The State of Digital Twin and Smart City Development in Cities in Japan

Survey Results

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July 30, 2024

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Acknowledgements: The author likes to thank Prof. Keiichi Yasumoto and his colleagues Prof. Hirohiko Suwa, Prof. Hiroki Matsui and Prof. Yuki Matsuda for their support and valuable feedback during his research stay at the Nara Institute of Science and Technology, as well as Masaki Sakaguchi from the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) for distributing the survey.

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1 Introduction

Many cities nowadays are trying to use digital transformation and associated technologies to become smart cities. The International Telecommunications Union, ITU-T, defines a smart sustainable city as “an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operations and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects” (ITU-T 2014). In Japan, the cross-ministerial Strategic Innovation Promotion Program uses a similar definition of "a city or region that provides people (residents, businesses and visitors) with better services and quality of life, both now and in the future, from a social, economic and environmental perspective, through management (planning, development, management and operation, etc.) in various fields that make effective use of new technologies such as ICT and various public and private sector data, with the aim of solving global problems and local problems faced by cities and regions, and creating new value." (Cabinet Office Japan 2023, 6). Both definitions show clearly that smart city is not just a technological concept, but instead the quality of life of the people, or more generally speaking, public value (Müller and Haller 2023) needs to be in the focus of city planners in their development strategies.[1]

In recent years, cities have started to set up so-called digital twins of their cities (Alva, Biljecki, and Stouffs 2022; Lehtola et al. 2022; Papyshev and Yarime 2021; Seto, Furuhashi, and Uchiyama 2023). An urban digital twin consists typically of a 3-dimensional model of the built environment (current, but also historical as well as planned) combined with other data in order to plan the future development of the city and necessary policies, to develop disaster management plans, to change mobility behaviour into a more sustainable way and other use cases. Visualisation and simulations support these use cases. In Japan, the nation-wide PLATEAU (Ministry of Land, Infrastructure, Transport and Tourism 2024, n.d.; Seto, Furuhashi, and Uchiyama 2023) programme, led by the Ministry of Land, Infrastructure, Transport and Tourism, is supporting cities regarding the build-up and use of 3D models.

As part of a research project on urban digital twins together with Ubiquitous Computing Systems Laboratory of the Nara Institute of Science and Technology, we conducted a survey among cities in Japan with the objective to understand the overall state of development regarding smart cities and urban digital twins in Japan. This report summarizes the results of the survey.

2 Survey Distribution

For the survey, a questionnaire in Japanese was built using Qualtrics[2] addressing city officials in Japan. The link to the survey was sent out to the members of the Smart City Public-Private Partnership Platform[3] (SCPF) through its secretariat at the International and Digital Policy Division, Urban Affairs Bureau, of the Ministry of Land, Infrastructure, Transport and Tourism on June 4, 2024, and responses were collected until June 30.

The list of members of this platform includes (as of April 22) 659 organisations, whereof 187 are local public bodies and among these 168 cities. Recipients – in particular, prefectural bodies – were also encouraged to forward the link to other cities.

3 Responses Overall

In total, complete responses were received from 31 municipalities. 18 of these municipalities are not on the member list of the platform, which shows that the link was forwarded to non-members as well. Answers were received from all over Japan, which is shown in Figure 1and Figure 2.

[1] Another good example of a public-value approach to smart cities is the city of Boston in the USA (City of Boston 2020; Green and Franklin-Hodge 2020)

[2] Cf. *https://www.qualtrics.com/*

[3] Cf. *https://www.mlit.go.jp/scpf/*

Figure 1: Location of the municipalities that responded

Prefecture	Number of answers
Aichi	1
Chiba	2
Ehime	8
Fukushima	1
Gifu	1
Gunma	1
Hyogo	1
Kagoshima	1
Mie	1
Nagasaki	2
Miyagi	1
Niigata	1
Oita	1
Osaka	1
Saitama	1
Shimane	3
Tokyo	1
Tottori	1
Toyama	1
Wakayama	1

Figure 2: Number of city answers per prefecture

Municipalities in Japan are categorized as cities (市), towns (町), villages (村) and 23 special wards (区) with a similar status as a city in the Tokyo metropolitan area. Most of the answers came from cities, as shown in Table 1.

Municipality Type	Total Number in Japan[4]	Number of Responses
City (市)	792	28
Town (町)	743	2
Village (村)	189	0
Special Ward (区)	23	1

Table 1: Responses according to municipality type

[4] According to the official list of municipalities available at *https://www.soumu.go.jp/denshijiti/code.html*

With just little more than 3% of all cities responding, quantitative statements valid for the whole of Japan are not justified. Still though some value can be gained from the individual responses provided.

We also wanted to investigate to what extent municipalities were pursuing both smart city as well as digital twin activities. The hypothesis that municipalities would only start looking at digital twins once they have a certain maturity regarding smart city can be dismissed. While most cities that have ongoing activities regarding digital twins do also have an ongoing smart city programme, this is not always the case, as Figure 3 shows. There are some cities with digital twin activities that have no smart city plans, as well as vice versa, cities with smart city activities that are not pursuing the implementation of a digital twin.

