtual environments. AI systems are designed to operate with varying levels of autonomy" [1]. The OECD Recommendation on Artificial Intelligence (AI) is claimed by OECD to be the first intergovernmental standard on AI. The Recommendation was adopted by forty-two countries including OECD member countries in May 2019. The Recommendation consists of two sections, namely, principles for responsible stewardship of trustworthy AI, and national policies and international cooperation for trustworthy AI [2].

Other organizations are also working on developing international standards for the governance of AI. The International Organization for Standardization and the International Electrotechnical Commission jointly developed standards regarding big data in 2020 and are currently in the process of developing standards on the AI ecosystem [3].

In international discussions, there is an increasing urgency to develop a robust framework to govern AI, especially for fields such as basic human rights [4] and sustainability [5]; however, it remains to be seen whether the same levels of urgency can be seen in Japan. Through a preliminary literature review, the authors found that the bulk of existing literature on AI in Japanese focused on the technology and application of AI, and there was limited information regarding the governance of AI, and even less regarding the governance of AI in social infrastructure relevant to basic human needs such as water supply and wastewater management. This study, therefore, aimed to take stock of the current situation and assess the gaps and challenges remaining regarding the governance of AI in water and wastewater management. Our main objective in clarifying what is required of public and private entities lay in providing direction and guidance for future decision-making in the water sector in Japan.

2. Materials and Methods

To obtain an understanding of the full picture, a review was carried out on existing frameworks on AI in general, regardless of whether they cover water management or not. The study on frameworks was then followed by an in-depth consideration into which specific aspects of water and wastewater management AI could support. Lastly, we conducted a review of existing legislation relevant to the specific applications of AI in water and wastewater management.

The desk-based literature review consisted of web-based searches in English and Japanese. Search engines used included Web of Science, Science Direct, Google Scholar, and Google. We relied on the e-Gov portal [6] managed by the Ministry of Internal Affairs and Communications of the Government of Japan for text in laws and legislations. The English translations of laws and legislations were cited from the Japanese Law Translation website [7] maintained by the Ministry of Justice, the Government of Japan.

This study was limited by our inability to access information outside literature searchable online, especially during the novel coronavirus pandemic. We attempted to supplement this by carrying out non-structured informal consultations through web and telephone-based meetings with multistakeholders in both the public and private sector. The consultations were kept informal and confidential due to a limitation of those surveyed to speak freely while on record. For this reason, the contents of the informal consultations have been used to provide a general direction of the recommendations and have not been cited or explicitly referred to in this study.

3. Findings

3.1. Frameworks on AI in Japan

3.1.1. Positioning of AI in Growth and Development Strategies

Under the auspices of the prime minister at that time, a series of conferences to discuss future financial investment strategies was held from 2013 to 2020. As direct outcomes of these meetings, frameworks were published or updated on an annual basis.

Published frameworks were as follows:

- Japan Renaissance Strategy 2013 (revised in 2014 and 2015);
- Japan Renaissance Strategy 2016;
- Future Investment Strategy 2017;
- Future Investment Strategy 2018;
- Growth Strategy 2019;
- Growth Strategy 2020.

In the earlier Japan Renaissance Strategies of 2013 and 2014, the term AI did not appear, however, there was an emphasis on the ambition to scale up investment for governance of information technology (IT). The section outlining IT strategies in 2013 was placed under one of the three pillars of action on revitalizing the private sector. Action items included legislative and institutional reform, disclosure of government data to the general public, and strengthening of cybersecurity in critical infrastructure systems. The term AI-first

appeared in the revised Japan Renaissance Strategy of 2015, and in the most recent Growth Strategy 2020, AI is mentioned as a cross-cutting topic in the fields of mobility, finance, energy, education, and urban planning [8].

Under the new cabinet inaugurated in September 2020, the action item on urban planning has been delineated as the "Super City" initiative, a strategy that expanded a preexisting framework governing national strategic special zones [9]. Under the new framework, underscored by an act to amend the National Strategic Special Zone Act (no.36/2020), designated national strategic special zones will aim to utilize big data and AI for the well-being of residents and the environment [10].

3.1.2. Strategies on AI

A strategy to govern the development and application of AI (the "AI Strategy") was established in 2019 by the Cabinet Office. The objective of the AI Strategy is to set the scene for utilizing AI for contributing to solving global and local challenges. The AI strategy describes a roadmap and an action plan which consists of six components: (1) human resource development for AI; (2) implementation of AI applications in five priority areas (health care, agriculture, infrastructure, transportation, and regional development), (3) promotion of research and development; (4) support for AI utilizing entities (small businesses and municipalities); (5) data infrastructure construction; and (6) ethical principles in AI utilization [11]. The AI Strategy stresses the importance of putting people at the center of AI management in line with the Social Principles of Human-Centric AI, laid out by the Cabinet Office in 2019 [12]. The three pillars of the Social Principles of Human-Centric AI consist of dignity, diversity and inclusion, and sustainability. Although diversity and inclusion are laid out as a key pillar of the Social Principles of Human-Centric AI, meeting records show that the council which determined the Social Principles had only five women out of the total of 25 members [12].

