Roadmap for Applications of Digital Twin Technology as a Social Infrastructure

March 2024 Third Edition

(Summary Version)

Tokyo Metropolitan Government Digital Twin Project

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0. Introduction

The Japanese government has proposed "Society 5.0," a human-centered society that uses cutting-edge technology to achieve both economic development and solutions to social issues. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has been working on the realization of a "super-smart society.

As part of this effort, MLIT is working on the development and open data creation of 3D city models nationwide under the Urban Digital Transformation (DX) project for urban development titled "Project PLATEAU.

The Tokyo Metropolitan Government, while aligning its vector with the efforts of the national government, has set forth the "Promotion of Digital Twin to Support the Realization of Smart Tokyo" in the "Smart Tokyo Implementation Strategy" released in February 2020. In FY2020, the "Tokyo 3D Visualization Demonstration Project" will be implemented as a related project, and in FY2021, as the "Tokyo Digital Twin Project" a "Study Group for the Social Implementation of the Urban Digital Twin in Tokyo" (see below), consisting of experts, will be established to accelerate the social implementation of the urban digital twin. In FY2021, the "Tokyo Digital Twin Project" established the "Study Group for the Social Implementation of 'Urban Digital Twin' in Tokyo" (hereinafter referred to as the "Study Group"), consisting of experts, to accelerate social implementation of urban digital twin. Based on a total of four discussions on the desirable way to proceed with the construction of an urban digital twin, a "Roadmap for the Social Implementation of a Digital Twin (hereinafter referred to as the "Roadmap")" (first edition) was created. From FY2022, as the " Tokyo Digital Twin Project " in addition to the above efforts, the Tokyo Metropolitan Government will launch the "Tokyo Digital Twin Project" to consolidate and utilize geospatial data and various types of 3D data within the Tokyo Metropolitan Government. In addition to the above efforts, since FY2022, the Tokyo Digital Twin Project " has promoted the construction and operation of a data linkage infrastructure for the aggregation and utilization of geospatial data and various 3D data within the Agency, and has additionally undertaken projects related to the acquisition and maintenance of point cloud data and its utilization. Regarding this roadmap, a clear definition of "Digital Twin" did not necessarily exist when the first edition was formulated in FY2021, the concept of "Urban Digital Twin" within it, the components of the digital twin project to be implemented by the Tokyo Metropolitan Government and steps toward its realization, and areas of utilization aiming at 2030, The Tokyo Metropolitan Government's approach was compiled and presented. The second edition of the report follows the contents of the first edition, and adds the concept of digital twin and classification by scale, as well as additional information on the scope of Tokyo's efforts, policies for short-, medium-, and long-term initiatives, and the significance of open administrative data.

The third edition of the report clarifies the scope of urban digital twin initiatives, based on the discussions at the study groups and overseas examples studied, and reorganizes the significance of urban digital twin, the steps to realization, three key elements of the initiatives, and implementation items, and clarifies the immediate project policy The roadmap also clarifies the immediate project policy and future steps toward the realization of the digital twin. In the future, we will build a cooperative framework across organizations and fields to implement the contents described in this roadmap and promote the realization of the digital twin. The purpose of this document is to communicate these steps in an easy-to-understand manner to the citizens of Tokyo and the private sector.

1. Concept of the Digital Twin

1.1. What is the Digital Twin?

▼Reproduce physical space in cyber space to build and utilize "twins“.

As shown in Figure 1-1, a digital twin is a cyberspace (virtual space on a computer or computer network) that reproduces various elements like buildings, roads and other infrastructure, economic activities, and human flows as "twins" based on data acquired from sensors and other sources.

Based on real-time data obtained from activities in various fields in physical space (real space), advanced analysis and simulation are performed in cyber space (virtual space), and the results are fed back to physical space in a high-speed and interactive manner. Utilization of the digital twin refers to the state in which this continuous loop is realized.

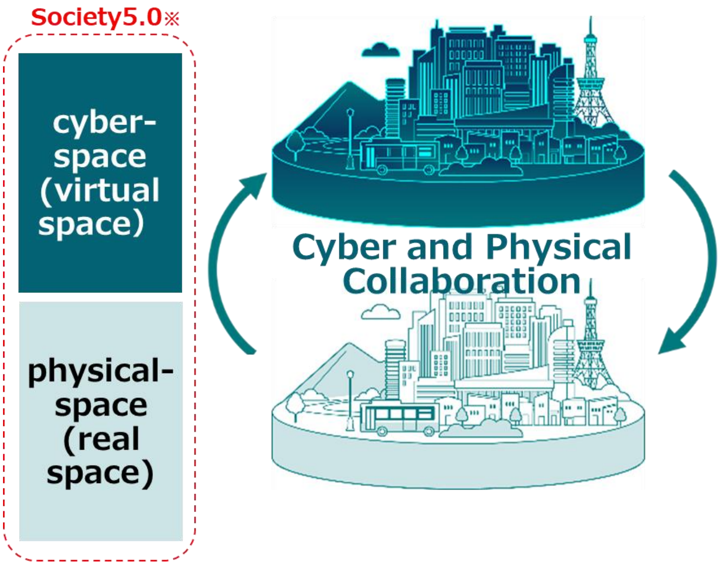


Figure 1-1 What is the Digital Twin?

▼Urban digital twin built primarily to solve urban issues

Digital twins exist on various scales, depending on their purpose and target. The Tokyo Metropolitan Government's "Urban Digital Twin" project has as its main objective solving city problems and improving services for residents.

Narrow area/ detailed

Digital Twin scales

Wide range

	image	Scope of the Digital Twin	Main purpose of digital twin
Manufacturing Digital Twin		Material procurement, Product design, ,Production lines, Entire plants, etc. (automobiles, aero engines, etc.)	■ **Consideration of optimal production line in factory** **Example:** Plan the manufacturing process of automobiles, etc. on a digital twin to achieve smooth operations (Germany, SIEMENS)
Digital Twin for the Construction		Entire high-rise buildings and structures, travel routes for heavy machinery, etc.	■ **Shortening construction time, improving quality, and preventive measures** **Example:** Building wind simulation to evaluate the impact on the surrounding environment and digitalize the construction process to manage progress (KAJIMA CORPORATION)
Area Digital Twin		Entire areas (city blocks, smart cities, airports, ports, etc.)	■ **Grasp the environment within a certain area and examine measures for management** **Example :** Visualization of real-time passenger movement, logistics, and flight schedules for decision-making and collaboration among passengers, aircraft, etc. to improve the efficiency of airport operations (Vancouver International Airport)
Urban Digital Twin		**whole city**	■ **Solving city-wide problems and improving services for residents** **Example:** Visualization of wind direction, sunshine hours, and shade, and visualization of the effects of measures to increase awareness of energy use (Finland)

Figure 1-2　Digital Twin Scale

Source:
SIEMENS ”Digital Twin Production in the Automotive Industry”
https://new.siemens.com/jp/ja/markets/automotive-manufacturing/digital-twin-production.html (1/30/2024)
KAJIMA CORPORATION ”First in Japan! Achieving “Digital Twin” using BIM in all phases of a building”
https://www.kajima.co.jp/news/press/202005/11a1-j.htm　(1/30/2024)
SHIMIZU CORPORATION ”Digital Twin” https://www.shimz.co.jp/toyosu/concept/digitaltwin/　(1/30/2024)
Vancouver International Airport「Introducing our digital twin」, https://www.yvr.ca/en/blog/2022/yvr-digital-twin-launch (2024/1/30)

1.2. What is Urban Digital Twin?

▼There are three stages of the digital twin

According to a study by Werner Kritzinger et al. there are three stages of the digital twin.

The first stage is called a digital model, in which the interconversion between existing physical objects and the virtual space that represents them is done in a manual way. In the urban digital twin, this is the state in which historical data already in possession (e.g., reproduction of human flow data) is reproduced on a 3D city.

The second stage is called digital shadow, in which there is a one-way data flow that automatically converts physical objects into digital objects.

The third stage is the digital twin, where physical and digital objects are fully integrated in both directions, and changes in each object are automatically reflected in the other. The third stage of urban digital twin is positioned by the Cabinet Office and other organizations as the future society that is being pursued as "Society 5.0".

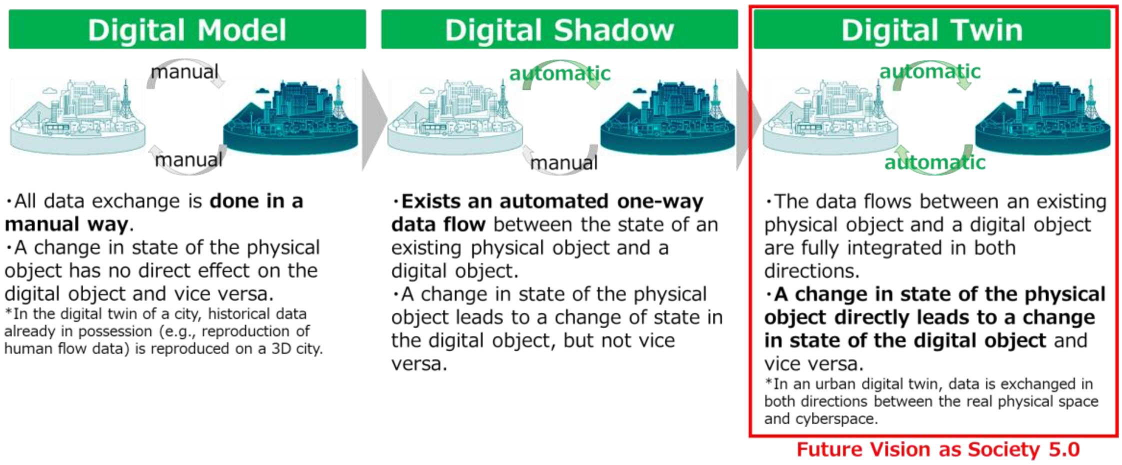


Figure 1-3 Three stages of the digital twin

Source:
Ministry of Land, Infrastructure, Transport and Tourism "Third Study Group on a New Urban Transportation Research System" https://www.mlit.go.jp/toshi/tosiko/content/001463899.pdf (1/30/2024)
Werner Kritzinger et al. "Digital twin in manufacturing: a review and categorization of the literature by category" https://www.sciencedirect.com/science/article/pii/S2405896318316021 (1/30/2024)
Figure is prepared by the Secretariat with reference to the source.

▼Initiatives related to the Urban Digital Twin are underway in many countries around the world.

There are examples of companies around the world that are using the digital twin to solve problems. In particular, the following examples can be seen in developed countries.

In Australia, digital 3D models of cities are being built by the national science agency CSIRO, and real-time traffic congestion forecasting, management, and simulation is being conducted by the New South Wales Department of Transport. Infrastructure is also maintained by the state government agency Roads and Maritime Services (RMS) using a multitude of sensors. In addition, the state's Department of the Environment is using air pollution (index: OEH NSW Air Quality Index) monitoring as a countermeasure to wildfires and to disseminate health advice.

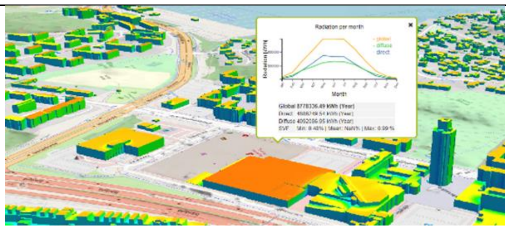
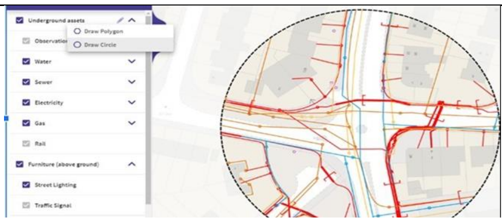
In Finland, a government-led project is being implemented to digitize cities against the backdrop of BIM utilization in the private sector. In Helsinki, the city is building a 3D city model, creating and publishing a viewer, and creating open data in the Kalasatama area of the city. The city of Helsinki is developing an analysis function for wind environment, amount of sunlight, shadows of buildings, etc. as a platform for the modeling of the city.

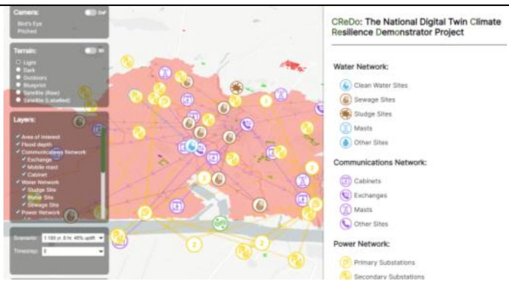
In Singapore, the Singapore Land Authority (SLA) has established One map 3D, a platform that provides geospatial information of roads and buildings, land ownership, nearest schools, and demographic data of the location/neighborhood, etc. One map 3D's functions include flight path planning for drones, One map 3D's functions include planning of drone flight paths, visualization of information such as bus stop waiting times, etc. In the United Kingdom, the National Underground Asset Register (NUAR) is being developed by the government (Geospatial Commission) to design a map information infrastructure for underground infrastructure owners to securely share existing underground asset data with authorized users (telecommunications, electricity, gas, water, sewerage, local governments, etc.). The NUAR (National Underground Asset Register) is being developed by the Administration (Geospatial Commission). This is intended to provide map information and data necessary for the planning and implementation of underground excavation, and to facilitate smooth communication. In addition, the Climate Resilience Demonstrator (CReDo) developed by Connected Places Catapult is being used to simulate the resilience of critical infrastructure assets such as energy, water, and communications on digital maps.

In South Korea, a 3D map is being developed for the entire city of Seoul, and a viewer with superimposition and street view functions for construction and traffic information, etc. is being developed. Visualization of wind direction and fire spread simulation results are being used to counter the heat island phenomenon.

In the Netherlands, a 3D city model, Rotterdam 3D, is being built by the city of Rotterdam to optimize and enhance various aspects of urban life, including energy consumption analysis, underground infrastructure asset management, urban flooding applications, mobility and healthcare systems, and other applications to optimize and enhance various aspects of urban life, such as energy consumption analysis, underground infrastructure asset management, urban flooding applications, mobility and medical systems.

In Canada, a digital city model has been created in Toronto by MetaworldX, a private company, to collect data on infrastructure related to water pipes, waste, and transportation, including drinking water, wastewater, and storm water, on IoT sensors and monitor it in real time on a digital map.