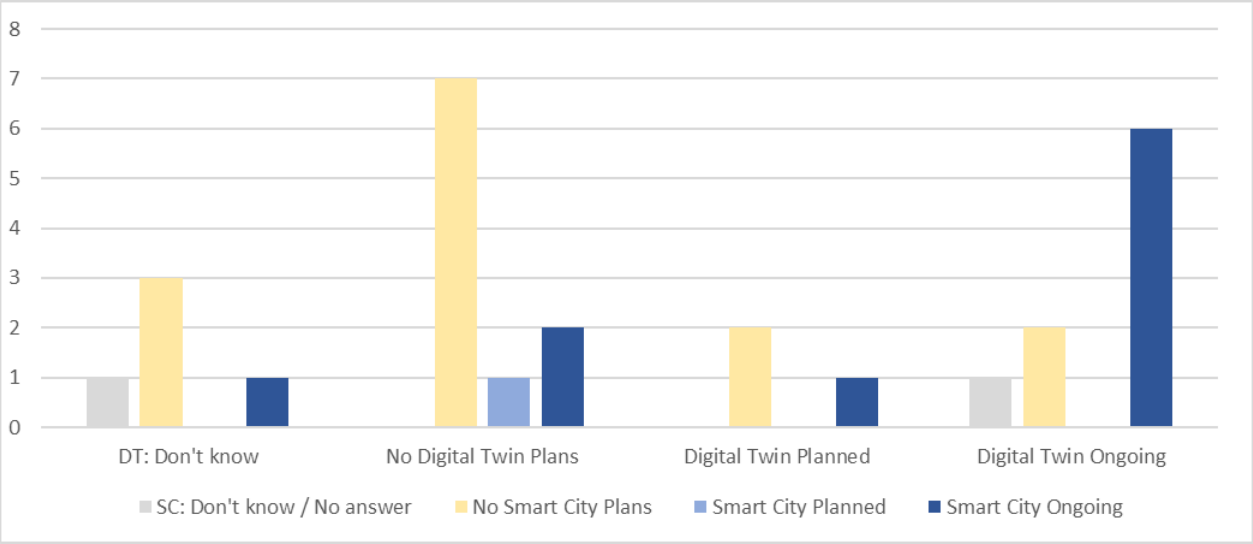

Figure 3: Smart City vs. Digital Twin activities

4 Smart City

4.1 Smart City Activities

In the first question, municipalities were asked regarding their smart city activities. As can be seen in Figure 3, and not surprisingly, municipalities that are already a member of the SCPF have for the most part already a smart city program running or at least have started pilots. Among the non-members, only one city has plans to start smart city activities, but most others have at least plans for digital transformation.

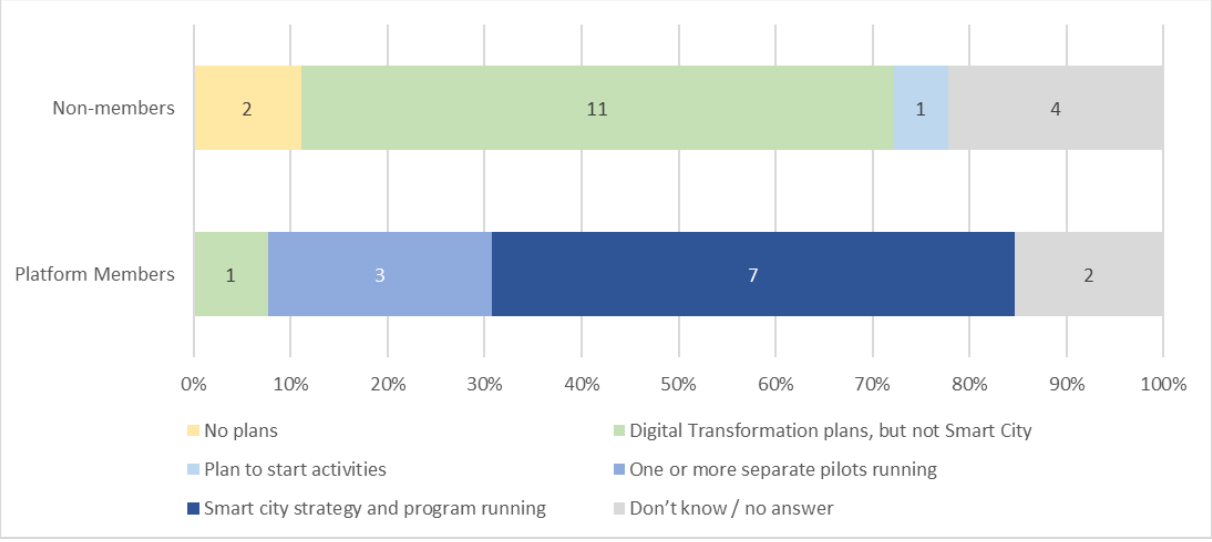

Figure 4: Smart city activities depending on platform membership (the numbers show the absolute count of responses)

Figure 4 breaks down the smart city activities by the population size of the municipality. It shows that bigger municipalities tend to be further in their efforts to become a smart city. One of the reasons for this may be that smaller municipalities often seem to believe that «smart city» is only something for big cities. However, if one looks at the definitions of a smart city shown in chapter 1, it becomes clear that the concept is also applicable to smaller municipalities, as they should also be interested in providing better services and increasing the quality of life of its people. Offering smart city infrastructure and services may help especially rural communities in retaining their young population and local businesses, or even attract new talents and enterprises according to the goals of the Digital Garden Nation (Cabinet Secretariat Japan 2023).

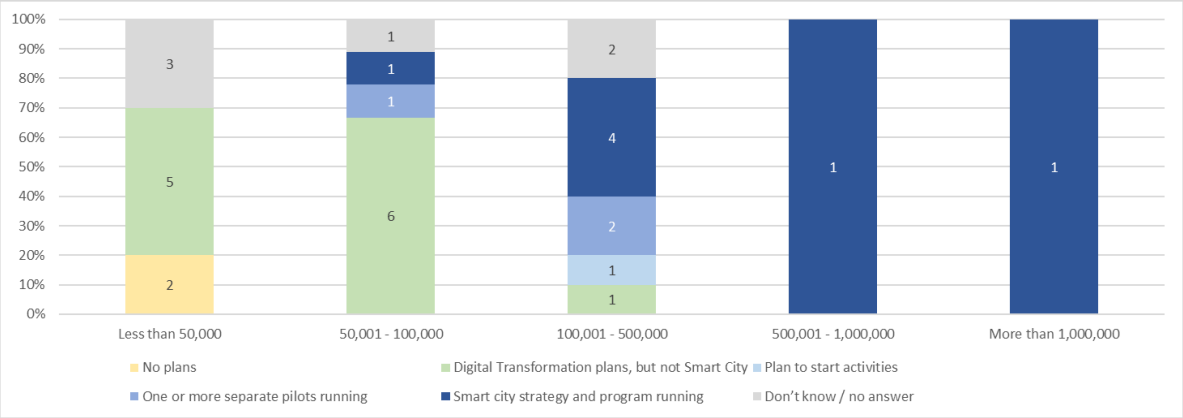

Figure 5: Smart city activities depending on the size of the municipality

4.2 Reasons for not becoming a smart city

Respondents that had answered that their city has no smart city activities planned or just digital transformation plans were asked for reasons why their city didn't have smart city plans. From the answers, two main reasons can be identified:

1. Lack of resources, in particular financial resources.
2. General digital transformation issues, e.g., establishment of online processes and digital contact points, have currently higher priority and need to be implemented first. Smart city activities may come at a later stage.

The answer of one respondent summarizes the issue well: "We don't think it's irrelevant, we are working to improve our services and develop human resources based on our digitalization plan, and we are also considering initiatives that will lead to smart cities as we consider improving our services."

A complete list of the answers given can be found in Appendix A.

4.3 Reasons for becoming a smart city

Respondents that had indicated that their city had ongoing smart city activities or was at least planning to start some were asked to explain the motivation for doing so. The answers were quite diverse. The word cloud generated from the answers provided (see Figure 5) gives some hints: Societal demands (社会), sustainability（持続可能）, change (化), regional issues (地域), and transportation (交通) seem to be some of the top motivations. But each city has its own priorities, so other issues like the ageing of society and population decline were mentioned as well.