The progress in the implementation of the AI Strategy as reported by the Cabinet Office [11] is shown in Table 1. The total number of projects covered by the AI Strategy was 89 in fiscal year 2019, which nearly doubled to 171 in fiscal year 2020. Of these, 87% were fully implemented in fiscal year 2019 and 90% were fully implemented in 2020.

Table 1. Implementation status of the AI Strategy.

Action Plan Component	Fiscal Year * 2019		Fiscal Year * 2020	
	Total Number of Projects	Number of Projects on Track (% of Total in Brackets)	Total Number of Projects	Number of Projects on Track (% of Total in Brackets)
(1) Human resource development	31	27 (87%)	63	58 (92%)
(2) Implementation of AI applications in priority areas	16	11 (69%)	35	33 (94%)
(3) Promotion of research and development	26	24 (92%)	44	43 (98%)
(4) Support for AI-utilizing entities	9	8 (89%)	12	9 (75%)
(5) Data infrastructure construction	3	3 (100%)	10	6 (60%)
(6) Ethical principles in AI utilization	4	4 (100%)	7	5 (71%)
Total	**89**	**77 (87%)**	**171**	**154 (90%)**

(Source: compiled by authors based on Cabinet Office, 2021 [11]). * The Japanese fiscal year runs from 1 April to 31 March of the subsequent year.

3.1.3. Other Relevant Frameworks

The Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) of Japan manages sewerage policies. MLIT runs a program called Breakthrough by Dynamic Approach in Sewage High Technology Project (B-DASH), which calls upon businesses to conduct experimental projects utilizing cutting-edge technology. B-DASH has been running since 2011 and projects related to AI have been awarded to various consortiums since 2015 [13]. Since B-DASH allows the private sector to trial new technology while receiving financial support for capital expenses, the continued proposal and selection of AI-related projects seems to indicate sustained high levels of interest by both the public sector and private sector in using AI for wastewater management. On the other hand, the fact that there are still projects in the feasibility testing stage as of 2021 also indicates that the implementation of AI is still not at the stage where the private sector has the capacity to profit from developing and implementing AI-supported solutions in wastewater management.

The Ministry of Economy, Trade, and Industry (METI) published a guideline for contracts on AI and data utilization in 2018 [14]. With regards to software development and utilization of AI technology, new legal issues include how to handle ownership rights and identifying who is legally responsible should any incidents occur. The basic technical concept of AI technology is inductive, meaning assumptions are inferred from data. It is fundamentally different from the conventional technical concept of deductive software, which derives conclusions based on hypotheses. One challenge in signing contracts for the application of AI technology is that the performance of the produced software is not strictly defined when the contract is concluded and depends on the given dataset. To assist private companies with limited experience in utilizing AI technology, the METI guideline explains how to draft contracts for the development and utilization of AI software [14]. METI has also developed guidelines for small- and medium-sized enterprises to implement AI in daily operations [15], and is supporting capacity-building through providing free online courses for AI development and management [16].

The Ministry of Health, Labour, and Welfare (MHLW) issued an amendment to the Water Supply Act (no.177/1957) in 2018 and mandated water service providers to update and maintain databases on water supply infrastructure [17]. Based on the amended Water Supply Act, guidelines for databases on water supply infrastructure were published in 2018. Based on the long-standing issue that information systems for water supply infrastructure varied between local governments, making it difficult to consolidate information across administrative borders, these guidelines laid the basis for digitizing information with the aim of sharing data among local governments [18].

Figure 1 gives an overview of the legislations pertaining to AI and water management, respectively.

