Development of the Standard Data Product Specification for 3D City Models Using CityGML

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Abstract

In response to the rising demand for digital twins, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) launched Project PLATEAU, a 3D city model initiative. Japan has over 1,700 municipalities, each with unique characteristics that may lead to diverse 3D city models. However, differing specifications may compromise data reusability.
This paper presents the "Standard Data Product Specification for 3D City Models" (SDPS-3DCM), designed to facilitate the development, utilization, and availability of 3D city models. The SDPS-3DCM adopts CityGML and its Urban Planning Application Domain Extension (i-UR) as its application schema. We provided feedback to i-UR based on city use cases regarding missing features and attributes. Incorporating the updated i-UR improved the comprehensiveness of the SDPS-3DCM. Additionally, the SDPS-D3CM defines the subdivisions of Level of Detail (LOD) to promote a common understanding among data creators and users, increasing production efficiency and ensuring consistency. Each city can localize its specification by profiling the SDPS-3DCM, resulting in a 3D city model grounded in a unified specification while allowing for specific contextual variations. By 2024, over 200 cities developed 3D city models compliant with the SDPS-3DCM and made them publicly available as open data. The SDPS-3DCM not only accelerates the rapid development of 3D city models but also streamlines the creation and utilization of related tools. The SDPS-3DCM is expected to standardize 3D city models, address societal issues, and create new value across public and private sectors.

1. Introduction

Japan's Society 5.0 is an initiative that aims to build a human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space. In Society 5.0, every element of society will be built as a digital twin in cyberspace, restructured in terms of systems, business design, urban and regional development, etc., and then reflected in physical space to transform society (Government of Japan, 2021).

The construction of digital twins necessitates 3D city models that act as the foundational platform for integrating various datasets. To address this societal need, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan initiated the Project PLATEAU [1], aimed at developing, utilizing, and providing open data for 3D city models.

In Japan, there are over 1700 municipalities and each municipality has been developing basic urban planning maps and conducting basic urban planning surveys in accordance with the City Planning Law. PLATEAU has identified municipalities as the key stakeholders in the creation of 3D city models, aiming to ensure comprehensiveness and continuity by leveraging the mapping results and statistical surveys conducted by municipalities as resources for these models. PLATEAU has made significant strides in ensuring effective urban planning and resource management.

However, due to the variations in scale, environment, culture, and history among cities in Japan, if each municipality independently develops its own 3D city model, inconsistencies in specifications may emerge, ultimately diminishing data reusability. In fact, there are numerous precedents for the development of 3D city models in cities worldwide. These models have often been created for specific purposes, resulting in variations in their specifications and quality, which consequently lead to inconsistencies in the datasets (Lei et al., 2022).

While variations in specifications among cities may not present significant issues when 3D city models are applied within individual municipalities, they become problematic when comparing models across cities or integrating them over broader regions. Furthermore, challenges emerge when applications designed for one city's 3D city model are implemented in other municipalities.

To address these concerns, this paper developed a unified data product specification for 3D city models, titled "Standard Data Product Specification for 3D City Models" (hereafter "SDPS-3DCM"), intended for nationwide use by municipalities. This paper presents both the development and application of the SDPS-3DCM. The development process includes the refinement of Levels of Detail (LODs) to enhance understanding among stakeholders, as well as the implementation of a profiling mechanism to respond to the uniqueness of each city.

2. Related Works

2.1 Standardization of Data Product Specifications

A data product specification (hereafter "DPS") is a specification of a dataset or dataset series together with additional information that will enable it to be created, supplied to and used by another party, and the content and structure of a DPS is

[1] https://www.mlit.go.jp/plateau/

outlined in the *ISO 19131 – Data Product Specifications* (ISO, 2022).

The specific content of a DPS is contingent upon the universe of discourse; therefore, ISO 19131 outlines the required components and their structural organization without detailing the specifics. Each application domain implements its own DPS in accordance with ISO 19131, resulting in geospatial data derived from that DPS as shown in Figure 1.

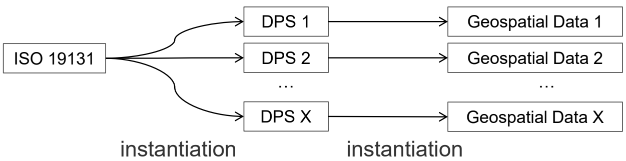

Figure 1. Relationships among ISO 19131, DPS and geospatial data.

2.2 Case Studies of Existing Data Product Specifications

DPSs have been developed across various domains. Consequently, we examined the DPSs utilized by multiple data-producing organizations and explored the innovations that have emerged.