 Australia(New South Wales) Forecasting traffic congestion, identifying air pollution caused by wildfires, etc.	 Finland (Helsinki) Decision-making on environmental policies
 Singapore Platform for urban development and infrastructure management	 United Kingdom(ENG & WAL all areas) Secure sharing of underground infrastructure information
 South Korea(Seoul) Traffic management, crime prevention, etc.	 Netherlands(Rotterdam) Reflect and manage underground infrastructure on a 3D model



United Kingdom

Simulation of the impact on infrastructure due to disasters

Canada(Toronto)

Monitoring of infrastructure through IoT sensors

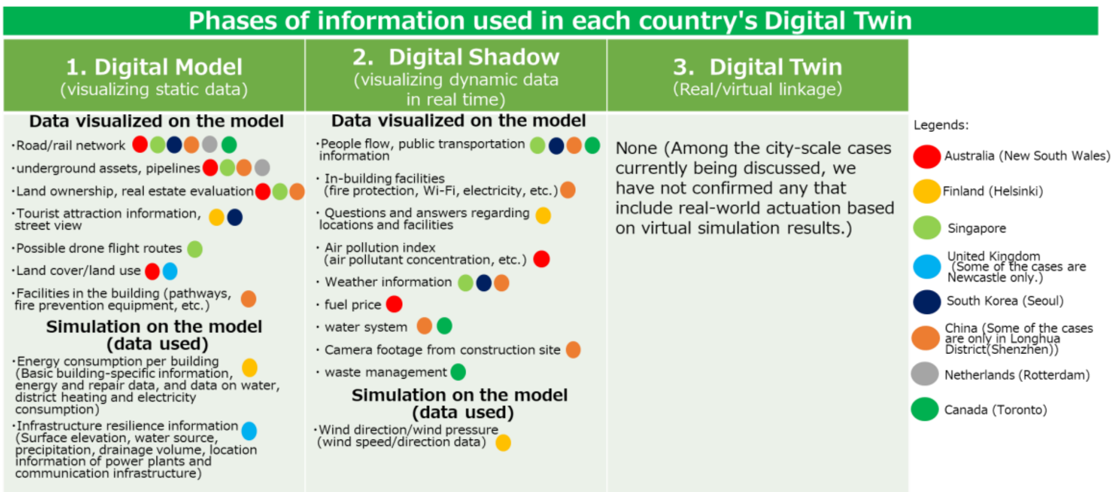
Figure 1-4 Examples of advanced initiatives related to the "urban digital twin" in other countries

Source: Written in Appendix 1

1.3. Urban Digital Twins in each country

▼Digital twin in foreign cities is a digital model - shadow stage

In terms of digital twin initiatives in overseas cities, the digital model stage, which involves visualization of static data such as road and rail networks, underground assets, and real estate information, is currently the most common. In some cities, examples of the digital shadow stage, which involves visualization and automation of dynamic data such as People flow, public transportation, and weather information, have also been observed, but it is estimated that there have been no city-scale efforts to build a digital twin that links the real and virtual.



※The TMG estimated from each city's published sources based on the definition on Fig.1-3.

Figure 1-5 Stages of information used in digital twin initiatives in other cities

1.4. Urban Digital Twin in Tokyo

▼Based on examples from overseas cities, the three main pillars in the digital twins are defined as "data preparation," "data visualization," and "data analysis".

Based on examples from overseas cities, three main pillars in the digital twins can be defined as "Data accumulation," "Data visualization," and "Data analytics".

"Data accumulation" refers to the maintenance and consolidation of geospatial information handled on the digital twin, such as 3D digital maps, point cloud data, and GIS data. "Data visualization" refers to the use of visualization systems, such as 3D viewers, to intuitively grasp geospatial information and the results of analysis by the various bureaus. "Data analytics" refers to the use of various applications and simulators to analyze the data on the digital twin and utilize it in policies.

Figure 1-6 three main pillars in digital twins

Source:
Walter Lohman, Hans Cornelissen, Jeroen Borst, Ralph Klerkx , Yashar Araghi, Erwin Walraven「Building digital twins of cities using the Inter Model Broker framework」,
Future Generation Computer Systems,Volume 148, 2023, Pages 501-513, ISSN 0167 739X
https://www.sciencedirect.com/science/article/pii/S0167739X23002455 (2024/1/30)

▼Data Integration Platform of Tokyo Metropolitan Government will play the role of data accumulation and data visualization, leading to data analysis and utilization in each of the Agency's projects.

Assumed roles in the realization of the three pillars of the city's digital twin are shown in Figure 1-7. It shows the division of roles in the realization of the three pillars of the Urban digital twin. The Data Integration Platform of Tokyo Metropolitan Government will play the role of data accumulation and data visualization, and will lead to the analysis and utilization of the data implemented in each of the Agency's projects.

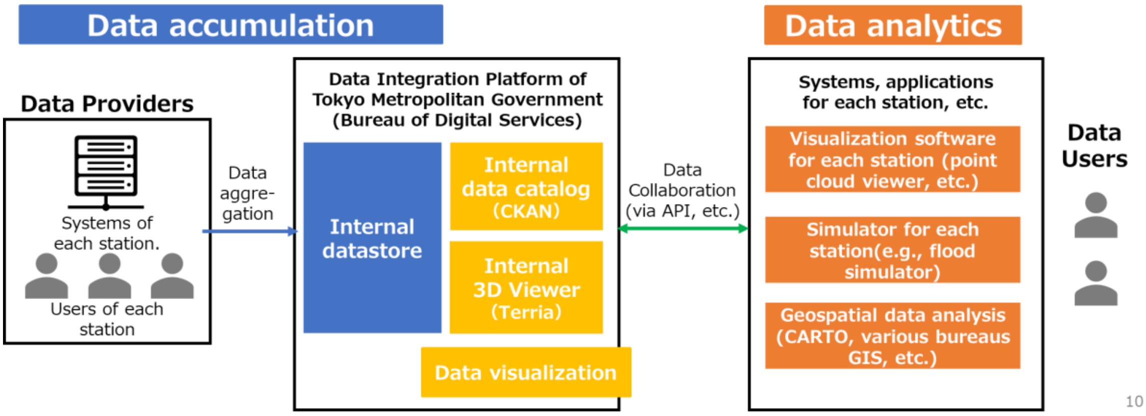


Figure 1-7 Policy for realizing the three main pillars in digital twins

2. Our goal through the Digital Twin

2.1. Significance of working on the Urban Digital Twin

▼Urban digital twin is expected to reduce urban management costs and serve as a comprehensive urban management tool

A study by ABI Research on "Cost Savings from Using the Digital Twin for Urban Planning" states that "Efficient urban planning with the digital twin is expected to save a cumulative US$280 billion worldwide by 2030." (ABI Research, "The Use of Digital Twins"). (Translated from ABI Research, "The Use of Digital Twins for Urban Planning to Yield US$28 Billion in Cost Savings By 2030, https://www.abiresearch.com/press/use-digital-twins-urban-planning-yield-us280-billion-cost-savings-2030/)

▼Aiming to resolve urban issues facing Tokyo by developing digital social infrastructure and promoting ongoing initiatives.

The promotion of digital twin is "to develop a digital social infrastructure to solve urban issues," and it is significant for the Tokyo Metropolitan Government, which faces a variety of urban issues. Gartner Hype Cycle For Digital Government Technology, 2019"), the digital twin in public administration will be in its innovation trigger as of 2019 and is expected to reach a stable period of productivity in 5-10 years. By positioning the digital twin as part of Tokyo's long-term strategy and promoting it on an ongoing basis, it is thought that it can be used as a digital social infrastructure to solve urban issues in the future.

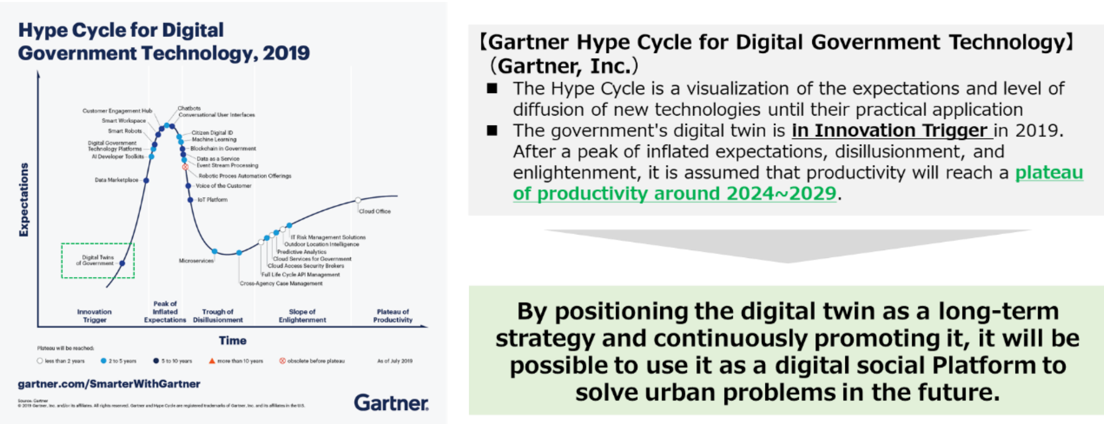


Figure 2-1 Objectives for Digital Twin

Source: Gartner "Top Trends From Gartner Hype Cycle For Digital Government Technology 2019"
https://www.gartner.com/smarterwithgartner/top-trends-from-gartner-hype-cycle-for-digital-government-technology-2019 (1/30/2024)

▼Data and technology are still in the process of development, and efforts must be made from a long-term perspective to realize the urban digital twin.

The "number of years required for mainstream adoption" in the "Hype Cycle of Future-Oriented Infrastructure Technologies in Japan" shows that while some technologies have approached the 2-5 year mark and others have fallen outside the scope of the Hype Cycle, Digital Twin has remained unchanged at 5-10 years. "10 years," while some technologies are approaching "2 to 5 years" and others are no longer subject to the hype cycle. This confirms that the speed of progress of digital twin technology is slow, and that it is still in the process of medium- to long-term initiatives.

2.2. Significance of Tokyo Metropolitan Government's Urban Digital Twin Approach

▼Implement initiatives aimed at resolving various urban issues faced by the Tokyo.

An important objective of the digital twin promotion is to solve urban issues by utilizing digital twin technology, which in turn improves the QOS of the metropolitan government and the quality of life of the citizens.

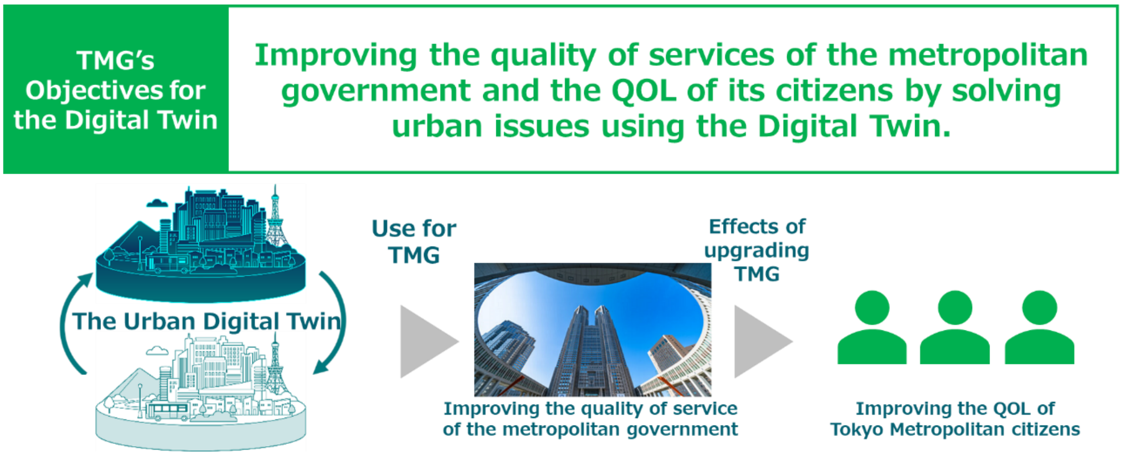


Figure 2-2 Tokyo Metropolitan Government's Objectives for the Digital Twin

▼Improvement of the quality of life of the citizens through the use of digital technology such as the Digital Twin is positioned as a long-term strategy of the Tokyo Metropolitan Government.

The promotion of the digital twin has been clearly positioned in the long-term strategy formulated by the Tokyo Metropolitan Government to date.

In "The 'Future Tokyo' Strategy" released in March 2021, the concept of a digital twin was positioned for the first time as "building a public-private partnership data platform that enables the aggregation and coordination of various data while building consensus among Tokyo residents, private businesses, etc., and promoting the development and deployment of new services using the data to realize a digital twin through the fusion of cyberspace and physical space. The concept of a digital twin was positioned for the first time as "the realization of a digital twin through the fusion of cyberspace and physical space by promoting the development and deployment of new services utilizing data.

In "The 'Future Tokyo' Strategy version up 2022," released in February 2022, the Agency stated that it would accelerate the development of the infrastructure for the realization of a digital twin, including the development of 3D topographic data, the basis of the digital twin, throughout the metropolitan area, the prior use of such data in disaster prevention, and the promotion of efforts toward the full-scale operation of the Tokyo Data Platform. The "Digital Twin" strategy will accelerate the development of the infrastructure for the realization of the Digital Twin.

In "The 'Future Tokyo' Strategy version up 2023" released in January 2023, it was stated that the Agency will promote the expansion of the effective use of the digital twin, including the promotion of the expansion of the use of the digital twin and the implementation of advanced policy formation through the digital twin.

In addition, "The 'Future Tokyo' Strategy version up 2024," released in January 2024, positions digital twin initiatives in the promotion of urban implementation of cross-sectoral services, such as expanding the use of the digital twin data collaboration platform and the development of 3D geospatial data, as well as actions such as the prior use of digital twin data in the disaster prevention field and the promotion of efforts toward full-scale operation of the Tokyo Data Platform (TDPF).

2.3. How the Tokyo Metropolitan Government's Digital Twin Will Work by 2030

▼Studying the digital twin for the year 2030. Establish a Platform for future use of the digital twin.