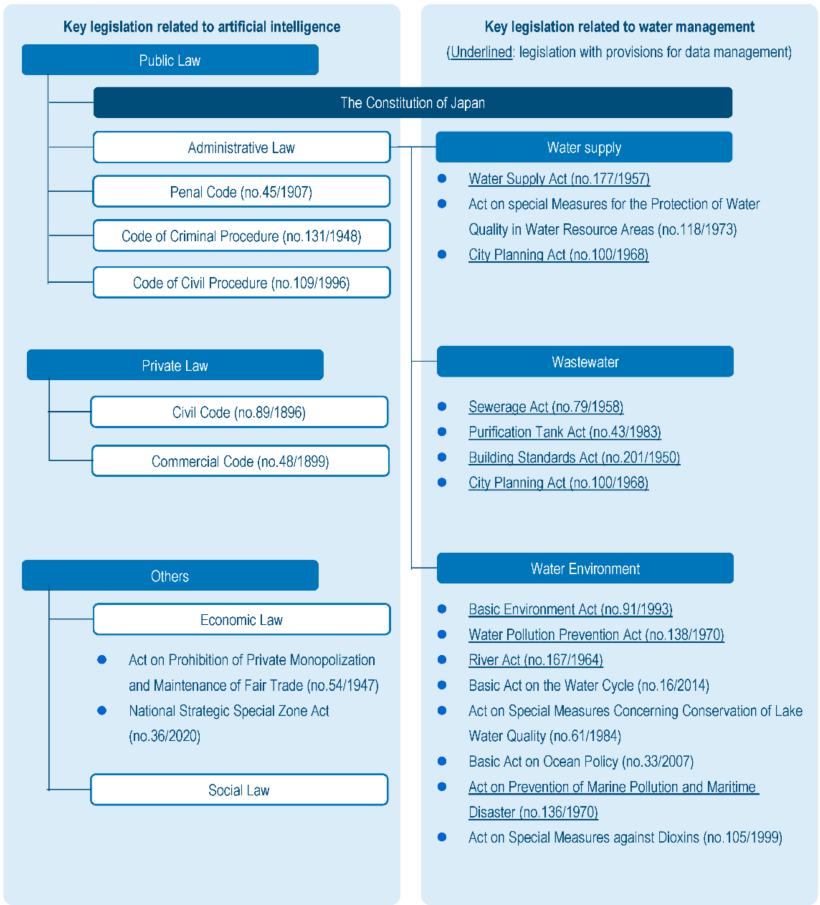

Figure 1. Overview of key legislation pertaining to artificial intelligence and water in Japan (compiled by authors based on the Ministry of Internal Affairs and Communications [6]).

3.2. Applications of AI in Water and Wastewater Management

Earliest references that mention the application of AI in water management in Japan date back to over half a century ago. Orita (1965) alluded to water supply management as a potential field for AI to make a significant contribution [19].

Earlier software decision support systems used programmed expert systems or rule-based algorithms to derive outputs or decisions by narrowing the available choices. However, these systems rapidly become incapable in modern dynamic conditions and with competing interests due to various factors including climate change, aging population, and shifting socioeconomic requirements. AI-based tools can overcome these issues with features such as pattern recognition, which employs a set of inputs, weighing factors, summation, and transfer functions that are autonomously and dynamically updated as new information is presented. Water and wastewater utilities are now equipped with data-driven technologies that allow them to incorporate previously unreachable information about water supply and demand, influent characteristics, and system operations.

Table 2 summarizes key existing and potential applications of AI in water supply and wastewater management. The degree of applications of AI ranges from simple chatbots for customer support to significant systems to advise or support the operation and maintenance of water and wastewater treatment. The scope also ranges from the source (water resources) to the sink (wastewater discharge), indicating that AI could potentially support the sustainable management of the integrated water cycle. This is especially critical in water treatment processes utilizing biological technology such as conventional wastewater treatment, given the nature of the process that does not allow us to see what is happening at the scale of microorganisms. In this regard, the "black box" nature of wastewater treatment processes can be said to have a high synergy with AI systems which are like black boxes themselves, operating on a given set of conditions and providing outputs without operators necessarily understanding the algorithm itself.

Yokohama City, which is a city in central Japan with the second largest population in the country, has a long-term plan for information and communication technology. One of the key policies laid out in the plan is the deliberation of the utilization of AI in water supply services [20].

An AI chatbot "Water Droplet Consultation Room" was introduced to the Tokyo Waterworks Bureau website for the purpose of improving customer service in 2018. According to the Tokyo Waterworks Bureau, this is the first example of an AI chatbot implemented in the water industry in Japan [21]. Current AI chatbots dynamically evolve based on interactions with users, rather than answering users with given sets of prepared responses. These kinds of applications could reduce operator costs and responding time.

Table 2. Key existing and potential applications of AI in water supply and wastewater management.

Classification	Application	Description of Case Studies
Water resource management	Short and long-term water demand predictions/management	Smart tools coupled with geospatial information and modeling to detect and predict water resource management issues [22]
Water and wastewater treatment	Performance evaluation	Water quality data mining [23,24]
	Optimization of operation	Optimize and control systems including pumping rates impacting energy costs [25]
	Prediction of water quality	Prediction of raw water quality or treated water quality based on multiple input parameters [26–30]
Water supply	Leak detection	Identify leaks and non-revenue water [31,32]
	Pipe aging monitoring	Modeling and prediction of deterioration of water and wastewater pipes [33]
	Optimization of water use	Smart home devices to control water consumption [34]
Wastewater discharge	Management of wastewater discharge	Coordination of wastewater discharge to avoid combined sewer overflow during rainy periods, and to reduce pumping cost. Similarly, water withdrawals [26]
	Tracing pollutants	Identification of the source of pollutants observed downstream [23]
Treatment of sludge	Management of sludge treatment	Optimization of incineration processes utilizing AI [20]