2.2.1 INSPIRE Data Specifications: INSPIRE Data Specifications are harmonised DPSs for themes adopted as Implementing Rules (INSPIRE Data Specifications Drafting Team, 2014). For the 34 spatial data themes defined in the INSPIRE Directive, DPSs have been developed in accordance with the ISO 19100 series, aiming to maximize the interoperability of spatial data across borders and sectors within the EU (INSPIRE Data Specifications Drafting Team, 2008a).

These DPSs are designed to facilitate the sharing of existing data held by member states without incurring excessive costs. To achieve this, a harmonization approach based on gap analysis has been adopted, considering the political, economic, cultural, and organizational differences among these states. For instance, both mandatory and optional features and properties have been assigned to them (INSPIRE Data Specifications Drafting Team, 2008b).

The series of INSPIRE DPSs does not encompass all the features that constitute a city; however, it includes certain elements such as buildings, topography, and geology, which may incorporate 3D models.

2.2.2 Standard Data Product Specification to Produce 1:2500 Digital Topographic Data: The Standard Data Product Specification to Produce 1:2500 Digital Topographic Map Data is a DPS issued by the Geospatial Information Authority of Japan (GSI) for creating digital maps. Within the framework of the Survey Act, both the production of digital maps and the execution of aerial photogrammetric surveys by municipalities are classified as public surveying (Geospatial Authority of Japan, 2025b). Each municipality is required to prepare a DPS when conducting public surveying (Geospatial Authority of Japan, 2025a), and the GSI strongly advocates for its adoption. Consequently, each municipality develops the urban planning base map in accordance with this DPS.

This DPS is grounded in the 'Rules for the Operation Provided by Article 34 of the Survey Act, Appendix 7: Digital Topographic Map Data File Specifications' Historically, this guideline has served as the technical standard for public surveying, facilitating its adoption by municipalities. The DPS encompasses all features present in urban areas that should be represented on topographic maps. However, its primary emphasis on cartographic representation complicates analytical use and diminishes the reusability of the data.

2.3 CityGML

CityGML is an open data model and XML-based format for the storage and exchange of virtual 3D city models (Gröger et al., 2012). Its development aims to establish a common definition of the basic features, attributes, and relationships within a 3D city model, thus facilitating the reuse of the same data across various application domains.

CityGML has two primary characteristics. The first is a mechanism for defining the spatial attributes of features at multiple scales, referred to as Level of Detail (LOD). The second is a framework for extensions, known as Application Domain Extensions (ADE).

2.3.1 LOD: LOD is a mechanism defined in CityGML to support multiscale representation of an object. The same object can be represented simultaneously at different LODs, enabling analysis and visualization from various resolution perspectives, as well as the integration of datasets containing the same object across differing LODs.

2.3.2 ADE: ADE serves as a mechanism for developing a new conceptual model and XML schema that extends CityGML. This process ensures that the XML schema aligns with the defined conceptual model, providing a more rigorously defined data structure than the generic features and attributes encompassed by the Generic Modules in CityGML.

2.4 CityGML Urban Planning ADE

The CityGML Urban Planning ADE (hereafter 'i-UR') is specifically designed for urban planning, encompassing detailed attributes of urban objects as well as mechanisms for global representation and analysis essential for effective urban planning (Akahoshi et al., 2020). This ADE was developed with a focus on the fundamental urban planning surveys routinely conducted by municipalities in Japan under the Urban Planning Law. Its aim is to standardize the data collected through these surveys and to facilitate consensus building among the various stakeholders involved in urban regeneration.

Until now, the data models and formats for basic urban planning surveys have been determined by individual municipalities, leading to low reusability. However, the development of the i-UR has standardized the data for these surveys across cities, facilitating the analysis of temporal changes and enabling comparisons between cities using the accumulated data.

3. Development of the Standard Data Product Specification for 3D City Models

A unified DPS is essential to enhance the reusability of 3D city models developed for individual cities. However, related works have indicated that there are currently no unified DPSs for 3D city models that encompasses the features that define a city. In light of this gap, this paper introduces the SDPS-3DCM as a unified DPS specifically designed for 3D city models in Japan.

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3.1 Methodology

The SDPS-3DCM is formulated in accordance with ISO 19131. Table 1 presents the key components of the SDPS-3DCM, along with the details developed in this paper.

Key Components of DPS	SDPS-3DCM
Application Schema	CityGML and i-UR
Coordinate Reference System	JGD 2011, TP / (B, L), H
Temporal Reference System	GC / JST
Data Quality	Incorporates relevant sections from the Standard Data Product Specification to Produce 1:2500 Digital Topographic Data by reference.
Encoding Specification	CityGML and i-UR
Metadata Specification	JMP 2.0 (Japan Metadata Profile 2.0)[2]

Table 1. Main Components of the DPS of 3D City Models.

