Detecting Underground Geospatial Features for Protection of Rights in 3D Space: Korean Cases

Sang Keun Bae and Jung Ok Kim

Abstract: Interest in underground space development is increasing owing to overcrowding in urban areas, and this trend is expected to continue in the future. Therefore, there exists a need to systematically establish and manage information on underground spaces. This information includes both the physical status, that indicates the location or shape of the space, and the status of property rights related to the ownership and use of the space. In this study, a technique to register an entire underground shopping center space including individual store spaces along with the relationship with the above-ground parcels is proposed. The study considers the current management and operation system of the underground shopping center. 3D data were acquired from the Gwangbok Underground Shopping Center in Busan Metropolitan City, Korea using terrestrial LiDAR equipment. The VWorld data of the Korean Ministry of Land, Infrastructure, and Transport were also used as pre-built data. Furthermore, a spatial information-based management system was implemented. The data used comprise registration information for establishing property rights. These have the physical status and rights status information of the ground parcels as attribute information.

Keywords: urban underground space; underground space governance; right registration; property right; 3D spatial information

1. Introduction

Land use is gradually becoming complex and diversified owing to rapid urbanization and overpopulation. This has resulted in increasing interest in underground space development as part of sustainable national land development and the creation of a pleasant environment [1–7]. In general, underground space refers to the space beneath the surface of the ground where essential infrastructure, necessary for our daily life, is normally located. This includes subways, walkways, roadways, shopping centers, water and sewage facilities, as well as electricity, gas, and communication facilities [8,9].

However, a more realistic and concrete definition is required, as the former abstract definition makes it virtually impossible for humans to use the underground space located under the surface indefinitely [10]. Accordingly, the American Underground Space Association (AUSA) defines it as a spatial resource of a certain scale that is naturally or artificially created under the surface of the earth within the range that can be used for a purpose [11]. With reference to this definition, it is defined as a spatial resource of a certain scale that is naturally created or artificially created under the surface of the earth within the range that can be used for a purpose [12,13]. The underground space covered in this study is an underground shopping center for the passage of citizens and commercial activities, which belongs to the ‘underground facility space’ of artificially built spaces.

An underground space refers to a space that is symmetrical, with the ground space centering around the surface of the earth. In the cadastral field that involves the registration...
of land, the concept of the 3D cadaster was introduced to efficiently manage and utilize the national territorial space [14–16]. A ‘3D cadastral system’ is defined as a system that still registers rights and limited rights on 2D parcels but also gives more insight on the juridical and factual situation above and under the surface in case this is relevant with respect to legal security [17].

In this study, a technique to register an underground shopping center space and individual store spaces in relation to the above-ground parcels is proposed. Previous studies and the current management and operation system of the underground shopping center are considered. Existing studies have mostly generated underground spatial information via surveys or field investigations. However, in terms of establishing the rights relationship, only the concept of underground spaces and the general directions for establishing rights relationship were investigated.

In this study, in addition to conduction of a survey, existing public data are used to generate individual object-level underground spatial information. This study is different from previous studies in that the data used to generate the physical status and rights status information of the ground parcels, as registration information, are also used to establish property rights in the underground space. The attribute information required for the registration is also obtained.

The rest of this paper is organized as follows. Section 2 introduces the research methods, equipment, and data used to generate the underground spatial information. The generation of the 3D underground spatial information is presented in Section 3, whereas Section 4 describes how to register the underground information. Lastly, a summary of the main conclusions of this study is presented in Section 5.

2. Methodology

In this study, store-level 3D spatial data were generated by conducting a survey and using a pre-built data processing method for underground space registration. By using the two methods in parallel, data can be obtained for an area without pre-built spatial data, by surveying, and 3D spatial data can be generated for an area with pre-built data. After generating the store-level 3D spatial data, underground space registration data were generated as the spatial status information (location, boundary, etc.) for the above and underground space. The data were entered for attribute information necessary for registration as shown in Figure 1.

![Figure 1. Processes used in this study.](image)

Mobile terrestrial LiDAR equipment known as a 3D Mapping Trolley from NavVis was used to acquire data during the survey. This equipment is equipped with an optical digital camera and a laser scanner, and hence, it can easily capture spatial data by acquiring both
point cloud and image data simultaneously. The detailed specifications of the equipment are presented in Table 1.