A complete list of the answers given can be found in Appendix A.

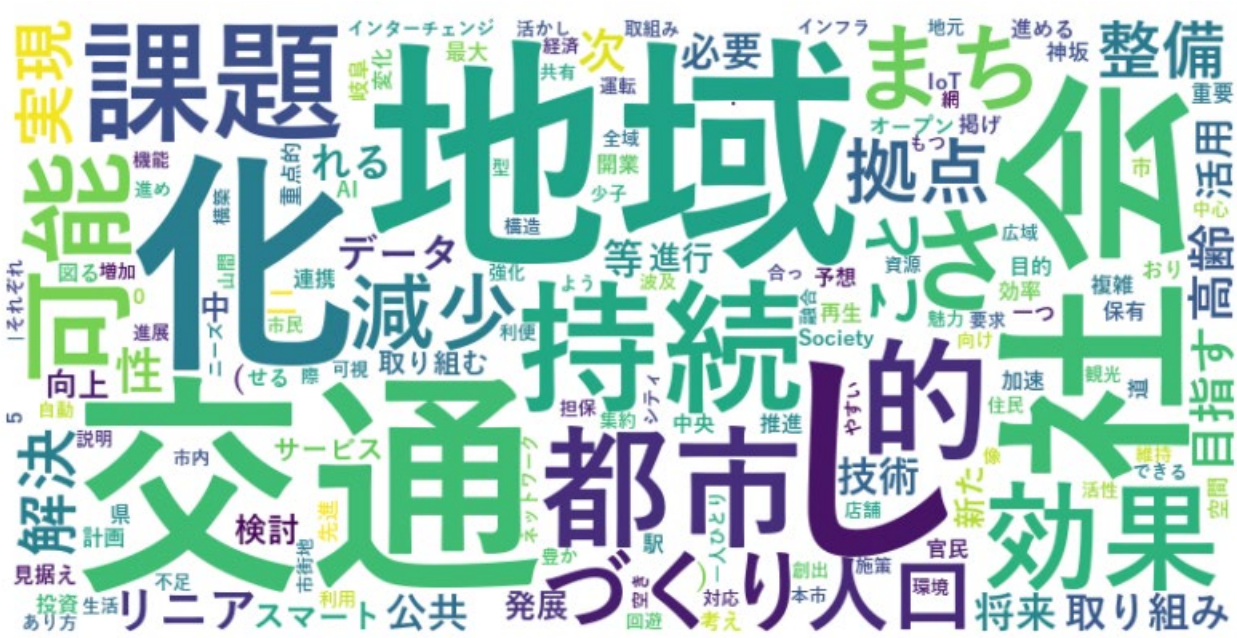

Figure 6: Word cloud generated from the answers regarding the motivation for becoming a smart city

4.4 Smart city application domains

The 11 respondents working in cities that have or plan to have smart city activities were next asked to rate the importance of several application domains. The possible answers were the domains listed in Japan's Smart City Reference Architecture (Cabinet Office Japan 2023, 86). Respondents also had the opportunity to add other application domains, but none did so. The results can be seen in Figure 6.

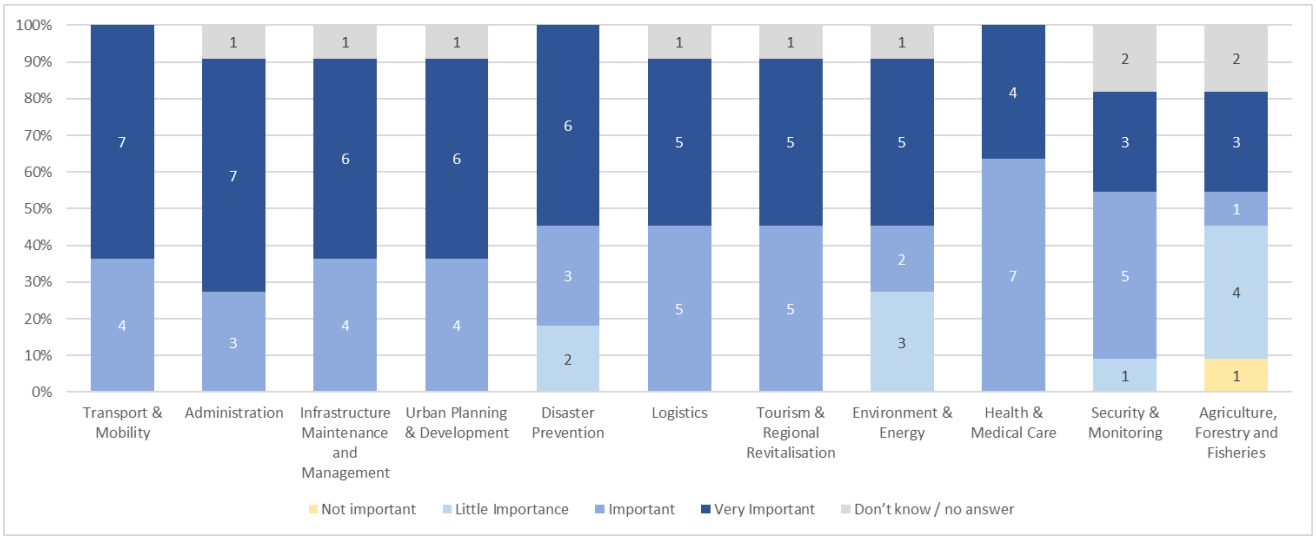

Figure 7: Importance of smart city application domains

With the exception of agriculture, forestry and fisheries, all application domains were rated by the majority of respondents as important or very important. This can serve as an indication that smart city activities should be tackled from a cross-application perspective; and that infrastructure is needed to support several application areas.

Even though the number of respondents is small and therefore the results cannot be generalized, two points are still somewhat surprising. Firstly, environment & energy is rated relatively low; in Europe, this is one of the most important application domains for smart cities. And secondly, one would expect that mainly rural municipalities would rate agriculture, forestry and fisheries high. In the data however, the two biggest cities participating rated this application domain as very important.

4.5 Smart city reference architecture

As shown in Figure 7, less than half of the respondents working in smart cities indicated a familiarity with the Smart City Reference Architecture (SCRA). Only two cities are actively using it, and a third city indicated that it plans to do so in the future. These cities also indicated which provider they are using the implement a CityOS (Table 2).