CityGML and i-UR are adopted for the application schema and the encoding specification to enhance the reusability of 3D city models. Additionally, the determination of other components is guided by the need for consistency with relevant legislation pertaining to public surveys and the existing DPSs currently in use.

To improve the “applicability” (sustainability for various use cases) and “understandability” (shared understanding among all relevant stakeholders) of the SDPS-3DCM, revisions have been made based on the results obtained from the implementation of 3D city models that conform to the SDPS-3DCM.

3.2 Extension of Features and LODs Based on Use Cases

In the first version of the SDPS-3DCM formulated in 2021, the fundamental use cases for 3D city models encompassed "visualization of urban planning in 3D space" and "3D visualization of disaster risk." These use cases included essential features that define a city, such as Buildings, Roads, Land Use, Urban Planning, Disaster Risk, and Relief Features. Since this first version, the features incorporated into the SDPS-3DCM have been expanded in the third version, published in 2023, to better align with a diverse range of use cases proposed by municipalities, as detailed in Table 2.

Feature		LOD0	LOD1	LOD2	LOD3	LOD4
Building		v1	v1	v1	v1	v1
Land Use			v1			
Transportation	Road	v3	v1	v2	v2	
	Track	v3	v3	v3	v3	
	Square	v3	v3	v3	v3	
	Railway	v3	v3	v3	v3	
	Waterway[2]	v3	v3	v3		
Urban Planning[1]			v1, v2			
Disaster Risk[1]			v1, v2			
City Furniture			v2	v2	v2	
Vegetation			v2	v2	v2	
Water Body		v3	v3	v3	v3	
Relief Feature			v1	v2	v2	
Bridge		v3	v3	v3	v3	v3
Tunnel		v3	v3	v3	v3	v3
Other Construction[2]		v3	v3	v3	v3	
Underground Building[1]			v3	v3	v3	v3
Utility Network[1]		v3	v3	v3	v3	
Zone[1]			v3			
Generic City Object		v1	v2	v2	v2	v3

1 Features defined in Urban Planning ADE
2 Features defined in Urban Planning ADE while ensuring consistency with CityGML 3.0

Table 2 Extension of Features and LODs

In terms of applicability, feedback concerning any features and attributes identified as lacking in the use cases for each city are provided to the i-UR, particularly when they are deemed beneficial for deployment in other cities or application domains. This feedback aims to standardize and integrate widely shareable information into the SDPS-3DCM.

For instance, the concept of sediment disaster was initially not included in Disaster Risk, necessitating the use of the Generic City Object, which allows for modeling and exchanging 3D objects not covered by any other features in CityGML. However, sediment disaster was subsequently defined in i-UR as a subtype of Disaster Risk, acknowledging their critical importance to many municipalities.

3.3 LOD Refinement

LOD in CityGML 2.0 encompasses five levels, ranging from LOD0 to LOD4. Although conceptual definitions for each LOD have been established, there is a notable deficiency in rigor when applying these definitions to data implementation. As a result, even when developing models at the same LOD, variations may emerge due to the materials utilized and the expertise of the technicians involved in the creation process.

Figure 2 presents building models in LOD2 created in two different cities. In LOD2, the outer facade of a building can be differentiated by boundary surface features such as the roof surface and wall surface. In contrast, in LOD1, a building is represented as a simple block without detailed differentiation. Additionally, outer building installations can be represented in LOD2. The building depicted in Figure 2 for City A features roof installations and accurately captures the intricate geometries of the wall surfaces. In contrast, the building in City B omits roof installations and presents a simplified representation of the wall surfaces.

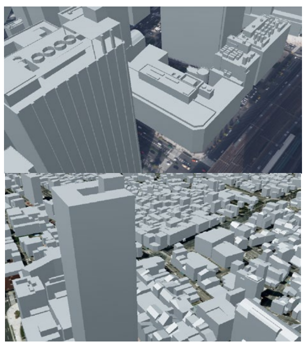


Figure 2. Examples of variations in shape reproducibility within the same LOD.