Table 2. *Cont.*

Classification	Application	Description of Case Studies
Customer service	Awareness, and additional services.	Customer engagement using AI tools such as chatbots [21]
	Tariffs and subsidiaries	Optimization of service through cumulative data management and predictions [35]
Resilience	Cybersecurity	AI has been proposed as a proactive tool to protect critical infrastructure against cyberattacks [22]
	Resilience against natural hazards	AI-powered early warning systems against urban flooding [20,36]

3.3. Legislative Issues

Discussions are ongoing regarding the integration of topics related to the governance of AI into the constitution (1947) [37], private law such as the Civil Code (no.89/1896) [38], criminal law such as the Penal Code (no.45/1907) [39], administrative law, and the Intellectual Property Basic Act (no.122/2002) [40] (Figure 1). Administrative law includes legislation pertaining to local governments, which traditionally manage and operate water and sewage systems. Intellectual property rights are protected under the principles of private law, which aims at the adjustment and distribution of personal interests. AI systems may be considered a part of intellectual property unless they violate compulsory provisions. On the other hand, under public law, which governs the administration field, the state or public entity has the authority to confront a private person as a principal public power, based on the discipline of control relations and power relations. Under administrative law, a balance between public interest and private interest is required. Therefore, a different set of principles apply when comparing the implementation of AI systems to the public sector and the private sector due to differences in public and public law.

Article 2–14 of the Local Autonomy Act (no.67/1947) establishes the principle of generating maximum effect from minimum cost for governmental services [41]. This principle aims at economic rationality, under which it seems applicable to include optimized decision-making by AI. However, it is important to note that public interest carries considerable weight in the administrative field. For example, even if uniform water rate hikes and expansion of wastewater networks are found to be economically rational, the options may not necessarily be selected in view of the public interest dependent upon stakeholder opinions. This infers the conclusion that even if AI is introduced in the administrative field including water and wastewater management, ultimate decisions and the responsibilities thereof should be made by people as long as the public deems it to be appropriate. In this case the role of AI will be limited to supporting human judgment rather than replacing it.

4. Discussion

From the status outlined above, we discuss existing gaps and challenges and conclude with policy recommendations.

4.1. Gaps and Challenges

4.1.1. Data Collection and Management

The social impact and risk of rapid expansion of AI are immeasurable [42]. Since the law covers social life, it is necessary also to consider legal issues. A discussion platform established by the Cabinet Office (CAO) has listed issues to be considered for AI and human society according to the sector, which included legal issues. According to the platform, legal issues regarding AI are generally organized into macro issues including principles and ideologies, and micro issues including the creation of rules for solving specific legal problems. Regarding the former, discussions are starting on whether a standalone law can govern robots and AI. Discussions on the latter revolve around relevant laws and contracts when utilizing AI, and accountability for the consequences of actions based on decisions made by AI [12].

Systems supported by AI often require a large amount of data such as sensors, materials, and images. For example, data such as water level, water quality, and chemical

amounts collected from various sensors in the water treatment plant correspond to the data. Data themselves have no ownership rights. Non-personal data, such as water quality data for water purification plants, being provided online is not in the works and, in principle, can be collected or used freely [42]. In addition, the Copyright Act (no.48/1970) [43] was revised in 2018 to include provisions to flexibly restrict rights corresponding to the progress of digitization and networking. The scope of using copyrighted work without the permission of the copyright holder is expanded when learning data required for machine learning is created. On the other hand, there may be cases where a private company entrusted with the maintenance and management of water supply projects holds a large amount of data. At first glance, it seems that data can be freely used, but there should most likely be contracts in place to restrict free use. Even if data are used as part of maintenance, it is crucial to conduct research and development with the consent of the water supplier.

Regarding secondary data such as a collection of raw data or data processed from raw data used for training AI, they may fall under different legislations depending on the circumstances. When data are systematically constructed and creativity is recognized in the choice or systematic composition of information, this falls under the category of copyrighted databases. However, recent amendments to the Copyright Act [43] limit the rights of copyright holders, and the law may not always ensure the protection of such secondary data. The mere presentation of information cannot be considered a technical idea, and individual data do not fall under the category of invention. Secondary data are, therefore, not protected by the Patent Act (no.121/1959) [44].

The possibility of protecting secondary data as a "business secret" under the Unfair Competition Prevention Act (no.47/1993) [45] has been discussed. However, in order to be recognized as a "business secret", requirements include identification and specification of information subject to secrecy management, setting of access restrictions, and signing of a secrecy agreement. Many challenges remain, such as the need for thorough enforcement of secrecy control measures when receiving protection from the Unfair Competition Prevention Act.

Against this backdrop, the Unfair Competition Prevention Act was revised in 2018 [45] to cover the illegal acquisition of private data such as those protected with IDs and passwords. It is aimed at creating an environment that encourages investment in data creation, acquisition, processing, organization, and appropriate utilization. Requirements of data considered eligible are described in the Guidelines on Shared Data with Limited Access issued by the Ministry of Economy, Trade, and Industry [46].