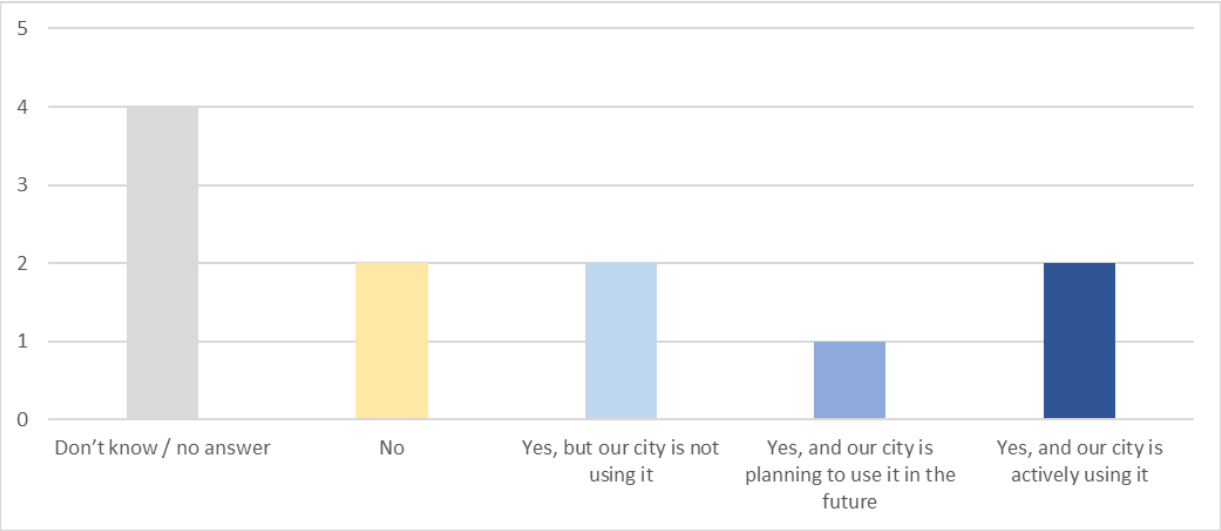

Figure 8: Familiarity with Smart City Reference Architecture

Asked for the reason why they use the SCRA, the two cities answered the following:

- "Compliance with standardisation, wide-area cooperation."
- "Gives an overall overview of smart cities."

On the other hand, one of the cities that is not using it even though they are familiar with it, said the reason was that they haven't developed yet a smart city plan. According to an earlier question regarding smart city activities, this city is currently running one or more pilots.

City	SCRA Use	Component / Provider
City 1	Active use	Data Utilisation Infrastructure Services (FIWARE-compliant) / NEC Corp.
City 2	Active use	Area Data Utilisation Service / Intec Inc.
City 3	Planned	AWS / NTT Business Solutions Inc.

Table 2: Components used to implement CityOS

5 Digital Twin

In the second part of the survey, municipalities were asked regarding their digital twin activities. As can be seen in Figure 8, most municipalities have already or are planning to start digital twin activities. Also, almost all of the municipalities that are not SCPF members have such programs.

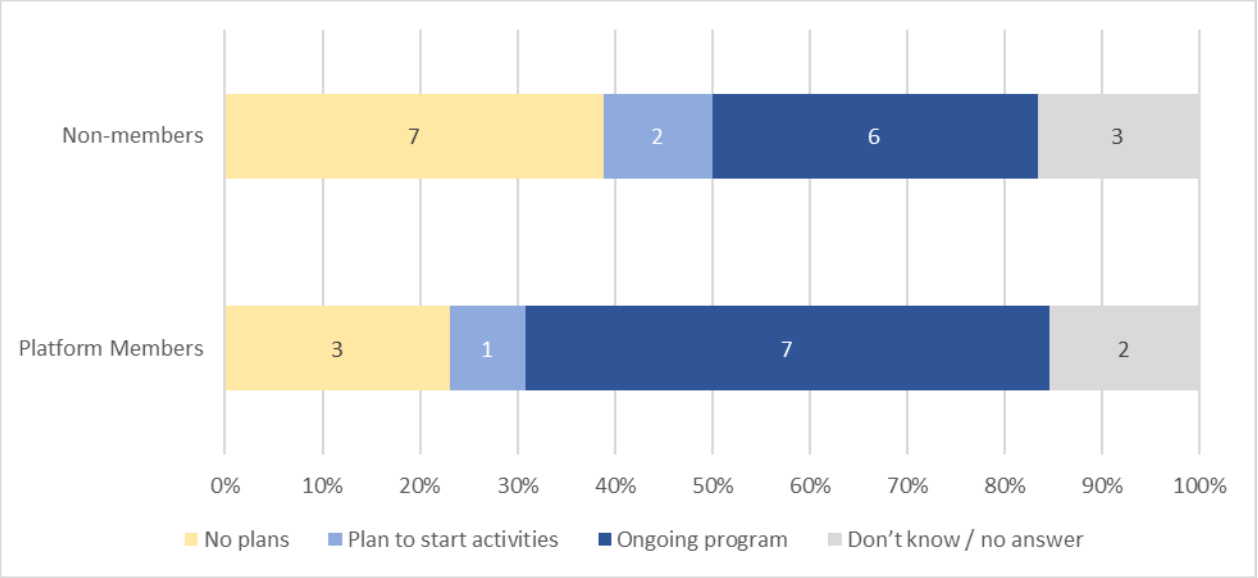

Figure 9: Digital twin activities depending on platform membership.

Figure 4 breaks down the digital twin activities by the population size of the municipality. As we have seen already in the case of smart city activities, also regarding digital twins bigger municipalities tend to be further in their developments.

