19th WORLD CONFERENCE OF THE ASSOCIATED RESEARCH CENTRES FOR THE URBAN UNDERGROUND SPACE
Belgrade, Serbia, November 4-7, 2025.

ACUUS BELGRADE 2025

Paper No: 5.6.54
DOI: 10.46793/ACUUS2025.5.6.54

BUILDING A NAVIGATION SYSTEM USING DIGITAL TWINS OF INFORMATION FROM ABOVE AND BELOW GROUND

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Abstract: In recent years, the advanced usage of underground spaces has progressed, and facilities such as underground shopping arcades, stations, and walkways, have combined to form networks covering wide areas. Furthermore, cities have developed by connecting the basement levels of buildings to underground spaces, creating urban areas where above-ground, underground, indoor, and outdoor spaces, have all become interconnected. While urban areas expect to see improvements in accessibility, complicated connections lead to issues such as maze.

In order to respond to these challenges, the Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT) has created 3D foundation maps that combine information from above and below ground, through balancing 3D city models, BIM models, etc., and is developing and conducting proof-of-concept tests on navigation systems that use these maps, under the PLATEAU project creating digital twins of Japan cities promoted by MLIT. This paper introduces an overview of the project and the usefulness of digital twin technology for underground spaces.

Keywords: 3D City Model, Digital Twins, Navigation Systems, Project PLATEAU

1. INTRODUCTION

MLIT has been promoting “Project PLATEAU”, a project for the development, utilization, and open data of 3D city models since FY2020. The 3D city model data provided by PLATEAU has three major characteristics: “high quality (controlled accuracy as physical location and shape data of buildings, etc.)”, “structured (LOD definition as a 3D map and attribute information)”, and “open data (adoption of standardized open format)” [1].

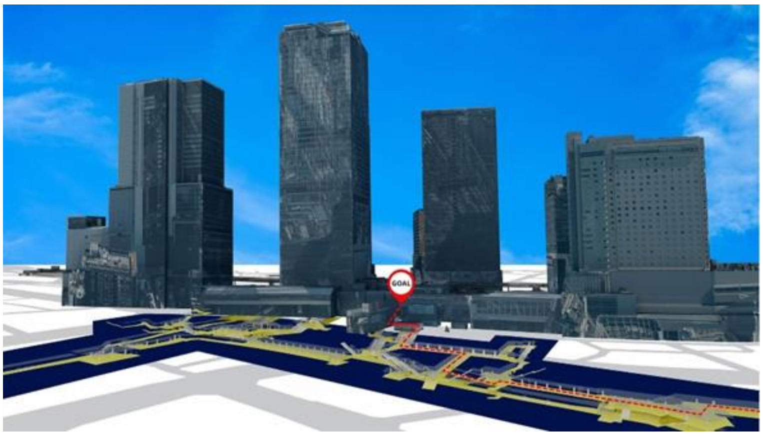

Figure 1. *The 3D navigation system that combine information from above and below ground*

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The 3D city models provided by PLATEU are basically intended for “outdoor information” based on aerial surveys, so detailed models including “indoor information” are required depending on the intended use. In response, PLATEAU has defined architectural models (LOD4) that is compatible with IFC2×3, the international standard for BIM models, through verification studies conducted in previous years, and enables linkage (conversion and integration) with BIM data [2].

Regarding navigation systems utilizing 3D city models, Yan, Zlatanova et al. (2021) demonstrated that by constructing an integrated 3D space-based navigation model (U3DSNM) for a university campus, a navigation system can be realized across different spaces (facilities) such as indoor, semi-indoor, semi-outdoor, and outdoor environments [3]. However, a navigation system that constructs 3D foundation maps across the ground and underground for actual large urban spaces, and further incorporates indoor positioning technology, has yet to be demonstrated.

In this verification, we constructed 3D foundation maps that seamlessly integrates the existing 3D city models of the area and the converted 3D city models based on BIM data across the ground and underground. And we developed a 3D navigation system based on the infrastructure incorporating indoor positioning technology (Figure 1). This paper presents an overview of the system, its validation results, and the usefulness of digital twin technology in underground spaces.

2. SYSTEM OUTLINE

The 3D navigation system is based on the “Tokyo Station Navi” provided by JR East Consultants Company and has been modified to additionally implement (1) 3D navigation functions using 3D city models and (2) AR navigation functions using 3D city models. In addition, as the 3D city models to be used, an underground mall models (LOD4), which is formulated in the Standard Data Product Specification for 3D City Model, Version 5.0, was created. In addition, building models (LOD4) of representative buildings in the target area were converted from BIM models and generated. The building model (LOD4) is a model that represents the inner shape of buildings (indoor spaces) and is data that can be used for indoor navigation.

