Design and Implementation of 3D Underground Cadastral System in Korea

31-10-2016

Sangmin Kim

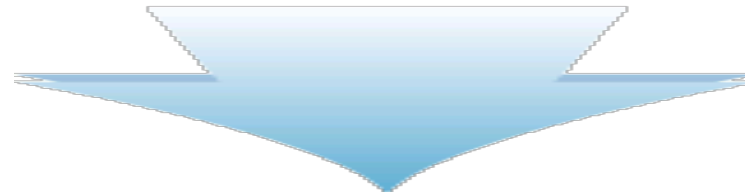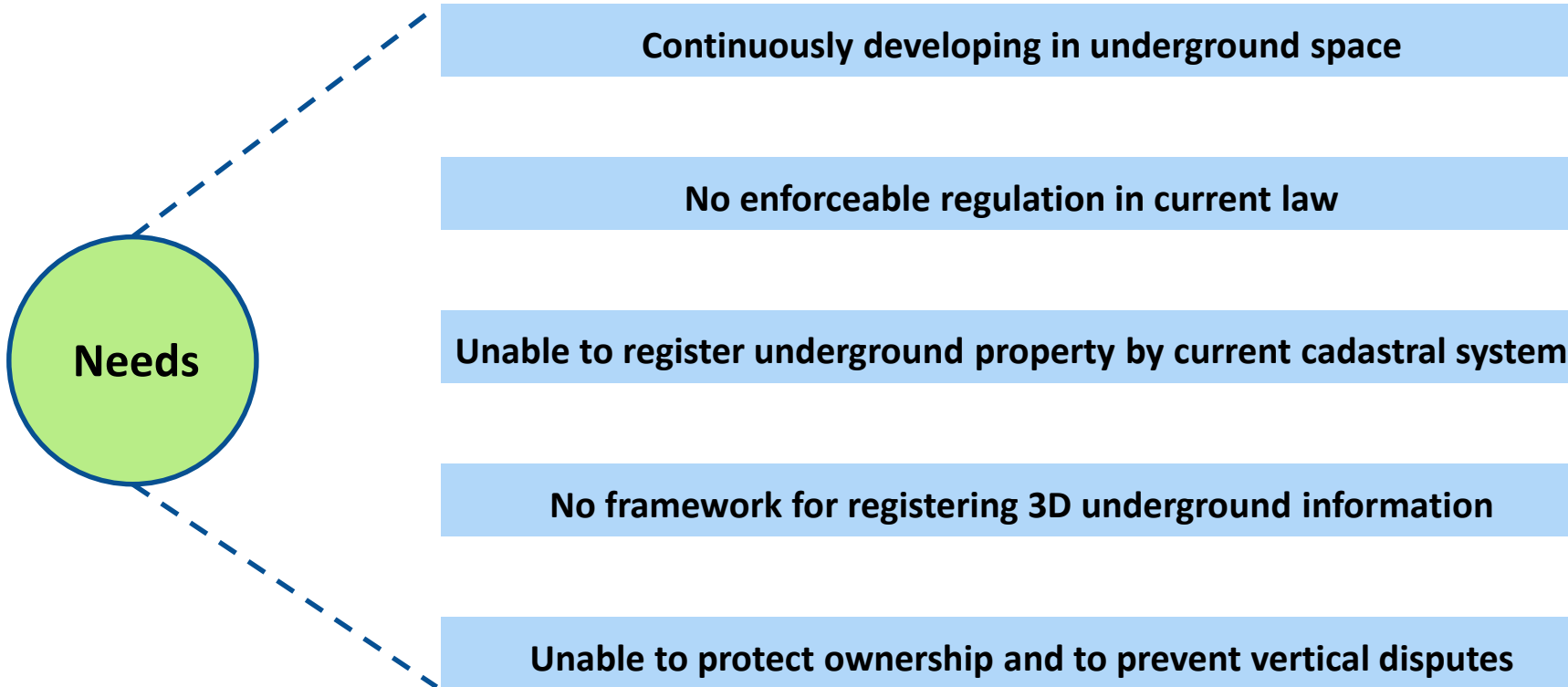# Contents

Overview
& Objectives

Overview & Objectives

- **Current status of registering and managing for underground space**

Needs

- Continuously developing in underground space
- No enforceable regulation in current law
- Unable to register underground property by current cadastral system
- No framework for registering 3D underground information
- Unable to protect ownership and to prevent vertical disputes

Needs for 3D Underground Cadastral System

- **Research Objectives**

  ➢ To establish the fundamental and systematical framework of 3D underground cadastral system

1. Development of registration framework

2. Development of conceptual data model

3. Development of 3D underground cadastral mapping

Registration of 3D Underground Parcel in Korean Cadastral System

Registration of 3D Underground Parcel in Korean Cadastral System

- **Issues of unregistered underground parcel**

  - ✓ The ambiguity with the definition of 'the scope of justifiable profit' causes the conflict between public and private rights.

  - ✓ Establishment of underground private right under the state-own parcel is prohibited by the state property act.

  - ✓ Management of underground space have been maintained by different authorities in different legitimizations. It causes administrative confusion.

  - ✓ The lack of location information with an accurate map causes unexpected accidents during new construction.

  - ✓ The lack of systematic registration method occurs reckless development for underground space.

Registration of 3D Underground Parcel in Korean Cadastral System

- ## Legal, administrative and technical limitations

Legal limitation	Administrative limitation	Technical limitation
➤ Article 212 of the Civil Act stipulates, "Within the scope, where a justifiable profit exists, the ownership of land extends both above and below its surface" ➤ 'Sectional Superficies' in Article 289-2 of the Civil Act was newly added in the 1984 Amendment of the Civil Act ➤ Clause 4 of Article 2 ('Definition') of the Act on The Establishment, Management, etc. of Spatial Data stipulates "cadastral survey"	➤ Inadequate management system and spatial database for underground space ➤ The inability of the cadastral system to support the registration of underground spaces ➤ Divided authorities to register and protect underground ownership	➤ No efficient mapping method for underground spaces ➤ Korea does not have standard procedures of underground cadastral surveying to acquire accurate spatial information ➤ Public records and maps for the registration of underground spaces have not yet addressed

Category of Law		Name of Law
Rights	Ownership	Constitution and the *Civil Act*
	Use	*Civil Act*, Urban Railroad Act, Railroad Construction Act ,Land Compensation Act, State Properties Act, Act on the Administration of Common Properties and Goods
Compensation		Land Compensation Act, Act on Planning and Use of National Territory, Urban Railroad Act and *Railroad Construction Act*
Development and management		National Land Planning and Use Act, Building Act, Parking Lot Act, Korea Railroad Corporation Act, Special Act on Safety Control for Infrastructure, *Act on The Establishment, Management, etc. of Spatial Data*, National Spatial Data Infrastructure Act.

• Precondition

➤ *Article 2 (Definitions) of Act on The Establishment, Management, etc. of Spatial Data*

20. The term **"definition of land"** means details registered in the cadastral record, such as the location, parcel number, land category, area, boundary, or land coordinate;

21. The term ***"parcel"*** *means a unit for the registration of land, which is partitioned as prescribed by Presidential Decree;*

22. The term "parcel number"

23. The term "parcel numbering region"

24. The term "land category"

25. The term "boundary point"

26. The term "boundary"

27. The term "area"

➤ *Article 4 (Deep underground) of Administrative Rules of the Railroad Construction Act*

3D underground parcel

- "parcel" means a unit for the registration of land, which is partitioned as prescribed by Presidential Decree

(Act on The Establishment, Management, etc. of Spatial Data)
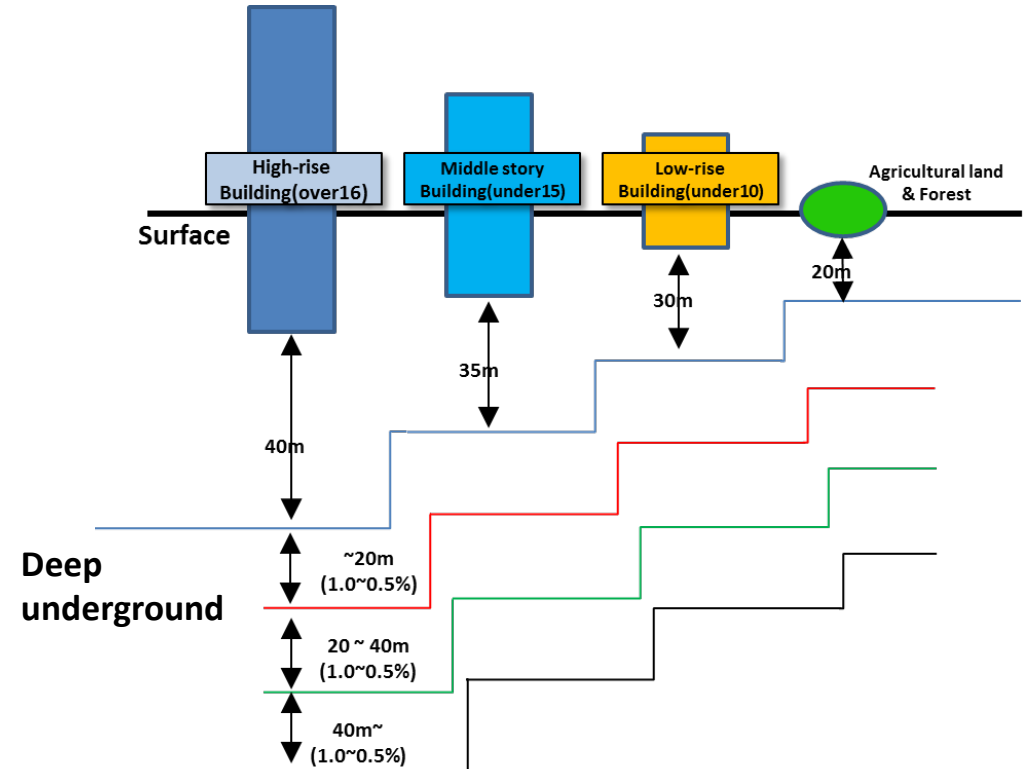
Deep underground

- 'depth, underground spaces below which are not expected to be used by the land owners and the installation of underground facilities below which does not hinder ordinary land uses'
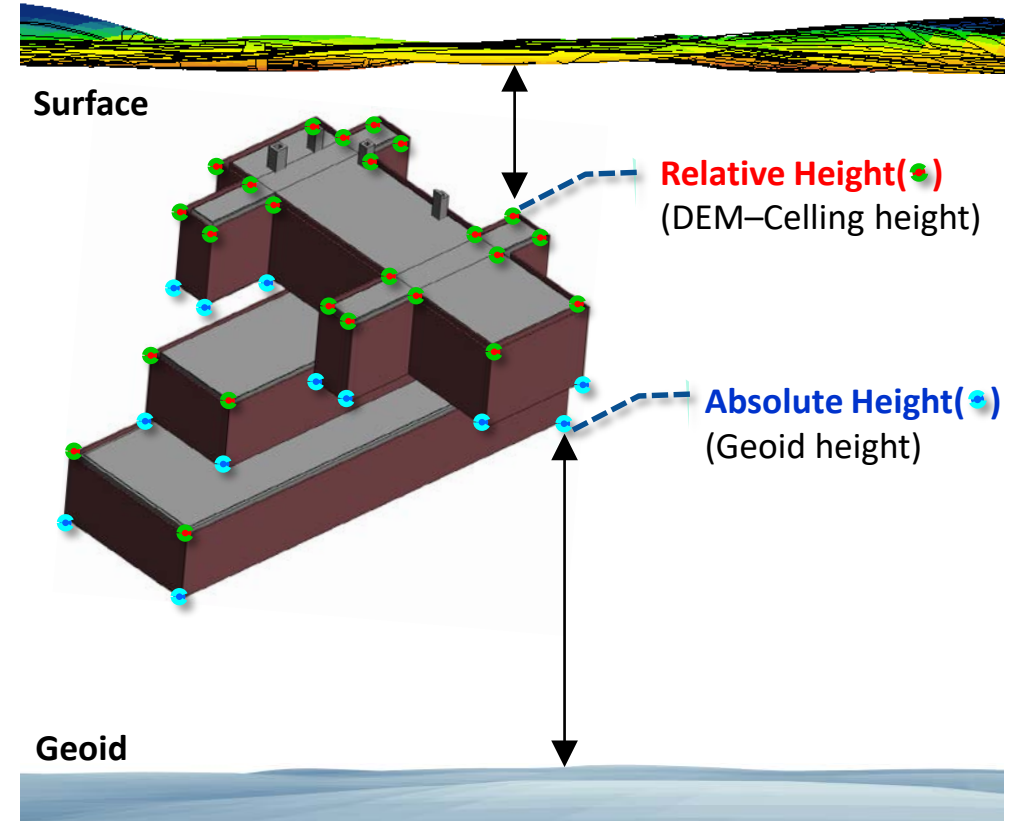
(Administrative Rules of the Railroad Construction Act)

Registration of 3D Underground Parcel in Korean Cadastral System

- **Proposed 3D underground height system**

Elevation map of underground parcels

Surface

Relative Height(●)
(DEM–Celling height)

Absolute Height(●)
(Geoid height)

Geoid
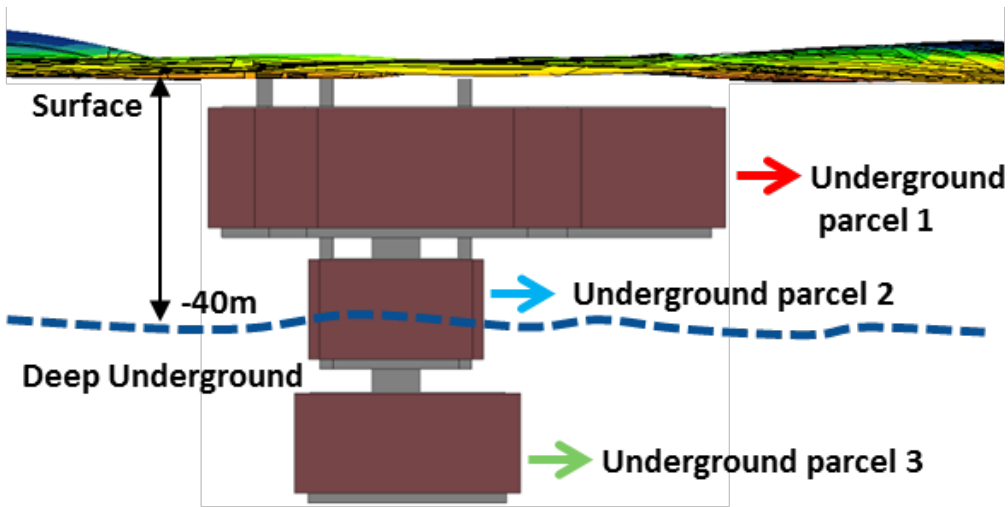
● **Absolute height**
- Support to maintain current national spatial information system