Both building models meet the definition of LOD2 and are considered valid models at this level. However, applications requiring detailed models, such as that of City A, cannot be adequately supported by the simplified model from City B. Conversely, supplying a detailed model like that of City A to applications designed for simpler representations, like that of City B, may result in excessive data volume and subsequent operational challenges. Both detailed and simplified LOD2 building models possess distinct advantages and disadvantages, making it difficult to assert the superiority of one over the other. The key factor is to establish a consensus on the definition of

[2] https://www.gsi.go.jp/common/000259949.pdf

https://doi.org/10.5194/isprs-annals-X-4-W6-2025-129-2025

LOD2 between data providers and data users. This mutual agreement is essential for ensuring effective communication and utilization of the data in various applications.

Biljecki (Biljecki et al., 2016) has identified the absence of precise specifications for each LOD and the generality of LOD as significant challenges. To address these issues, he proposed a subdivision of the LOD based on a comprehensive literature review, analysis of acquisition workflows, and examination of published specifications.

In this study, to ensure the homogeneity and continuity of the 3D city model, municipalities are designated as the responsible entities for maintenance. LODs are subdivided based on data owned by these municipalities. Specifically, LOD0, LOD1 and LOD2 can be created using aerial photographs or aerial laser point cloud data held by municipalities, thereby encompassing the entire city. LOD3 can be derived from data specifically acquired for individual use cases, primarily comprising images and point cloud data obtained through Mobile Mapping Systems. Furthermore, for highly detailed LOD3 representations, the incorporation of Building Information Modeling (BIM) data may also be considered.

The LOD2 model in CityGML 2.0 features differentiated roof structures and thematically distinct boundary surfaces, and it may also include external building installations. In contrast, the LOD3 model can incorporate openings in addition to the features represented in the LOD2 model.

The definitions of LOD subdivisions have been established to align with the definitions of LOD2 and LOD3 in CityGML 2.0. LOD2 provides a detailed representation of the upper surface geometry of features, whereas LOD3 offers a detailed representation of the side surface geometry. Figure 3 presents an overview of the LOD subdivisions. Definitions of each LOD subdivision are presented in Table 3 and Table 4.

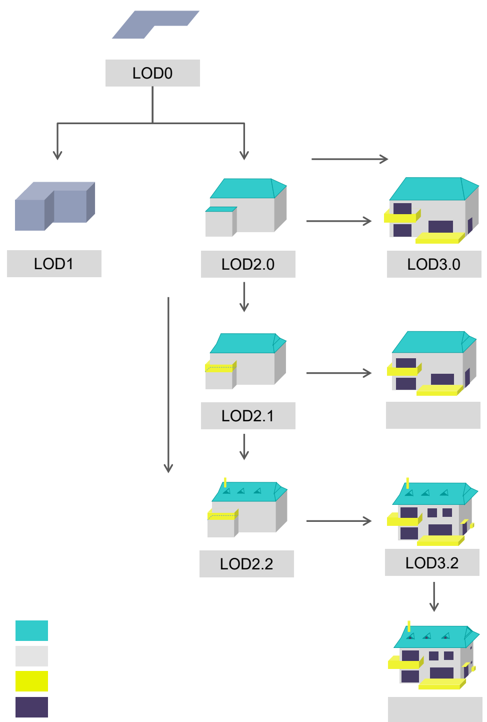


Figure 3. Overview of Refined LODs for Buildings.

FeatureType	LOD2.0	LOD2.1	LOD2.2
Building	M	M	M
BuildingPart	C Required when a single building is divided into parts with different themes.	C Identical to the left.	C Identical to the left.
RoofSurface	M Projected length of the shorter side > 3m	M Projected length of the shorter side > 3m Or Projected length of the shorter side > 1m and projected area > $3m^2$	M Projected length of the shorter side > 1m Or Projected area > $1m^2$
GroundSurface	M	M	M
WallSurface	M	M	M
ClosureSurface[1]	C Required when utilizing BuildingPart.	C Identical to the left.	C Identical to the left.
OuterFloorSurface[2]		O	O
OuterCeilingSurface[3]			
BuildingInstallation		M Projected length of the shorter side > 3m Or Projected length of the shorter side > 1m and projected area > $3m^2$	M Projected length of the shorter side > 1m

M : Mandatory C : Conditional O : Optional -
1: Virtual surface used to seal the building shell.
2: Horizontal surface belonging to the outer building shell and having the orientation pointing upwards.
3 Horizontal surface belonging to the outer building shell and having the orientation pointing downwards.