2.1. Ability to create map data using 3D city models

The 3D city models and the BIM models were combined by developing a converter that converts the IFC files of the BIM models to CityGML, which is the data format used by the 3D city models provided by PLATEAU [4]. Among the functions of the system, those related to the creation of map data are shown in Table 1.

Table 1. *List of Functions (Map Data Creation)*

ID	Function	Description
001	Editing BIM Models	Create and edit BIM models in Autodesk Revit, a BIM tool
002	IFC to CityGML conversion function	Using FME Desktop, convert the BIM models in IFC format into 3D city models in CityGML format.
003	CityGML to FBX conversion function	Using FME Desktop, convert the 3D city models in CityGML format to 3D model data in FBX format for use in each application.
004	Processing of GIS data	Using QGIS, process and output from the geometry and attribute data of the 3D city models to JSON format, which is the building master data, for advanced conversion of floors.
005	OBJ to USDZ conversion function	Using Reality Composer, combine OBJ generated from 3D city models and building master data and convert to USDZ format as map data for AR applications.

2.2. Navigation Functions

The 3D navigation system is a navigation application for pedestrians that seamlessly connects ground/underground and indoor/outdoor pedestrian spaces centered on stations. The system consists of 3D and AR navigation functions as its main features.

The route guidance, which is the basis of the 3D navigation function (Figure 2), uses POI (Point of Interest, data on representative points of buildings, facilities, stores, equipment, etc., which serve as destinations in route guidance) and network data (data related to travel routes consisting of node data indicating the starting and ending points of routes and points such as intersections, and link data indicating line segments connecting nodes and nodes) currently in operation in the existing "Tokyo Station Navi" system. The 3D route search results can be displayed on the 3D map by adding the height (elevation) information extracted from the building master data (JSON format), which compiles the floor height (elevation) information of each location.

The route search function is based on the shortest route search logic based on the Dijkstra method, using network data, and is able to search for "barrier-free step-elimination routes" that pass through elevators, slopes, and other step-elimination facilities by applying its own weighting. This system is based on the existing "Tokyo Station Navi". To estimate self-position for route search, the iOS version uses indoor positioning using Core Location, while the Android version uses the results of indoor positioning using the proprietary logic that combines Beacon and Fused Location Provider API. In the target area, map data creations and radio surveys are being conducted to enable indoor positioning of Core Location.

The AR navigation function allows users to intuitively understand which direction buildings and destinations on the ground are located while in underground spaces. When an app user in the underground space holds the smartphone up to the ceiling, wireframes of the destination building is displayed through the camera's reflection on the ceiling. This allows the user to see the 3D models of the above-ground building and the POI of the destination from the smartphone screen even while staying in the underground mall, and to confirm the direction to the destination. Also, the route from its own position to the destination and the surrounding facility POI can be displayed. (Figure-3)

Finally, we describe the software used in this development. Both the 3D navigation and AR navigation systems were developed using Unity, a widely used game development platform. This created WebGL data compatible with web browsers, which is visualized via a WebView within the Station Navigation App. Also, geospatial information—such as store and facility details, Points of Interest (POI), and route network data—was organized into a database using PostGIS and PostgreSQL. This data is acquired via Web APIs and utilized within the 3D navigation system.