In cases where personal data such as family structure and water consumption of each resident are collected for demand forecasting, for example, a special note needs to be taken of the regulations under the Act on the Protection of Personal Information (no.57/2003) [42,47].

4.1.2. Development of AI

During the process of developing AI systems, programs and trained models may be legally protected. Many AI programs are open-source software. There are also patented or commercialized AI products that have features not found in open-source software, and consideration is required for the protection of economic benefits as compensation for the costs which went into the development of such systems. AI programs may be considered creative if they have a complicated structure to a certain extent, and many are considered to be copyrighted material [42].

On the other hand, products covered by the Patent Act are required to be inventive [44]. With AI programs released as open-source software, the issue is whether the product in focus may be evaluated as something inventive, or in other words, something which cannot easily be conceived from openly available AI programs [42]. Copyright may be considered preferable over a patent for protection of an AI program, since application and registration in each country are required for a patent whereas copyright is international. If the program is confidential, it is also protected as a trade secret as in the case of training data. For

trained models, the training process requires considerable human resources and time. In addition, since the accuracy of the program changes depending on the training method, the training process is considered important intellectual property for those aiming to gain a profit from development and sales of AI systems. The protected content of the trained model is considered to be similar to the protection of the AI program.

However, for an AI program and its parameters to be eligible for "the copyright of a program" protected by copyright law, they must be regarded as a comprehensive entity with an organic interconnection. This makes the status of AI programs under the intellectual property law extremely unstable. To address this issue, the government is discussing the possibility of applying appropriate protection through contracts, including specific requirements and scope of intellectual property for patenting the trained model [11].

4.1.3. Utilization of AI

During the phase of AI utilization, civil liability for any accidents caused by the use of the trained model is a key concern. If an accident occurs and damages are incurred because of an error generated by the trained model, it is not clear who is responsible for the damages. Assume, for example, that the operation of a drinking water treatment plant was automated by AI, and the program caused a malfunction, causing disruption to the water supply. The financial extent of the damage includes labor costs related to water supply and compensation to users for the cut-off water.

Developers, sellers, and users each have the potential to become the bearers of responsibility. There may be a claim for damages based on liability under private law. Product liability is often pursued based on Article 3 of the Product Liability Act (no.85/1994) [48], which reduces the burden of consumers who have suffered from defects of products. Here, defect refers to the state of a product when its characteristics or its expected form of use lack safety which the product should normally have (Product Liability Act Article 2, Section 2) [48]. However, in the case of AI systems, the existence of a defect is fundamentally difficult to prove. Even if an AI system was not arbitrarily designed with a defect, it is difficult to predict how the system will change during a self-learning process. Thus, it is difficult to prove the defects of an AI program [42]. There are also opinions that the black box nature of AI products may act disadvantageously to manufacturers with regard to the burden of proof of product liability.

The problem of civil liability for an accident caused by the use of a trained model is very complex, as technological elements unique to artificial intelligence are added to a dispute over the product itself. It is a question that cannot be neglected in the future, and it is to be hoped that this problem including the period, psychology, and the costs can be discussed as early as possible in preparation. The protection of the individual through insurance also needs to be addressed.

4.2. Policy Recommendations

Based on the above, it is recommended that the national government accelerates the process of putting legislative measures into place for providing a safe environment, to benefit from AI systems. At the same time, a balanced approach is required to prevent these legislative measures from being too restrictive. This will enable developers to keep on innovating. As the Japanese fiscal budget is in an especially uncertain situation given the COVID-19 pandemic as well as the Olympic and Paralympic Games held in Japan during the summer of 2021 which were held under extraordinary circumstances, it would benefit both the private and public sector if the private sector became empowered to profit sustainably from innovations including AI systems without relying on public subsidies.

In this regard, many financial incentives for empowering the private sector in AI development are emerging. Subsidies for academic research, through to implementation of pilot projects, of AI, are supporting the creation of new jobs. Sharing study results with beneficiaries and other private companies supported by public subsidies can lead to better transparency and further accelerate innovation.

Frameworks for monitoring and evaluation of AI in the water management field, including enabling legislative mechanisms for the monitoring and evaluation, can increase functionality and sustainability.

Education and training programs on AI, including legal issues, need to ensure that the decision-making process including development and utilization of AI are inclusive of all stakeholders including women, persons with disabilities, and other disproportionately affected individuals. Training of trainers needs to occur concurrently to ensure there are enough trainers to meet the demand of education opportunities, especially that of schoolteachers and the children they teach. It is crucial that the AI literacy gap be as small as possible in order for AI not to become a determining factor in socio-economic disparities. People who are aware of AI and its legal issues may have better opportunities because of the knowledge. The government needs to address this gap now while it is still relatively small, as the longer it is left unaddressed, the larger it will grow. Developers, including the private sector, need to be involved in designing such education programs from the beginning. This will be beneficial to the private sector as well, as it will ultimately benefit the whole of society.