Table 3. Definitions of Each LOD2 Subdivision

FeatureType	LOD3.0	LOD3.1	LOD3.2	LOD3.3
Building	M	M	M	M
BuildingPart	C Matches the definition in LOD2.	C Identical to the left.	C Identical to the left.	C Identical to the left.
RoofSurface	M Length of the shorter side > 3m	M Length of the shorter side > 1m and projected area > $3m^2$	M Length of the shorter side > 1m Or Projected area > $1m^2$	M All roof surfaces
GroundSurface	M	M	M	M
WallSurface	M Length of the shorter side > 3m	M Length of the shorter side > 1m and projected area > $3m^2$	M Length of the shorter side > 1m Or Projected area > $1m^2$	M All wall surfaces
WallSurface (Overhang)	M A distance between the roof edge and the wall > 3m	M A distance between the roof edge and the wall > 1m	M Identical to the left.	M All overhangs.
ClosureSurface	C Matches the definition in LOD2.	C Identical to the left.	C Identical to the left.	C Identical to the left.
OuterFloorSurface	O	O	O	O
OuterCeilingSurface	O	O	O	O
BuildingInstallation	M Length of the shorter side > 3m Or Length of the shorter side > 1m and projected area > $3m^2$	M Identical to the left.	M Length of the shorter side > 1m Or Projected area > $1m^2$	M All installations
Door	M Length of the shorter side > 1m	M Identical to the left.	M Projected area > $1m^2$	M All doors
Window	M Length of the shorter side > 1m	M Identical to the left.	M Projected area > $1m^2$	M All windows

M : Mandatory C : Conditional O : Optional

Table 4. Definitions of Each LOD3 Subdivision

The LOD subdivisions outlined in this paper are practical categories that align with the LOD concept of CityGML 2.0, considering the feasibility of data production. This approach clarifies the features to be captured and their respective sizes, while avoiding over-specification in data production. For instance, the LOD2 subdivisions are designed to be produced from aerial photographs, which results in the exclusion of overhangs in the representation. Figure 4 illustrates examples of buildings represented across each LOD subdivision.

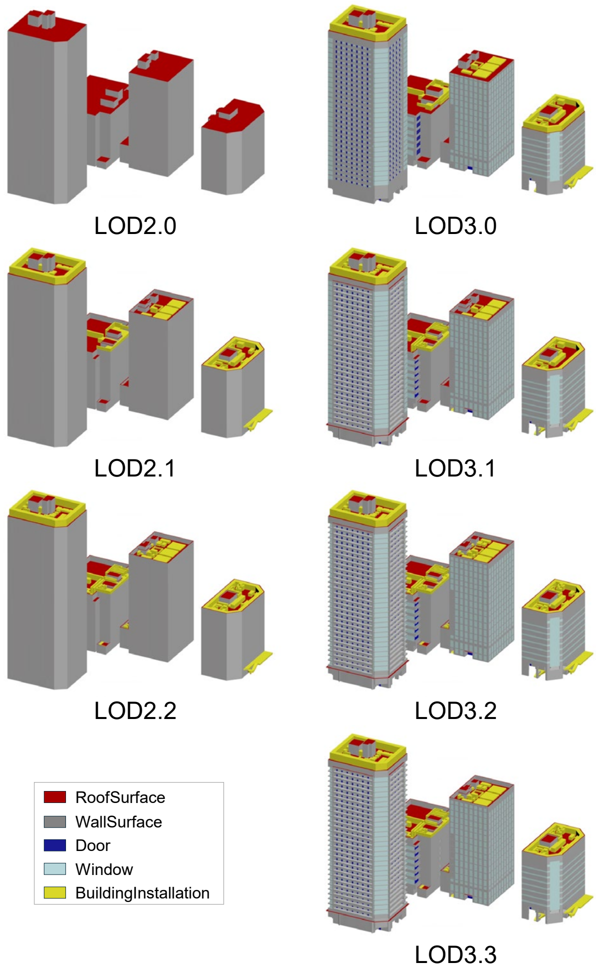


Figure 4. Examples of Building applying refined LODs.

Figure 5 highlights the areas where discrepancies in representation occur due to the LOD subdivisions. The main difference between LOD2.0 and LOD2.1/LOD2.2 lies in the inclusion of building installations. Additionally, LOD2.1 and LOD2.2 have different criteria for the size of the BuildingInstallation to be included, with LOD2.2 allowing for smaller building installations. In LOD3, in addition to the features acquired in LOD2, there are differences in the representation of openings and sides. LOD3.0 does not represent the overhangs on the sides, while LOD3.1 and higher subdivisions do. LOD3.1 and LOD3.2 further define different criteria regarding the size of openings and side overhangs that should be represented. Notably, LOD3.3, which offers the most detailed representation within LOD3, encompasses even smaller openings and overhangs.