The digital twin that the Tokyo Metropolitan Government aims to realize by 2030 is defined as "a state in which 3D city models and interfaces will be developed and continuously updated, and a variable system will be established in which "some" data of cities in all subject areas can be used to make decisions for the metropolitan government, businesses, and citizens, and to formulate policies for the metropolitan government, with a variable nature"**.** The goal is to expand the use of the digital twin in 2030, both in terms of the users (Agency, Companies, Citizens of Tokyo) and in terms of the fields where the digital twin is expected to be used, and to use the digital twin in the targeted focus areas. In addition, for the 3D urban models and interfaces of the digital twin, a mechanism will be established to ensure variability and continuous updating.

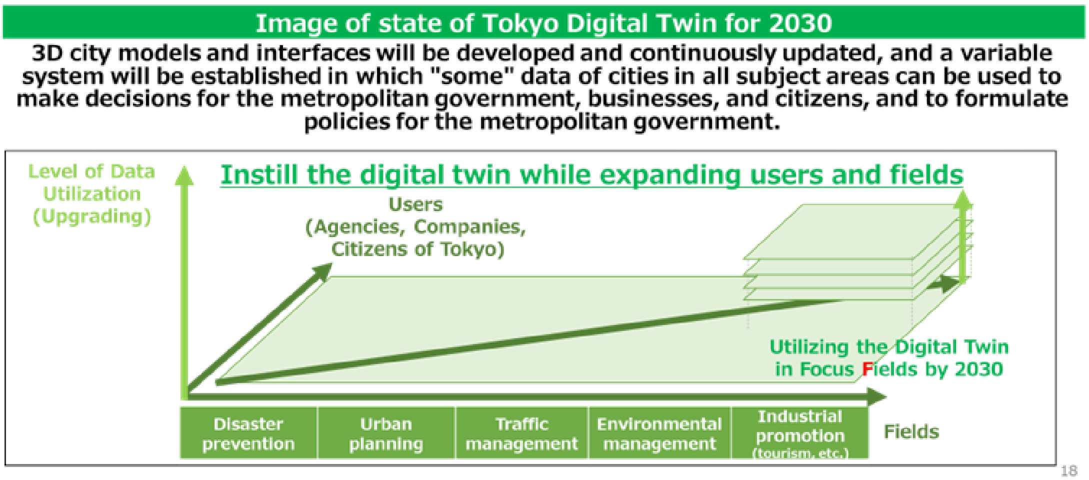


Figure 2-3 Image of State of Tokyo Digital Twin that aims to realize

2.4. Digital Twin's immediate business policy

▼Digital twin promotion for short-, medium-, and long-term use cases

In the promotion of Digital Twin in TMG, a clear distinction will be made between initiatives for short-term use cases and medium- and long-term use cases. Short-term use case initiatives assume use cases that can be implemented at this time, and will be studied, developed, and implemented according to the needs of each bureau within the Tokyo Metropolitan Government. On the other hand, the mid- to long-term use case initiatives assume more advanced use cases, and back-cast study and development of the elements necessary to realize the future vision will be carried out.

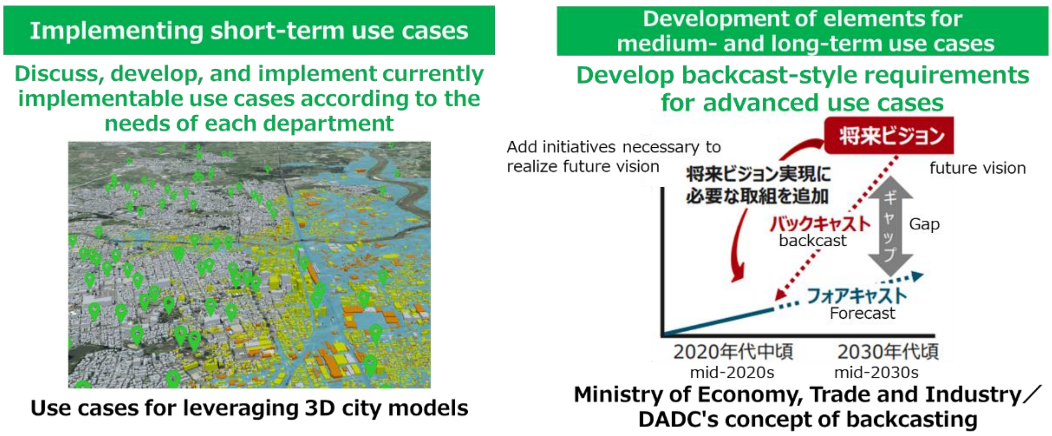


Figure 2-4 Image of digital twin promotion for short-, medium-, and long-

term use cases

Source:

Left figure: PLATEAU “Disaster prevention planning study based on visualization of vertically evacuable buildings, etc.” https://www.mlit.go.jp/plateau/use-case/uc20-012/ (1/30/2024)
Right figure: Ministry of Economy, Trade and Industry/Digital Architecture Design Center “3D spatial information infrastructure architecture design Report” https://www.digital.go.jp/assets/contents/node/basic_page/field_ref_resources/9f4e70e2-2335-4181-8293-258c12549d31/df4f46e8/ 20220927_policies_mobility_report_03.pdf (1/30/2024)

▼Promote efforts to explore needs for utilization of 3D data in the short term and dynamic data in the medium term, and for social implementation.

Short-term use cases are envisioned for data visualization and simulation using 3D Digital Map. For example, in PLATEAU of the Ministry of Land, Infrastructure, Transport and Tourism, simulations of inundation and urban development are being considered as use cases, as shown in Figure 24. In addition, as medium-term use cases, linkage with dynamic data inside and outside the agency and dynamic data acquisition, utilization, and sharing will be explored as useful cases and supported for realization.

▼Creating open innovation through visualization and openness of the government data, etc.

The "Summary of the Council for Realization of Digital Transformation of Urban Development" (https://www.mlit.go.jp/toshi/daisei/toshi_daisei_fr_000050.html) of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) describes cities as "platforms where diverse people, values, goods, information, and data can move back and forth. The report states, "In order to realize Community development DX, it is necessary to further exploit the role of cities as platforms, and to promote the creation of open innovation and its social implementation. The report states. Furthermore, as a keyword for the development of measures to achieve this, Figure 2-5 shows the "three commons" as keywords for the development of measures to achieve this goal.

The Tokyo Metropolitan Government also seeing urban data as a common goods in Town Planning, we aim to jointly manage and operate data by local communities and create innovation by visualizing data on the digital twin and Converting it to open data.

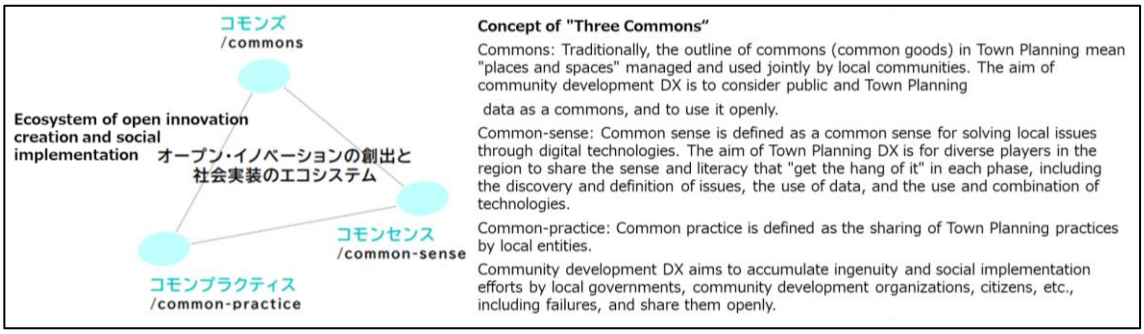


Figure 2-5　Concept of "Three Commons“

Source: Ministry of Land, Infrastructure, Transport and Tourism "Vision for Realization of Digital Transformation of Urban Development (ver1.0)"
https://www.mlit.go.jp/toshi/daisei/toshi_daisei_fr_000050.html (1/30/2024)

▼The elemental technologies of the digital twin that should be implemented will be considered in light of the necessity and cost-effectiveness of each project.

Digital twin is an initiative that requires advanced technology, and care should be taken to ensure that the implementation of elemental technologies is not excessive in relation to the needs. Therefore, it is desirable to consider the elemental technologies of the digital twin to be implemented, considering the necessity and cost-effectiveness of each project. The following are examples of points to be considered.

Regarding the reproduction of real space by 3D maps, aerial survey point cloud data, etc. that complement the 3D digital maps of the Urban Development Bureau have been developed as a common infrastructure, but acquisition and updating of more specific and detailed data will be considered based on necessity.

Regarding the acquisition of real-time data, if sensors are to be installed and maintained to monitor urban activities, the necessity and cost of such sensors and the project effects must be carefully examined, and the utilization of data acquired and maintained by private companies, etc., should also be considered.

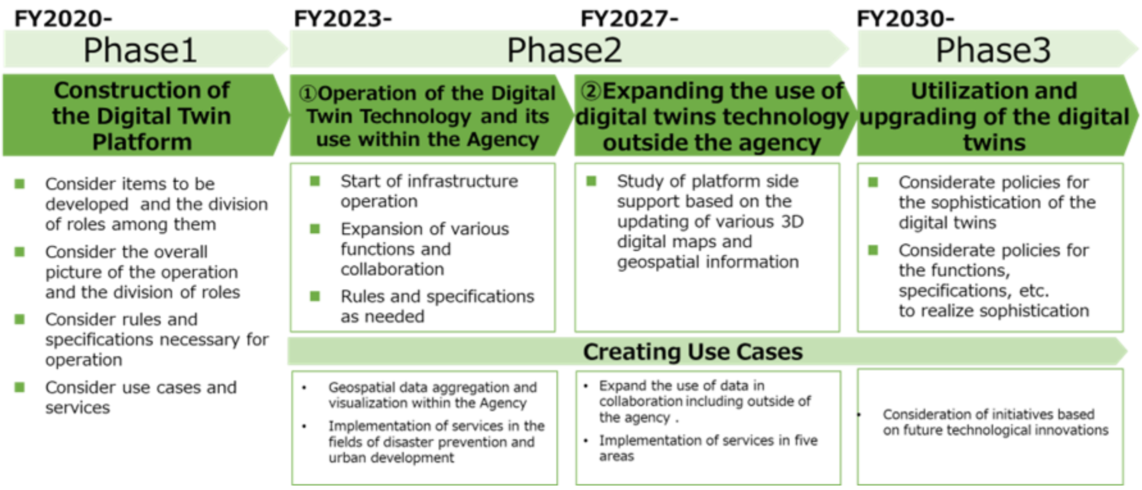
Regarding analysis and simulation, confirm whether real-time visualization and analysis are necessary in the case or whether analysis of static data is meaningful and cost-effective.

Regarding feedback to real space, feedback in the form of automatic control of equipment, etc. (digital twin) is considered to require consideration based on feasibility, scale of implementation, and technological trends.

2.5. Steps to utilize the Digital Twin Technology

▼Supposing three phases to utilize the Digital Twin by 2030.

The "Tokyo Digital Twin" is a digital twin that is being developed by the Tokyo Metropolitan Government. As indicated in Section 2.2.1, TMG aims to realize a digital twin by 2030, and to develop it into a continuous improvement cycle by 2040. Toward the realization of a digital twin, As shown in Figure 2-6, the following three phases will be set up for the realization of the digital twin: " Construction of Digital Twin Platform " phase (Phase 1) starting in FY2020, " Operation of the Digital Twin and its use within the Agency, Expanding the use of digital twins outside the agency " phase (Phase 2) starting in FY2023, and " Realization and upgrading of digital twins " phase (Phase 3) starting in FY2030.



*TDPF:TOKYO DATA PLATFORM

Figure 2-6 Three phases to three phases to utilize the Digital Twin

▼Based on the Platform construction phase, aim to expand operation and utilization, and expand functions.

In Phase 1, which is the phase to build the infrastructure for the Digital Twin, the first step is to establish the Digital Twin infrastructure and data ecosystem so that the Digital Twin can be used in the Agency's internal operations. In this phase, we will initially study and develop the specifications and rules for the construction, operation, and maintenance of the digital twin infrastructure and data ecosystem, and implement use cases and beta projects for service implementation.

In Phase 2, which is the operation, expansion of use, and external linkage of the Digital Twin after the establishment of the Platform, work will be conducted in two phases: operation and utilization within the agency of the Digital Twin, and expansion of use of the Digital Twin. In the operation and internal use phase, functions will be expanded and linked with other bureaus' systems based on the operational status of the infrastructure, and specifications and rules will be added and updated based on trends in operation and the government, etc. Use cases will be created for the consolidation and visualization of geospatial data within the agency and the implementation of services in the disaster prevention and urban planning fields. In the utilization expansion phase, the project will examine how to respond to the updating of various 3D digital maps and geospatial information, implement services in the five fields, and expand the use of data, including outside of the agency.

In Phase 3, the policy for advancement of the digital twin and its functions and specifications will be studied. In terms of the creation of use cases, we will examine approaches based on technological innovations.

The steps in the realization of the digital twin. Figure 2-7 shows the steps in the realization of the digital twin. The strategies required for each phase shall be reviewed and updated, reflecting the opinions of experts at the study group, etc., and shall be revised each time there is a decision or change in policy direction.

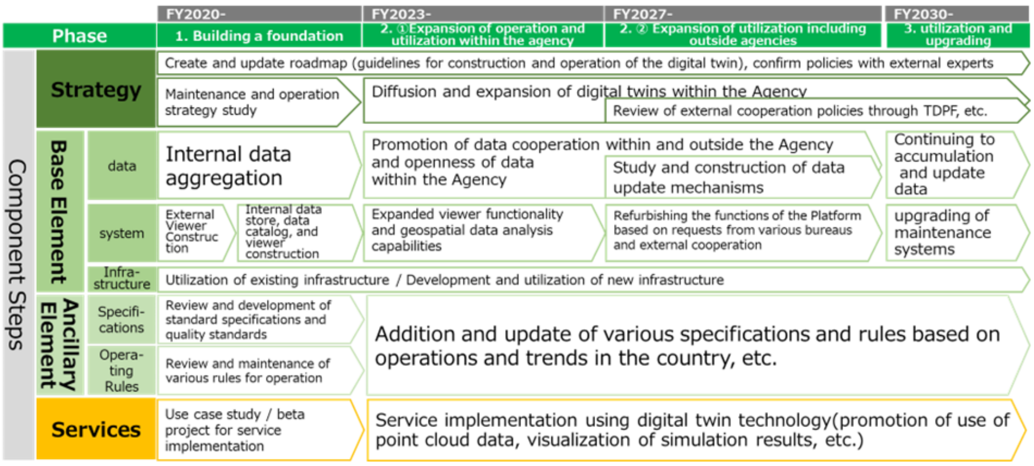


Figure 2-7 Steps to realize Digital Twin

3. Components of the Digital Twin

3.1. Overall Picture of the Digital Twin

▼The digital twin consists of 4 elements: Strategy, Foundational Elements, Ancillary Elements, and Services

Figure 3-1 shows the elements required to realize the digital twin. The digital twin consists of four elements: strategy, base elements, ancillary elements, and services. Each element is not independent of the others, but rather they influence each other. That is why it is important to consider the constraints and influences of other elements appropriately.