● **Relative height**
- Support to register various legal information including Rights, Responsibilities, and Restrictions (RRRs)

Registration of 3D Underground Parcel in Korean Cadastral System

- **Proposed new concepts of 3D underground parcel**

  ➢ Registration extent of 3D underground parcel (3D underground construction parcel, 3D underground legal space parcel)
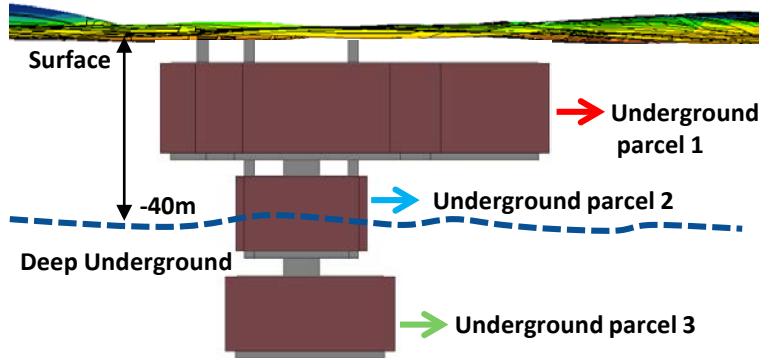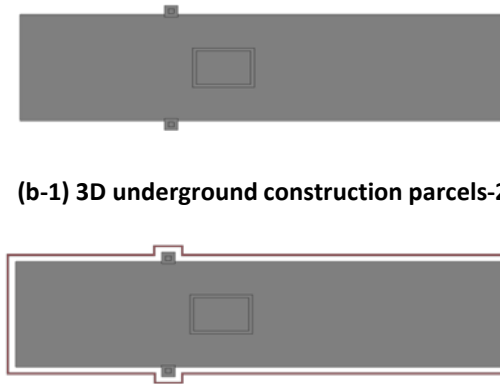

Elevation map of underground parcels
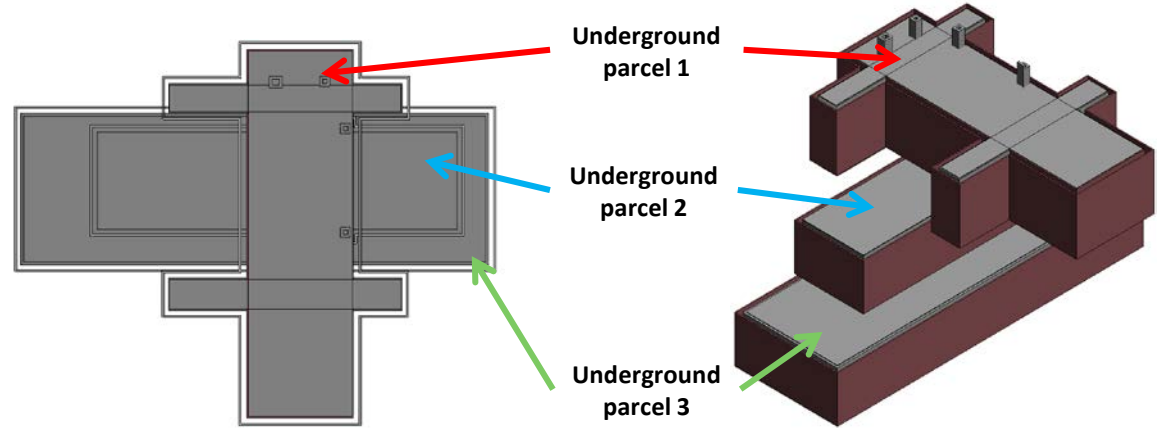
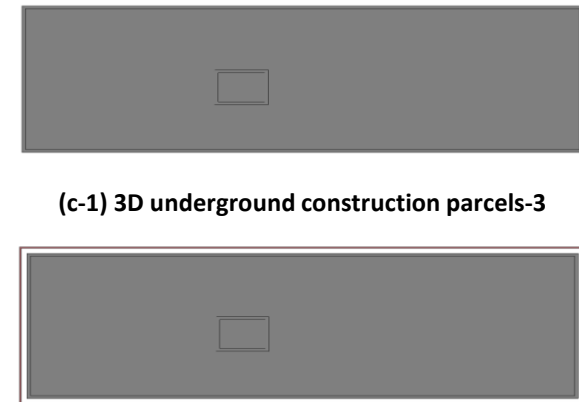Floor plan of underground parcels

3D view of underground parcels
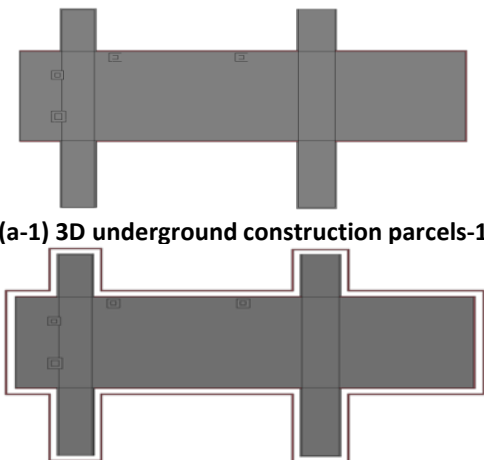
(a-1) 3D underground construction parcels-1

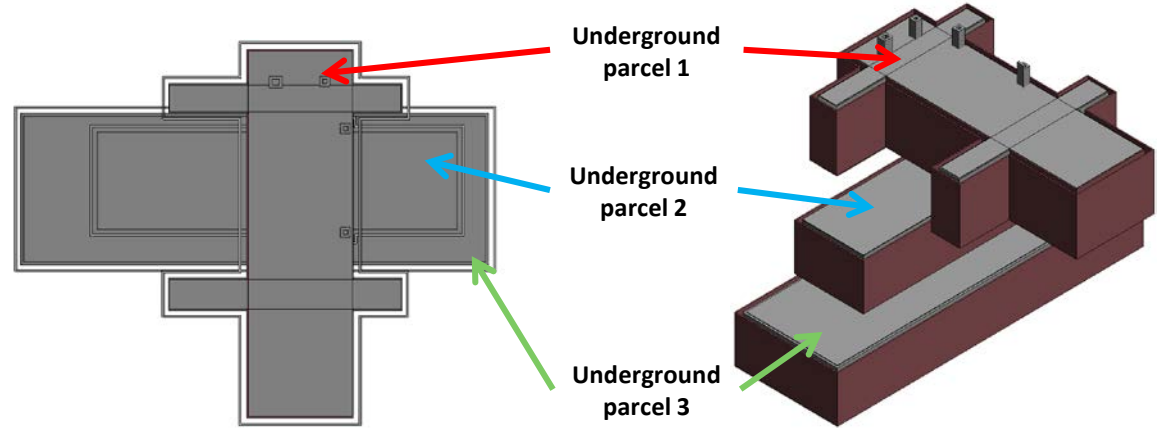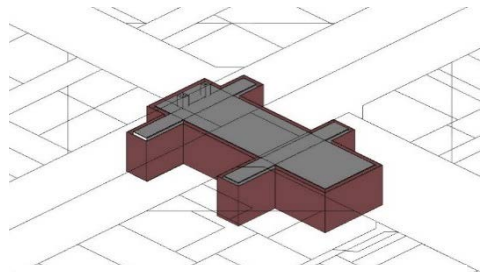(b-1) 3D underground construction parcels-2

(c-1) 3D underground construction parcels-3

(a-2) 3D underground legal space parcels-1

(b-2) 3D underground legal space parcels-2

(c-2) 3D underground legal space parcels-3

- **Proposed new concepts of 3D underground parcel**

➢ Registration **unit** of 3D underground parcel (3D underground fragmented parcel, 3D underground consolidated parcel)
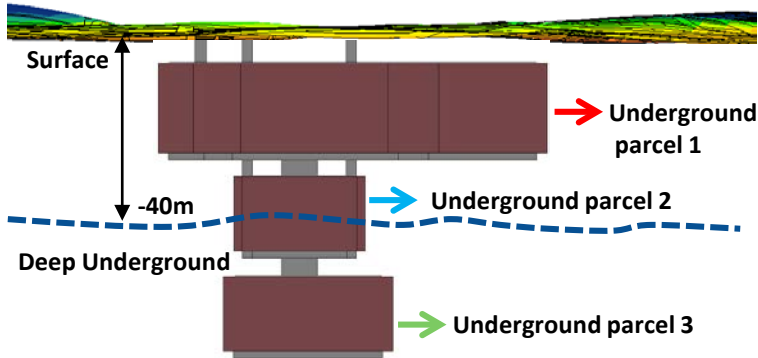
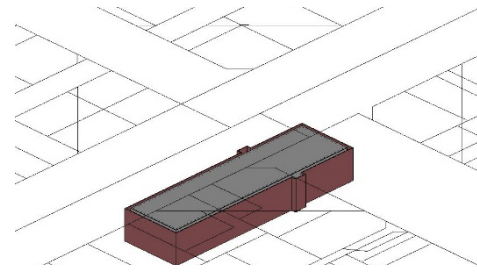Elevation map of underground parcels
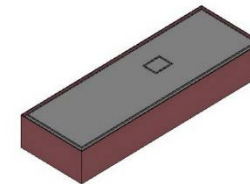
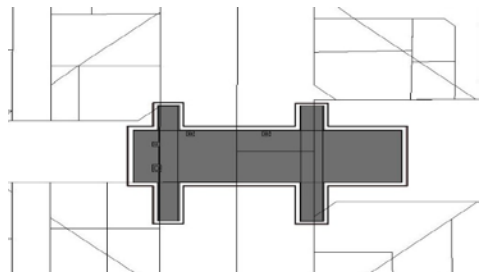Floor plan of underground parcels

3D view of underground parcels

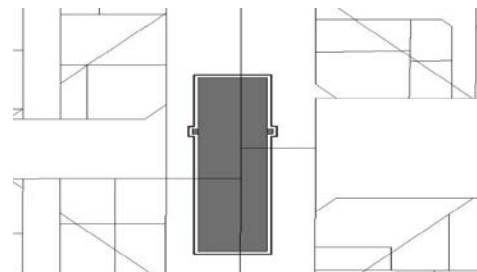(a-1) 3D underground fragmented parcels-1

(b-1) 3D underground fragmented parcels-2

(c-1) 3D underground consolidated parcels-3

(a-2) 2D underground fragmented parcels-1
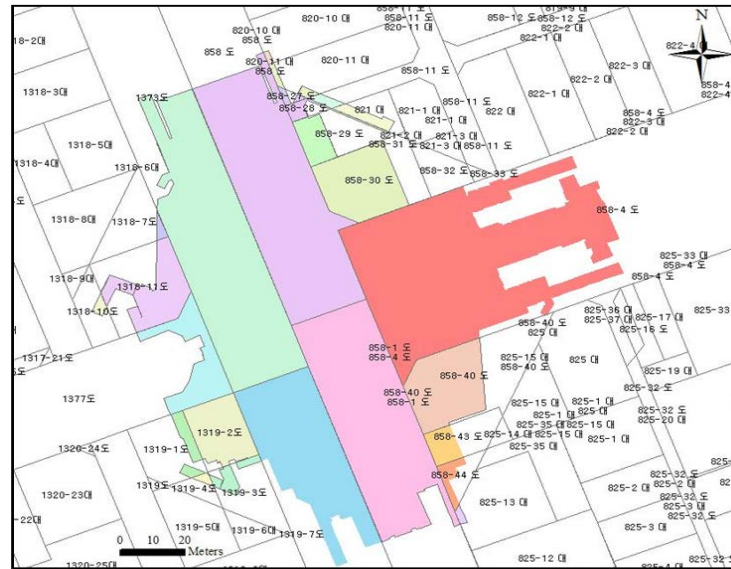
(b-2) 2D underground fragmented parcels-2

(c-2) 2D underground consolidated parcels-3

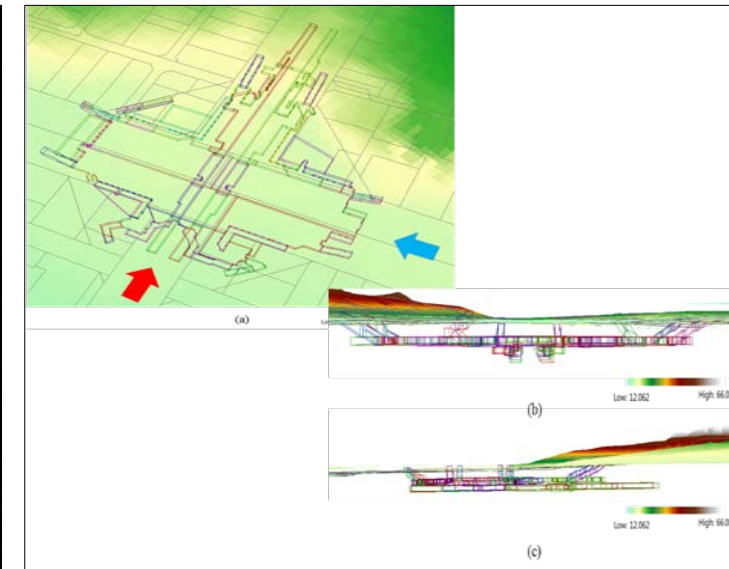# Registration of 3D Underground Parcel in Korean Cadastral System