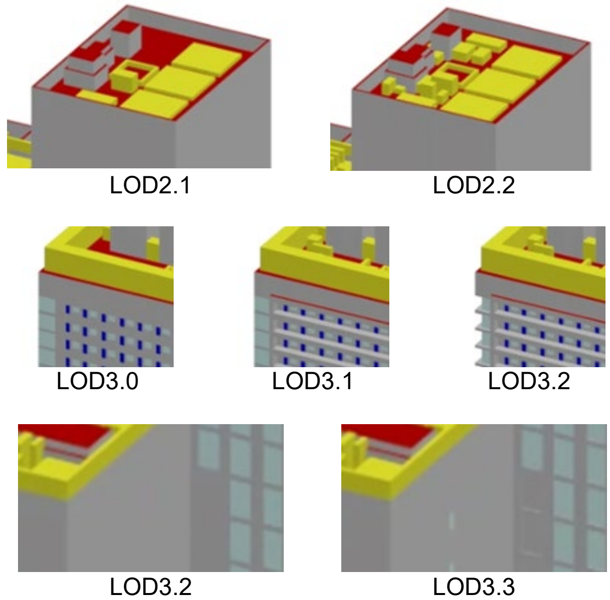


Figure 5. Shape Representation Variations Using Refined LODs.

Using a similar methodology, the essential LOD subdivisions were established for additional features, including Transportation (Roads, Tracks, Squares, Railways), City Furniture, Tunnels, Bridges, Other Constructions, and Underground Buildings. The subdivision of LOD, along with its clear definitions, enhances communication between data creators and users, improving data production efficiency and ensuring homogeneity. Moreover, by considering the resources available to municipalities, which are responsible for the maintenance and management of 3D city models, these LOD subdivisions become applicable to all cities in Japan.

3.4 Profile Mechanism of the Standard Data Product Specifications for 3D City Models by City

The comprehensiveness of the SDPS-3DCM can be enhanced to accommodate a wide range of use cases. However, in practice, not all use cases within each city necessitate all the features and attributes defined in the SDPS-3DCM. Additionally, certain use cases may require features or attributes that are not included in the SDPS-3DCM. Therefore, the SDPS-3DCM offers a profiling mechanism tailored to the specific use cases of each city.

Ishimaru (Ishimaru, 2025) proposed "StandardsOps" as a methodology for efficiently applying standards. This methodology encompasses a cycle of localizing open standards, formulating DPS, developing systems in parallel with the data creation based on the specifications for rapid operation, and incorporating the results back into the open standards.

Standards are established through consensus-building among relevant stakeholders, resulting in the presentation of multiple options or the provision of a meta-concept that encompasses all options. Consequently, when applying these standards, it is essential to develop implementation specifications (DPSs) through profiling that aligns with the universe of discourse for a specific city.

In the same way, the comprehensive DPS developed in this paper is designated as the "Standard" Data Product Specification (SDPS-3DCM). Each city can then localize the SDPS-3DCM by profiling the geographical features, attributes, and LODs necessary to address their specific use cases. This results in a 3D city model grounded in a unified DPS, referred to as the Standard Data Product Specification for 3D City Models[3], while accounting for variations in the specific contexts to be developed for each city.

4. Application of the Standard Data Product Specification for 3D City Models

Defining the SDPS-3DCM not only accelerates the rapid development of 3D city models and associated use case systems across various Japanese cities, but also streamlines the development of common software solutions, such as quality control and data conversion.

4.1 Data and Use Case Development in Accordance with the Standard Data Product Specification for 3D City Models

4.1.1 Data Development: Between 2020 and 2024, a total of 264 cities developed their DPSs localized to their specific use cases, serving as profiles of the SDPS-3DCM. These cities subsequently created 3D city models based on their localized DPSs. Table 5 shows the number of cities for which data has been developed and opened for each feature, based on a list published by the G-Spatial Information Center, which is the data portal for 3D city models (Geospatial Information Center, 2025).

Feature		Number of Cities
Building		264
Land Use		250
Transportation	Road	259
	Track	18
	Square	5
	Railway	4
	Waterway[2]	2
Urban Planning[1]		243
Disaster Risk[1]		252
City Furniture		45
Vegetation		33
Water Body		3
Relief Feature		260
Bridge		39
Tunnel		0
Other Construction[2]		4
Underground Building[1]		6
Utility Network[1]		1
Zone[1]		11

1: Features defined in Urban Planning ADE
2: Features defined in Urban Planning ADE while ensuring consistency with CityGML 3.0.

Table 5 Number of Cities that Have Each Feature

The number of cities that have developed and made available data for tunnels is 0, as indicated in Table 5. This absence is attributed to the fact that, although the data was produced, it could not be published as open data due to security concerns and other considerations.