### Table 1. Characteristics of surveying equipment.

| Classification | Specification | Quantity | Product Image |
|----------------|---------------|----------|---------------|
| Optical Camera | - Individual image resolution: 7360 × 4912  
- Fisheye 7.5 mm  
- Full Frame CMOS Sensors  
- Image aspect ratio: 3:2, 16:9  
- Dynamic range function included  
- Camera automatic control and synchronization function  
- Image log autosave function  
- Panoramic image autostitch function  
- Panoramic image: 32 megapixel supported  
- Field of view horizontal: 270°  
- Angular Resolution: 0.25°  
- Rotation Frequency: 1/160 s  
- Camera automatic control and synchronization function  
- Image log autosave function  
- Panoramic image autostitch function  
- Panoramic image: 32 megapixel supported | 6 | |
| Laser Scanner | - Field of view horizontal: 270°  
- Angular Resolution: 0.25°  
- Rotation Frequency: 1/160 s  
- Camera automatic control and synchronization function  
- Image log autosave function  
- Panoramic image autostitch function  
- Panoramic image: 32 megapixel supported  
- Points per Second 43,200 (1080 × 40) | 3 | |
| Sensors | - Sensor: IMU, Magnetometer  
- WiFi: 2.4 + 5.0 GHz, 802.11a/b/g/n/ac  
- Bluetooth: Bluetooth4.0LE  
- Measurement error between two points within 100 m: 20–30 mm  
- Panorama resolution (stitched): 32 megapixel  
- Point cloud: XYZ, Normals  
- Color from images  
- Density: up to 5 mm  
- Point cloud formats: LAS, PLY, PTS, XYZ  
- Other Outputs: 2D Map  
- Create Navigation Graph  
- Create WiFi Fingerprints | 1 | |

In this study, the VWorld data of the Korean Ministry of Land was used as pre-built data to generate 3D spatial data. There were differences in the data format and universality, operable programs, and coordinate systems, as the agents for data generation and management were different. The characteristics of each data are presented in Table 2. VWorld is an open platform for spatial information that is built on the basis of spatial information accumulated by the Korean government and is being serviced through the web. It provides 2D and 3D spatial information free of charge through an open application program interface (API).

### Table 2. Characteristics of used data.

| Operating Body | Ministry of Land, Infrastructure and Transport (Korea) |
|----------------|--------------------------------------------------------|
| Raw data open  | Restricted disclosure (approval required)             |
| Service scope  | Administration-use and public-use                     |
| 2D             | shp, dwg, dxf                                         |
| 3D             | imp, asc, 3ds, max                                    |
| Data format    | 3D texture code table, structured layer definition, structured classified code |
| Attributes     | classification table, position layer classification table, POI classification table, building code design table |
| Data universality | Raw data (imp format file) can be operated in specific software |
| Main operating programs | Autodesk 3D MAX, AutoCAD, Leica Cyclone |
| Data coordinate system | Absolute coordinates |
| Data usability | Difference in constructed data between data generations periods, information inconsistency between 3D data and POI |
3. Results

In this study, 3D data were acquired from the Gwangbok Underground Shopping Center in Busan Metropolitan City, Korea using a direct survey method. The representative 3D data acquisition methods for underground spaces include using a total station and terrestrial LiDAR equipment. A total station is an optical instrument commonly used in surveying and civil engineering. It is useful for measuring horizontal angles, vertical angles, and distance. In this study, the data were acquired using the terrestrial LiDAR since the method of employing the total station has the disadvantage that it is difficult to capture the detailed shape of the data, although the volume of data acquired is smaller than that acquired using the terrestrial LiDAR equipment.