- **Proposed new concepts of 3D underground cadastral maps**

  - Difficulty in confirming the physical state of underground structures
  - Impossible to protect the private or public underground space ownership
  - Require to register 3D underground parcel efficiently to designate legal contents
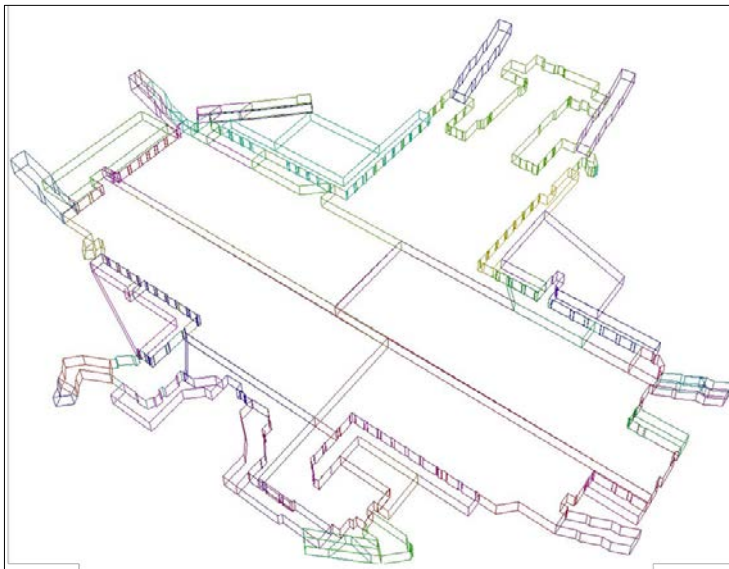
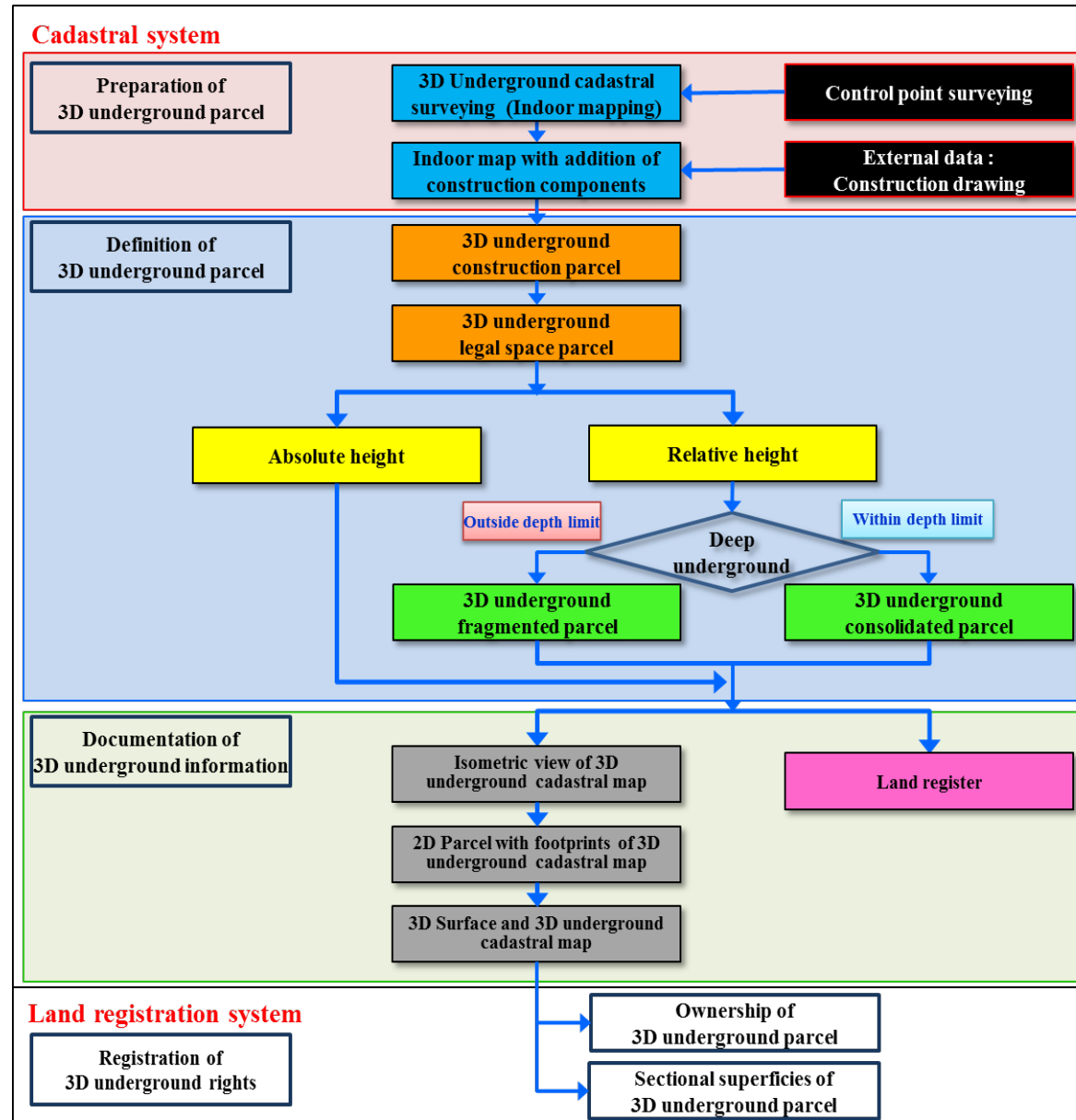Isometric view of 3D underground cadastral map

2D surface parcel with
foot print of 3D underground cadastral map

3D surface and 3D underground cadastral map

Registration of 3D Underground Parcel in Korean Cadastral System

- **Proposed registration framework of 3D underground parcel**

Development of 3D Underground Cadastral Data Model in Korea: Based on the Land Administration Domain Model

Development of 3D Underground Cadastral Data Model in Korea: Based on the Land Administration Domain Model

- **Research Background**

Data modeling

- Fundamental and crucial step to design an effective and efficient system by eliminating duplication of data and improving compatibility.

- Represents relationship between various data sets and formalizes the complex system into understandable representations.
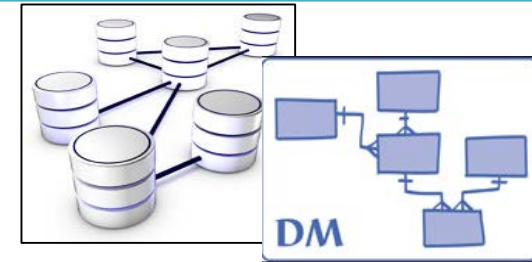
ISO TC 211 19152 Land Administration Domain Model (LADM)

- International Organization for Standardization (ISO) in 2012 as an international standard to support efficient land administration system in worldwide.

- Covers core of land information included in cadastral system and land registry system by registering with parcel boundary and RRRs
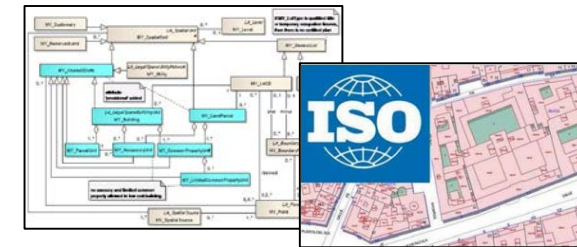
International Property Measurement Standards (IPMS)

- Provide a measurement standard of building area floor by floor, and provide semantic information of property.

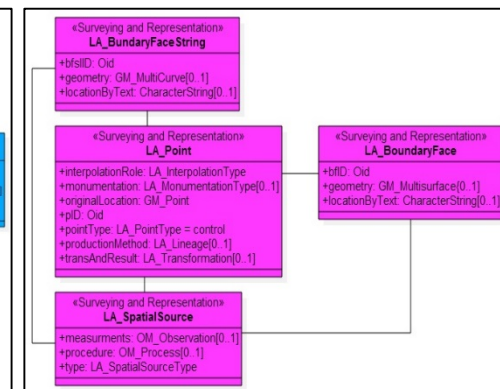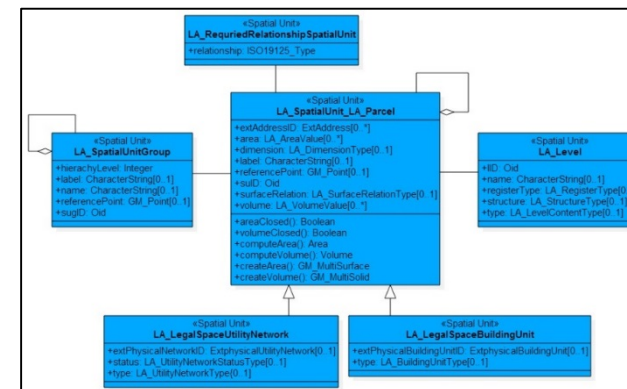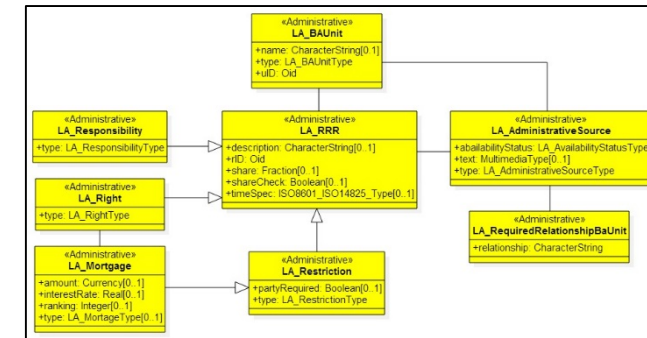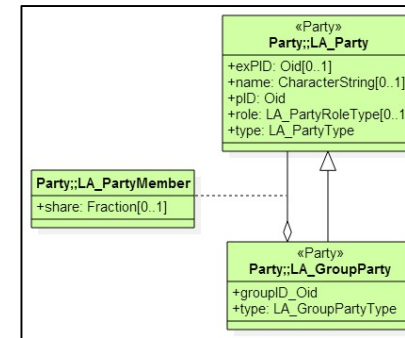- Ensure that property assets are measured in a consistent way, creating a more transparent marketplace.
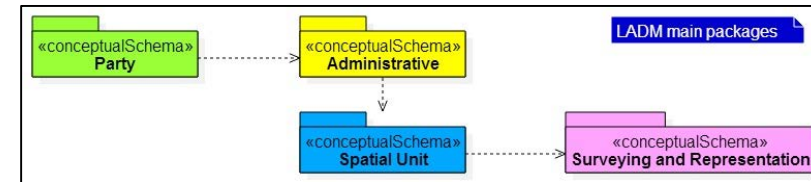

Needs for Data Modeling of 3D Underground Cadastral information

Development of 3D Underground Cadastral Data Model in Korea: Based on the Land Administration Domain Model

- ## Land Administration Domain Model (LADM)

- LADM is based on consensus and adopted by ISO

- LADM covers **complete land administration spectrum** both the legal and spatial aspects of cadastral objects : survey, cadastral maps, rights, restrictions, responsibilities, mortgages, persons, etc.

- LADM allows meaningful **data exchange**: 1. within country, SDI-setting (other types of data), 2. between countries/states (same type)

- LADM focuses on information, not on process/organization aspect

- LADM is modular (packages) and extensible country profiles

- LADM links essential land information data to source documents, both spatial (survey) and legal (title, deed)

- LADM provides an abstract model to build concrete application 3D cadastral model.

Needs for adaptation of benefits of LADM

Development of 3D Underground Cadastral Data Model in Korea: Based on the Land Administration Domain Model

- ## International Property Measurement Standards (IPMS)

- IPMS was formed at the World Bank meeting in 2013

- IPMS covers consistent way to measure property assets, creating a more transparent marketplace, greater public trust, stronger investor confidence, and increased market stability

- IPMS allows meaningful data exchange by 8 categories

Needs for adaptation of benefits of IPMS

Development of 3D Underground Cadastral Data Model in Korea: Based on the Land Administration Domain Model

- **Proposed cadastral data modeling in Korea**

Cadastral data model in Korea (201...)

New Korea Country Pr...

Korean LADM country profile to build a 3D cadastre model (2015)
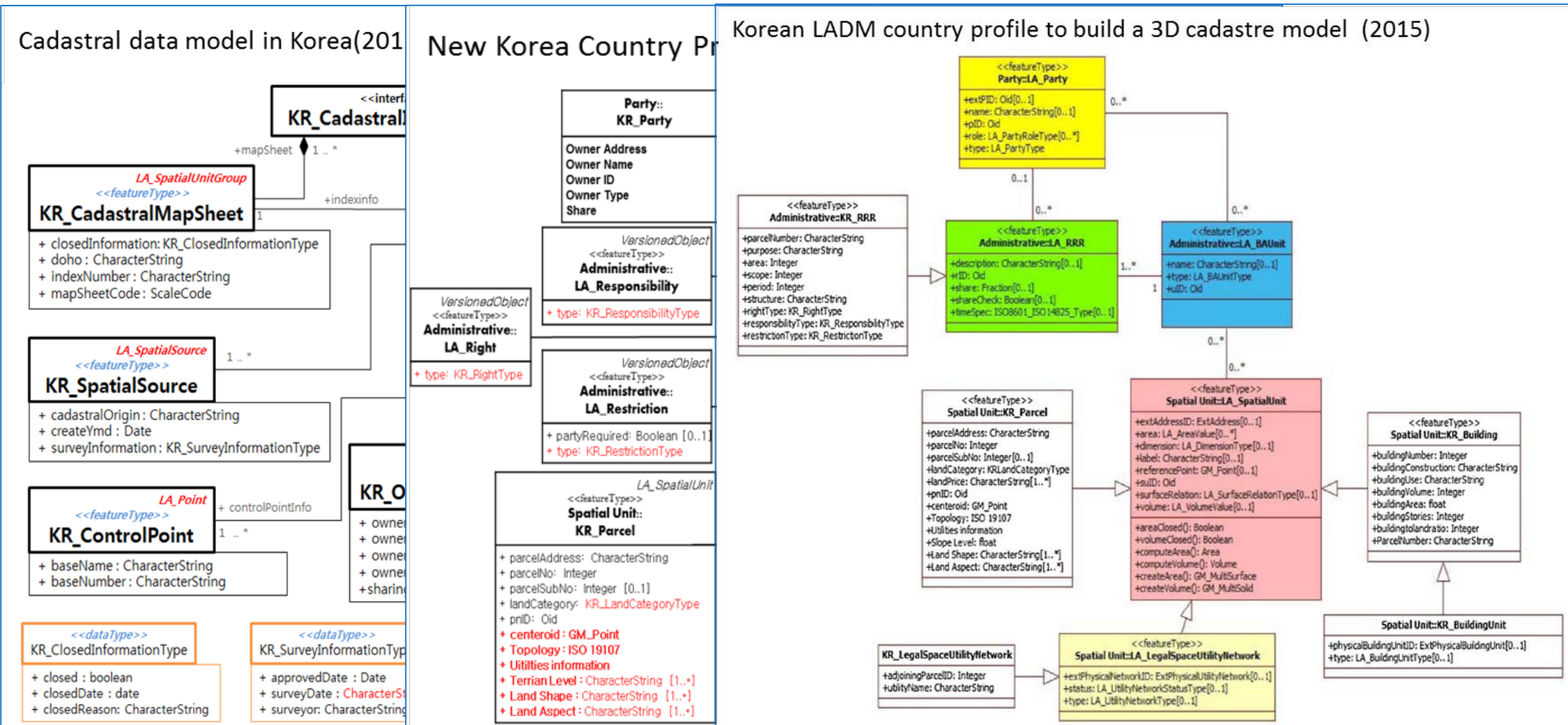
Needs Specific Data Model for Korean 3D Underground Cadastral System