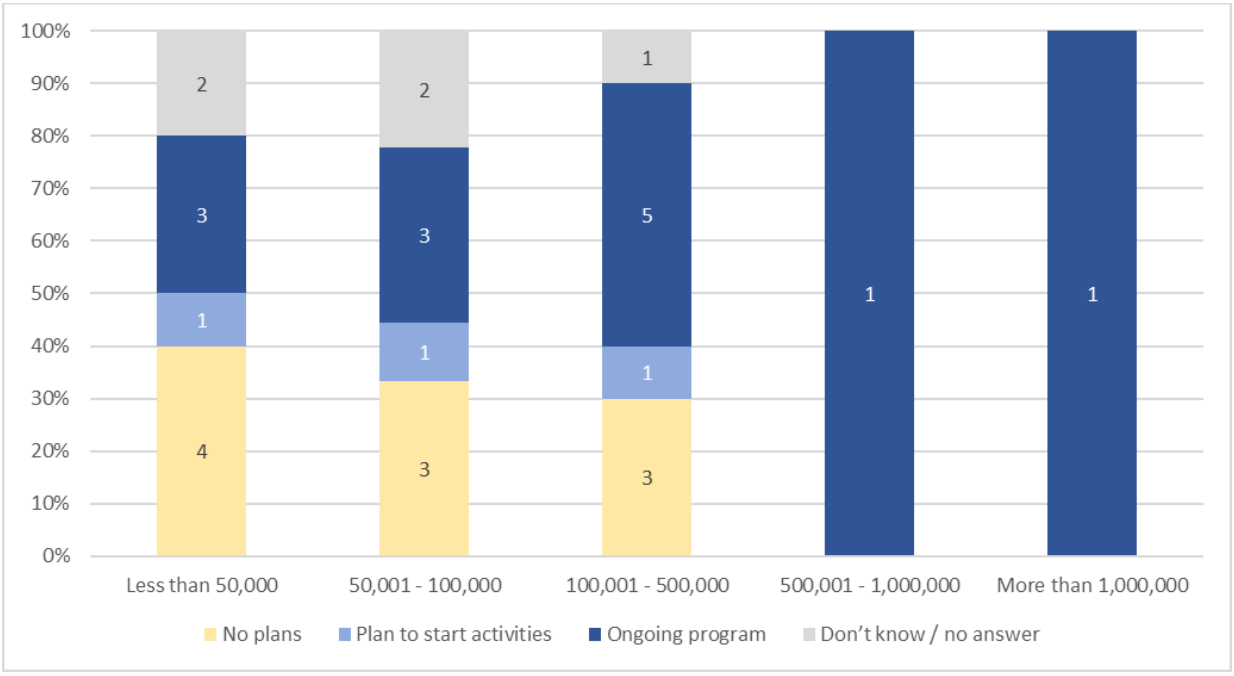

Figure 10: Digital twin activities depending on the size of the municipality

5.1 Reasons for not engaging in digital twin activities

Respondents that had answered that their city has no plans regarding the use of a digital twin were asked for reasons why their city didn't have such plans. From the answers, the following reasons can be identified:

1. Lack of resources, in particular financial resources. This was by far the most mentioned reason. The creation of an initial 3D model was considered expensive, but also the required maintenance to keep the model up to date.
2. The benefits for the city of a digital twin and a 3D model are not clear.

3. Other digitalization activities have a higher priority.

One responded mentioned that in their city there was “only a limited area with multi-storey structures” and thus 3D models weren’t cost effective. This raises the question if 3D models are always necessary and for what purposes, and when a 2D model may suffice.

A complete list of the answers given can be found in Appendix B.

5.2 Reasons for engaging in digital twin activities

Respondents that had indicated that their city had ongoing digital twin activities or was at least planning to start some were asked to explain the motivation for doing so. The following reasons were mentioned often:

1. Urban planning
2. Disaster prevention and mitigation

These answers are not surprising, as currently most pilot projects in Japan focus on these areas (Ministry of Land, Infrastructure, Transport and Tourism 2024). The use of simulations and visualisations in these applications is also stressed by several respondents.

A complete list of the answers given can be found in Appendix B.

5.3 Why 3D models?

In a separate question, respondents were also asked for which use cases they believe a 3D model is required. The answers reflect the answers regarding why cities engage in digital twin activities: disaster prevention, e.g., simulation of floods and landslides, as well as urban planning. In the generated word cloud also the word resident (主民) stands out as several respondents highlighted that simulations and 3D visualisations are very useful in explaining to residents about future developments, enabling even resident participation, as well as for educational purposes.

Figure 11: Word cloud generated from the answers regarding the use cases needing a 3D model.

A complete list of the answers given can be found in Appendix C.

5.4 Digital twin use cases

The 16 respondents working in cities that have or plan to have digital twin activities were next asked to rate the importance of several use cases. The possible answers were taken from the typical use cases mentioned in Al-Sehravy et al. (2021) and Alva et al. (2022). Respondents also had the opportunity to add other use cases, but none did so. The results can be seen in Figure 12.

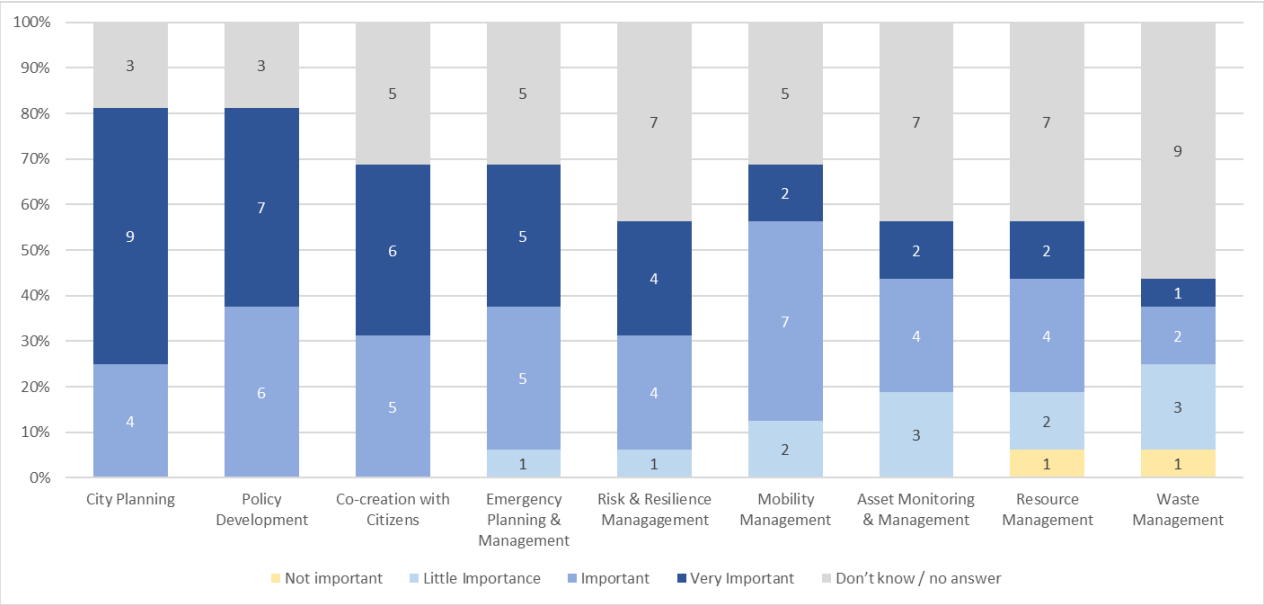

Figure 12: Importance of digital twin use cases

Not surprisingly, city planning and policy development are regarded as the most important use cases. More interesting however is another point. Although many respondents had mentioned disaster prevention as one important reason why they were engaged in digital twin activities, the related use cases "emergency planning & management" and "risk & resilience management" are not ranked below co-creation with citizens. This can be taken as a positive indication of how the digital transformation is affecting the way public administrations think and work, and how this is thus contributing to further democratization of the society.