Taking the above issues into account, the following recommendations are given to water management entities in the public sector.

- Public entities need to prepare a legal structure to outsource their services pertaining to AI to private entities. Currently, service providers are expected to provide collected big data (such as operation and maintenance, water quality, accidents, etc.) to the platform founded by the government for creating or improving an AI system without financial incentive. In the worst-case scenario, the data provided ends up profiting a rival company. The creation of AI systems is costly, and analysis of big data collected from other entities is necessary. Therefore, a legal framework is required to ensure the private sector is protected, as well as to ensure that the best data becomes available for the users to benefit from a robust AI system developed by feeding the big data. The process of promoting private participation in water and sewerage services also contributes to achieving better service efficiency. To utilize the output of the AI, municipalities should consider the approval process before implementation. If there is a possibility that any given outcome of a decision-making process including AI could induce critical issues such as human loss, injuries, or health problems, the output of the AI algorithm should not be automatically reflected in the service operation, and a safeguard process including human decision-making should judge if the output is reasonable. This has the triple function of ensuring user safety, operator safety, and protection of the AI development company. The decision-making process should be transparent and inclusive.

Regarding the approach for the private sector, formulating a capable AI system is a key business opportunity to contribute to public service provision. The following issues should be considered by private companies to establish the AI system.

- The decision-making process which the AI system will support needs to be considered carefully in consultation with the relevant public sector entity and multistakeholders in an inclusive and transparent method.
- Analyzing big data provided by the current service providers is necessary to create a good AI system. Intellectual property rights of such data should be legally obtained, and data should be controlled and guarded carefully.
- Regardless of the technical levels of an AI system, it may not be feasible to glean how outcomes or outputs from the AI system were achieved. Utilities should carefully monitor or have redundant processes to check if the output is accurate considering the purpose of the analysis and the actual impact of the output on the services. Safeguards should be implemented for deploying countermeasures in case an output is not appropriate. This can prevent unnecessary economic or human damage to municipalities or users.

- The governance systems including laws and legislations regarding AI are expected to develop rapidly. The private sector needs to stay alert to how the public sector governs the AI system as well as property rights issues of information.
- Considering the current governmental policies, it is highly probable that subsides for AI systems will increase. It is recommended for private companies to take advantage of such subsidies to accelerate the development of the AI system.

5. Conclusions

When considering the governance of the integration of AI into water and wastewater management systems, it is critical to keep a cross-sectoral and holistic outlook from the viewpoint of the public and private sectors so that a balance can be maintained between the differing interests. Several key recommendations from this study are listed as follows:

- There is increasing evidence that AI systems are highly useful in water and wastewater management. A robust governance framework at national and local levels including strategies and legislations is required to support the rapid development of technologies.
- The Japanese Government established the AI Strategy in 2019 and has doubled the number of subsidized projects under this strategy from 2019 to 2020. It would benefit the private sector to maximize this opportunity to innovate existing technologies and services utilizing cutting-edge AI technologies.
- The public sector needs to focus on mechanisms, including education and training, to enable the private sector to profit sustainably from AI systems without relying on subsidies.
- The private sector, whether responsible for developing or utilizing AI systems in water and wastewater management, needs to ensure that safeguards and backup systems are in place to take over if the AI systems fail or malfunction.
- Multistakeholder collaboration is required for AI governance, including the decision-making process, to become inclusive and accessible.
- Speeding up and scaling up of discussions to update governance frameworks and legislation surrounding AI in water and wastewater management are required; furthermore, this will benefit the whole of society given the holistic outlook is maintained.

This research will further benefit from a comparative study with other countries, as well as further detailed review regarding up-to-date technologies available on the market.

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Abbreviations

AI	Artificial Intelligence
B-DASH	Breakthrough by Dynamic Approach in Sewage High Technology Project
CAO	Cabinet Office
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
IT	Information Technology
METI	Ministry of Economy, Trade, and Industry
MHLW	Ministry of Health, Labour, and Welfare
MLIT	Ministry of Land, Infrastructure, Transport, and Tourism
OECD	Organisation for Economic Co-operation and Development
UN	United Nations