Development of 3D Underground Cadastral Data Model in Korea: Based on the Land Administration Domain Model

- ## Proposed data model for Korean 3D underground parcel package

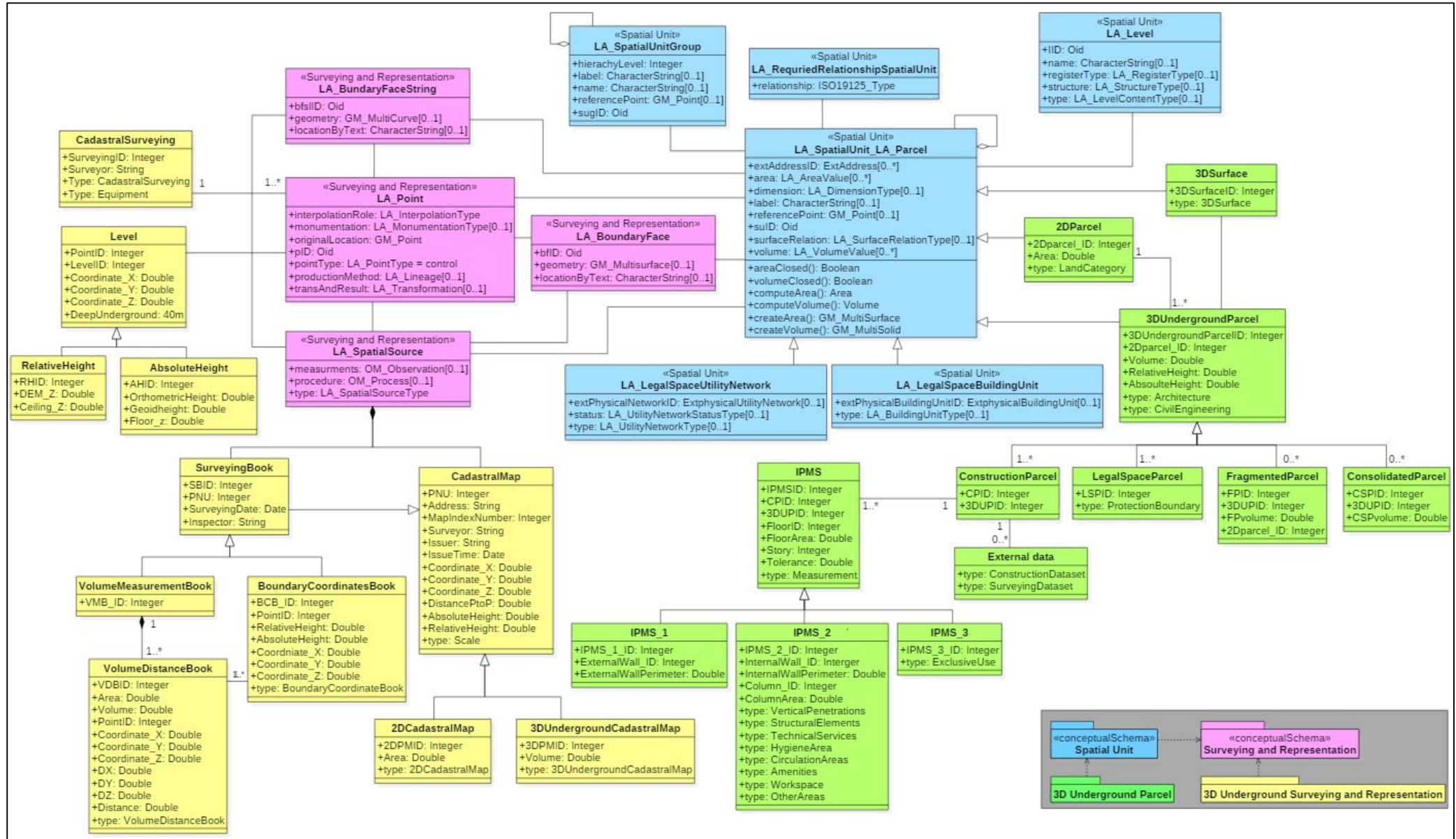| Class	Attributes	Code list	Description
Parcel	PNU, address, map index number and reference point	Dimension, Scale	Describes property units with general information including 2D surface and 3D underground parcel
2D Parcel	2D Parcel ID and area	Land Category	Registration unit of land surface
3D Underground Parcel	3DUPID, 2D Parcel ID, volume, relative and absolute height	Architecture and Civil Engineering	Registration unit of underground physical objects
Construction Parcel	CPID and 3DUPID		Registration extent of underground parcel based on unified surveying map and construction data
Legal Space Parcel	LSPID	Protection Boundary	Registration extent to register of protected or restricted zone around underground parcel
Fragmented Parcel	FPID, 3DUPID, FP volume and 2D parcel ID		Registration unit of individual underground parcel based on 2D surface parcel
Consolidated Parcel	CSPID, 3DUPID and CSP volume		Registration unit of linked underground parcel, unrelated to the 2D surface rights
IPMS	IPMS ID, CPID, 3D UPID, floor ID, floor area, story and tolerance	Measurement	International Property Measurement Standards, managing semantic information of utilization of underground parcel
IPMS 1	IMPS 1 ID, external wall ID and perimeter		The area of building floor and external wall perimeter
IPMS 2	IMPS 2 ID, internal wall ID and perimeter, column id and column area	Vertical penetrations, structural elements, technical services, hygiene area, circulation areas, amenities, workspace and other areas	The area of building components and internal wall perimeter, it can be divided by eight components
IPMS 3	IMPS 3 ID	Exclusive use	The area of building floor, described by exclusive usage
External data		Construction and surveying data set	Kinds of construction drawing and spatial information

Development of 3D Underground Cadastral Data Model in Korea: Based on the Land Administration Domain Model

- **Proposed data model for Korean 3D underground cadastral surveying and mapping package**

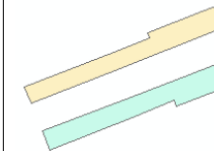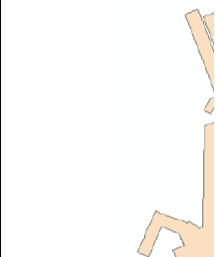| Class	Attributes	Code list	Description
Cadastral map	PNU, address, map index number, surveyor, issuer, issue time, coordinate x, y and z, distance point to point, absolute and relative height	Scale	Representing the detail of the land shape on drawings. Cadastral map can be divided 2D parcel map and 3D underground parcel map
2D parcel map	2DPMID, area	2D parcel map	Representing land surface parcel, 2D footprint of 3D parcel and land utilization status with IPMS
3D underground parcel map	3DPMID, volume	3D underground parcel map	Represent 3D underground parcel as individual type
GM surface			ISO 19107 spatial schema
GM point			ISO 19107 spatial schema
GM solid			ISO 19107 spatial schema
Surveying book	SBID, PNU, surveying date and inspector		Documenting the detail of the spatial information of 3D underground parcel
Volume measurement book	VMB ID		Combining the spatial information of volume parcel
Volume distance book	VDBID, area, volume, point ID, coordinate x, y and z, DY,		Documenting the individual parcel such as volume and distance between two points
Boundary coordinates book	BCB ID, point ID, relative and absolute height, coordinate x, y and z		Documenting each single boundary point consisting of volume parcel by the coordinate value
Cadastral surveying	Surveying ID, Surveyor	Cadastral surveying, equipment	Documenting the information of cadastral surveying type
Cadastral surveying point	Point ID, point name, 2D point, 3D point and surveying date	Survey point, monument and coordinate system	Documenting the detail of surveying point including monument and coordinate system information
Level	Point ID, level ID, coordinate x, y and z, and deep underground		Representing precisely measured elevation reference point for leveling
Absolute height	AHID, orthometric and geoid height, and floor height z		Representing height information based on national height reference system
Relative height	RHID, DEM z and ceiling z		Representing depth information of underground parcel based on surface height information

- **Integrated KUCDM and LADM**

Development of 3D Underground Cadastral Data Model in Korea: Based on the Land Administration Domain Model

- **Proposed data model for Korean 3D underground cadastral data model**

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea

- **Research Background**

Data acquisition

- Most of existing methods, unfortunately, are designed for extraction and reconstruction only of external building in cadastral domain.

- TLS is able to acquire large numbers of point clouds containing abundant 3D location information, and to handle sharp corners and edges.
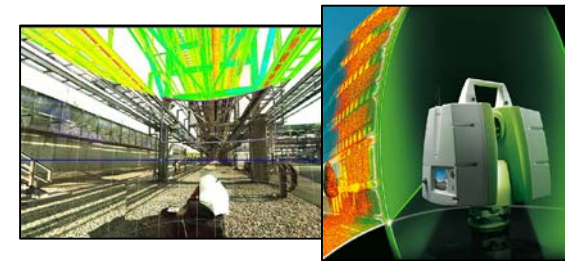
Indoor mapping for as-built BIM

- Indoor mapping is becoming more commonly used for as-built BIM. It has emerged as a powerful tool for compiling information on actual building modeling.

- Indoor mapping methods can be considered for appropriate representation of various types of 3D underground properties.
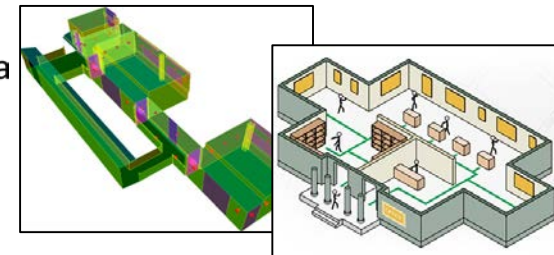
3D underground cadastral maps

- Currently, most of cadastral systems are still maintained in the 2D cadastral map format.

- Propose three types of 3D underground cadastral maps. isometric view, 2D surface parcel, and 3D surface and 3D underground cadastral map.
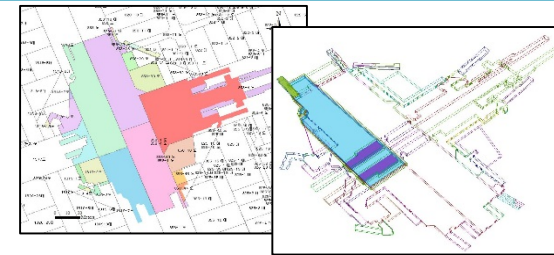
Needs for framework or 3D Underground Cadastral mapping system

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea

- ## Application

| Categories	Specifications
Target study area	Gangnam subway station: underground shopping center and subway station platform (Gangnam-gu, Seoul, Korea)
Extent of subway station (along centerline)	Length = 254.116 m Width = 177.5 m Height = 7.05 m
Type of terrestrial laser scanner	Scanner model: Leica Scan Station P20 3D position accuracy: 3mm at 50m, 6mm at 100m Linearity error: ≤1mm Angular accuracy: 8" (horizontal/vertical)
Laser scanning data	Number of stations: 171 stations (1st floor: 126, 2nd floor: 45) Data size: 4.85 GB Number of points: 106.7 million
Coordinate system	Project coordinate system: Korea 2000 central belt 2010 Datum: Korea 2000 (KGD2002) Ellipsoid: GRS1980 Projection: Transverse Mercator
Processing environment	CPU: Intel® Core™ i7-4790 CPU @ 3.60GHz RAM: 32.0GB OS: Windows 7 64-bit
Software	Point cloud processing: Matlab 8.1.0 As-built Modeling: Autodesk Revit 2014

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea

- **Proposed Method**

```
                    ┌─────────────────────┐
                    │     Point cloud     │
                    └─────────────────────┘
                              ⇩
```

Geometric Modeling

RANSAC Segmentation	Refinement	Boundary Tracing

⇩

As-built BIM

Level & Grid Creation	Floor & Wall & Ceiling Creation	Detail Modeling

⇩

Accuracy Assessment

Control Points Surveying	Targets Acquisition	Accuracy Assessment

⇩

3D Underground Cadastral Map

Isometric view of 3D underground cadastral map	2D surface with 3D underground cadastral map	3D surface and 3D underground cadastral map

⇩

```
                    ┌───────────────────────────────────┐
                    │  3D Underground Cadastral System  │
                    └───────────────────────────────────┘
```