3.1. Direct Survey Method

The method for acquiring the 3D data of an underground shopping center can be mainly divided into surveying control points and 3D laser scanning. To acquire the absolute coordinates of the underground shopping center, the cadastral supplementary control point near the Gwangbok Underground Shopping Center was used, and then 3D laser scanning was carried out by scanning the inside of the shopping center using the LiDAR equipment. In the process of verifying the supplementary control point using the total station, we found that there are four first-grade traverse lines with good control points at the start and end of the Gwangbok Underground Shopping Center. Using this as a starting point and an occluded point, a supplementary control survey was conducted using a closed or fixed traverse. Global navigation satellite system (GNSS) surveying equipment was used to obtain World Geodetic System-based results; however, direct observation was difficult due to interference from adjacent high-rise buildings. Therefore, the World Geodetic System (WGS) coordinates were calculated by installing an arbitrary point and connecting it to the supplementary control point used in the survey. The supplementary control points used in the survey are presented in Table 3. In Table 3, Bessel is Datum: Tokyo, Ellipsoid: Bessel (1841), coordinate system: TM, and WGS is Datum: ITRF2000, Ellipsoid: GRS80, coordinate system: TM.

Table 3. Supplementary control points used in the survey.

| Supplementary Control Points Used | Bessel Result | World Geodetic System Result | Elevation | Remarks |
|----------------------------------|---------------|-----------------------------|-----------|---------|
|                                  | X Coordinate  | Y Coordinate                | X Coordinate | Y Coordinate |          |
| 1048                             | 177,746.24    | 203,190.68                  | 278,056.11  | 203,249.15  | 2.477 m  |
| 903                              | 177,723.78    | 203,066.15                  | 278,033.60  | 203,124.64  | 1.979 m  |
| 129                              | 178,099.64    | 203,280.58                  | 278,409.46  | 203,338.97  | 1.599 m  |
| 130                              | 178,058.39    | 203,254.60                  | 278,368.23  | 203,312.98  | 1.492 m  |

Ten supplementary control points, connecting the ground and underground, were established to acquire 3D data of the underground shopping center, and the elevation value for each supplementary control point was calculated. The Gwangbok Underground Shopping Center is located in an area where the average horizontal distance from the sea level is approximately 150–200 m. Therefore, the elevation value of the supplementary control point in the underground shopping center, excluding the ground, was measured as a negative value (−), as presented in Table 4 [18].
Table 4. Newly established supplementary control points.

| Newly Established Supplementary Control Points | Bessel Result | World Geodetic System Result | Elevation (H) | Remarks          |
|-----------------------------------------------|---------------|------------------------------|--------------|------------------|
| X Coordinate | Y Coordinate | X Coordinate | Y Coordinate |                |                  |
| 1  | 177,689.45 | 203,172.56 | 277,999.29 | 203,231.05 | 2.041 | Ground installation |
| 2  | 177,678.09 | 203,144.73 | 277,987.93 | 203,203.23 | 2.629 | Ground installation |
| 3  | 177,669.29 | 203,120.48 | 277,979.12 | 203,178.98 | −6.792 | Underground installation |
| 4  | 177,651.40 | 203,129.27 | 277,961.24 | 203,187.77 | −6.762 | Underground installation |
| 5  | 177,805.34 | 203,286.67 | 278,115.21 | 203,345.14 | −6.762 | Underground installation |
| 6  | 177,952.24 | 203,278.28 | 278,262.10 | 203,336.73 | −5.301 | Underground installation |
| 7  | 178,022.74 | 203,274.68 | 278,332.60 | 203,333.11 | −5.427 | Underground installation |
| 8  | 178,024.49 | 203,286.17 | 278,334.35 | 203,344.60 | −5.420 | Underground installation |
| 9  | 178,045.00 | 203,284.29 | 278,354.86 | 203,342.71 | 2.213 | Ground installation |

3D laser scanning was carried out to acquire the 3D coordinates of selected points of the shopping center based on the relative coordinates using the LiDAR equipment. Therefore, prior to laser scanning, 53 control points were observed near the point where three sides that can be recognized as points in a 3D space meet for conversion to absolute coordinates. After surveying and observing the control points, laser scanning was performed to acquire 3D spatial data inside the underground shopping center using the LiDAR equipment. Because of the nature of the equipment, there can be a shaded area due to the presence of pedestrians, therefore data acquisition was performed late at night and early morning when pedestrian traffic was relatively low.