The structure of the digital twin was examined by Government of Japan, by referring to the "Smart City Reference Architecture White Paper," which is a result of the "Strategic Innovation Program (SIP) Phase 2: Cyberspace Infrastructure Technology Architecture Development and Demonstration Research Project Using Big Data and AI" by the Cabinet Office.

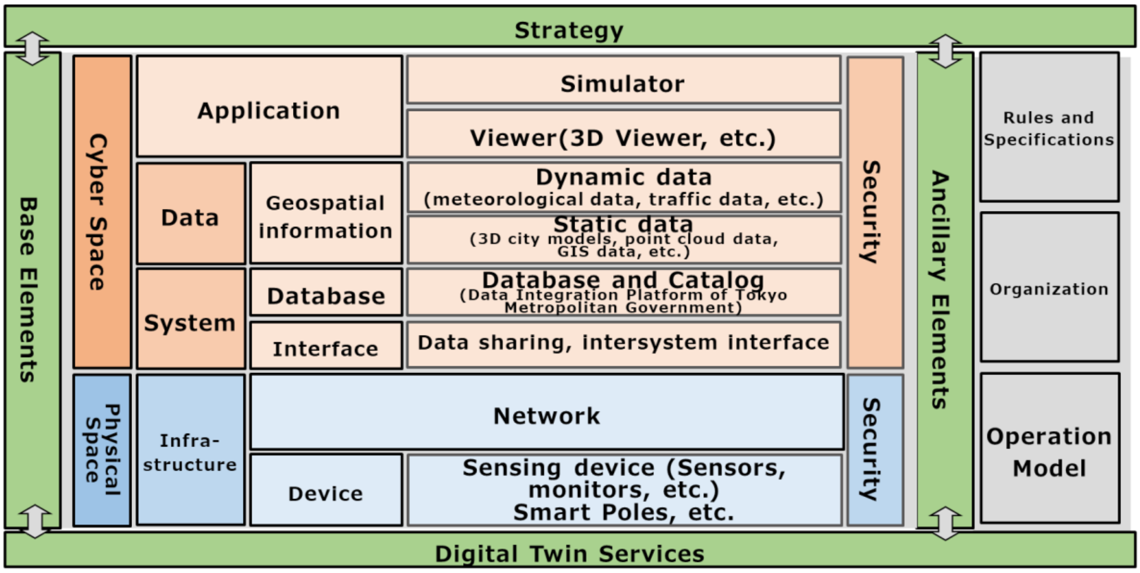


Figure 3-1 Overall verall Picture of the Digital Twin

Source: Cabinet Office "Smart City Reference Architecture White Paper(Japanese version)"
https://www8.cao.go.jp/cstp/stmain/20200318siparchitecture.html (3/1/2022)

3.2. Components of the Digital Twin

▼Data, Systems, Infrastructure, and Security are defined as the fundamental elements of the Digital Twin.

We have decomposed and defined the basic elements of the digital twin into three categories: cyberspace, physical space, and common. Cyber space consists of "data" to be utilized on the digital twin and "systems" that operate on the digital twin. Physical space consists of "infrastructure," which is facilities and equipment for generating and transmitting digital data to be utilized on the digital twin. In addition, "security" is an element that should be provided in both cyber and physical space, and is a necessary function to protect the digital twin from internal and external threats. On Table 3-1 , the components of the digital twin are listed.

Table 3-1 Components of the Digital Twin

Layer	Broad category	Middle category	Description
Cyber space	Application		Various software running on the Digital Twin
	Data		Data body to be utilized on the Digital Twin
		Geospatial information	Data with location information to be utilized on the digital twin
	System		Various systems operating on the Digital Twin
		Database	Environment for storing various data to be utilized on the Digital Twin
		Interface	Functions and APIs to link with each data and each system
Physical space	Infrastructure		Facilities and equipment for generating and transferring data to be utilized on the Digital Twin
		Network	Facilities for transferring digital data
		Device	Sensing device, etc., for acquiring and generating digital data
Common	Security		Functions and measures necessary to protect the Digital Twin from internal and external threats
		Technical measure	Security features that system and infrastructures should have
		Administrative measures	Administrative measures required in the maintenance and operating of the Digital Twin

3.3. Components of Cyber Space

▼Data and Systems are defined as components of Cyber Space.

Cyberspace shall consist of "data" and "systems". The data consists of "data" used for analysis and simulation on the digital twin. Systems consist of "applications" for simulations on the digital twin, "databases" as an environment for storing various data utilized on the digital twin, and "interfaces" for linking with data and systems. Table 3-2 shows the components of cyberspace, and Table 3-3 shows examples of data types handled by the digital twin.

Table 3-2 Components of Cyberspace

Broad category	Middle category	Sub category	Description
Data	Geospatial information	Dynamic data	Data acquired through API linkage, etc. that is continuous over a dynamically changing time axis. Real-time data showing real-time urban conditions with a sufficiently high update frequency, quasi-real-time data with a certain reduction in update frequency due to system problems, etc.
		Static data	Data that is updated relatively infrequently and stored and referenced for long periods of time. Includes map data showing the shape of the city, such as 3D city models and point cloud data.
Application	Application	Simulator	Software for simulation using data
		Viewer	Software for visualizing data
System	Database	Databases and Data Catalog	Environment for aggregating and managing data (internal data Platform)
	Interface	data sharing and intersystem interface	System to system connection

Table 3-3 Example of data

Category	Example	Description
Dynamic data	Sensing data	Data acquired from various sensing devices
	Movement data	Data on movement of people and mobility
	Meteorological data	Data on area weather information
Static data	Topographic map	Map information representing elevation, topography, rivers, coastlines, roads, buildings, etc.

Category	Example	Description
	Aerial image	Photographs taken by aircraft
	Satellite image	Data acquired from satellites
	Network data	Data represented by a combination of “nodes” and “links”
	GIS data	Data that can be used in Geographic Information System
	Point cloud data	3D point data with horizontal coordinate and height information
	3D digital map	Vector data with semantic structure of buildings, roads, and other geographic features
	BIM・CIM	Vector data reproducing detailed components of buildings and infrastructure structure
	Statistics data	Data on various statistics
	Analysis data	Result of data-driven analysis and simulation

3.4. Components of Physical Space

▼Infrastructure is defined as components of physical space.

The infrastructure that constitutes the physical space consists of "sensing devices" for data conversion and "networks" for linking them, with the objective of generating the data necessary to conduct analysis and simulation on the digital twin. Table 3-4 displays the components of the physical space.

Table 3-4 Components of Physical Space

Broad category	Middle category	Sub category	Description
Infrastruc-ture	Network	Short distance network	Network to deliver data generated from devices to repeater equipment
		Repeater equipment	Equipment to receive data generated from each device and transfer the data through long distance network such as Internet
		Long distance network	Network to deliver data from repeater equipment to remote servers, etc.
	Device	Sensing device	Equipment from which data is generated

3.5. Elements common to Cyber and Physical Space

▼Security is defined as a common element of Cyber and Physical Space.

Security refers to the functions and matters needed to protect the digital twin from internal and external threats. There are two types of security measures for a digital twin: those that the components of the digital twin should be equipped with (technical measures) and those that are necessary for operating and managing the digital twin (administrative measures). Table 3-5 shows the requirements of each.

Table 3-5 Security Requirements

Broad category	Middle category	Sub category	Description
Security	Technical measures	Certification	Functions to verify that users, services, systems, devices, etc. connected to the digital twin are the correct connection partners, and to grant access privileges to them
		Encryption	Functions to provide appropriate security encryption for communications and data managed by the digital twin according to each confidentiality
		Unauthorized access prevention (Firewall)	Functions to block unauthorized access to the digital twin
		Unauthorized access detection / blocking	Functions to detect and block unauthorized access that cannot be handled by firewalls, such as DoS attacks and attacks on application layer vulnerabilities
	Administrative measures	Vulnerability management	Collect information on vulnerabilities and apply patches as needed to address them
		Log management	Obtain logs of communications and processes performed by the digital twin

3.6. Digital twin strategies, ancillary elements and services

▼Present elements and ideas on Strategy, Ancillary Elements, and Services.

In realizing the digital twin, it is also necessary to consider three elements: "strategy," which serves as a guideline for designing the digital twin, "ancillary elements" related to operations, and "services." The concepts of these elements are shown in Table 3-6.

Table 3-6 Other Factors

Layer	Category	Factor	Description
Strategy	Strategy		Guideline for designing the foundational elements, ancillary elements, and services of the digital twin
		Target	Goals to be achieved through the realization of the digital twin
		Evaluation index	Quantitative indicators to show the degree of achievement for each goal (KGI, KPI)
Ancillary elements	Operation model		Mechanisms for maintaining and operating the digital twin
	Organization		Entities and roles for the development and operation of the digital twin
		Entities	Entities related to the digital twin
		Roles	Roles of each entity
	Rules and specifications		Rules and specifications required for the maintenance and operation of the digital twin
		Laws and regulations	Laws, regulations, and ordinances to be complied with in the development and operation of the digital twin
		Terms and Guidelines	Rules for the maintenance and operation of the digital twin and terms for the use of data and services
		Standard specifications	Specifications and quality indicators that should be standardized for mutual use of systems, data, etc. among entities
Services	Services		Services provided by using infrastructure elements of the digital twin
		Administrative services	Services provided by the public administration using the infrastructure elements of the digital twin
		Private services	Services provided by private companies and organizations (area

Layer	Category	Factor	Description
			management groups, etc.) using data, systems, etc. that are open to the public by the government

3.7. Ancillary elements

▼Digital twin is operated by linking data among various entities, and the operational model is externally evaluated.

The digital twin of the city maintained and operated by the Tokyo Metropolitan Government, Table 3-7 shows the operational model of the urban digital twin developed and operated by the Tokyo Metropolitan Government. The digital twin shall be operated by data providers, operators, agency users, and service providers and users mutually linking their data. In addition to this, an external evaluation should be conducted by advisors to assess whether the digital twin is operating appropriately.

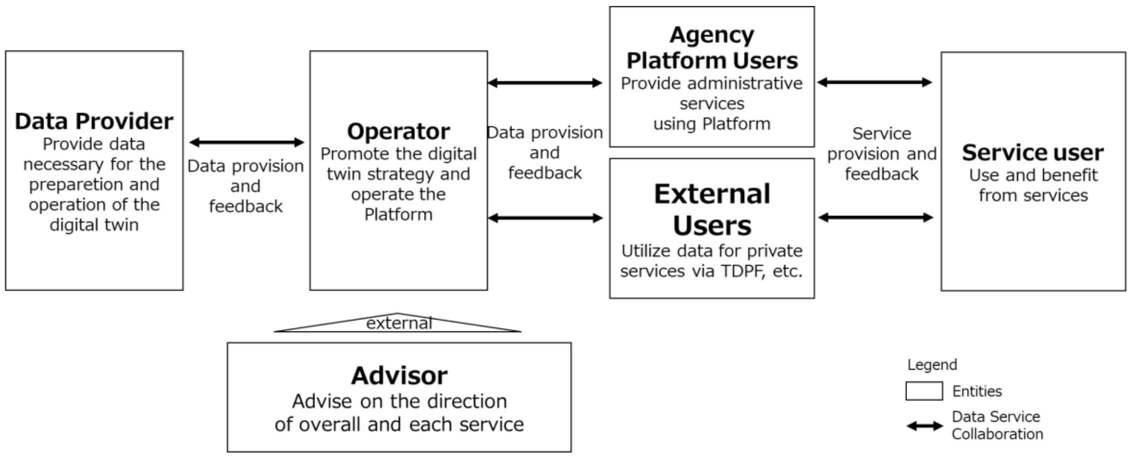


Figure 3-2 Operational model of Digital Twin

▼Six entities are defined as the main actors in the development and operation of the digital twin.

Examples of entities in the operational model of the urban digital twin to be developed by the Tokyo Metropolitan Government are shown in Table 3-7. Table 3-8 shows a detailed description of the roles of each entity in defining and designing the infrastructure requirements. However, the detailed roles of entities other than the "operator," "data provider," and " Agency Platform Users " will be continuously studied in the future. Examples of the roles of each entity are shown in Table 3-8 shows examples of the roles of each entity.

Table 3-7 Entities of Digital Twin (Example)

Entities	Description
Operator	Promote the digital twin and operate the platform (environment where data and systems are aggregated and provided)
Data provider	Maintain and provide data necessary for operation of the digital twin
Agency Platform Users	Provide administrative services using platform Use the data and systems of the digital twin Platform for internal operations
External Users	Use and service the digital twin data via TDPF, etc.
Service users	Use and benefit from the services provided through the digital twin
Advisor	Advice the promoting entities on the operation and direction of each service

Table 3-8 Roles of entities (example)

Entities	Roles	Description
Operator	Supervise overall and develop strategy	Develop and manage the overall strategy for the digital twin Provide overall management for the realization of the digital twin in accordance with the strategy
	Operate and manage organization	Establish and manage the organization of the promotional entity, and coordinate and collaborate with related entities to ensure the smooth operation of the digital twin
	Operate the digital twin infrastructure	Establish and operate the digital twin platform (environment where data are aggregated and provided)
	Review and release of standard specifications	Consider and publish data standard specifications, quality standards, etc.
	Review and public rules	Consider and publish rules and guidelines necessary for the maintenance and operation of the digital twin
Data Provider	Maintain and provide data	Maintain and acquire data and provide it to the digital twin platform
	Develop and operate infrastructure	Develop and operate infrastructure (sensing device, etc.) to acquire data
Internal users and service provider	Develop and operate systems	Develop and operate systems (simulators, etc.) required to provide services
	Develop and operate services	Plan, develop and operate services
Advisor	Advise	Advise on the strategy, operation, and policy of each service of the digital twin

▼Organize examples of items to consider regarding digital twin rules and specifications.