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea

- ## Proposed Method

- ## Application

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea
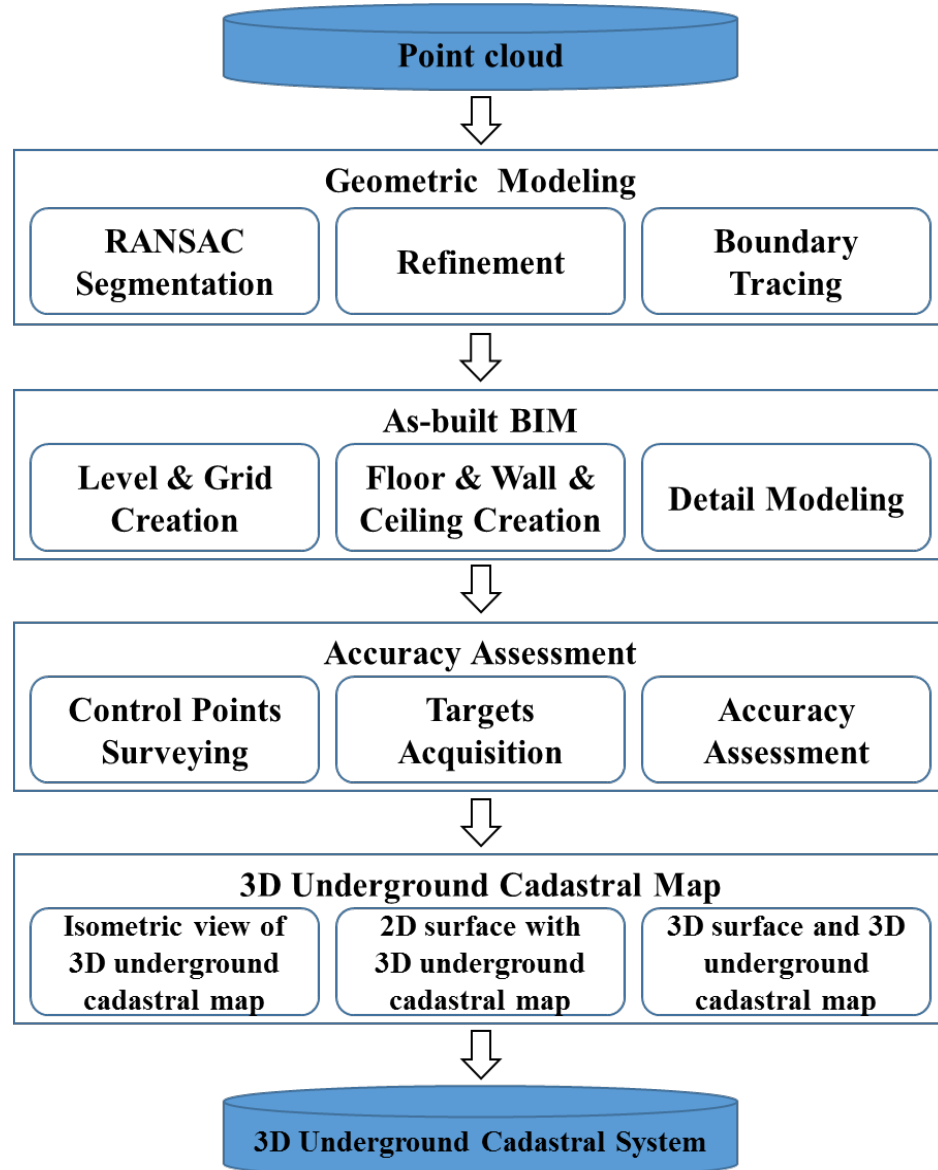
- **Proposed Method**

- **Application**

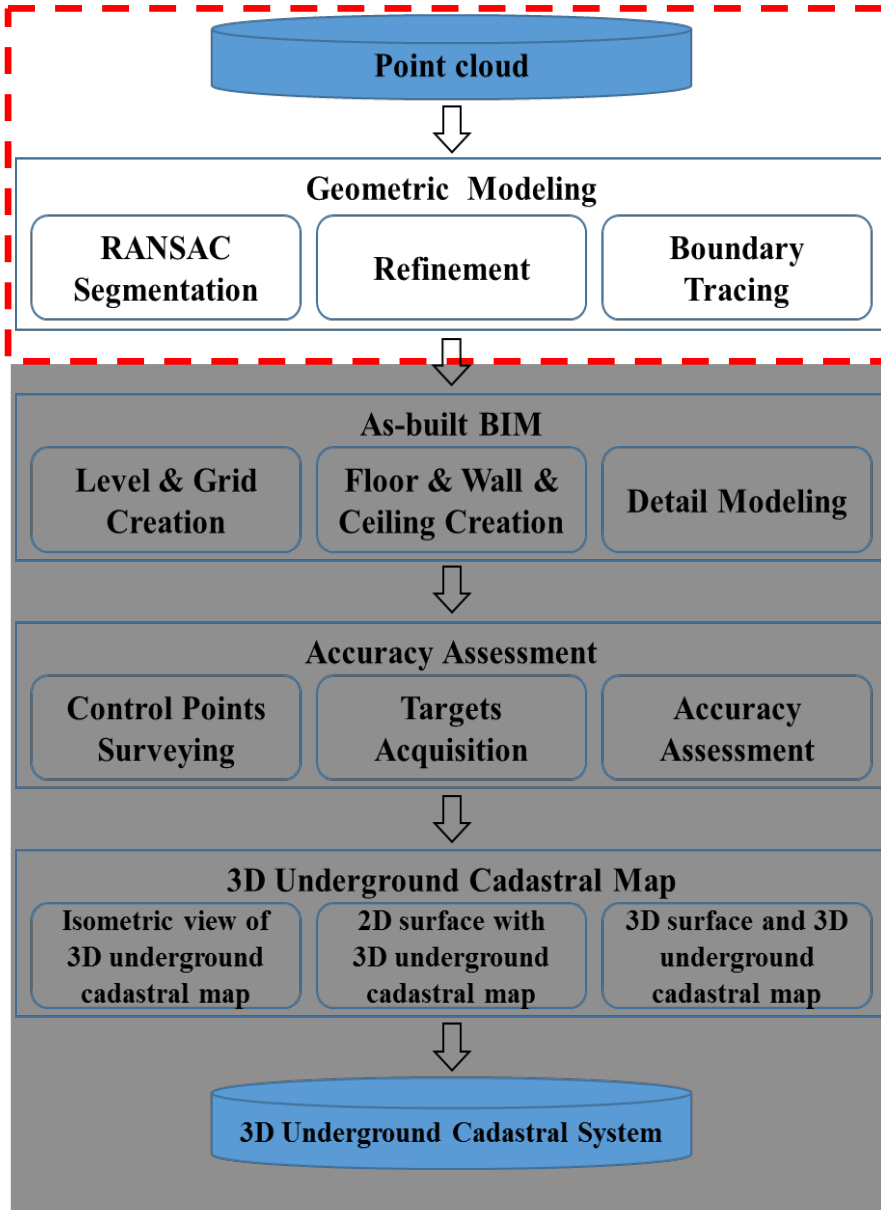
(a)

(b)

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea

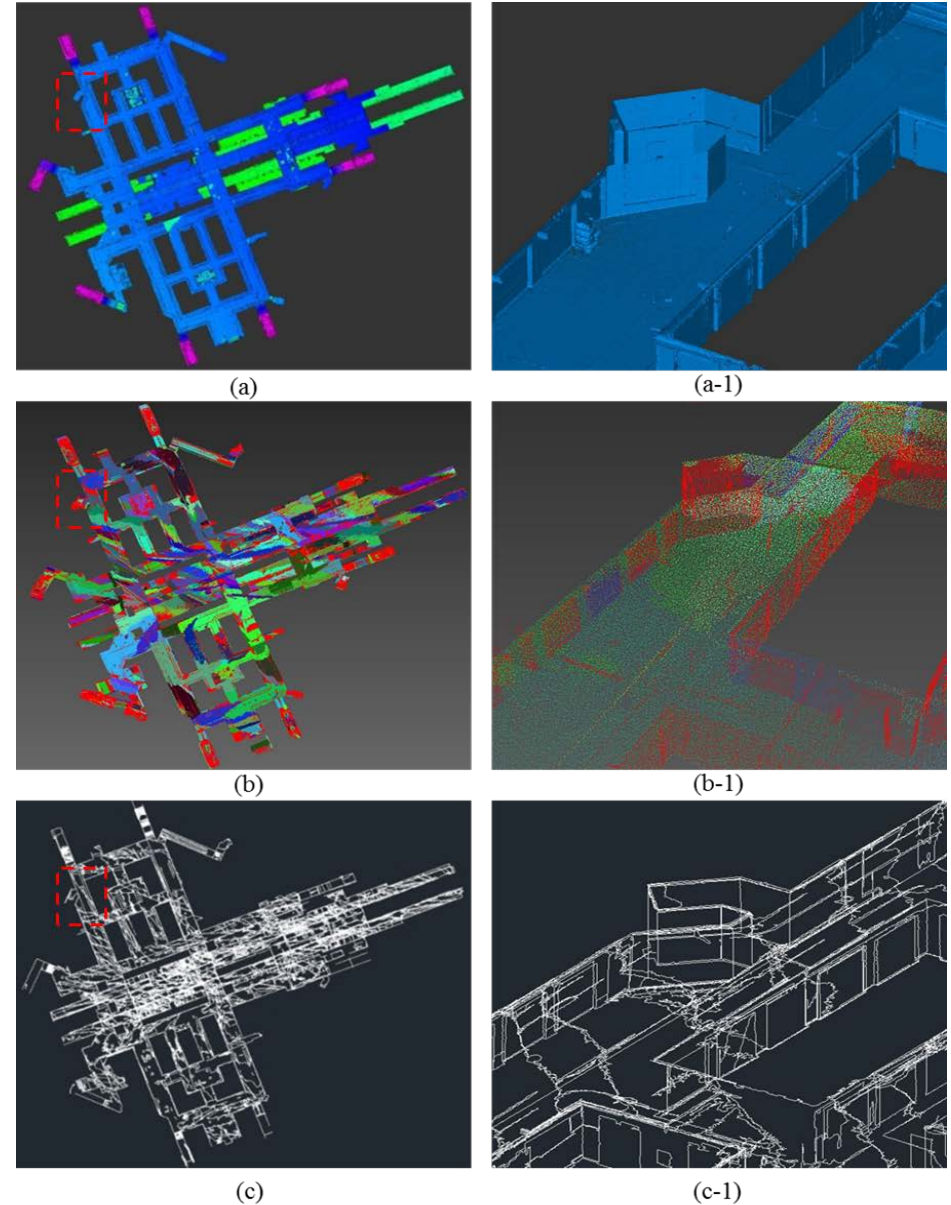- **Proposed Method**

- **Application**

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea

- **Proposed Method**

- **Application & Results**

Station	Angle D	Angle M	Angle S	Azimuth D	Azimuth M	Azimuth S	Distance (m)	Calculated Departure	Calculated Latitude	Adjustments Departure	Adjustments Latitude	Adjusted Departure	Adjusted Latitude	X (Departure)	Y (Latitude)	Z (Level)
1	96	40	49	127	35	16	46.021	36.468	-28.072	0.001	0.001	36.469	-28.071	1000.000	1000.000	100.000
2	263	18	14	210	53	30	31.190	-16.013	-26.765	0.000	0.000	-16.013	-26.765	1036.469	971.929	100.183
3	88	47	27	119	40	57	32.069	27.861	-15.880	0.000	0.000	27.861	-15.880	1020.455	945.164	100.389
4	91	47	2	31	27	59	30.857	16.107	26.319	0.000	0.000	16.108	26.319	1048.317	929.284	100.442
5	264	23	26	115	51	24	48.767	43.885	-21.268	0.001	0.001	43.885	-21.267	1064.424	955.603	100.191
6	94	54	25	30	45	49	37.923	19.398	32.587	0.000	0.001	19.398	32.588	1108.310	934.336	100.080
7	95	39	30	95	39	30	47.890	-38.536	28.433	0.001	0.001	-38.535	28.434	1127.707	966.923	99.834
8	172	36	33	172	36	33	35.320	-30.882	17.140	0.000	0.001	-30.882	17.141	1089.172	995.358	99.854
9	175	35	25	175	35	24	43.857	-39.870	18.272	0.001	0.000	-39.869	18.272	1058.290	1012.499	99.826
10	96	17	12	96	17	12	35.864	-18.422	-30.771	0.000	0.001	-18.421	-30.770	1018.421	1030.770	99.683