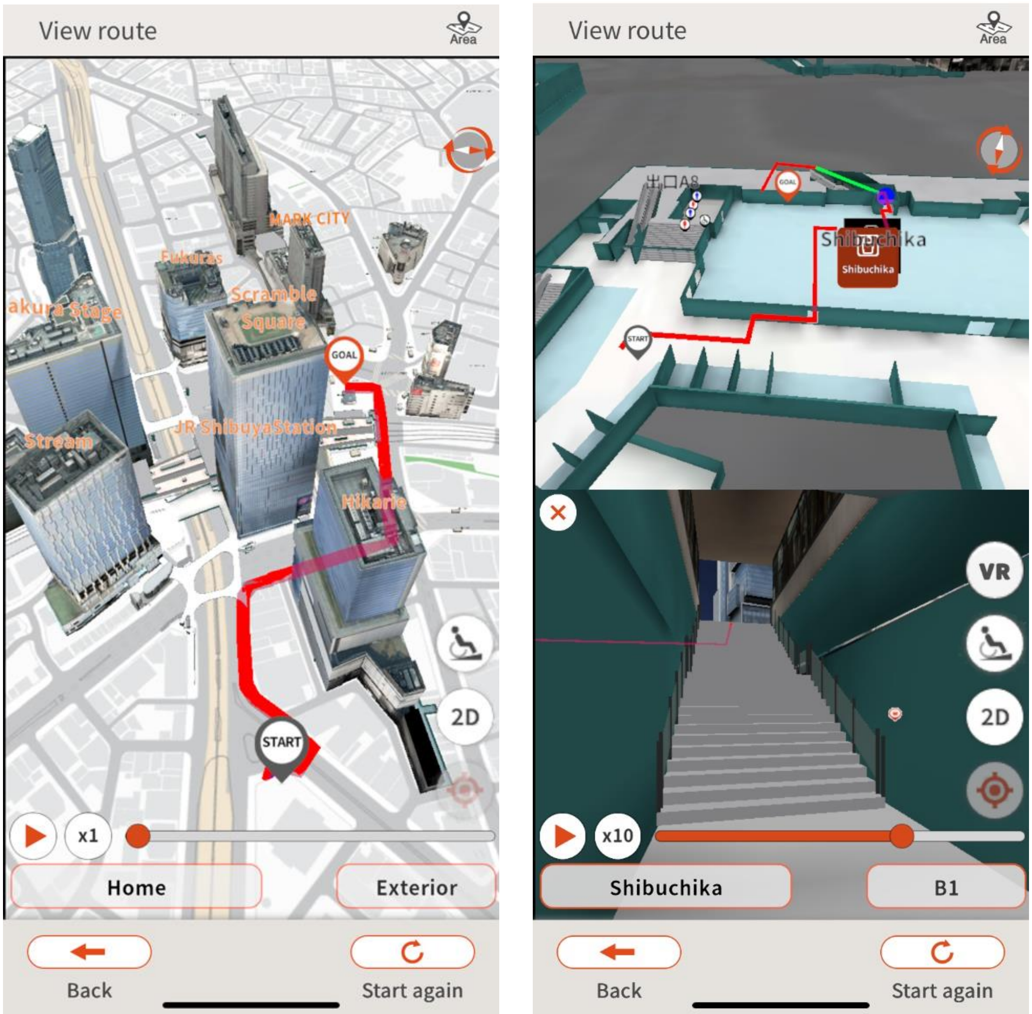

***Figure 2.** 2D/3D navigation function*

***Figure 3.** Screen image with AR navigation function*

3. RESULTS, ISSUES, AND CONSIDERATIONS OBTAINED FROM THE VERIFICATION

3.1. Verification Method

In the total of three areas (Shibuya Station, Sapporo Station, and Takamatsu Station), the functions developed in this verification were opened to the public from December 2, 2024 to January 31, 2025 for general users, and questionnaire surveys were conducted on the usefulness of the 3D navigation and AR navigation functions. The 3D navigation function was surveyed in terms of "ease of use of the search screen", "clarity of route guidance", "speed of display", and "clarity of 2D maps", while the AR navigation function was surveyed in terms of "convenience of AR navigation" and "display speed". The number of valid responses was 166 for the 3D navigation function and 153 for the AR navigation function, respectively.

3.2. Verification results and issues

The 3D and AR navigation functions developed in this verification were generally highly evaluated by general users (Table 2). On the other hand, it was found that user satisfaction was relatively low in terms of some usefulness aspects, such as display speed, and that improvements are needed. In addition, there were many requests for additional related information, such as store availability and train operation information, indicating the direction in which this development should be expanded.

3.3. Consideration

Through this demonstration, the superiority of the 3D city models provided by PLATEAU in terms of technology, business, and public policy was demonstrated. (Table 3)

Table 2. *Summary of Questionnaire Results (excerpts)*

Functions	Survey Items	Response Results
3D	Ease of use of the search screen	Positive responses were received from approximately 50% of users. Some users commented that it was easier to use than conventional 2D map applications.
	Clarity of route guidance	Nearly 60% of users answered that the system was easy to understand.
	Speed of display	More than 70% of users answered, “above average”. On the other hand, many users were able to use the system with a certain degree of comfort, but it was confirmed that there is room for improvement.
	Clarity of 2D maps	
AR	Convenience of AR navigation	While more than 60% of the users found the system convenient, there were many comments such as “it does not display correctly” and “I am not used to using it”, confirming that quality stability and improved positional accuracy are issues to be addressed.
	Speed of display	80% of users answered, “above average”.