The total length of the Gwangbok Underground Shopping Center is 411 m, and stores are located on the left, right, and center of the shopping center, and pedestrian passages were separated into two. Therefore, the total distance was approximately 820 m back and forth. The data acquisition process was performed by dividing the entire shopping center into five blocks and 12 gates, as shown in Figure 2. This minimizes the accumulating errors in the mobile equipment as the distance increases.

A transformation is a function that takes a point and maps the point onto another point. The coordinate transformation in the form of Equation (1) is called 3D affine transformation [19].

\[
\begin{pmatrix}
    x' \\
    y' \\
    z' \\
    1
\end{pmatrix} =
\begin{pmatrix}
    a_{11} & a_{12} & a_{13} & a_{14} \\
    a_{21} & a_{22} & a_{23} & a_{24} \\
    a_{31} & a_{32} & a_{33} & a_{34} \\
    0 & 0 & 0 & 1
\end{pmatrix}
\begin{pmatrix}
    x \\
    y \\
    z \\
    1
\end{pmatrix}
\]

(1)

In a 4 × 4 matrix, the upper-left 3 × 3 sub-matrix represents an orientation in space while the last column vector represents a position in space. The transformation of the point \( x \) to point \( x' \) can be found by multiplying the matrix by \( x \).

The point cloud data acquired in the form of relative coordinates was matched with the control point, converted into absolute coordinates, and integrated into a single data as shown in Figure 3. The point where the three faces meet is the relative coordinates of the point cloud (Figure 3b) acquired using LiDAR as \( x, y, z \). For coordinate transformation, the absolute coordinates of the reference point (Figure 3a) surveyed for the same point are set as \( x', y', z' \), and then 3D affine transformation was performed. After calculating 12 conversion coefficients using 53 reference points, the relative coordinates for the entire point cloud are converted to absolute coordinates. The point cloud data were absolute coordinated using at least four control points for each block, and the positional accuracy was improved by performing the process until the root mean square error (RMSE) decreased below 0.5 m.
Figure 2. Building point cloud data for each block. (a) Point cloud data for each block (inside the shopping center). (b) Point cloud data for each block (gates). Color is a relative height value, higher is red and lower is blue.
After integrating the point cloud datasets, wire framing was performed to extract topographic information from the point cloud data, as shown in Figure 4. The external boundary exposed toward the passage can be easily verified owing to the nature of the underground shopping center; however, it is often difficult to obtain the internal boundary of the store owing to changes in the structure or display of goods. Therefore, the boundaries of individual stores were established by referring to the drawings and the internal end points of stores located at the starting point of the underground shopping center [20].
After generating the 2D topographic information, 3D topographic information was generated through modeling, as shown in Figure 5, and the attribute information namely, store name, store number, store owner, type of business, contract date, area, and rent was mapped to each store. This information was obtained from the infrastructure technology corporation that manages the underground shopping center.

![Figure 5](image1)

**Figure 5.** Store-level 3D spatial data generation through 3D modeling and attribute information input. (a) 3D modeling. (b) Final result. The file format is 3DS.

### 3.2. Method of Using Pre-Built Data

In this study, the pre-built public data of the indoor spatial information were used as raw data to generate store-level 3D underground spatial information. In the indoor spatial information of the VWorld of Ministry of Land, Infrastructure, and Transport in Korea, point cloud data are first acquired through laser scanning and then, 3D spatial information is generated through modeling. Subsequently, 3D topographic information, excluding attribute information, is provided on the web after generating the data by dividing the underground shopping center into several blocks. In this study, the raw data generated for each block were categorized into individual stores in the form of independent polygons, and the previously provided attribute information was updated with reference to the private indoor map service; then, the topographic information and the attribute information for each store were combined (Figure 6).

![Figure 6](image2)

**Figure 6.** Cont.
4. Discussion

The public underground shopping center is the target of registration in this study. The public underground shopping center is a shared property of the local government which holds the ownership, and the stores are generally operated by the store owner [20]. Therefore, in this study, the underground shopping center and individual stores are the targets of registration to protect the ownership held by the local governments and the lease rights of the store owners for individual stores.