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea
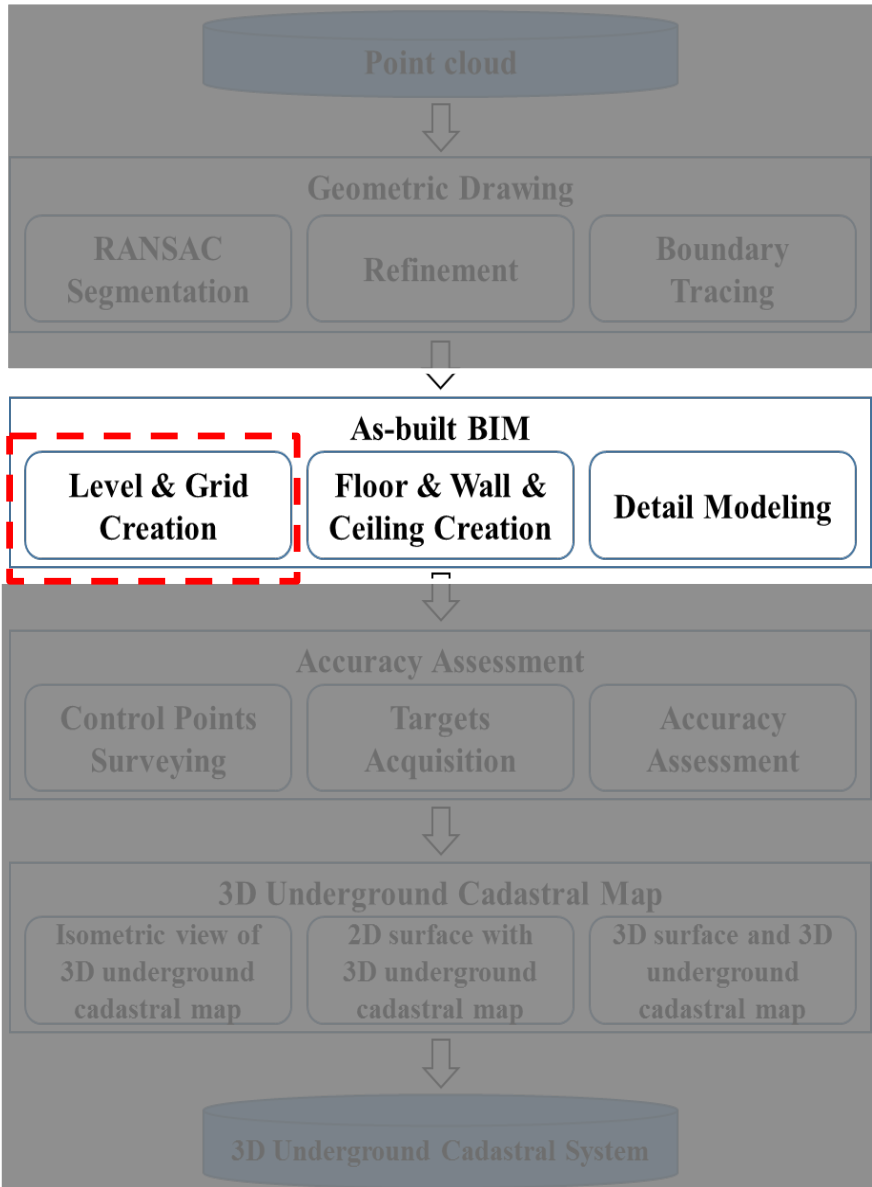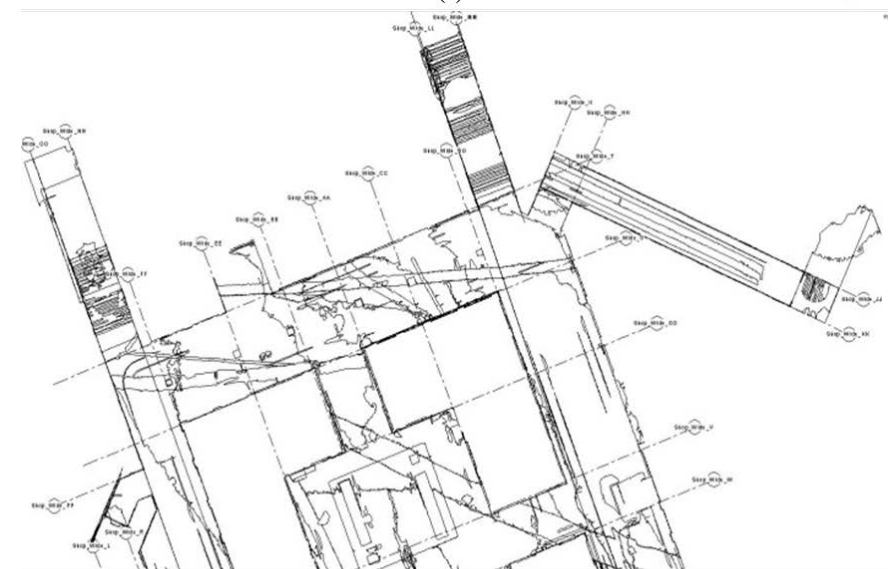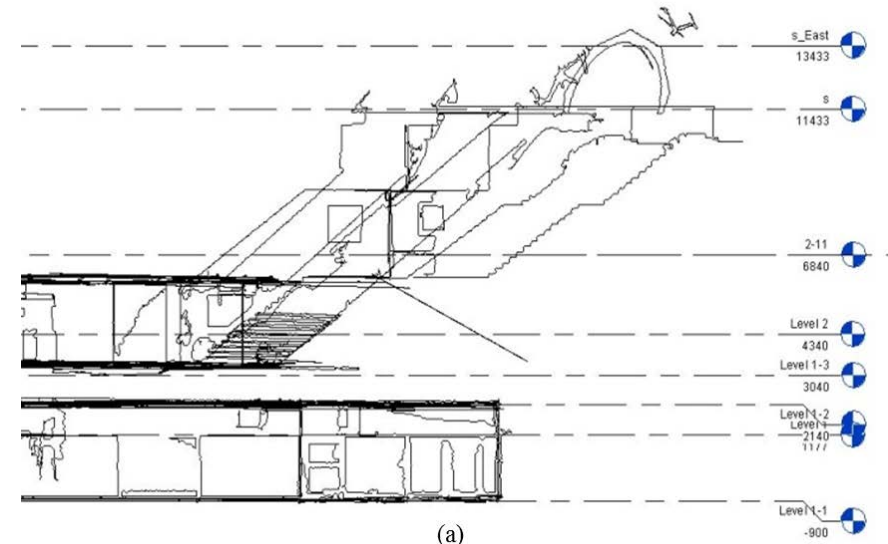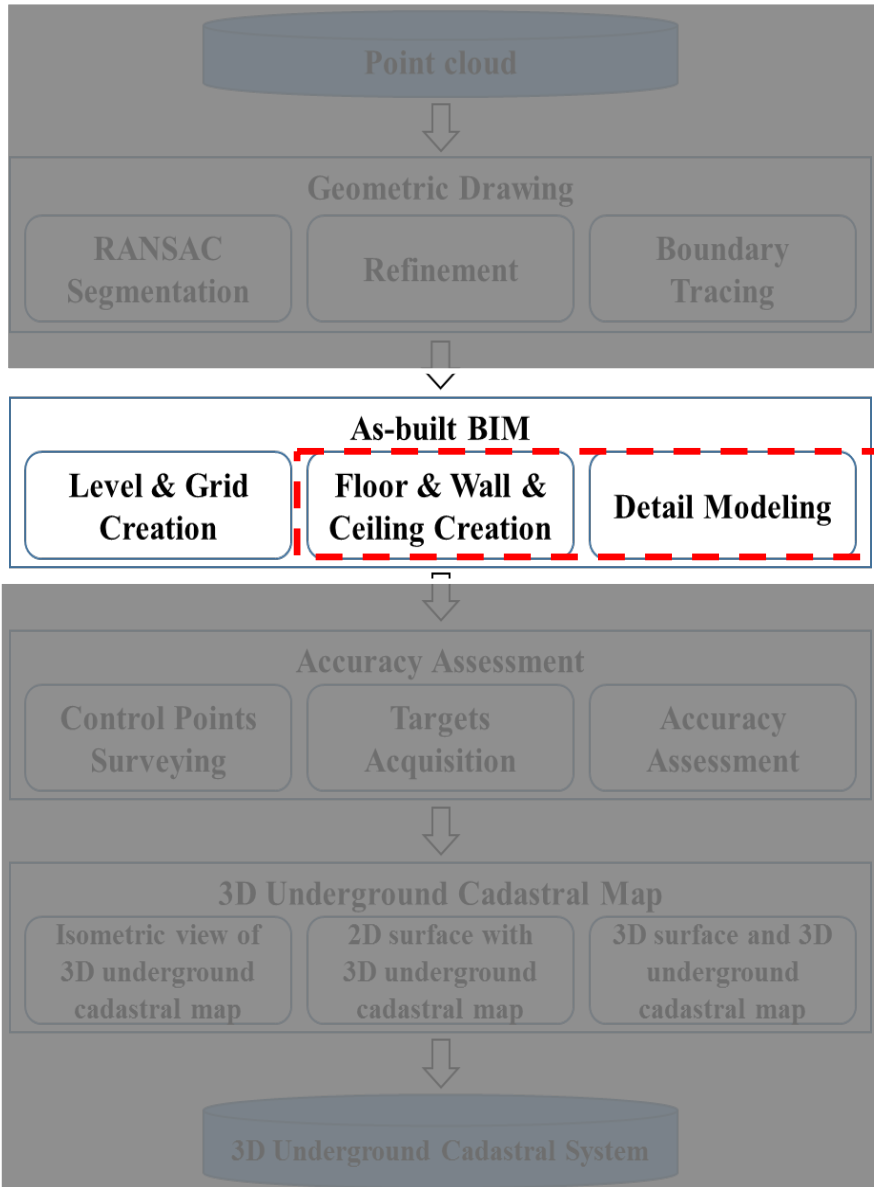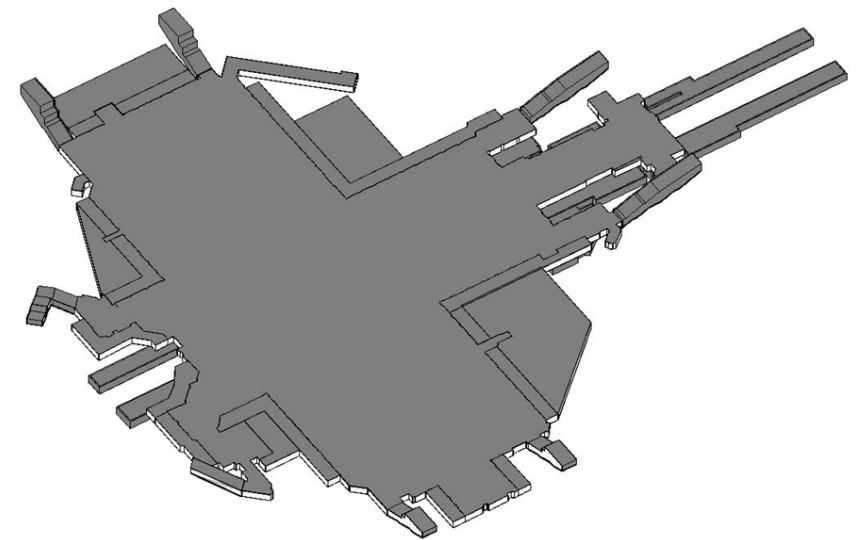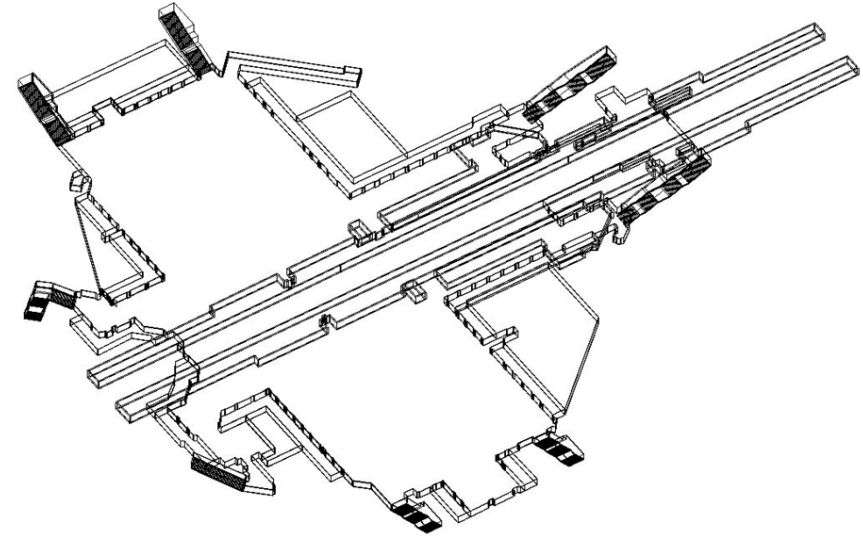
- **Proposed Method**