References

1. OECD. *Measuring the Digital Transformation*; OECD Publishing: Paris, France, 2019.
2. OECD. Recommendation of the Council on OECD Legal Instruments Artificial Intelligence; OECD/LEGAL/0449. Available online: https://legalinstruments.oecd.org/en/instruments/oecd-legal-0449 (accessed on 20 June 2021).
3. ISO/IEC JTC 1/SC 42. Available online: https://www.iso.org/committee/6794475.html (accessed on 31 May 2021).
4. Howes, A.; Pogrebna, G.; Yeung, K. AI Governance by Human Rights—Centered Design, Deliberation, and Oversight. In *The Oxford Handbook of Ethics of AI*, 1st ed.; Oxford University Press: Oxford, UK, 2020; p. 75.
5. Nishant, R.; Kennedy, M.; Corbett, J. Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda. *Int. J. Inf. Manag.* **2020**, *53*, 102104. [CrossRef]
6. e-Gov Portal. Available online: https://elaws.e-gov.go.jp/ (accessed on 20 July 2021).
7. Japanese Law Translation. Available online: http://www.japaneselawtranslation.go.jp/ (accessed on 20 July 2021).
8. Prime Minister of Japan and His Cabinet. Available online: https://www.kantei.go.jp/jp/singi/keizaisaisei/kettei.html (accessed on 31 May 2021).
9. The National Strategic Special Zones. Available online: https://www.chisou.go.jp/tiiki/kokusentoc/supercity/openlabo/supercitycontents.html (accessed on 31 May 2021).
10. Ministry of Internal Affairs and Communications. Act to Amend the National Strategic Special Zone Act (no.63/2019). Available online: https://elaws.e-gov.go.jp/document?lawid=425AC0000000107 (accessed on 10 August 2021).
11. AI Strategy. Available online: https://www8.cao.go.jp/cstp/ai/index.html (accessed on 31 May 2021).
12. Social Principles of Human-Centric AI. Available online: https://www.cas.go.jp/jp/seisaku/jinkouchinou/ (accessed on 20 July 2021).
13. Breakthrough by Dynamic Approach in Sewage High Technology (B-DASH) Project. Available online: http://www.nilim.go.jp/lab/ecg/bdash/bdash.htm (accessed on 31 May 2021).
14. Ministry of Economy, Trade and Industry. Contract Guidelines on Utilization of AI and Data, Version 1.1. Available online: https://www.meti.go.jp/press/2018/06/20180615001/20180615001.html (accessed on 31 May 2021).
15. Ministry of Economy, Trade and Industry. Guidebook for Implementing AI Systems in Small and Medium Enterprizes. Available online: https://www.meti.go.jp/press/2020/03/20210331010/20210331010.html (accessed on 31 May 2021).
16. Ministry of Economy, Trade and Industry. Navigation system for e-learning of the digital transformation. Available online: https://www.meti.go.jp/policy/it_policy/jinzai/sugomori/index.html (accessed on 31 May 2021).
17. Ministry of Internal Affairs and Communications. Amendment to the Water Supply Act (no.177/1957). Available online: https://elaws.e-gov.go.jp/document?lawid=332AC0000000177 (accessed on 20 June 2021).
18. Guidelines for Implementing Electronic Systems for Basic Inventories of Waterworks Facilities. Available online: https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/0000205762.html (accessed on 31 May 2021).
19. Orita, M. Learning Control Systems. *J. Soc. Instrum. Control Eng.* **1965**, *4*, 310–319. Available online: https://www.jstage.jst.go.jp/article/sicejl1962/4/5/4_5_310/_pdf/-char/ja (accessed on 20 June 2021).
20. Yokohama City. Basic Policy for Informatization of Yokohama. Available online: https://www.city.yokohama.lg.jp/city-info/gyosei-kansa/shigoto/ict/johoka-kihon/kihonhoushin.html (accessed on 31 May 2021).
21. Press Release. Available online: https://www.waterworks.metro.tokyo.lg.jp/press/h30/press180711-01.html (accessed on 23 July 2021).
22. Talaviya, T.; Shah, D.; Patel, N.; Yagnik, H.; Shah, M. Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides. *Artif. Intell. Agric.* **2020**, *4*, 58–73. [CrossRef]
23. Wang, P.; Yao, J.; Wang, G.; Hao, F.; Shrestha, S.; Xue, B.; Xie, G.; Peng, Y. Exploring the application of artificial intelligence technology for identification of water pollution characteristics and tracing the source of water quality pollutants. *Sci. Total Environ.* **2019**, *693*, 133440. [CrossRef] [PubMed]
24. Li, L.; Rong, S.; Wang, R.; Yu, S. Recent advances in artificial intelligence and machine learning for nonlinear relationship analysis and process control in drinking water treatment: A review. *Chem. Eng. J.* **2021**, *405*, 126673. [CrossRef]