In developing and operating a digital twin and providing various measures and services, it is important to comply with relevant laws and regulations set by the government. Setting appropriate rules for the entities operating the digital twin and related entities, and considering standard specifications to promote mutual use are also needed for this purpose. Examples of items to be considered in the development and operation of the digital twin are listed below in Table 3-10.

Table 3-9 Items to consider for digital twin rules and specifications (Example)

Element	Examples of items
Laws and regulations	Laws and regulations regarding data acquisition and the creation of the digital twins
	Laws and regulations regarding data analysis and simulation
	Laws and regulations regarding the release of data ant the provision of services
Terms and guidelines	Rules for data maintenance and acquisition
	Rules for providing and using data
	Rules for operating the digital twin platform
Standard specification	Standard for Data format
	Standard for data quality
	Specification for the tool and operating rules

4. Implementation Policy for the Digital Twin Components

4.1. Implementation of base elements

▼ Establishment of Data Integration Platform of Tokyo Metropolitan Government to serve as a node for data collaboration in order to consolidate and utilize data with geospatial information within the agency.

Since the Digital Twin is operated by linking data from each entity to each other, a secure environment is required to consolidate data from both inside and outside the Agency and to provide services that utilize such data. Therefore, a "Digital Twin Platform" consisting of an "Internal Data Store" that aggregates and stores data from both internal and external entities, a "Data Catalog" and "Interface" for referencing and using each data, and a "Viewer" for visualizing the data, should be constructed. The positioning of the digital twin platform in the data flow is shown below (Figure 4-1). The digital twin platform will be used as a nodal point to link each type of data.

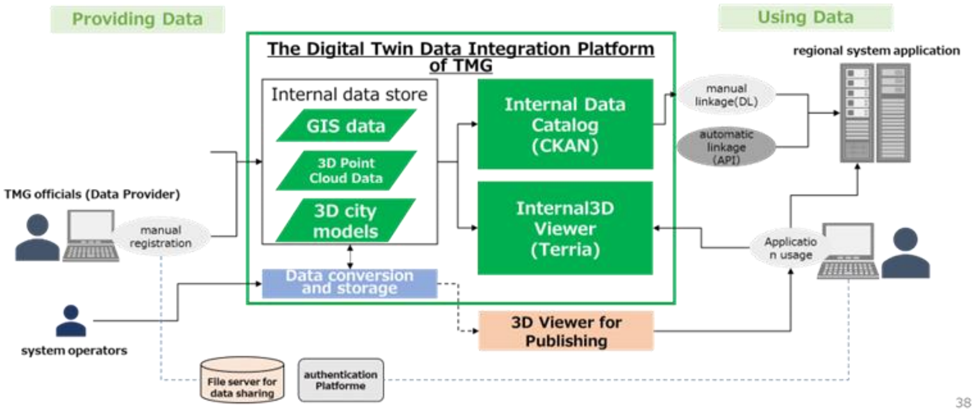


Figure 4-1 The positioning of the digital twin platform in the data flow of the project

▼Supporting data analysis by realizing data preparation and visualization with an Platform

The division of roles in the implementation of the platform elements is in the form of data maintenance and visualization realized by the Digital Twin Data Integration Platform of Tokyo Metropolitan Government, and support for each bureau to conduct analysis using the data.

▼Build a Platform that takes into account functionality, safety, and scalability

In building a digital twin Platform, consider functionality, safety, and scalability. The basic specifications of items to be considered in each of these areas are shown in Table 4-1 shows the basic specifications of items to be considered in each of these areas.

Table 4-1 Basic specifications to consider when building a digital twin Platform

Class	Item		Basic Specifications
① functionality	①-1	Data registration and storage	The Agency will also **consider using the existing internal system** to reduce the burden on The Tokyo Metropolitan Government officials for registration and storage.
	①-2	Data retrieval and extraction	By **introducing a data catalog service**, it will be possible to easily retrieve and extract data.

Class	Item		Basic Specifications
	①-3	Data conversion	By **introducing a data conversion tool**, it will be possible to easily perform data conversion necessary for visualization, etc.
	①-4	Data visualization	By **introducing a 3D viewer**, it will be possible to intuitively grasp geospatial data.
② safety	②-1	Security	Implement cost-effective security measures by utilizing the security services provided by the cloud.
③ Scalability	③-1	Feature Scalability	**In the future, support will be provided for intersystem cooperation such as real-time data and data cooperation including outside the Agency. Data will be provided in a form suitable for systems inside and outside the Agency** and used for simulations, etc.
	③-2	Performance Scalability	It will be **possible to respond flexibly to an increase in the number of users inside the Agency and an increase in the number of simultaneous accesses.** It will also **be possible to respond to an increase in the amount of data handled.**

▼Aim to complete the development of each element in phases by dividing the elements into common areas and areas.

Data, systems, and infrastructure need to be developed in accordance with the services to be realized. Each element is distinguished into two categories as shown in Figure 4-2: those to be commonly maintained in all fields, and those to be maintained after considering requirements and specifications according to the services to be realized in each field. At the start of Digital Twin operation (at the completion of Phase 1), viewers, databases, a part of geospatial data, and a part of static data shall be developed, and the remaining elements shall be developed and completed in stages.

As for the data, the Agency has begun consolidating its data and releasing it to viewers outside the Agency from FY2021(Table 4-2).

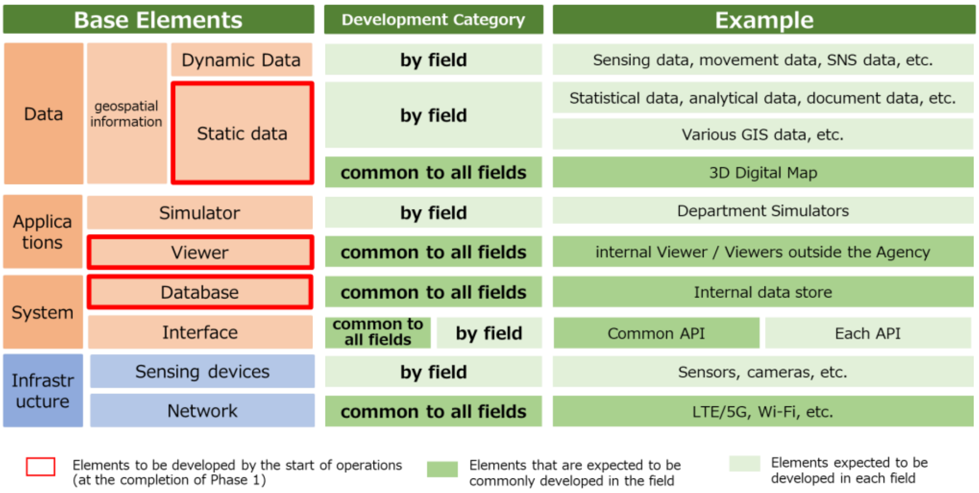


Figure 4-2　Image of Maintenance Categories

▼Consolidate each data mainly within the Agency and make it available to viewers outside the Agency, etc.

Note that the data will be available from fiscal year 2021., The Agency has begun consolidating the Agency's internal data as shown in Table 4-2 and releasing it to viewers outside the Agency. In the future, the Agency plans to publish the data on the Agency's internal viewer.

Table 4-2　Examples of Internal Data being aggregated and provided

Class	Category	Example of data
Dynamic data	Sensing data	・ Real-time broadcast of river monitoring ・ Data acquired from smart pole
	Movement data	・ Location of Tokyo bus
	Meteorological data	・ Rainfall data (water disaster prevention comprehensive information system)
Static data	Statistics data	・ Census: Total population, Rate of change in population
	3D digital map	・ Building Model ・ Underpass ・ Point Cloud Data (Aerial survey point cloud data, fixed scanner point cloud data, etc.) ・ Transportation infrastructure: roads, bridges
	Point cloud data	・ ICT-utilized construction 3D point cloud data
	GIS data	・ National land numerical data ・ GIS data of urban planning decisions

Class	Category	Example of data
		・ Flood inundation area map, storm surge inundation area map ・ Shelters, public facilities, bus stops and bus routes

4.2. Maintenance of ancillary elements

(Related Laws and Regulations)

▼Continue to consider legal measures to be taken by TMG based on the status of studies by the national government and other relevant organizations.

There are various legal and institutional issues involved in the development and operation of the digital twin. For example, when acquiring data and constructing a digital twin, there are issues related to "people," such as portrait and privacy rights when acquiring video data and personal information protection when acquiring location information, as well as "cities," such as the reflection of architectural and artistic works that are considered copyrightable. In addition, there is the viewpoint of whether the reproduction of real space in the construction of a digital twin will be regarded as a reproduction or adaptation of a copyrighted work, or an infringement of the right to preserve the identity of a work. In addition, it is necessary to consider whether the acquired data can be processed when analyzing the data, and whether institutional issues can be cleared when providing services and releasing data.

In the future, the Tokyo Metropolitan Government will consider its response to the realization of the digital twin based on the status of studies by the national government and related organizations after identifying the issues to be discussed.

Table 4-3 Examples of Tokyo Metropolitan Government's implementation matters regarding legal system

Item		Implementation
Data acquisition	People	・ How to handle the "**right of portrait and right to privacy**" of people who may appear in the video, etc. ・ Is the handling of location information (people flow) by GPS, etc. appropriate from the viewpoint of "**personal information**" protection? ・ Is prior consent from the target entity necessary? How is it appropriate to obtain consent (explanation of purpose, scope of use, etc.)?
	Cities	・ How to consider the possibility of architectural works, arts, etc., which are recognized as **copyrightable**, to be captured in the image.
Digital Twin Construction		・ Does the reproduction of real space constitute **a reproduction or adaptation of a work**? ・ Does the reproduction of real space constitute an infringement of the "**right to maintain identity**"?
data analysis (Simulation)		・ Is it possible to process data provided/shared by each entity or obtained through API linkage?
Data and service provision		・ Is the provision of services using a virtual space that reproduces real space **using a trademarks or unfair competition**? ・ How should the **terms of use** of the data and services provided by the Digital Twin be considered (i.e., is there any possibility of being held liable in any way for any deficiencies in the data, services, etc.)?
Data release		・ Is there a "**copyright**" problem in distributing processed data? ・ What "**security**" should be considered?

▼Two issues exist in the development and release of point clouds and the conversion of point clouds to open data.

What are the legal issues related to point cloud data with regard to the items that need to be addressed related to the development of a digital twin for the Tokyo Metropolitan Government? As shown in Table 4-5, it is assumed that legal issues related to point cloud data need to be considered from the viewpoints of "personal information and privacy" and "urban reproduction and secondary use". The national government and other organizations are also working on these issues, and we will establish a policy while exchanging opinions with each entity.

Table 4-4 Legal issues in point cloud development and publication and open data

Items	Issues
Perspective of personal information and privacy (Preparation and disclosure)	· Determine the policy by referring to the review policy of the national government's "Guidelines for the Handling of Personal Information in the Utilization of Geospatial Information" (including the Survey results, etc.) · According to the Guidelines, it is indicated that point cloud data acquired by surveying technology as of 2023 generally do not constitute personal information on their own
Perspectives of urban replication and secondary use (Converting to open data) use (open data conversion)	· Review based on national policy · Cabinet Secretariat Geospatial Information Utilization Promotion Office plans to revise the "Guidelines for the Promotion of Secondary Use of Geospatial Information" from FY 2024 on intellectual property-related issues (issues related to secondary use and open data conversion)

Table 4-5 Reference: Guidelines, etc. related to relevant laws and regulations

Item	Document Name	Document Content	Created by
Copyrights	Portrait Rights Guidelines	· Organized ideas as a basis for on-site personnel of digital archiving institutions to process portrait rights.	Japan Society for Digital Archive
	Guidelines for Promoting the Secondary Use of Geospatial Information	· Clarifying the concept of secondary use of geographical information in administrative agencies and other entities, and provide guidance on the appropriate rights management, as well as the provision and distribution of geospatial information.	Cabinet Secretariat Survey Results etc. version: Geographical Information Authority of Japan
Personal	Guidelines for	· Presenting	Cabinet Secretariat

Item	Document Name	Document Content	Created by
Information / Location Information	Handling Personal Information in the Utilization of Geospatial Information	principles for the proper handling of personal information under the personal information protection legislation, in relation to the applicability of personal information in geospatial information and the use and provision of geospatial information containing personal information.	Survey Results etc. version: Geographical Information Authority of Japan
	Guidelines on the Act on the Protection of Personal Information	・ Specific examples to support the activities of businesses in ensuring the proper handling of personal information.	Personal Information Protection Commission
	Guidelines for the Protection of Personal Information in the Telecommunications Business	・ A summary of restrictions on the use of location information and other information handled by telecommunications carriers.	Ministry of Internal Affairs and Communications
	Sufficient Anonymity" in the Telecommunications Business Guidelines	・ A compilation of rules on how location information handled by telecommunications carriers can be processed and used for social purposes, based on the purpose of protecting the secrecy of communications and privacy under the	Telecommunications Carriers Association, etc.

Item	Document Name	Document Content	Created by
		Telecommunications Business Law.	
	Guidelines for Utilization of "Device Location Data" such as location information	・ Industry-wide standards to promote sound and sustainable use of device location data	LBMA Japan
Data Terms of Use	Contractual guidelines for data use authorization	・ A summary of the methods and ideas used to contractually define appropriate and equitable authority to use data created, acquired, or collected in connection with transactions between businesses.	IoT Acceleration Consortium Ministry of Economy, Trade and Industry
Service Development and Provision	Guidelines for the development of AR services for use in facilities, etc.	・ AR A compilation of legal and ethical issues that are likely to cause problems in the provision of services, general ideas that can be used as reference for overcoming such problems, and examples of technical measures that have been adopted in practice.	XR Consortium

(Rules and Guidelines)

▼ Various documents are prepared for dissemination and utilization promotion within the Agency.

The documents related to the operational rules and standard specifications developed in FY2022 are Table 4-6.