In general, because the property rights for land in Korea are set based on above-ground parcels, it is necessary to register the entire underground shopping center space and individual store spaces, along with the physical and rights relation, with the above-ground parcel when registering underground spaces. In terms of physical relation, the spatial scope of the underground shopping center or the individual store occupying the underground space is the target of registration, and it is necessary to specify which parcel the corresponding underground space is located under. In terms of rights, the party, purpose, area, rights relation (owner, tenant, period, price, etc.) of the property rights, and changes in the physical and rights information need to be included as registration information.

4.1. Building Data on the Spatial Relation between Ground and Underground Space

To register an underground space based on the store-level 3D underground space data generated using a survey or pre-built data, the spatial status of the ground and underground space needs to be evaluated. It is necessary to consider the rights relation between the above-ground and underground of the surface since land ownership in Korea is set around the surface. When using the above-ground and underground spaces of a parcel owned by others, compensation must be made accordingly. Moreover, if the space is under different administrative districts, it is advisable to check both the parcel boundaries and administrative district boundaries since the management parties will also be different.

Therefore, in this study, the spatial status information of the underground and ground space was generated based on the generated 3D underground spatial data. First, to generate the current status information on the horizontal position as shown in Figure 7, we overlapped the underground space spatial data and the continuous cadastral map to analyze the consistency between the underground spatial object and the boundary on the surface (administrative zone boundary, above-ground parcel boundary). The underground shopping center is located in the underground of two administrative districts, as shown in Figure 7b, and one underground shopping store is located in the underground of two above-ground parcels, as shown in Figure 7c. Similarly, the spatial status information for the case where one shopping center or an individual store is located in the basement of

Figure 6. 3D spatial data generation using VWorld data. (a) VWorld raw data. (b) Store unit object generation. (c) Attribute information input. (d) 3D modeling (3DS).
several administrative boundaries or parcels can be effectively utilized in terms of facility management and property rights protection.

Figure 7. Generating horizontal location status information with above-ground parcels. (a) Boundary between the underground shopping center and administrative district. (b) Boundary between the underground shopping center and above-ground parcel (administrative area). The blue diagonal line on the left is Seocho-dong, and the orange diagonal line on the right is Yeoksam-dong. (c) Boundary between individual stores and above-ground parcels.

Next, the vertical location status information with the above-ground parcel was generated. The vertical position status information is extremely important information. It relates to the depth limits used to determine the need for compensation when using the underground space of a parcel owned by others. The depth limit refers to the depth at which the landowner is not expected to use the land. Hence, it is determined so that it does not hinder the use of the land below ground even if underground facilities are installed. However, such depth limits have not yet been established by law. In Seoul, the capital city of Korea, the ordinance stipulates a basement of 40 m for high-rise urban districts, 35 m for middle-rise, 30 m for low-rise and residential areas, and 20 m for farmland and forest areas. In this study, to generate vertical position status information of underground space objects, we built a digital elevation mode (DEM) using a 1:5000 numerical map to calculate the maximum and minimum depths from the above-ground parcel corresponding to the underground space, as shown in Figure 8. When the underground space object was located in the underground of several above-ground parcels (Figure 8a), the maximum and minimum depths from each parcel were extracted (Figure 8b) to protect the property rights of all parcels.

4.2. Building Data on the Rights Relation between Ground and Underground Space

To register an underground space, information on the rights status (attribute information) as well as the spatial status (topographic information) of the ground and underground spaces need to be generated. In this study, we reviewed a certified copy of the register, building ledger, and comprehensive real estate certificate, which are the representative public ledgers that prove the rights relation to land and buildings in Korea, to obtain information on the current status of rights.

According to subparagraph 1 of Article 2 of the “Registration of Real Estate Act”, the term register means a public ledger that records the rights relation and the status of real estate as the object of the right and is classified into land registers and building registers (Article 14 (1) of the Registration of Real Estate Act), indicating the history of each land/building. In accordance with Article 14 (1) of the “Registration of Real Estate Act”, a registration record for a sectioned building shall consist of the title section for the building, and the title section, section A, and section B shall be indicated in a section under each
exclusive ownership. The registrar shall record the parcel number, land category, building number, building statement, grounds for registration, and holder of a right.