- **Application**

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea

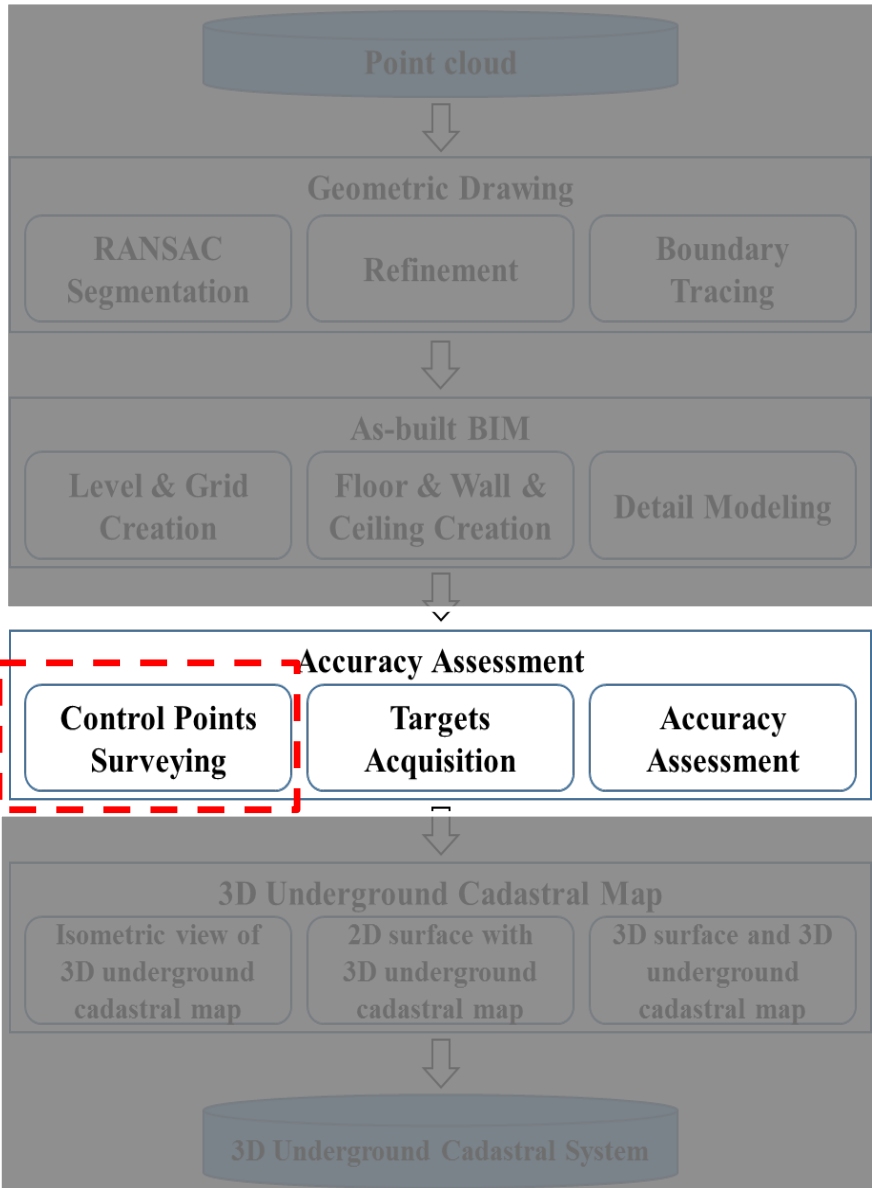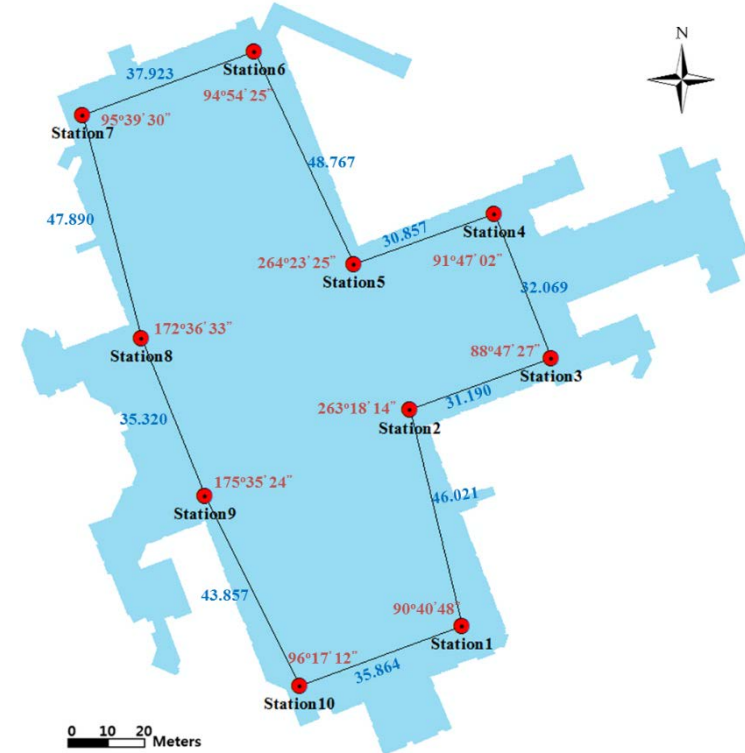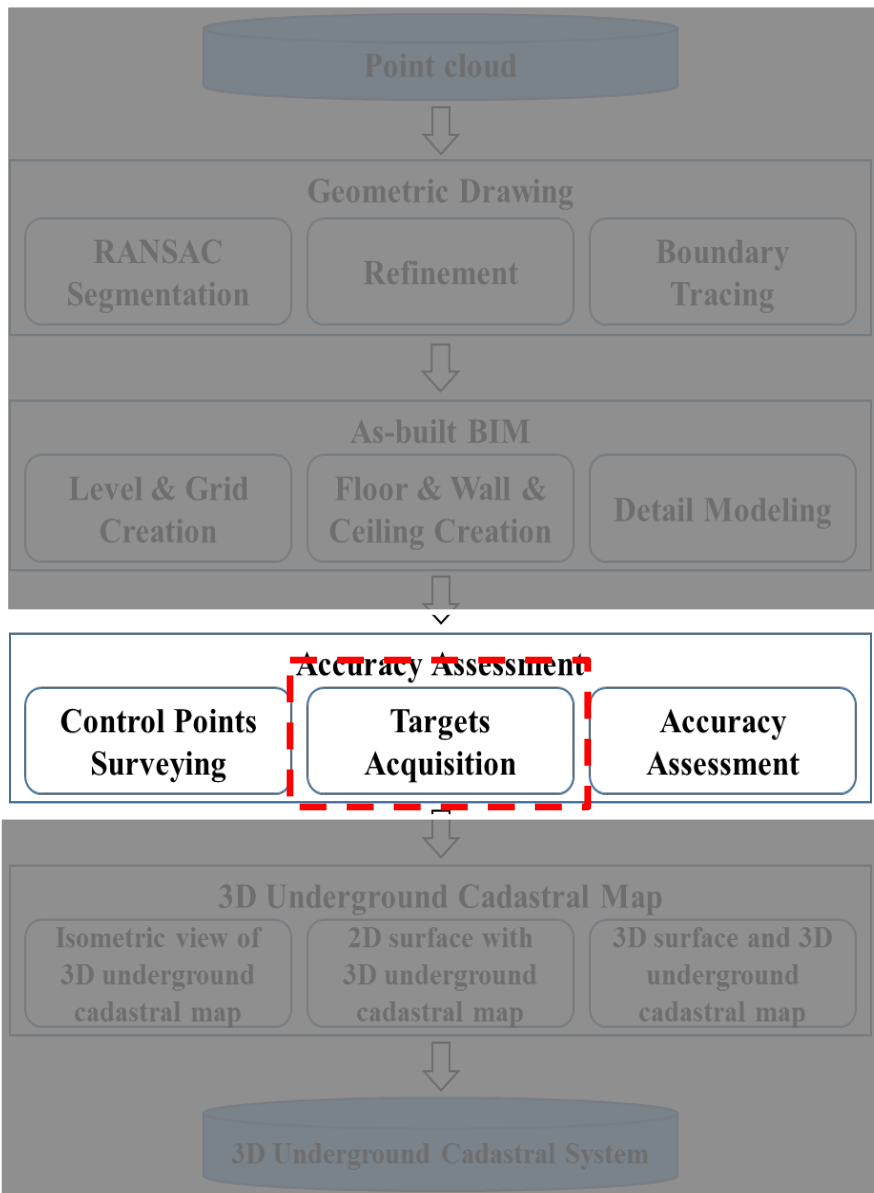## • Proposed Method
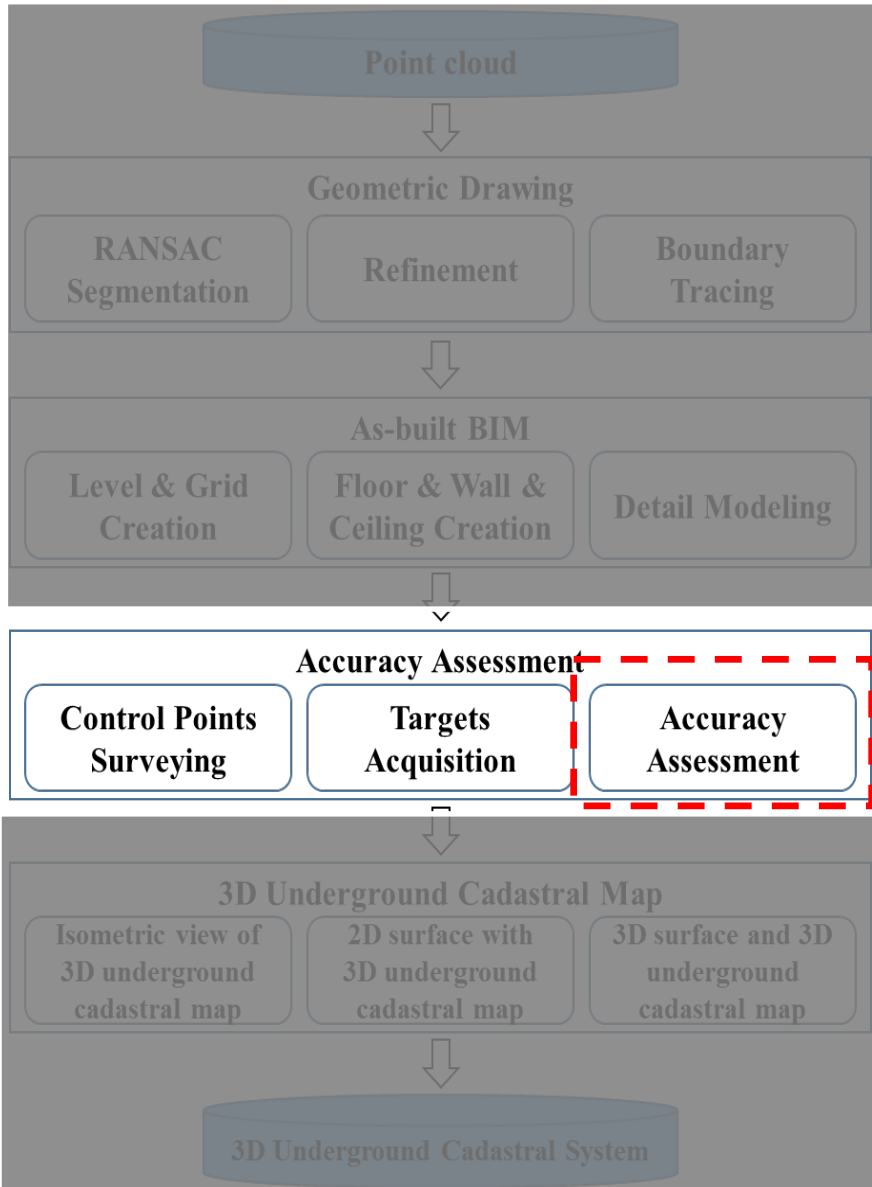
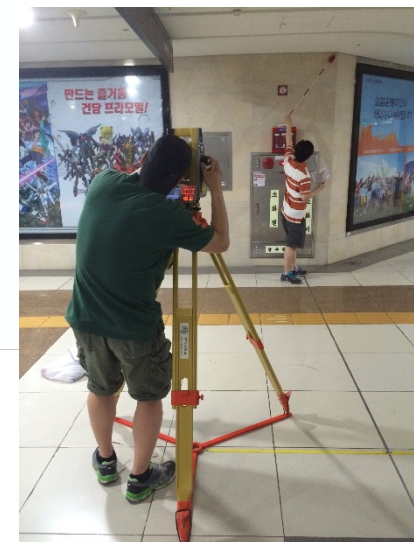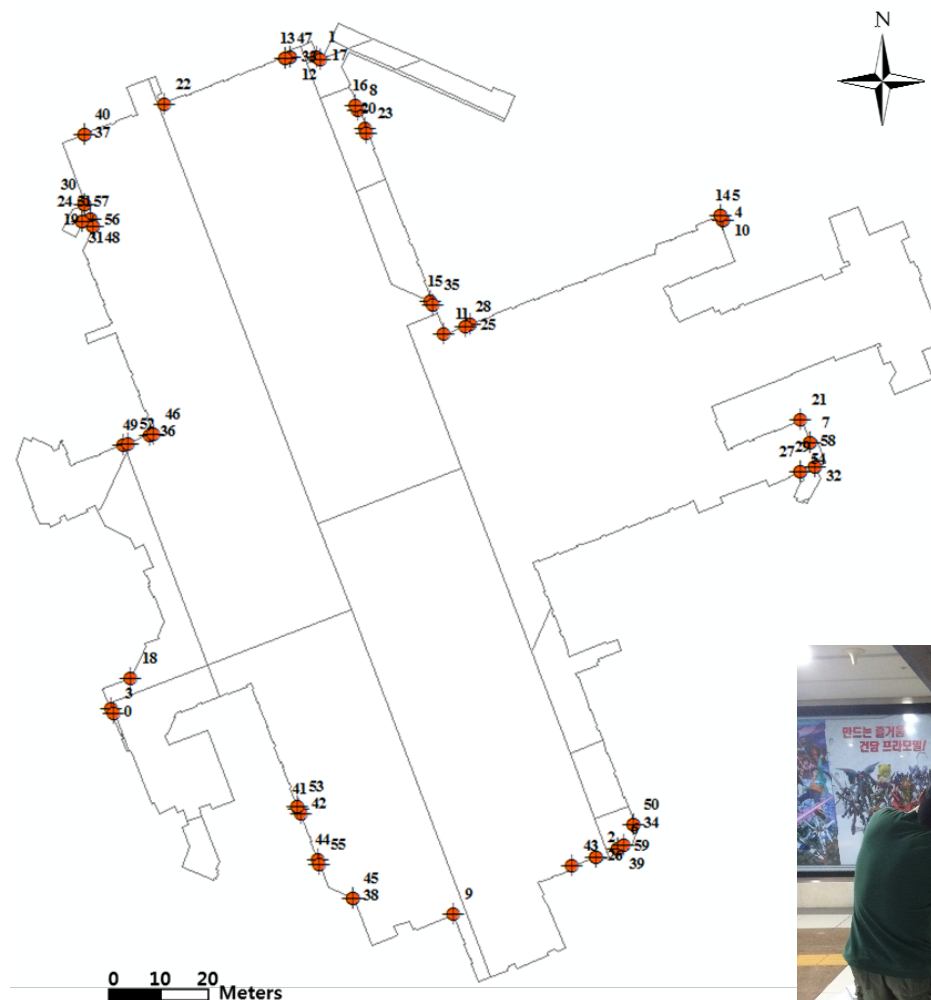## • Application & Results

Point ID	Error vector			Error	Point ID	Error vector			Error
	X	Y	Z			X	Y	Z	
1	0.119	-0.054	0.091	0.160	31	-0.049	-0.012	-0.088	0.101
2	0.021	0.007	0.141	0.143	32	-0.076	-0.021	-0.026	0.083
3	-0.067	-0.131	-0.085	0.170	33	-0.022	0.027	0.051	0.062
4	0.002	0.013	-0.181	0.181	34	-0.012	0.010	0.045	0.048
5	0.005	0.018	-0.174	0.175	35	0.012	-0.017	0.050	0.054
6	-0.036	0.046	0.112	0.126	36	-0.048	0.011	-0.071	0.086
7	0.078	0.106	-0.087	0.158	37	0.063	-0.001	0.016	0.065
8	-0.049	0.031	0.096	0.112	38	-0.010	-0.044	0.006	0.046
9	-0.031	0.102	0.053	0.119	39	-0.003	0.032	0.042	0.052
10	0.010	0.033	-0.138	0.142	40	0.066	0.002	-0.045	0.080
11	0.095	-0.042	0.047	0.115	41	-0.044	0.017	-0.004	0.047
12	-0.014	0.008	0.103	0.104	42	-0.030	-0.023	0.003	0.038
13	-0.010	-0.004	0.102	0.102	43	0.033	0.009	0.033	0.047
14	0.008	0.028	-0.134	0.137	44	-0.033	0.031	-0.002	0.046
15	0.021	-0.007	0.097	0.099	45	-0.008	-0.037	-0.053	0.066
16	0.012	-0.003	0.096	0.097	46	-0.010	0.025	-0.070	0.075
17	-0.024	0.004	0.095	0.098	47	-0.013	0.008	0.032	0.036
18	0.009	-0.010	-0.142	0.142	48	0.013	-0.026	-0.073	0.078
19	-0.091	0.044	-0.030	0.106	49	-0.005	0.015	-0.070	0.072
20	-0.001	-0.003	0.085	0.086	50	-0.017	-0.002	-0.058	0.060
21	0.008	-0.090	-0.020	0.093	51	0.001	-0.035	-0.061	0.070
22	0.008	-0.038	0.078	0.087	52	0.015	0.011	-0.066	0.068
23	-0.016	0.000	0.084	0.086	53	0.029	-0.021	-0.007	0.037
24	0.033	0.058	-0.095	0.116	54	-0.020	-0.011	0.007	0.024
25	0.012	-0.051	0.062	0.081	55	-0.006	0.017	-0.006	0.019
26	0.068	-0.013	0.047	0.084	56	0.008	-0.019	0.000	0.021
27	-0.001	0.014	-0.115	0.116	57	0.005	-0.030	-0.022	0.038
28	0.001	-0.044	0.059	0.074	58	0.003	0.022	-0.010	0.025
29	-0.082	-0.023	-0.015	0.086	59	0.043	0.006	0.035	0.056
30	0.028	0.056	0.030	0.069	60	-0.002	0.006	0.121	0.121
Average error						-	-	-	0.086
RMSE						0.039	0.038	0.078	0.095
SAS						-	-	-	0.129