5.5 Digital twin data and components

All cities with an ongoing digital twin programme reported that they use 3D data from Plateau, as can be seen in Figure 13. Other data and software components, including the Plateau SDK are only rarely used. This shows that there is still significant potential in the further development of digital twins in Japan. One respondent mentioned in the "other" category that they are using a traffic flow simulator.

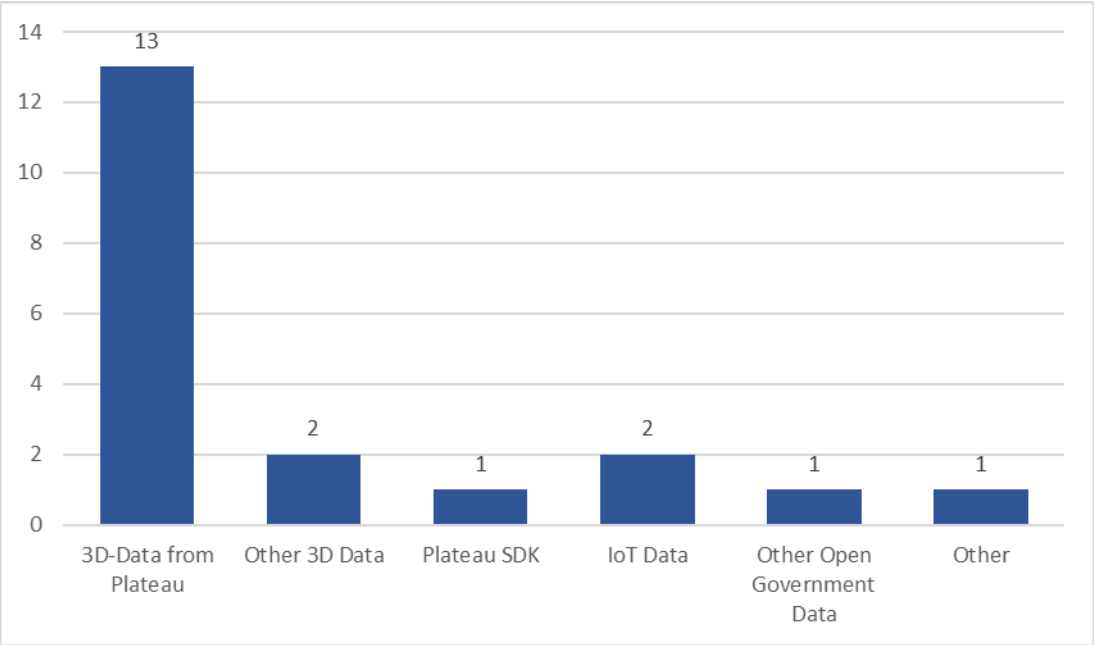

Figure 13: Digital twin data and components

6 Recommendations

As the results of this survey show, digital transformation in Japan is progressing and many cities have engaged in activities to become a smart city and to make use of urban digital twins. However, developments are still in early stages compared to what has been written in the published strategies of the central government. In addition to the answers to the specific questions described above, respondents also gave further comments regarding perceived gaps and other issues (see Appendix D).

According to the respondents, lack of both financial and human resources are issues that hinder the further progress regarding urban digital transformation, smart city and digital twin. While it would be desirable that more financial resources are invested into digital transformation, this may be difficult since these resources are limited and thus the prioritisation of investments would need to be changed.

The results of the survey, combined with author's experience in the field, were used to derive the following recommendations for cities.

Recommendation 1: Focus on public value, not technology.
Cities need to have clear understanding what benefits certain applications and use cases bring for society and its people. Even in the early experimentation and pilot stages, public value must be addressed and validated, i.e., if must be tested if the expected public can actually be realized. A clear understanding of the public value will also help to prioritize and justify the investments into new technologies. New technologies shouldn't however be introduced just for technology's sake or for the sake of looking innovative, but technologies should rather be used as a means to achieve public value.

Recommendation 2: Increase knowledge about smart cities and digital twins and digital skills of general of public administration officials.
Public administration officials, in particular if they are in decision-making positions, need to understand the possibilities and opportunities of new technologies, but also their challenges. They must be able to critically judge claims made by technology vendors. Regarding smart city, the familiarity with the Smart City Reference Architecture (Cabinet Office Japan 2023) must be increased, as this reference architecture provides an excellent basis.

Recommendation 3: Increase cooperation.
Digital transformation of the urban society is a task that cannot be done by city administrations alone. Many of the technologies, use cases and applications are new, so cooperation and information exchange between stakeholders is paramount. Both industry as well as academia can and should be involved, as they typically can offer a wide area of expertise. The use of public-private-partnerships is

one well-known instrument to do so. Furthermore, cooperation and information exchange between cities and regions is strongly encouraged, as everyone will benefit from this, for example through existing platforms like the Smart City Public-Private Partnership Platform. For smaller municipalities that are not active in the field yet, it is recommended that they start cooperating with neighbouring municipalities and start forming smart regions.

Recommendation 4: Further data use and integration of different data sources.
Data is the foundation for both smart cities as well as digital twins. Where this is not the case yet, these two areas should thus be combined, and the integration of different types of data beyond just 3D models should be fostered. The use of data spaces (Curry 2020; Information-technology Promotion Agency 2024) will facilitate access and integration of multiple data sources, taking into account also data protection aspects and fair use.

Recommendation 5: Use of common platforms for multiple applications and use cases.
Smart cities and digital twins have – as the answers of the respondents have shown –many potential applications and use cases. In line with recommendations 4 and 5, the use of a common platform like the CityOS (Cabinet Office Japan 2023) is therefore recommended.

Recommendation 6: Test interoperability between cities.
The Smart City Reference Architecture (Cabinet Office Japan 2023) doesn't prescribe exactly how or with what components a CityOS should be implemented. This approach is commendable, as it allows for competition among vendors as well as for cities to consider their own requirements. This survey has shown that different cities rely on different vendors for the implementation. However, for cities to be able to cooperate and to exchange data (see recommendation 3), interoperability between these different solutions must be tested. The same holds true for the implementation of data spaces.

Recommendation 7: Determine the true value of 3D modelling.
Several municipalities expressed concerns regarding the cost and effort of generating and updating 3D models in respect to the value they provide. It needs therefore to be evaluated further where a 3D model provides actual value and what that value is (see recommendation 1). In some use cases a 2D model of the municipality may be more cost-effective.

7 Conclusion & Outlook

This report summarized the results from a survey distributed via the Smart City Public-Private Partnership Platform in June of 2024, asking cities about their activities regarding smart cities and digital twins. While the number of responses was too small to extrapolate the results on the whole of Japan, some valuable insights could still be gained.