Figure 8. Generating vertical location status information with above-ground parcels. (a) Located under different above-ground parcels. (b) Highest and lowest points for each parcel.

According to Article 38 of the “Building Act”, the building register records and manages matters related to the characteristics of the building, such as the location, area, structure, use, and number of floors, and the owner’s status such as the name, address, and ownership interest of the building owner. Condominium buildings are those that are subject to the “Act on Ownership and Management of Condominium Buildings”, and the current status of buildings and lands is recorded in the condominium building register in accordance with subparagraph 2 of Article 4 of the “Regulations on the Registration and Management of Building Ledgers”.

The comprehensive real estate certificate defined in Article 76-4 of the “Act on the Establishment, Management, etc., of Spatial Data” shall record the boundaries and owner of the land and building, land use and regulation, real estate prices, and other matters necessary for the efficient use, management, and operation of real estate in accordance with Article 76-3 of the same Act. The service began in 2014 and initially provided 15 types of information, excluding registered information; however, three types of registered information have also been integrated since 2015, providing 18 types of information as of 2020.

In this study, a list of building status information such as location, name, main use, area, and contract information such as owners, tenants, lease contract required for the registration of the underground shopping center and individual stores was derived by referring to
three existing public ledgers. This was classified into administrative information, operation information, spatial information, and rights information according to the characteristics.

In the case of an underground shopping center, the local government holds the ownership of the entire shopping center, and it is extremely unlikely that there will be any changes. Therefore, information on the owner was included in the administrative information and no separate rights information item was added (Figure 9). However, in the case of individual stores, a separate rights information item was added as shown in Figure 10 for efficient information management, since the rights relation varies according to the lease agreement for each store, and it is common for such information to change constantly.

![Figure 9. Rights status information generation for underground shopping center.](image)

To systematically manage underground space registration information through public ledgers in the future, data modeling and standardization of registration information are required. Therefore, in this study, a data model for underground space registration was built using the Unified Modeling Language (UML), as shown in Figure 11. The underground shopping center class is the superclass of the feature model for registering underground spaces, and the store and management facility classes are the subclasses of the underground shopping center class.

The underground shopping center class consists of the object code, shopping center administrative information, shopping center operation information, and shopping center spatial information; the store class consists of the store administrative information, store operation information, store spatial information, and store rights information; the management facility class consists of the management facility code and management facility information. Among these, object code and management facility code are defined in the code lists, whereas the rest are defined in the data type lists. The object code and management facility code are managed by classifying each item (management operation facility, convenience facility, and other facilities) by the code number. The attribute information defined in the data type list defines the items required for registration and operation of each underground shopping center and individual stores by dividing them into administrative information, operation information, spatial information, and rights information. The attribute specification that describes each item is presented in Appendix A.
Figure 10. Rights status information generation for individual stores.

Figure 11. Data model for underground space registration information.
5. Conclusions and Recommendation

Information on underground spaces encompasses both the physical status information indicating the location or shape of the space and the right status information related to the ownership and use of the space. This study focused on public underpass shopping centers managed and operated by local governments in underground spaces. 3D underground space information was generated and used for each individual object as well as the use of structured public data. The underground spaces were registered based on this information.

In this study, store information was generated in individual object units. A spatial information-based management system was implemented, and we proposed a method to utilize this system. As the figure and attribute information are together for each store, such information can be effectively used for actual management tasks such as rental contract information management, statistical status identification, and facility and safety management. This information can be updated by continuously accumulating data generated for each store, and combining data collected from various sensors, floating population information, sales information for each store, and various field surveys such as commercial area analysis, disaster, and environmental management.

Moreover, a database was designed based on the store’s graphic information and attribute (rental) information as the data and management system were experimentally obtained for one underpass shopping center. The findings of this study could be useful in the future if the date of establishment of classified land rights and the coordinates of the establishment location are included in the commercial building information database. This also considers the shared land rights for above-ground parcels, protection of personal property rights, prevention of disputes, and the use of rational rights space.

This study provides the foundation for safeguarding the property rights of the state and citizens by generating 3D underground spatial information for individual objects and registering underground spaces by making the most of existing public data. A legal and institutional basis for development should be established as part of the national policy through further research to ensure a real-world application of the underground space registration plan proposed in the study.