Table 4-6 Maintenance Documents for Operational Rules and Standard Specifications (as of FY2023)

Maintenance Documents	Operational rules and standards
Guidelines for Data accumulation by The Tokyo Metropolitan Government officials (tentative) (for Data Providers)	Sorting out points of attention regarding data conversion and processing when posting geospatial data on the Data Integration Platform of Tokyo Metropolitan Government ・ Setting the Expose Scope of Data ・ Organize data update frequency and implementation procedures ・ Metadata accumulation ・ Review data items for each data type/format
Data accumulation procedure manual (for Data Providers)	・ Overall flow of data accumulation procedures ・ Scope and unit of data acquisition, data accuracy, and data acquisition method ・ Rules for setting metadata ・ Rules checklist for data quality assurance ・ Review and feedback on data quality ・ Legal arrangement of data (third-party provision, Converting to open data, etc.)
Data Visualization Specification (for Data Providers)	・ Procedures and Considerations for Visualizing Data in the 3D Viewer
System operation and maintenance procedure manual (For Operators)	・ Overview of operation and maintenance of the Data Integration Platform of Tokyo Metropolitan Government ・ Implementation system and work items
Data conversion and visualization procedure manual (For Operators)	・ Data visualization procedures, settings, and conversion patterns ・ Conversion patterns and conversion methods and tools ・
Operation manual (For Operators)	・ How to Use the Data Integration Platform of Tokyo Metropolitan Government for Business Operations (Flow of data registration, update, and deletion, system use method, and feedback inquiry method) ・

(Standard specification)

▼Data standards, data quality, tools, and operational rules are important for cross-organizational data collaboration.

On the operation of the digital twin, it is important for each entity to coordinate data across the board. Various organizations within and outside the Agency will be involved in the operation of the digital twin, but in case that each organization maintains and manages data based on its own individual specifications and rules, data utilization and coordination will be limited. To operate the digital twin efficiently and effectively through cross-organizational data coordination, it is important to create an environment that enables efficient data utilization and coordination across all entities involved in the digital twin operation. Therefore, for the time being "data standards," "data quality," "tools," and "operation rules" for data utilization will be developed with reference to the specifications and approaches of the Agency and related organizations(Table 4-7). Examples of guidelines related to the standard specifications are shown in Table 4-8.

Table 4-7 Examples of implementation related to standard specification

Items		Implementation
Data standard	Format	・ Consider standard specifications for map data ・ Consider recommended formats for static and real-time data / Create guidelines
	Metadata	・ Consider metadata items ・ (data title, description, update frequency, coordinate, etc.)
	Data link	・ Consider how to link map data and dynamic / real-time data (e.g., link between 3D city model and people flow using coordinate) ・ Consider how to link map data (e.g., link between 3d city model and BIM data) ・ Consider common vocabulary for each data and rules for assignment and conversion of facilities IDs, etc.
Data quality		・ Improve machine readability of data to be developed and provided ・ Organize and publish data quality standard
Tool	Data conversion	・ Provide data conversion software (converters, etc.) ・ Crate data conversion procedures
	Data catalog	・ Establish and operate internal data catalog to guide, search, and download data
Operation rules		・ Organize the process of data maintenance such as cleansing and the entities, and create procedure manuals

Table 4-8 Examples of documents related to standard

Items		Document	Author	Year of publica-tion
Data standards	Format	・ The requirements for the development and operation of a 3D digital map of the city ・ Data product specifications for 3D digital maps of the city	Tokyo Metropolitan Government	March 2022
		・ Fundamental Geospatial data, Source form database, Geospatial Data Product Specification (Draft) 【Numerical Topographic Maps】 Version 2.3	Geospatial Information Authority of Japan	April 2014
		・ Geospatial Data Product Specification Manual	Geospatial Information Authority of Japan	November 2019
		・ Standard Data Product Specification for 3D City Model (Version 3.3) ・ Standard Implementation Procedures for 3D city Model (Version 3.3)	Ministry of Land, Infrastructure, Transport and Tourism	November 2023
	Metadata	・ JMP2.0 Specification	Geospatial Information Authority of Japan	2003
		・ Geospatial Data Product Specification Manual	Geospatial Information Authority of Japan	November 2020
	Data link	・ Manual for the Integration of BIM Models in 3D City Model with CityGML (Version 3.0) ・ Manual for the Visualization of Disaster Risk with 3D City Models	Ministry of Land, Infrastructure, Transport and Tourism	March 2023 September 2023

Items		Document	Author	Year of publication
		(Version 2.0)		
		・ Basic information data linkage model for public administration	Cabinet Secretariat	June 2021
		・ Linkage model of administrative services and data (beta version)	Cabinet Secretariat	June 2021
Data quality		・ Data Quality Management Guidebook (beta version)	Cabinet Secretariat	August 2021
		・ Geospatial Data Product Specification Manual	Geospatial Information Authority of Japan	November 2020
Tool	Data conversion	・ 3D City Model Data Conversion Manual	Ministry of Land, Infrastructure, Transport and Tourism	March 2021

5. Division of roles in the maintenance and operation of the digital twin within the TMG

5.1. Outline of division of roles within the TMG

▼The Bureau of Digital Services aims to improve metropolitan government QoS and citizen's QoL by utilizing digital twins while promoting cooperation with each bureau's projects.

In operating digital twins, the Bureau of Digital Services (DS Bureau) acts as the operator, aiming to improve the Quality of Service (QoS) of metropolitan governant and the Quality of Life (QoL) of citizens through the use of digital twins, in collaboration with various bureau projects.

Regarding the division of roles, the Digital Services Bureau is responsible for strategy development, support for the development and development of components, study of ancillary elements, support for implementation of services in each bureaus, and promotion of openness of maintenance data, etc.

Other department and agencie collaborating will implement projects (services) utilizing components of the digital twin, such as geospatial data and real-time data, and will maintain data, systems, applications, and sensing equipment to enhance and streamline their departmental projects.

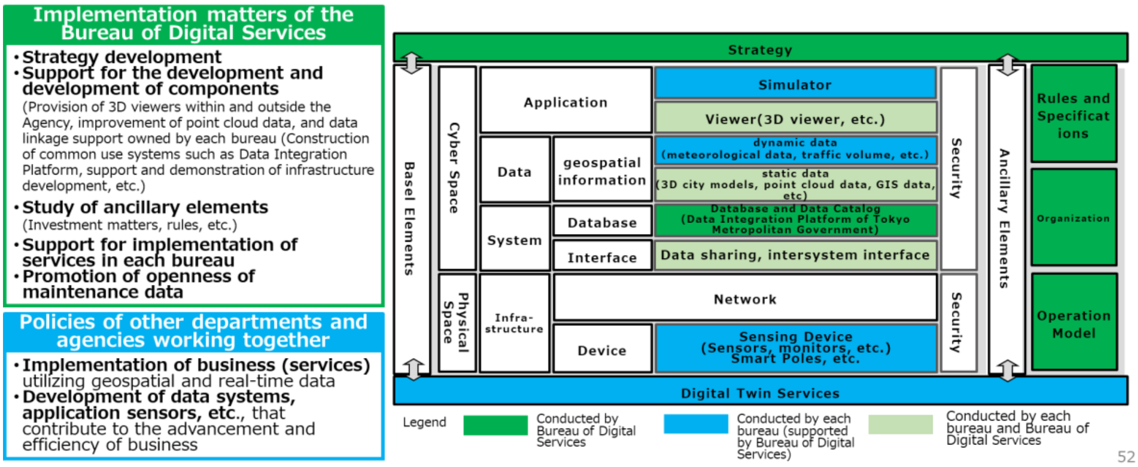


Figure 5-1 Outline of division of roles within the TMG

5.2. Division of roles in the operation of the Digital Twin

As shown in Figure 5-2 5Operation flow , the Digital Twin will be operated in an integrated manner, and each role are shared by both internal and external entities in accordance with the policy set by the infrastructure operator.

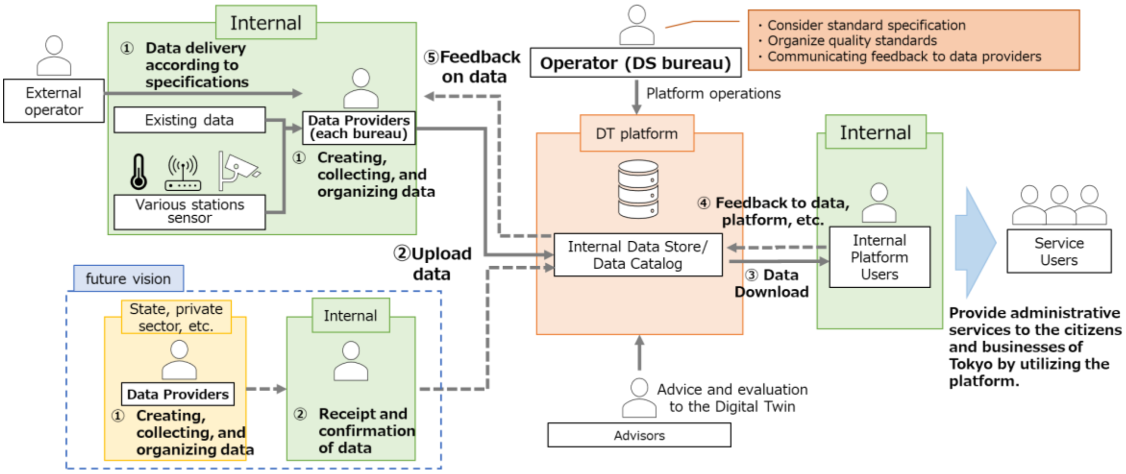


Figure 5-2 5Operation flow of the Digital Twin

In the operation of the Digital Twin, data coordination among data providers, operators, agency users, service providers, and users, i.e., provision of data and feedback, is important. For this reason, data providers such as the Tokyo Metropolitan Government's bureaus, digital twin operators, internal users, and service providers are positioned as the main entities involved in data providing and data coordination, and the construction of a data ecosystem through coordination among these entities.

The data ecosystem concept is illustrated in Figure 5-3 Data Ecosystem of Digital Twin. The data provider is responsible for the maintenance of data in accordance with the specifications and quality standards set by the infrastructure operator, and for setting the licensing and usage rules for the data. Then the data is stored in the digital twin infrastructure based on the rules. The operator has a responsibility of checking the metadata format of the provided data and providing feedback to the data provider, as well as visualizing the data on the viewer. Data users such as agency users and service providers shall download the provided data in accordance with the license and terms of use, perform data cleansing according to the intended use, and provide feedback to the data infrastructure from the user's perspective.

Specific details of the operation rules will be reviewed and updated based on the knowledge and issues obtained through the construction of the infrastructure and various projects in the future.

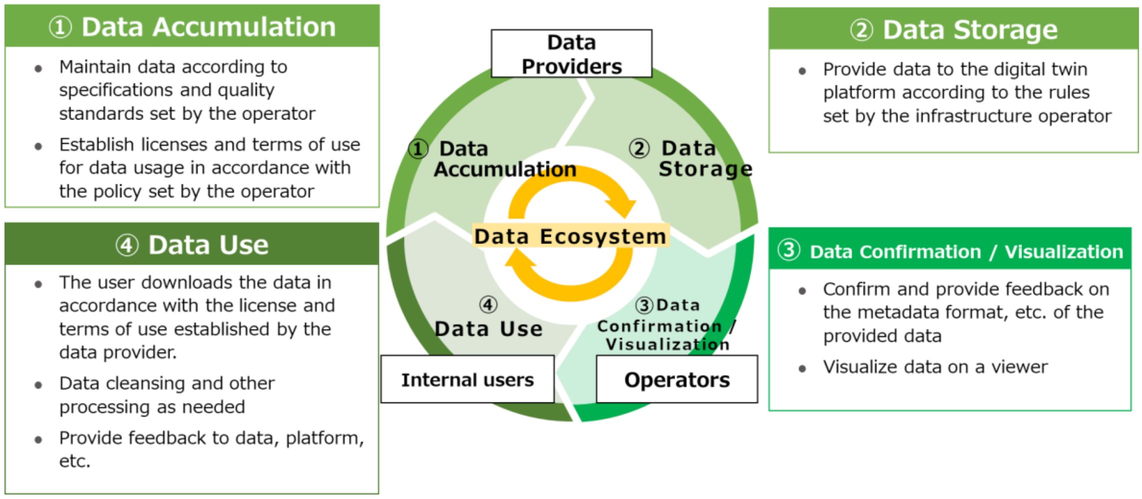


Figure 5-3 Data Ecosystem of Digital Twin

5.3. The Digital Twin Platform Management within the Agency

The Internal workflow for the operation of the Agency's Digital Twin Platform is shown in Figure 5-4 Internal workflow for the operation of the Agency's Digital Twin Platform shows the workflow within the Agency for the operation of the Digital Twin Platform within the Agency. In the data ecosystem, (1) data accumulation and (2) data storage require data preparation, setting of usage rules, and uploading and registration of data by each bureau as a data provider.

Next, the bureau of Digital Services, which is the operator, checks the data and sets up data conversion and visualization, and the visualization results are checked by each station and the bureau of Digital Services. If there are no problems, the digital service station releases the data.

Finally, each bureau, as a data user, uses the published data for business and other purposes.

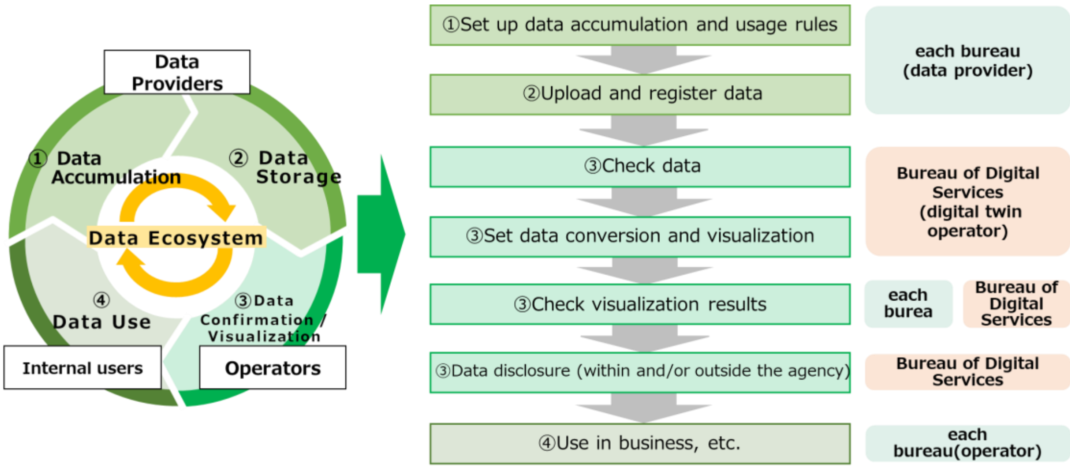


Figure 5-4 Internal workflow for the operation of the Agency's Digital Twin Platform

Appendix 1: International Case Studies of Urban Digital Twins Abroad

▼New South Wales, Australia - Transportation and Infrastructure Maintenance

Table Appendix 1-1 Case Study of New South Wales, Australia

Usage of digital twin technology	• Traffic congestion forecasting and management • Structural health monitoring
Challenges expected to be solved	• Significant improvements in the efficient management of traffic flow by anticipating and encouraging action • Allows maintenance scheduling based on bridge conditions to increase efficiency. Also improves user safety
Current initiatives	• traffic: simulating on digital maps • structures: monitoring
Usage data and its scope	• Data used: Traffic: Smart card (Opal card), GPS, historical traffic signal data, and real-time data, Structure: Vibration data of 2400 sensors installed on the bridge. • Range: Traffic: All over Sydney, Structure: Sydney Harbour Bridge only
Future prospects	No information.