The results show that activities in these two fields are taking place all over Japan, but that also that the stage of development at which these activities are is very different – from early plans to pilot implementations to concrete strategies and ongoing programmes.

A number of issues that hinder progress were identified and summarized in 7 recommendations. Cities, as well as academia and industry are encouraged to work on these recommendations.

8 References

Al-Sehrawy, Ramy, Bimal Kumar, and Richard Watson. 2021. "A Digital Twin Uses Classification System for Urban Planning & City Infrastructure Management." *Journal of Information Technology in Construction* 26: 832–362. doi:10.36680/j.itcon.2021.045.

Alva, P., F. Biljecki, and R. Stouffs. 2022. "Use Cases for District-Scale Urban Digital Twins." *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 48: 5–12. doi:10.5194/isprs-archives-XLVIII-4-W4-2022-5-2022.

Cabinet Office Japan. 2023. *スマートシティリファレンスアーキテクチャ　ホワイトペーパー [Smart City Reference Architecture Whitepaper]*. Cross-ministerial Strategic Innovation Promotion Program (SIP). https://www8.cao.go.jp/cstp/society5_0/smartcity/sc-whitepaper.html (May 8, 2024).

Cabinet Secretariat Japan. 2023. *デジタル田園都市国家構想総合戦略 [Comprehensive Strategy for the Digital Garden City National Initiative]*. https://www.cas.go.jp/jp/seisaku/digital_denen/pdf/20231226honbun.pdf (July 26, 2024).

City of Boston. 2020. "Boston Smart City Playbook." https://www.boston.gov/departments/new-urban-mechanics/smart-city-playbook (July 26, 2024).

Curry, Edward. 2020. "Dataspaces: Fundamentals, Principles, and Techniques." In *Real-Time Linked Dataspaces*, ed. Edward Curry. Cham: Springer International Publishing, 45–62. doi:10.1007/978-3-030-29665-0_ 3.

Green, Ben, and Jascha Franklin-Hodge. 2020. *The Smart Enough City: Putting Technology in Its Place to Reclaim Our Urban Future*. First MIT Press paperback edition. Cambridge, Massachusetts London, England: The MIT Press.

Information-technology Promotion Agency. 2024. "データスペースの推進 [Promotion of Data Spaces]." https://www.ipa.go.jp/digital/data/data-space.html (July 26, 2024).

ITU-T. 2014. *Smart Sustainable Cities: An Analysis of Definitions*. International Telecommunications Union, Focus Group on Smart Sustainable Cities. https://www.itu.int/en/ITU-T/focus groups/ssc/Documents/Approved_Deliverables/TR-Definitions.docx (July 26, 2024).

Lehtola, Ville V., Mila Koeva, Sander Oude Elberink, Paulo Raposo, Juho-Pekka Virtanen, Faridaddin Vahdatikhaki, and Simone Borsci. 2022. "Digital Twin of a City: Review of Technology Serving City Needs." *International Journal of Applied Earth Observation and Geoinformation* 114: 102915. doi:10.1016/j.jag.2022.102915.

Ministry of Land, Infrastructure, Transport and Tourism. 2024. "Project PLATEAU." https://www.mlit.go.jp/report/press/content/001742070.pdf (July 26, 2024).

Ministry of Land, Infrastructure, Transport and Tourism. "Project PLATEAU Website." *Project PLATEAU*. https://www.mlit.go.jp/plateau/about/ (July 26, 2024).

Müller, Jurek, and Stephan Haller. 2023. "The Struggle for Public Values at the Heart of Public Value Creation." In *European Academy of Management (EURAM)*, Dublin. 10.24451/arbor.20162.

Papyshev, Gleb, and Masaru Yarime. 2021. "Exploring City Digital Twins as Policy Tools: A Task-Based Approach to Generating Synthetic Data on Urban Mobility." *Data & Policy* 3: e16. doi:10.1017/dap.2021.17.

Seto, T., T. Furuhashi, and Y. Uchiyama. 2023. "Role of 3d City Model Data as Open Digital Commons: A Case Study of Openness in JAPAN'S Digital Twin 'PROJECT PLATEAU.'" *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 48: 201–8. doi:10.5194/isprs-archives-XLVIII-4-W7-2023-201-2023.

Appendix A Reasons for/against smart city activities

The following reasons were given why their municipality **didn't have any smart city plans**:

"Lack of human resources, budget, etc."
"We haven't considered it."
"Budgetary issues"
"They don't seem to feel much of a need for planning."
"Prior to smart cities, we are working on initiatives such as promoting online procedures, digitizing contact points, and building a system to promote smart municipalities based on the philosophy of local government DX."
"We are formulating a concept that draws out the basic principles with reference to the Smart City Guidebook."
"I don't know."
"I think it's because it's a low priority that needs to be budgeted for (before we can make it a surveillance society, we need to build infrastructure that hasn't been developed and maintained in time)."
"We are not well equipped to consider plans for smart cities."
"I don't have the financial resources"
"We don't think it's irrelevant, we are working to improve our services and develop human resources based on our digitalization plan, and we are also considering initiatives that will lead to smart cities as we consider improving our services."
"We are keeping a close eye on the situation in other cities."

The following reasons were given regarding the **motivation to engage in smart city activities**:

"To maximize and accelerate the return on investment in the development of public spaces in urban regeneration."

"In order to promote sustainable urban development in response to important social changes expected in the future."

"Population decline"

"Solving Local Issues"

"In order to promote efficient and effective urban development, we believe that it is necessary to work through public-private partnerships while utilizing urban planning data (open data) held by the city."

"One of our priority initiatives is the realization of Society 5.0 and sustainable local communities, and we aim to solve complex issues in cities and regions while utilizing advanced technologies such as AI and IoT."

"To solve social issues such as lack of mobility in the central urban area, population decline and aging, and increase in vacant stores"

"Social demands"

"When working on community development, it is easier to share issues and measures by visualizing explanations to local residents."

"Regional revitalization. To respond to the progress of an aging society with a declining birthrate. "

"In order to realize a smart city by combining the convenience of the city as a city and the richness of the region and building a sustainable environment, society, and economy by ensuring the sustainability of each service even in the face of a declining population, and allowing each citizen to use services that meet their own needs."