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Appendix A

| Classification | Item | Description | Data Type |
|----------------|------|-------------|-----------|
| Object code    | Store | Individual stores in the underground shopping center | Number Code |
|                | Management facility | Facilities, excluding individual stores | Number Code |
Table A1. Cont.

| Classification                        | Item                                      | Description                                                                 | Data Type       |
|---------------------------------------|-------------------------------------------|-----------------------------------------------------------------------------|-----------------|
| Shopping center administration information | ID                                        | Unique number of the underground shopping center                           | Character String|
|                                       | Shopping center name                      | Underground shopping center’s name                                          | Character String|
|                                       | Owner/Manager                             | Owner/manager’s information                                                 | Character String|
|                                       | Number of floors                          | Total number of floors                                                      | Integer         |
|                                       | Location                                  | Address of the underground shopping center                                  | Character String|
|                                       | Main use                                  | Main uses of the underground shopping center                                | Character String|
|                                       | Main structure                            | Main structure of the underground shopping center                           | Character String|
|                                       | Land use                                  | Use of the land where the underground shopping center is located            | Character String|
|                                       | Use approval date                         | Use approval date of the underground shopping center                        | Date            |
|                                       | Construction/Completion                   | Construction/completion dates of the underground shopping center            | Date            |
|                                       | Changes                                   | Changes in the underground shopping center                                  | Character String|
|                                       | Other information                         | Other items to be stated                                                    | Character String|
|                                       | Number of stores                          | Total number of stores                                                      | Integer         |
|                                       | Shopping center area                      | Area of the underground shopping center                                     | Character String|
|                                       | Land area                                 | Land area to which the underground shopping center belongs                  | Real            |
|                                       | Total floor area                          | Total floor area of the underground shopping center                         | Real            |
|                                       | Management facility                       | Facilities other than stores                                                | Character String|
|                                       | Floor height                              | Height of each floor                                                        | Real            |
|                                       | Control points                            | Control point and boundary point coordinates                               | Real            |
|                                       | Status drawing                            | Spatial status information between the underground shopping center and the above-ground parcel | Map or Image    |

Table A2. Store class attribute specification.

| Classification                     | Item                                      | Description                                                                 | Data Type       |
|------------------------------------|-------------------------------------------|-----------------------------------------------------------------------------|-----------------|
| Store administration information   | ID                                        | Unique number of the store                                                 | Character String|
|                                    | Number of floors                          | Number of basement floors where the store is located                       | Integer         |
|                                    | Address                                   | Address of the above-ground parcel where the store is located              | Character String|
|                                    | Other information                         | Other items to be stated                                                    | Character String|
|                                    | Store name                                | Name of each store                                                         | Character String|
|                                    | Store area                                | Area by store                                                               | Real            |
| Store operation information        | Business type                             | Business type by store                                                      | Character String|
|                                    | Depth                                     | Depth information from the ground surface to the store                     | Real            |
| Store spatial information          | Status drawing                            | Spatial status information between stores and above-ground parcels         | Map or Image    |
|                                    | Owner                                     | Store owner’s information                                                   | Character String|
|                                    | Lessee                                    | Store lessee’s information                                                  | Character String|
|                                    | Lease contract                            | Lease contract information                                                  | Character String|
| Store rights information           | Divided superificies                      | Matters related to the establishment of partitioned space rights           | Character String|
|                                    | Other rights                              | Rights other than lease                                                     | Character String|
|                                    | Changes in rights                         | History of changes in rights relation                                       | Character String|
Table A3. Attribute specification of management facility class.

| Classification | Item | Description | Data type |
|----------------|------|-------------|-----------|
| Management facility code | Operation facility | Facilities necessary for underground shopping centers and store management | Number Code |
| | Convenience facility | User convenience facilities | Number Code |
| | Other facilities | Other facilities | Number Code |
| Management facility information | ID | Unique number of the management facility | Character String |
| | Location | Facility’s location information in the shopping center | Character String |
| | Area | Area of facility | Real |
| | Use | Use of facility | Character String |

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