25. Torregrossa, D.; Leopold, U.; Hernández-Sancho, F.; Hansen, J. Machine learning for energy cost modelling in wastewater treatment plants. *J. Environ. Manag.* **2018**, *223*, 1061–1067. [CrossRef] [PubMed]
26. Zhao, L.; Dai, T.; Qiao, Z.; Sun, P.; Hao, J.; Yang, Y. Application of artificial intelligence to wastewater treatment: A bibliometric analysis and systematic review of technology, economy, management, and wastewater reuse. *Process. Saf. Environ. Prot.* **2020**, *133*, 169–182. [CrossRef]
27. Alam, G.; Ihsanullah, I.; Naushad, M.; Sillanpää, M. Applications of artificial intelligence in water treatment for the optimization and automation of the adsorption process: Recent advances and prospects. *Chem. Eng. J.* **2021**, *427*, 130011. [CrossRef]
28. Tiyasha, T.; Tung, T.M.; Bhagat, S.K.; Tan, M.L.; Jawad, A.H.; Mohtar, W.H.M.W.; Yaseen, Z.M. Functionalization of remote sensing and on-site data for simulating surface water dissolved oxygen: Development of hybrid tree-based artificial intelligence models. *Mar. Pollut. Bull.* **2021**, *170*, 112639. [CrossRef] [PubMed]
29. News Release. Available online: https://nissin.jp/news/200514/ (accessed on 20 July 2021).
30. News Release. Available online: https://www.hitachi.co.jp/New/cnews/month/2021/04/0412.html (accessed on 20 July 2021).
31. StreamLabs. Available online: https://www.streamlabswater.com/ (accessed on 20 July 2021).
32. eMeter. Available online: https://linkjapan.co.jp/product/emeter/ (accessed on 20 July 2021).
33. Dawood, T.; Elwakil, E.; Novoa, H.M.; Delgado, J.F.G. Artificial intelligence for the modeling of water pipes deterioration mechanisms. *Autom. Constr.* **2020**, *120*, 103398. [CrossRef]
34. Chester, M.; Underwood, B.S.; Allenby, B.; Garcia, M.; Samaras, C.; Markolf, S.; Sanders, K.; Preston, B.; Miller, T.R. Infrastructure resilience to navigate increasingly uncertain and complex conditions in the Anthropocene. *npj Urban Sustain.* **2021**, *1*, 1–6. [CrossRef]
35. KDDI IoT Cloud-Management of Toilet Booths. Available online: https://biz.kddi.com/service/iot/iot-cloud-toiletdoor/ (accessed on 20 July 2021).
36. Saravi, S.; Kalawsky, R.; Joannou, D.; Rivas Casado, M.; Fu, G.; Meng, F. Use of Artificial Intelligence to Improve Resilience and Preparedness Against Adverse Flood Events. *Water* **2019**, *11*, 973. [CrossRef]
37. Ministry of Internal Affairs and Communications. The Constitution of Japan; 1947. Available online: https://elaws.e-gov.go.jp/document?lawid=321CONSTITUTION (accessed on 31 May 2021).
38. Ministry of Internal Affairs and Communications. Civil Code (no.89/1896). Available online: https://elaws.e-gov.go.jp/document?lawid=129AC0000000089 (accessed on 10 August 2021).
39. Ministry of Internal Affairs and Communications. Penal Code (no.45/1907). Available online: https://elaws.e-gov.go.jp/document?lawid=140AC0000000045 (accessed on 10 August 2021).
40. Ministry of Internal Affairs and Communications. Intellectual Property Basic Act (no.122/2002). Available online: https://elaws.e-gov.go.jp/document?lawid=414AC0000000122 (accessed on 20 June 2021).
41. Ministry of Internal Affairs and Communications. Local Autonomy Act (no.67/1947). Available online: https://elaws.e-gov.go.jp/document?lawid=322AC0000000067 (accessed on 10 August 2021).
42. Yanaga, M.; Shishido, G. *Robots, AI and the Law*; Yuhikaku Publishing, Co., Ltd.: Tokyo, Japan, 2018. (In Japanese)
43. Ministry of Internal Affairs and Communications. Copyright Act (no.48/1970). Available online: https://elaws.e-gov.go.jp/document?lawid=345AC0000000048 (accessed on 31 May 2021).
44. Ministry of Internal Affairs and Communications. Patent Act (no.121/1959). Available online: https://elaws.e-gov.go.jp/document?lawid=334AC0000000121 (accessed on 10 August 2021).
45. Ministry of Internal Affairs and Communications. Unfair Competition Prevention Act (no.47/1993). Available online: https://elaws.e-gov.go.jp/document?lawid=405AC0000000047 (accessed on 10 August 2021).
46. Ministry of Economy, Trade, and Industry. Guidelines on Shared Data with Limited Access 2019. Available online: https://www.meti.go.jp/english/policy/economy/chizai/chiteki/pdf/guidelines_on_shared_data_with_limited_access.pdf (accessed on 10 August 2021).
47. Ministry of Internal Affairs and Communications. Act on the Protection of Personal Information (no.57/2003). Available online: https://elaws.e-gov.go.jp/document?lawid=415AC0000000057 (accessed on 10 August 2021).
48. Ministry of Internal Affairs and Communications. Product Liability Act (no.85/1994). Available online: https://elaws.e-gov.go.jp/document?lawid=406AC0000000085 (accessed on 10 August 2021).