"[…] we will consider new transportation networks (primary transportation) […] as well as public transportation (secondary transportation) that makes use of local living bases and tourism resources, and promote the maintenance and improvement of regional transportation and the development of sustainable urban development.
Regional Issues
・Initiatives for sustainable development in mountainous areas where the population is declining and aging, and improving the attractiveness of each base
・It is necessary to consider the effects of the development of transportation infrastructure in terms of strengthening the functions of secondary transportation.
Vision for the future
・Through autonomous driving technology and the creation of new bases, the company aims to spread the effects of the development of wide-area transportation […] to the entire city and realize an integrated urban structure with a multi-base network."[5]

[5] Note: references to concrete locations were removed from this quote for anonymization purposes.

Appendix B Reasons for/against digital twin activities

The following reasons were given why their municipality **didn't have any digital twin activities**:

"We haven't considered it."
"It requires a lot of money to prepare the underlying data, and it is difficult to show a clear effect."
"It is difficult to secure a budget for building a 3D city model to take advantage of the plateau because it costs a lot of money."
"I don't know anything about digital twins."
"This is probably because it costs a lot of money not only to install the equipment to build the 3D model, but also to improve the operating environment, and it is difficult to understand the cost-effectiveness at present."
"I don't have the financial resources"
"There are issues that can be considered for utilization, but first we need to absorb the efforts based on the digitalization plan."
"There is no state in which it can be used at this time."
"We believe that the cities where digital twins are most effective are overcrowded cities with three-dimensional urban structures, but in this city there are only a limited area with multi-storey structures. As for the cost of maintaining and managing 3D city models, it is felt that it is not cost-effective compared to the areas where it can be used at present. "
"We don't have enough finances or staff."

The following reasons were given regarding the **motivation to engage in digital twin activities**:

"We will accelerate land use by building a system that can provide the data acquired by the city as basic data, and by allowing each land user entity to easily conduct simulations and other design and design studies."

" As the digitalization of society progresses, urban infrastructure that can integrate and visualize urban information is necessary to promote urban development in cooperation with not only the government but also private companies and residents.

In addition, in the field of autonomous driving services, the company aims to take a step up in the implementation of autonomous driving services by taking advantage of the advantages of digital twins and examining various driving conditions and vehicle parameters that can be realized in a virtual environment based on the results of simulations that have been repeated through trial and error, in response to issues in terms of safety assurance and actual operability, which have been highlighted in previous initiatives. "

"To enable data visualization, analysis, and spatial analysis in urban planning and disaster prevention"

"For the formulation of a disaster prevention-resilient urban development plan"

"Revision of the Urban Planning Master Plan"

"With the aim of realizing a sophisticated fusion of physical space and cyberspace, we aim to improve urban planning and simulate and analyze urban activities."

"We would like to reduce costs by utilizing the government's subsidy system and updating the basic urban planning map (topographic map) in an integrated manner in line with the development of 3D city models and open data, and in the future, we will use it for solving various issues and formulating data-based policies, and by providing visual and easy-to-understand urban planning information to the public, we hope to lead to participatory urban development."

"To be used for urban development in the central city area and disaster prevention and mitigation measures by visualizing disaster risks"

"For the study of slope land regeneration and urban development against flood risk"

"To digitally integrate various data and conduct business efficiently and effectively to effectively support the safe, secure, and prosperous lives of citizens."

"To take advantage of the 3D city model"

"Because it was adopted as a project under the direct control of the national government as an initiative to develop use cases that solve social issues."

"In order to share information with local residents about what kind of cityscape will change depending on the current situation and measures in the promotion of urban development."

"Improvement of mobility and creation of liveliness in the city center of [...] City.

To aim for the resolution of regional issues and the growth of the local economy through the creation of open innovation. "

Appendix C Use cases requiring 3D

The following answers were given when asking **which use cases required a 3D model**:

"Cases where the building has a complex structure that extends to high-rise or underground, cases where there is a lot of traffic of people and vehicles, and cases where the environment has a special climate, etc."

"Urban Planning, Disaster Prevention"

"We believe that it is necessary for areas that have been flooded many times in history and are expected to be affected by disasters."

"I don't think it's necessary (except for things that are specific to 3D city models)."

"Use cases that make it easy for residents to participate (visualization of traffic volume, flow of people, disasters, etc.)"

"In this city, we are first developing a 3D visualization of disaster information (river inundation)."

"Improving the efficiency of maintenance and management and saving labor by developing a digital infrastructure ledger"

"Since the purpose of the 3D city model in our city is to regenerate slopes and create a city that responds to flood risk, we recognize that height data that can only be expressed in 3D, such as topography, slope, and inundation depth, is effective."

"I don't know"

"Examination and Explanation of Residents at the Time of Construction of Huge Structures"

"It is considered necessary for use cases such as disaster prevention and crime prevention, infrastructure management, etc."

"We will share with residents what kind of changes the city will make as a result of the measures."

"The results of use are as follows
- Use as a tool for community development with resident participation ([…] City)
- Use as a disaster prevention education tool (educational institutions)"

Appendix D Gaps and additional comments

The following answers were given when asking about **gaps between the development goals and requirements of their respective city compared to what current technology is offering**:

"I feel that there are still many areas that are not within the capabilities of humans, and human correction and prediction must be intervened (e.g., autonomous driving, sensor accuracy, etc.)"

"It will be implemented in the future."

"It uses an urban operating system, which is considered to be the de facto standard, but it is not cost-efficient and the number of engineers who can handle it is limited, so it is doubtful whether it is really a widespread technology."

"I feel that we do not have a system (human resources, software, operation methods) that can fully utilize technology."

"Cost-effectiveness unknown"

"Feel [that there are gaps]"

"As for how to use the technology (3D city model), we would like to use it in the tourism field, but it has not been concrete, so it is difficult to answer this question."

"I don't feel anything special in the field of urban planning."

"I feel like there's a gap, but I think it's inevitable that rural areas can't keep up with the technology that's advancing by metropolitan standards, because the situation is different."

"It feels like what current technology is offering is sporadic and not something that can be synergized to organically form a smart city."

"Many new technologies are designed to make them more convenient and dense in densely populated areas, and it is difficult to achieve cost-effectiveness unless the population size is constant. I feel that technological innovation is still necessary to mature into a model that can be introduced inexpensively and easily to use even in rural areas where the population is declining significantly. "

"We have not yet been able to build a cooperative system with private companies for the horizontal deployment of smart city model cases and realize autonomous operation. Regarding 3D city models, we believe that it is necessary to first foster understanding of 3D city models by citizens and companies."

The following answers were given when asking about **additional comments**:

"We don't have staff with specialized knowledge, so we don't have a lot of people to develop it."

"Even though the technology is advanced, there is no operating environment to use it, so even if you receive training, there is no environment where you can put it into practice."

"It seems to me that a lot of what current technology offers is aimed at novelty, and I would like to see the good use of withered technologies in other fields."

"There is nothing better than making the world more convenient through ICT."