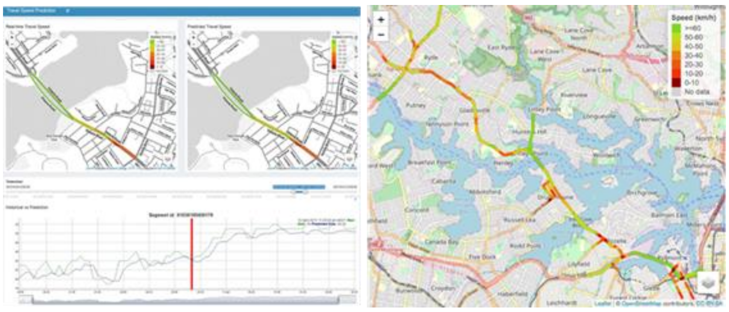


Figure Appendix 1-1 Digital Map Screen (Artificial Intelligence Engine for Traffic Congestion Management)

Figure Appendix 1-2 Sydney Harbour Bridge

Source:
CSIRO "Predicting and managing traffic congestion" https://www.csiro.au/en/research/technology-space/ai/Predicting-and-managing-traffic-congestion (1/30/2024)
CSIRO "How data science can help you beat traffic congestion"
https://www.csiro.au/en/news/All/Articles/2019/March/how-data-science-can-help-you-beat-traffic-congestion (1/30/2024)
CSIRO "Monitoring the health of structures"
https://www.csiro.au/en/research/technology-space/data/Monitoring-the-health-of-structures (1/30/2024)

▼Australia, New South Wales - Air Pollution & Energy

Table Appendix 1- 2 Case Studies in New South Wales, Australia

Usage of digital twin technology	• Observation of air pollution (OEH NSW Air Quality Index) • Real-time fuel selling price (Fuel API)
Challenges expected to be solved	• Checking air pollution caused by wildfires and providing health advice
Current initiatives	• Display on a digital map
Usage data and its scope	• Data used: AQI: Ozone, Carbon Monoxide, Sulfur Dioxide, Nitrogen Dioxide, Suspended Particles, Visibility Measurements Standardized to One Easy-to-Understand Index Fuel API: Real-time fuel prices for all gas stations. • Range: All of New South Wales
Future prospects	No information

Figure Appendix 1-3 Digital Map Screen (OEH NSW Air Quality Index)

Figure Appendix 1-4 Digital Map Screen (Fuel API)

Source**:**
NWS Spatial Digital Twin ”OEH NSW Air Quality Index” https://nsw.digitaltwin.terria.io/ (1/30/2024)
A NSW Government website "Air Quality Health advice" https://www.airquality.nsw.gov.au/health-advice (3/12/2024)
NSW ”Fuel API” https://api.nsw.gov.au/Product/Index/22 (12/25/2023)

▼Helsinki, Finland Thermal Environment and Wind Simulation

Table Appendix 1-3 Case Study of Helsinki, Finland

Usage of digital twin technology	• Simulation of thermal environment • Advanced simulation of wind direction and pressure • Communication between users about location
Challenges expected to be solved	• Visualization of energy consumption facilitates decision-making on environmental measures • Safety is improved by using it when planning building reconstruction • Citizen participation in urban development is increased by sharing information on locations and facilities in real time
Current initiatives	• Thermal Environment, Wind: Display and Simulation on Digital Maps • Communication between Users: Display on Digital Maps
Usage data and its scope	• Data used: Thermal Environment, Wind: Estimates energy consumption from basic building-specific information, energy and repair data, and data on water, district heating, and electricity consumption. Real-time data such as wind speed and direction Communication between users: Posting to users' platforms • Range: All over Helsinki
Future prospects	No information

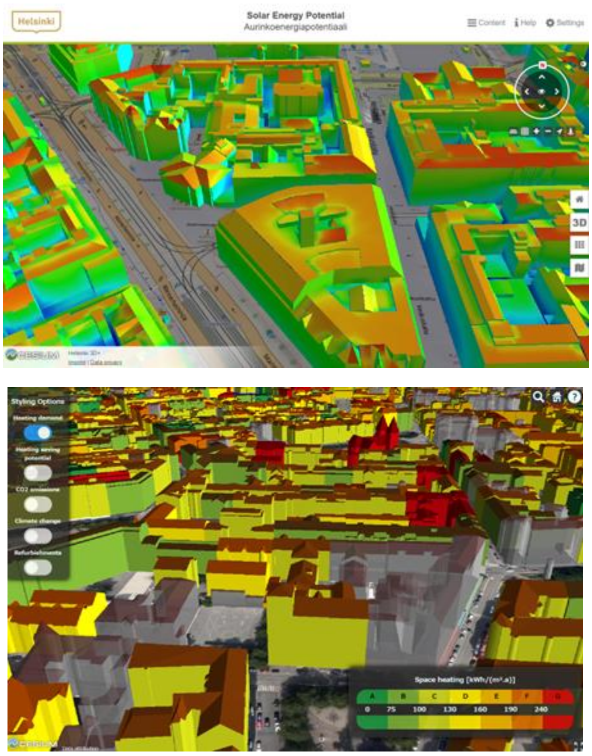


Figure Appendix 1-5 Visualization of energy amounts, etc.

Source:
"Energy and Climate Atlas" https://kartta.hel.fi/3d/atlas/#/ (1/30/2024)
"The Kalasatama Digital Twins Project"
https://www.hel.fi/static/liitteet-2019/Kaupunginkanslia/Helsinki3D_Kalasatama_Digital_Twins.pdf
(1/30/2024)

▼Singapore - Virtual Singapore, Onemap3D, ODP

Table Appendix 1-4 1 Singapore Cases

Usage of digital twin technology	• Building **a platform for urban development management** (Virtual Singapore, VS), a system **for visualizing geospatial information on roads and buildings, land ownership, demographics, and drone flight paths** through 3D geospatial data development and public/private sharing (Onemap3D, O3D) • Building **a platform for urban infrastructure management and facility management** (ODP) at government-owned enterprises (JTC) using 3D data in common
Challenges expected to be solved	• Use to examine urban planning in public administration • Use to obtain information on real estate by private companies and citizens
Current initiatives	• To provide a platform VS (= viewer/simulator) and O3D/ODP (= viewer) for urban development management.
Usage data and its scope	• Data used VS: static data such as geospatial, graphic content, and base maps), climate, human flow, traffic conditions, and traffic accidents (real-time data) • O3D: rental and transaction property prices, drone flight airspace information • ODP: data collected from sensors such as temperature, weather, electricity consumption, and human flow in the area • Range VS: All of Singapore, ODP: Punggol Digital District (PDD)
Future prospects	• VS、O3D : Implementation of (Underground space, climate, etc.) in urban environmental design • ODP : The construction of each facility will begin, and development will proceed for the sequential operation of the facilities after 2024

Figure Appendix 1-6 Virtual Singapore introductory image

Figure Appendix 1-7　ODP platform introduction image

Source:
ONEMAP "The Most Detailed and Comprehensive Map of Singapore" https://www.onemap.gov.sg/home/ (3/12/2024)
ONEMAP POPULATION QUERY "Population Dashboard" https://popquery.onemap.gov.sg/ (3/12/2024)
Singapore Land Authority(SLA) "SLA LAUNCHES ONEMAP3D, AND SIGNS MOUS WITH NINJA VAN, KABAM AND PROPNEX TO FURTHER THE USE OF ONEMAP" https://www.sla.gov.sg/articles/press-releases/2021/sla-launches-onemap3d-and-signs-mous-with-ninja-van-kabam-and-propnex-to-further-the-use-of-onemap (1/30/2024)
Nikkei Business Publications "37 Singapore Punggol: Deepening the exchange between industry and academia in a smart city" https://project.nikkeibp.co.jp/atclppp/PPP/080200047/091100049/?P=1 (1/30/2024)
JTC "First-of-its-kind Open Digital Platform for Smart City Solutions in Punggol Digital District" https://www.jtc.gov.sg/about-jtc/news-and-stories/press-releases/first-of-its-kind-open-digital-platform-for-smart-city-solutions-in-punggol-digital-district (1/30/2024)
Fig.National Research Foundation Singapore "Use of Virtual Singapore" https://www.bing.com/videos/riverview/relatedvideo?q=virtual%20singapore&mid=8159FE84936ED4AF47408159FE84936ED4AF4740&ajaxhist=0 (3/13/2024)
Fig.JTC Corp "Open Digital Platform: A smart district operating system" https://www.youtube.com/watch?v=35DbSdV-t3U&list=PLa8-2_hYc-AJxKmU0RKJnemsNjoQX2P12&index=2 (3/13/2024)

▼United Kingdom - National Underground Asset Register

Table Appendix 1- 5　Case Studies in the United Kingdom

Usage of digital twin technology	• Underground infrastructure owners are developing a mapping platform **to securely share existing underground asset data with authorized users**
Challenges expected to be solved	• Improved operational efficiency and safety by providing map information and data necessary for planning and implementing underground excavations • Facilitated communication among stakeholders involved in construction • Reduced disruption to the general public and business activities due to damage to underground infrastructure and accidents
Current initiatives	• Provision of a digital map platform (viewer)

Usage data and its scope	• Data used: water and sewerage network data, large-scale transmission network and tower location data, gas piping network data, communication network data • Range: All parts of England and Wales
Future prospects	Full operation of the digital mapping platform covering all areas of England and Wales by the end of 2025 (Privacy management of data providers and users and legal development are underway)

Figure Appendix 1-8 Digital Map Operation Screen

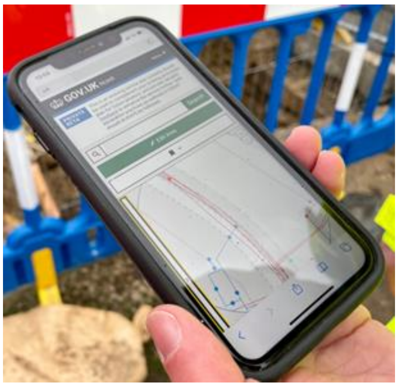


Figure Appendix 1-9 Examples of situations in which users utilize digital maps

Source:
CDBB ”Case Study: National Underground Asset Register (NUAR) Pilot Programm”
https://www.cdbb.cam.ac.uk/news/case-study-NUAR-pilot-programme (10/17/2022)
GOV.UK "Getting under the surface of our National Underground Asset Register (NUAR) team"
https://geospatialcommission.blog.gov.uk/2019/12/18/getting-under-the-surface-of-our-national-underground-assets-register-nuar-team/ (1/30/2024)
Geospatial Commission”NUAR project update – November2023”
https://assets.publishing.service.gov.uk/media/655e49ef3e1c2e000d693722/NUAR_Project_Update_-_November_2023.pdf (1/30/2024)

▼UK-Climate Resilience Demonstrator (CReDo)

Table Appendix 1-6 Case Studies in the United Kingdom

Usage of digital twin technology	• **Simulated the resilience of critical infrastructure** assets such as energy, water, and communications from climate threats such as flooding and extreme heat
Challenges expected to be solved	• It can predict the damage to infrastructure caused by climate change disasters and consider countermeasures • It will facilitate decision-making on disaster prevention measures
Current initiatives	• Simulation on a digital map
Usage data and its scope	• Data used: water and sewer network data, large grid and tower location data, gas network data, communications network data, flood data • Range: East Anglia area
Future prospects	• During FY 2024, demonstration projects in several infrastructure sectors will be shifted to a national scale to develop opportunities to create commercially sustainable products • Addressing the challenges of extreme heat as well as flooding

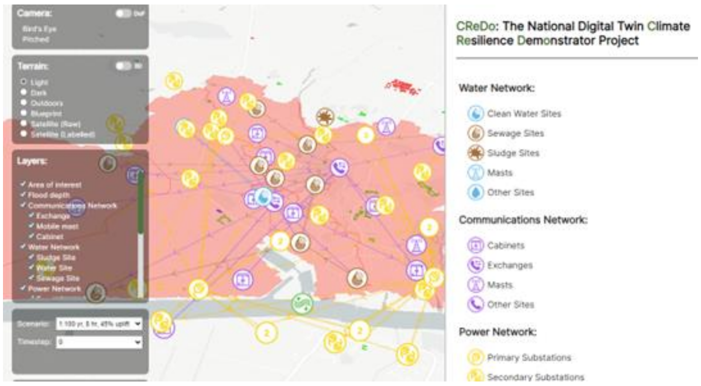


Figure Appendix 1-10 Digital map screen (CReDo visualisation)

Source**:**
DigitalTwinHub "What is CReDo?" https://digitaltwinhub.co.uk/credo/credo/ (1/30/2024)
DigitalTwinHub "CREDO WINS AT THE CLIMATE INNOVATION AWARDS"
https://digitaltwinhub.co.uk/articles/articles/credo-wins-at-the-climate-innovation-awards%C2%A0-r286/
(1/30/2024)
DigitalTwinHub"CReDo visualization" https://digitaltwinhub.co.uk/credo/visualisation/ (1/30/2024)

▼Seoul,Korea - S-map (3D digital map)