4.1.2 Use Case Development: The 3D city models developed in each city were utilized to implement their respective use cases. Figure 6 illustrates the use cases for 74 municipalities that were developed under the subsidy program[4] from FY 2022 to FY 2024, which allowed for multiple responses. Many municipalities are actively engaged in disaster prevention and urban planning initiatives. To support these efforts, they have developed product specifications derived from profiles based on the SDPS-3DCM framework and created corresponding 3D city models that comply with these specifications.

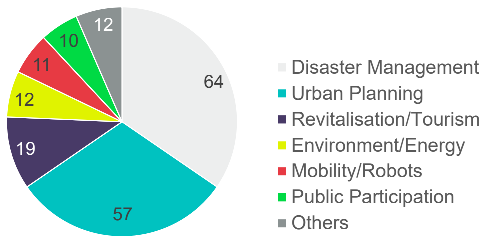
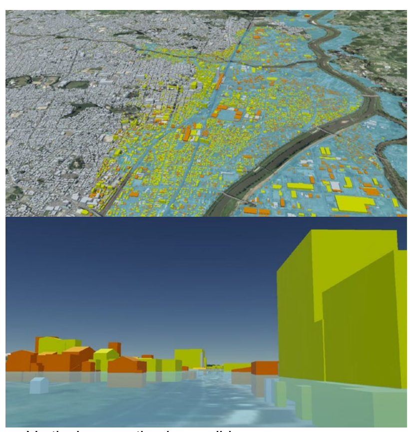


Figure 6. Use Cases for Municipalities Developed through the Subsidy Program.

The creation of such profiles enables the establishment of DPSs that are more closely aligned with specific use cases. For example, Figure 7 illustrates a case of flood assessment that incorporates unique adaptations. In Japan, many municipalities face the risk of flooding due to the abundance of mountains and rivers, and these municipalities prepare shelters for residents. However, during sudden heavy rainfall, it is not always possible to evacuate to these shelters. Consequently, this city has independently integrated additional information, such as building structural types, to evaluate the feasibility of vertical evacuation. The colored buildings in Figure 7 indicate varying levels of flood risk: orange buildings denote structures where vertical evacuation is possible, while yellow buildings signify those where vertical evacuation is not viable, highlighting the need for evacuation to shelters or other safe locations. In this case, the incorporation of use case-specific information, such as building structure types, significantly enhances the DPS. This methodology enables a more nuanced analysis that extends beyond the mere identification of flood-prone areas; it also facilitates the assessment of the most efficient evacuation routes, thereby equipping residents with practical options to ensure their safety.



Orange: Vertical evacuation is possible.
Yellow: Vertical evacuation is not possible.

Figure 7. Examples of Use Cases for 3D City Models.

[3] https://www.mlit.go.jp/plateaudocument/

[4] https://www.mlit.go.jp/toshi/daisei/plateau_hojo.html

The 3D city models offer the advantage of intuitively demonstrating the extent to which individual buildings are at risk of flooding by overlaying flood levels directly onto the urban landscape. Furthermore, this use case includes simulations that assess whether it would be more advantageous for occupants to evacuate to alternative locations or to seek refuge in the building's upper floors, based on attributes such as the number of stories and structural types. Given the challenges posed by an aging population and potential manpower shortages, there may be scenarios where safe evacuation outside the building is difficult. In such instances, vertical evacuation presents a viable alternative, and this use case serves as an effective means of proposing more appropriate evacuation strategies.

These 3D city models are not only utilized for the specific use cases but are also accessible to a diverse range of users, as they have been published as open data[5]. In addition, all use case developments carried out in the PLATEAU project have been made publicly available to municipalities and others interested in similar applications, facilitating knowledge sharing[6]. The technical findings are published as reports[7], and the developed systems are accessible as open-source software[8] on the project's website.

4.2 Software Development in Accordance with the Standard Data Product Specification for 3D City Models

By establishing the SDPS-3DCM, the development of common software streamlined, allowing for a focused allocation of resources to non-standardized areas. These software solutions are available as open source and can be deployed in cities planning to develop 3D city models in the future. Historically, systems have been developed individually for each city and application; however, by utilizing common software, efficient system development can be achieved.

4.2.1 PLATEAU-Builder: PLATEAU-Builder is software designed for the straightforward and efficient editing, quality checking, and output of 3D city models in CityGML format, adhering to the SDPS-3DCM. The software was developed to enable not only surveying companies with specialized technical skills but also individuals looking to use and create 3D city models, as well as vendors from various fields who lack expertise in 3D city modeling, to easily generate 3D city models for research and validation purposes.