Main result items	Result items	Superiority
Technology	Seamless switching between multiple viewpoints	・ In the case of use for navigation applications, the 2D map can be substituted by displaying the map vertically from directly above. ・ In the case of 3D city models provided by PLATEAU, correct height information is retained, allowing simple 3D display without artificially adding height information. ・ 3D view of land objects makes it easy to grasp vertical movement
	Landscape restoration and understanding of current location	・ 3D city models make it easy to reproduce the landscape of a location through the use of textures, etc.
	Select the type of land object	・ CityGML uses component tags to represent each type of building component, so the tags can be used to easily extract the necessary geographic features
	Elevation	・ It is difficult to express in the 2D map when spatially connected facilities have different hierarchical names, but in the 3D city models, it is easy to create a seamless map without being bound by hierarchical names because of the use of elevation.
Business	Reduction of development and operation costs through open data	・ The data is maintained as public open data, and operating costs can be reduced as the open data is updated in the future.
	Scalability of business through wide scope of maintenance	・ In terms of business scale, the development of 3D city models nationwide will enable utilization that is not limited to specific regions.
Public policy	Advancement of community development	・ By disseminating information on the navigation application for everyday use that utilizes 3D city models, it is possible to

	and information dissemination	easily disseminate city planning and other related information.

Table 3. *Superiority of 3D city models*

4. CONCLUSION

This paper presents the overview of navigation systems that utilize digital twins integrating above and below ground spaces and the usefulness of digital twins technology in the underground spaces. The verification results reaffirmed the high social demand for seamless three-dimensional navigation between the terminal station, indoor and outdoor, and above and below ground. In addition, it was also confirmed that the construction of a 3D foundation maps that can be commonly used by different facility managers (station and town) from BIM and its use in the navigation application can contribute to the advancement of information dissemination about the station and town. Furthermore, by utilizing the elevation information contained within the 3D city model data provided by PLATEAU, it is possible to offer barrier-free routes that account for steps and slopes. This contributes to realizing an urban environment where everyone can move comfortably, representing one of the core values of digital twin utilization within this service.

In addition, the capability to integrate CityGML-format GIS data — which handles urban spatial information —with BIM data — which handles design information in the architecture and civil engineering fields — enables the comprehensive utilization of an integrated information infrastructure for the entire city. This is also of significant importance for the future development of this project.

In order to develop this navigation system in the future, it is necessary to continue to improve the UI/UX required for the navigation application based on user requests, and to encourage the participation of facility managers in the existing area. It is also important to accelerate the incorporation of real-time information that is expected to expand in the future (e.g., information on vacancies in facilities, stores, coin lockers, etc., and the opening and acceptance status of evacuation centers and facilities for people having difficulty returning home).

Through this verification, the method of constructing 3D foundation maps utilizing 3D city models and BIM data owned by facility managers is considered to have been largely established.

In line with the development of 3D city models and the spread of open data in various regions, it is expected that the diffusion and expansion of 3D foundation maps that allows both city development businesses and visitors to share information will continue in various areas.

5. BIBLIOGRAPHY

[1] Yuri Tsubaki (2024). Project PLATEAU-The Initiative of Digital Twin in Japan-, Intelligence. Informatics and Infrastructure, Volume 5, Issue 2, 1-12. https://doi.org/10.11532/jsceiii.5.2_1.
[2] Manual for the Integration of BIM Models in 3D City Models with CityGML Version 4.0. https://www.mlit.go.jp/plateau/file/libraries/doc/plateau_doc_0003_ver04.pdf.
[3] Yan, Zlatanova & Diakité (2021). A unified 3D space-based navigation model for seamless navigation in indoor and outdoor. International Journal of Digital Earth, Vol. 14, No. 8.
[4] Conversion template from IFC to CityGML2.0 building models (LOD4) using FME. https://github.com/Project-PLATEAU/PLATEAU-IFC-to-CityGML2.0-LOD4.
[5] Technical Report on Navigation System Utilizing Underground 3D City Models v2.0. https://www.mlit.go.jp/plateau/file/libraries/doc/plateau_tech_doc_0108_ver01.pdf.
[6] Technical Report on Navigation System Utilizing Underground 3D City Models. https://www.mlit.go.jp/plateau/file/libraries/doc/plateau_tech_doc_0075_ver01.pdf.