Table Appendix 1-7 Case Study of Seoul, Korea

Usage of digital twin technology	• Provision of traffic and disaster information • Crime prevention measures by managing cameras installed in cities • Dissemination of information on wildfire risk
Challenges expected to be solved	• Significant improvements in the efficient management of traffic flow by anticipating and encouraging action • Improvements in urban security • Ascertainment in advance and information dissemination will be possible, leading to reduced damage
Current initiatives	• Display on a digital map • Real-time monitoring (wildfire risk updated hourly)
Usage data and its scope	• Data used: Traffic and Crime Prevention: Data acquired from integrated terminals including a total of 849 CCTV, 341 road light signs, 95 lane control systems (LCS), bus management systems and traffic card readers for traffic/disaster use. Wildfire Risk: Meteorological data. • Range: All areas of Seoul
Future prospects	No information

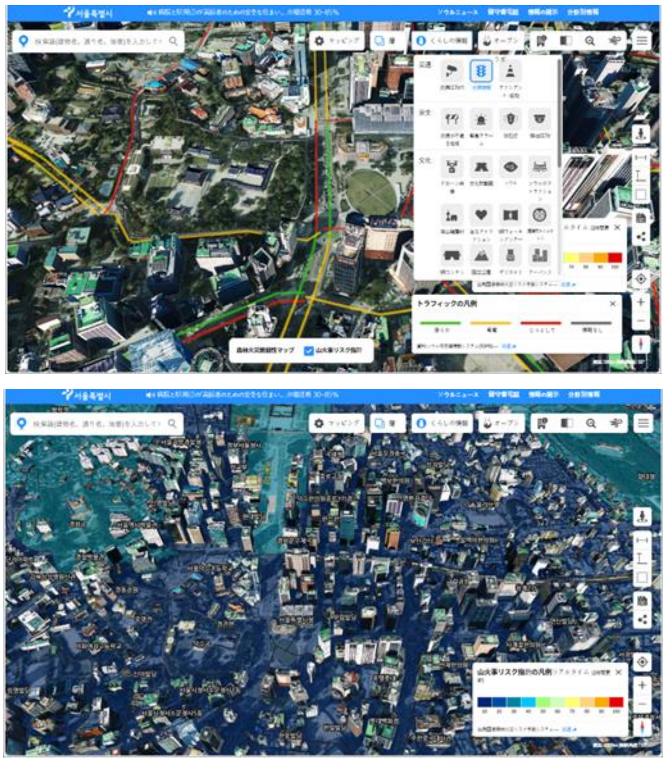


Figure Appendix 1-11 Digital Map Screen

Source:
Seoul Metropolitan Government "S-map" https://smap.seoul.go.kr/ (12/25/2023)
Seoul Solution "Seoul Transport Operation & Information Service: TOPIS 01"
https://seoulsolution.kr/en/content/9348 (12/25/2023)
"National Forest Fire Risk Prediction System" http://forestfire.nifos.go.kr/main.action (12/25/2023)
"S-MAP" https://smap.seoul.go.kr/m/ (12/25/2023)

▼Rotterdam, Netherlands - Rotterdam 3D

Table Appendix 1-8 Case Study of Rotterdam, the Netherlands

Usage of digital twin technology	• Use of applications to optimize and enhance various aspects of urban life, such as energy consumption analysis, underground infrastructure asset management, urban flooding applications, mobility and medical systems
Challenges expected to be solved	• Reduction of greenhouse gas emissions through improved energy consumption efficiency • Improve urban planning processes
Current initiatives	• Display on digital 3D model • Real-time data acquisition
Usage data and its scope	• Data used: • topography, trees (including route information), underground infrastructure, streetlights (various types), traffic lights, geospatial information on cable pipelines, IoT sensor data, etc. • Range: The entire city of Rotterdam
Future prospects	Combining big data analytics and artificial intelligence (AI) predictive capabilities with digital twin models to further improve the urban planning process

Figure Appendix 1-12 Digital Map Screen

Source:
Gemeente Rotterdam ”Rotterdam 3D” https://www.3drotterdam.nl/#/ (1/26/2024)
GW Prime ”3D-Evolution of the Dutch City of Rotterdam, The Netherlands”
https://www.geospatialworld.net/prime/case-study/aec/3d-evolution-of-the-dutch-city-of-rotterdam-the-netherlands/ (1/26/2024)

▼**Shenzhen, China (mainly in Longhua District) - Disaster prevention and building equipment monitoring**

Table Appendix 1-9 Case Studies in Shenzhen, China (mainly in Longhua District)

Usage of digital twin technology	• Rapid provision of building environmental information in the event of a fire. • Real-time monitoring of flood conditions for efficient implementation of related works. • IoT sensors monitor fire protection, Wi-Fi, power equipment, etc. of buildings in the area.
Challenges expected to be solved	• Faster response to disasters. • Efficient implementation of flood control, distribution, drainage, and flood control works. • Decision-making through real-time monitoring and dynamic assessment of cities and regions.
Current initiatives	• Display on digital map. • Real-time monitoring and warnings of abnormalities and hazards.
Usage data and its scope	• Data used: • population, corporation, basic city data, geological borehole and underground pipeline location data, IoT sensor data (water level, flood conditions, equipment in buildings, etc.), etc. • Range: Shenzhen, especially Longhua District
Future prospects	Establish an all-round digital twin base, form a three-level CIM platform at the "city level, district level, and regional level", and cultivate three types of new urban construction industry Internet platforms at the "industry level, enterprise level, and project level.

Source: Shenzhen "Longhua Digital Twin City is gradually being built"
https://www.sz.gov.cn/cn/xxgk/zfxxgj/gqdt/content/post_10391396.html (1/26/2024)

▼Toronto - Water, Waste & Transportation Management

Table Appendix 1-10 1 Toronto Case Studies

Usage of digital twin technology	• Infrastructure related to water pipes, waste, and transportation, including drinking water, wastewater, and rainwater, is monitored by IoT sensors.
Challenges expected to be solved	• Reduction in long-term consumption of water resources. • Simplification and efficiency of infrastructure maintenance and repair.
Current initiatives	• Display on digital map • Real-time monitoring
Usage data and its scope	• Data used: water and wastewater location data, IoT sensor data (installed in infrastructure related to water, waste, transportation, etc.), meteorological data. • Range: City of Toronto
Future prospects	The goal is to monitor all infrastructure and use a digital twin to simulate usage scenarios that may lead to improved sustainability.

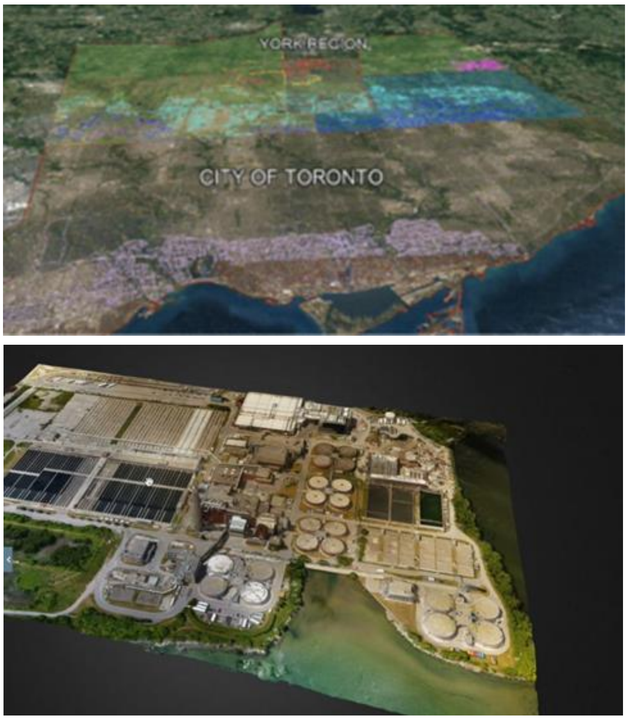


Figure Appendix 1-13 Digital Map Screen

Source:
IEEE ”Toronto has got its Digital Twin” https://cmte.ieee.org/futuredirections/2023/03/06/toronto-has-got-its-digital-twin/ (2/2/2024)
itbusiness.ca ”Drones, digital twins, and connected sensor grids: How Toronto Water keeps the pipes flowing today and in the future” https://www.itbusiness.ca/news/drones-digital-twins-and-connected-sensor-grids-how-toronto-water-keeps-the-pipes-flowing-today-and-in-the-future/107604 (2/2/2024)

Appendix 2: Open Source Software (OSS) and Data Used in the Digital Twin

The Tokyo Metropolitan Government Digital Twin Platform uses the open source software TerriaJS and CKAN. Reference information for each software is shown in Table Appendix 2-1 shows reference information for each software.

Table Appendix 2-1 Table 3-1

	OSS Name	User and reference information
OSS used in the Digital Twin Data Integration Platform of Tokyo Metropolitan Government	**TerriaJS**	■ Official website: https://terria.io/ ■ Publication page: https://github.com/TerriaJS/terriajs ■ Technical Information: https://docs-v8.terria.io/guide/
	CKAN	■ official website : https://ckan.org/ ■ community extension list : https://extensions.ckan.org/ ■ Japanese manual : https://opendatastack.jp/document/ckan_user_manual/
	CARTO	■ Official website: https://carto.com/ ■ Technical information: https://docs.carto.com/

The 3D viewer also utilizes map data released by external entities as background maps. The source and reference information for each data are listed in Table Appendix 2-2 shows the source and reference information for each data.

Table Appendix 2-2 External public data utilized for background maps in the 3D Viewer

	Data Name	Source	User and Reference Information
Externally published data used for 3D viewer background maps, etc.	**Base map information Digital elevation model**	Geospatial Information Authority of Japan	■ Used for creating terrain data used for 3D viewers ■ official website : https://fgd.gsi.go.jp/download/ref_dem.html

	Data Name	Source	User and Reference Information
	GSI tile	Geospatial Information Authority of Japan	■ official website : https://maps.gsi.go.jp/development/ichiran.html ■ Summary: https://maps.gsi.go.jp/development/siyou.html
	Vector Map Level 0 (VMAP0)	National Imagery and Mapping Agency (U.S.A.)	■ MSU Map Library: https://lib.msu.edu/branches/map/findingaids/VMAP0/

Appendix 3: Examples of services using the Digital Twin

Future digital twin services will be implemented and utilized in the five fields where they are expected to be utilized, based on the use cases of digital twin services considered by the bureaus, the results of demonstrations such as beta projects, and the efforts of private companies.

In each field, the following services are envisioned as examples. The services listed below are only examples, and are not limited to those planned for service implementation. The contents of the services will be revised as necessary as the plans and related policies of each field and the use cases of the digital twin for each field are discussed with the bureaus and private operators.

(1) Examples of Disaster Prevention Field Services

▼Disaster Simulation

By simulating disasters in a virtual space and predicting and analyzing the damage, the system will be used to formulate safe and secure urban development plans and evacuation plans.

▼Real-time monitoring and abnormality detection of structures

Monitoring and forecasting of data on flow rate, flow direction, and water pressure of drainage pipes, to detect abnormalities such as leakage and backflow at an early stage and utilize the data for prevention of flooding and inundation, review of inspection work (increase in frequency of daily inspection, etc.).

▼Simulation of the scope of impact of a disaster

By observing the height structure of the ground surface using satellite images, areas that will be affected by disasters like torrential rains and volcanic eruptions will be predicted and signs will be detected, which will be used to formulate safe and secure urban development plans and evacuation plans, as well as to disseminate information.

(2) Examples of Town Planning Field Services

▼Urban Congestion Forecasting

Data on indoor and outdoor spaces in Tokyo (public spaces, metropolitan facilities, underground spaces, etc.) will be acquired to monitor and forecast congestion and used to disseminate congestion information to Tokyo residents and improve daily operational operations.

▼Urban Development Simulation

Setting hypothetical conditions for urban regeneration, urban development, landscaping, and other future visions of the city, and simulating sunlight, wind direction. This information will be utilized in development plans and explanations to the citizens of the city.

▼Smart planning

Utilizing data on human flow, person trips, and other data related to movement, and simulating of optimal facility layout, traffic measures, and redistribution of space such as roads in order to predict the effects of implementing each measure. These results are also used in the formulation, evaluation, and review of urban planning.

(3) Examples of Mobility Field Services

▼Urban traffic congestion forecasting

The system acquires information of public transportation operations and traffic congestion in Tokyo, as well as on the availability of parking spaces at Tokyo facilities and grasps and predicts congestion conditions for use in disseminating congestion information to Tokyo residents, improving operation operations, and studying measures to relieve traffic congestion.

▼Simulation of traffic network opening

Establishing hypothetical conditions such as traffic volume when a new transportation network is opened, and simulating traffic volume and congestion occurrence. Then the simulation results will be used in the transportation network development plan

▼Road maintenance management using 3D data

Using MMS point cloud data and applications for analysis, observe rutted road surfaces and create roadside facility ledgers, etc., for use in urban planning and other activities that contribute to the safe operation of mobility vehicles.

(4) Examples of Energy Sector Services

▼Simulation of urban CO_2 emissions

Toward the realization of a "Zero Emission Tokyo" that contributes to virtually zero CO_2 emissions, various urban data will be used to understand and forecast CO_2 emissions from urban activities. These results will be used to study and implement various measures to reduce emissions.

▼Estimation of solar power generation potential

Estimating the potential for solar power generation on roofs and walls of building facilities in Tokyo and analyzing the effects of reducing environmental impact through the use of re-energy. Then using the results to examine decarbonization measures.

▼Simulation of optimal placement of charging facilities for ZEVs

To promote the introduction and spread of Zero Emission Vehicles (ZEVs), simulate the optimal placement of charging facilities through traffic simulation, and use it to study the placement plan of charging facilities.

▼Projections of climate change

Utilizing past meteorological data, various urban data, the system predicts and displays climate change, the extent of guerrilla downpours, and the extent of impact at the time of eruptions such as Mt. Fuji.

(5) Examples of industrial (tourism, etc.) sector services

▼Implementation of remote construction meetings

Conducting construction discussions via remote meetings using underground 3D models will significantly reduce the time required for travel and status checks, contributing to the creation of extra time.

▼Conduct training, seminars, etc. using XR technology

Contribute to the efficiency of seminars, training, etc. for employees, students, etc. by providing training simulators, etc. for those in professions related to the city that utilize XR technology.

▼Development of virtual tourism events

Develop a virtual tourism event in the city that can be attended by a variety of people from remote locations in Japan and abroad in cyberspace, contributing to the city's economic revitalization.

▼Social Studies Learning with Virtual Archives of Cities

By recording the city's history and the past of local cultural assets in a virtual space, XR technology can be used as an experiential history teaching tool for fieldwork and contribute to a better understanding of the region.