4.2.2 PLATEAU-View: PLATEAU-VIEW is a browser-based GIS that visualizes 3D city models developed in accordance with standard product specifications. It also allows for the overlay of various geospatial data.

4.2.3 PLATEAU-GIS-Converter: PLATEAU-GIS - Converter is a software application designed to convert 3D city models from CityGML format—created in accordance with the SDPS-3DCM —into other widely used GIS data formats, including GeoPackage, GeoJSON, and Shapefile.

[5] https://front.geospatial.jp/plateau_portal_site/
[6] https://www.mlit.go.jp/plateau/use-case/
[7] https://www.mlit.go.jp/plateau/libraries/technical-reports/
[8] https://github.com/Project-PLATEAU

5. Discussion and Findings

This paper aims to ensure the reusability of 3D city models by developing the SDPS-3DCM. By adopting CityGML and i-UR as the application schema and encoding specifications of the SDPS-3DCM, we enhanced its comprehensiveness and implemented a profiling mechanism tailored to urban use cases, making it applicable to a diverse range of cities throughout Japan. Additionally, we refined the LODs by subdividing them based on the materials held by municipalities and established quantitative criteria for each subdivision. This approach not only ensures the continuity of maintenance by the municipalities but also mitigates ambiguities arising from variations in materials and the experience levels of the creators, thereby contributing to enhanced homogeneity in the 3D city models. Furthermore, the unification of data product specifications for 3D city models facilitates the efficient development of software tools.

5.1 Improvement of Machine Readability

Despite the clarification of definitions for each LOD subdivision through the establishment of quantitative criteria, ambiguities persist in defining features and attributes. This ambiguity arises from the necessity for documentation of the application schema, which accompany the UML class diagram that illustrates the conceptual structure of features (ISO, 2015); this documentation is expressed in natural language. While natural language enhances human readability, it is also prone to ambiguities and inconsistencies, complicating efforts to maintain consistency and coherence. Consequently, there is an urgent need to enhance machine readability and improve the reliability of the SDPS-3DCM.

5.2 Transition to CityGML 3.0

In addition, while the SDPS-3DCM adopts CityGML 2.0, it is important to note that the CityGML 3.0 Conceptual Model Standard was published in 2021 (Kolbe et al., 2021), followed by the CityGML 3.0 GML Encoding Standard in 2023 (Kutzner et al., 2023). CityGML 3.0 introduces new features and refines existing ones, significantly enhancing its usability for a broader range of applications (Kolbe, et al., 2021). The necessity to migrate to CityGML 3.0 is anticipated in the near feature.

In particular, LODs have been refined to represent only geometric detail, excluding semantic granularity. This separation enables the development of models that integrate outdoor and indoor features at different LODs. Such an approach proves to be highly efficient for applications centered around indoor environments, as it allows for the creation of 3D city models that simplify external appearances while providing detailed representations of interiors. However, the ability to combine different LODs expands the range of possibilities but also introduces increased complexity. This complexity can impose additional burdens on both data creators and users. Therefore, it is essential to explore how the SDPS-3DCM can effectively delineate which combinations of LODs are best suited for specific use cases.

In addition, PLATEAU has already developed 3D city models and software compatible with CityGML 2.0. It is important to consider the utilization of these existing assets if PLATEAU transitions to CityGML 3.0. For instance, alongside the development of converters to upgrade 3D city models from CityGML 2.0 to CityGML 3.0, there is an emerging need to create converters that can downgrade CityGML 3.0-compliant

3D city models back to CityGML 2.0. This is particularly relevant, as there is often little motivation to transition to CityGML 3.0 for use cases that can be effectively addressed with CityGML 2.0. The availability of a downgrade converter would allow for the efficient utilization of existing assets without necessitating modification.

6. Conclusions

This paper presents the development of the Standard Data Product Specification for 3D City Models (SDPS-3DCM) within the PLATEAU. By establishing the SDPS-3DCM that complies with international standards, 3D city models serve as a foundational framework for digital twins, applicable across diverse domains. Furthermore, data standardization streamlines the development of tools for creating and utilizing 3D city models, enhancing data reusability and facilitating the effective allocation of limited resources to non-standardized areas.

The SDPS-3DCM considers existing data development frameworks, such as basic urban planning maps and urban planning surveys, thereby increasing the feasibility and sustainability of data development initiatives. Since this specification is derived from user requirements, it must be periodically reviewed to adapt to changes in social and usage environments. In such instances, adopting standards such as CityGML 3.0 can further enhance data reusability. Additionally, careful attention must be given to data implementation and strategies for ongoing updates, including facilitating machine readability and effectively utilizing existing assets.

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