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea

- ## Proposed Method

- ## Application & Results

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea
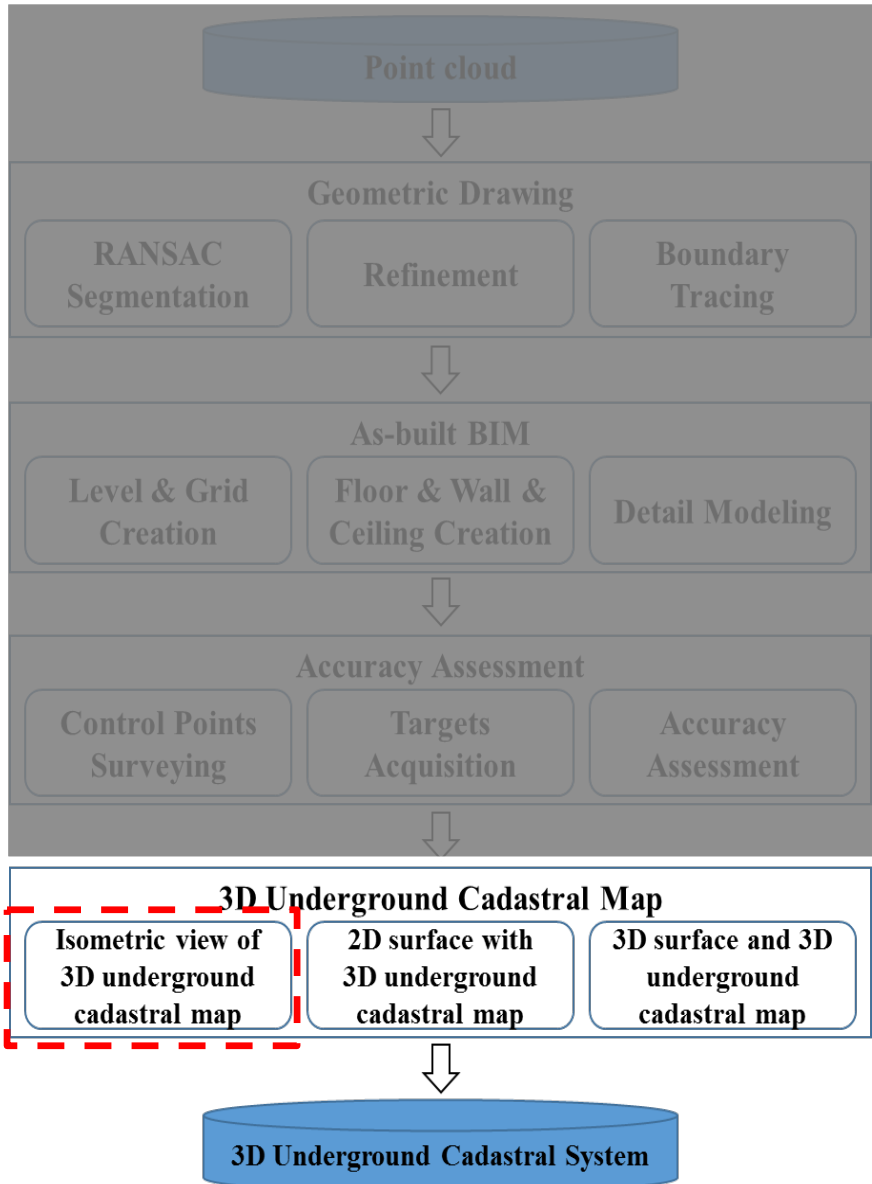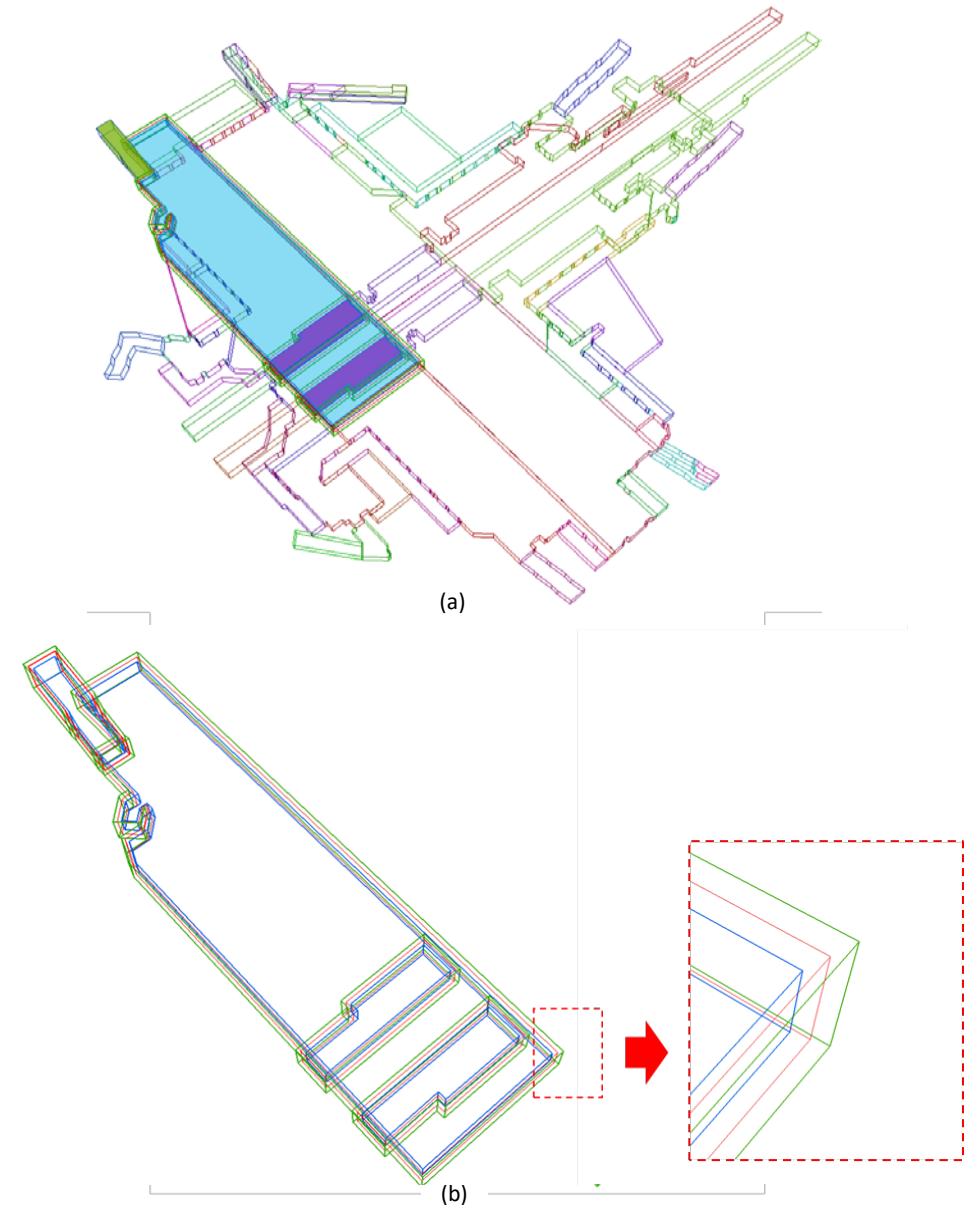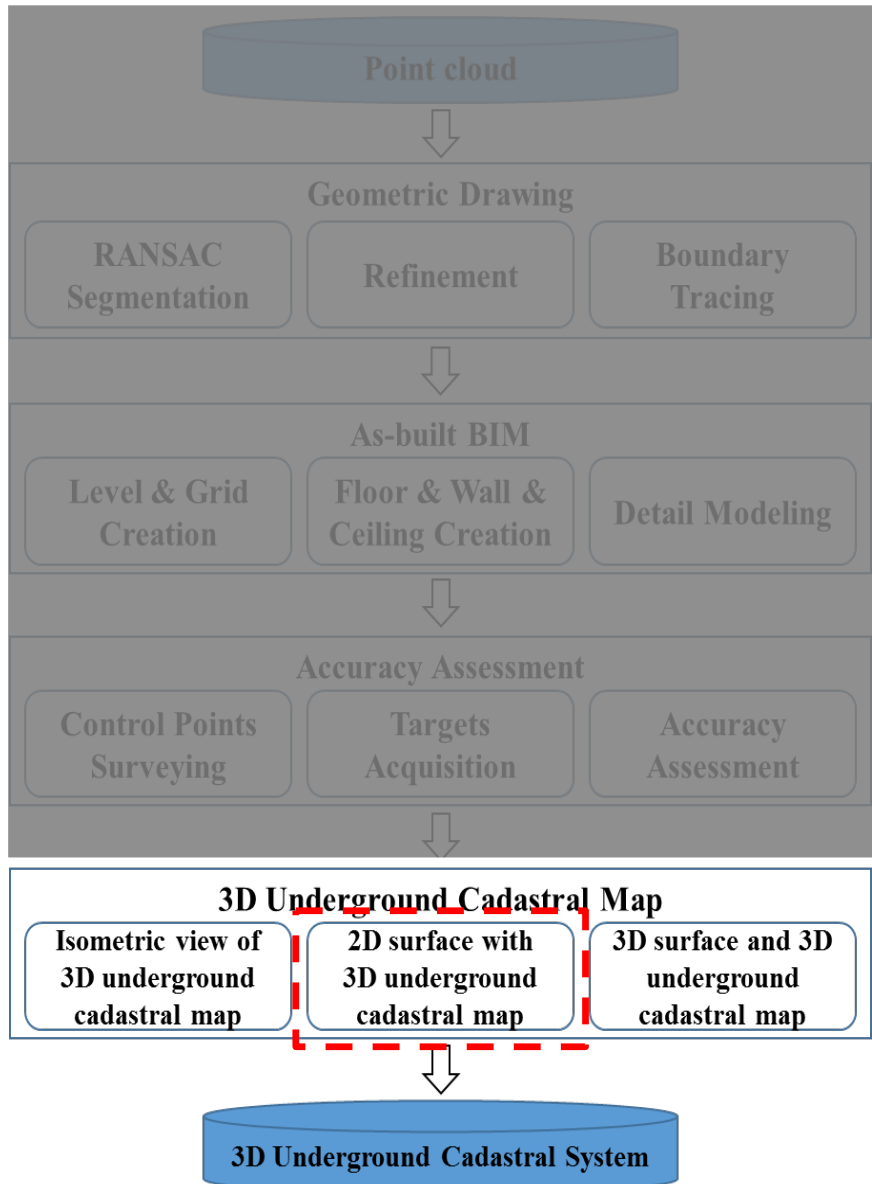
## • Proposed Method

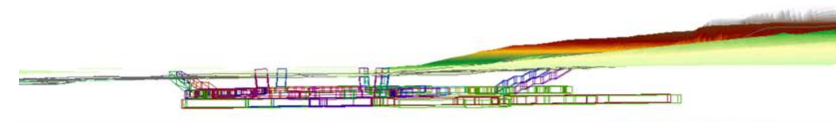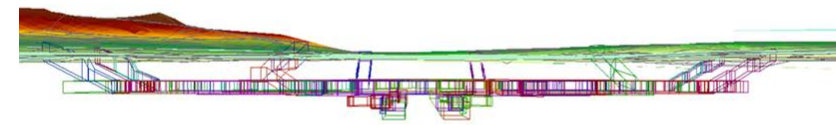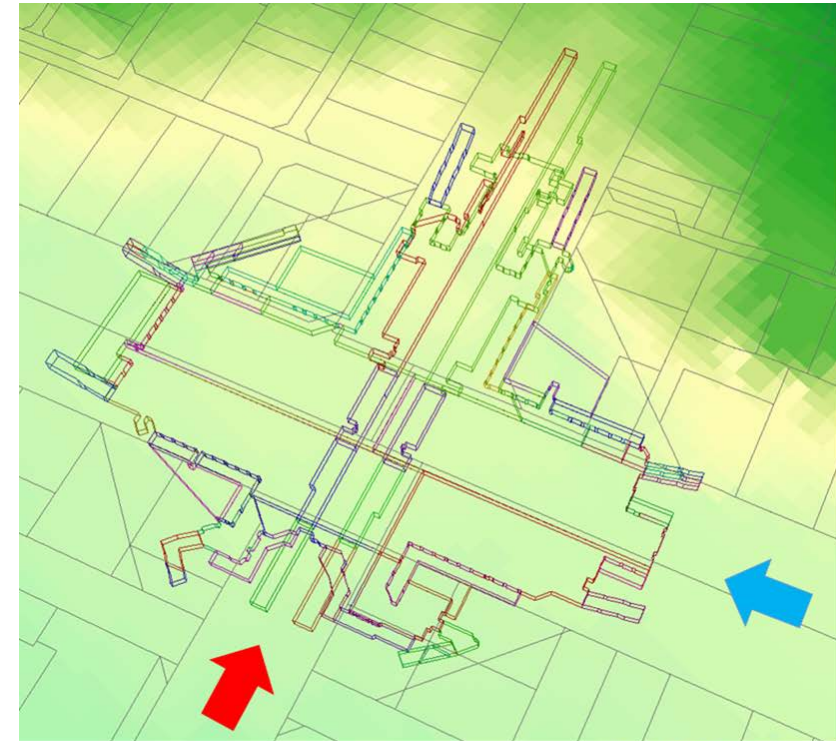| 2D Surface Parcel		3D Underground Parcel					
Parcel Number	Land Category	Underground Parcel Number	Utiliza-tion	Ownership	Right	Area (m^2)	Volume (m^3)
858-4	Road	858-4-1	US	SMG	FO	3475.3	9035.8
858-40	Road	858-40-1	US	SMG	FO	610.2	1586.4
858-43	Road	858-43-1	US	SMG	FO	116.4	302.7
858-44	Road	858-44-1	US	SMG	FO	82.7	215.1
825-13	Building site	825-13-1	US(Exit)	Private land	SS	21.9	56.9
858-1	Road	858-1-1	US	SMG	FO	1956.2	5086.1
1374	Road	1374-0-1	US	SMG	FO	1380.5	3589.2
1319-3	Road	1319-3-1	US	SMG	FO	107.1	278.5
1319-4	Road	1319-4-1	US	SMG	FO	23.2	60.3
1319-1	Road	1319-1-1	US	SMG	FO	119.3	310.3
1319-2	Road	1319-2-1	US	SMG	FO	377.4	981.1
1377	Road	1377-0-1	US	SMG	FO	430.7	1119.8
1318-10	Road	1318-10-1	US	SMG	FO	33.9	88.0
1318-11	Road	1318-11-1	US	SMG	FO	442.9	1151.5
1318-7	Road	1318-7-1	US	SMG	FO	29.1	75.6
1373	Road	1373-0-1	US	SMG	FO	2377.6	6181.8
858	Road	858-0-1	US	SMG	FO	2220.2	5772.5
820-10	Building site	820-10-1	US (Exit)	Private land	SS	15.0	39.0
820-11	Building site	820-11-1	US (Exit)	Private land	SS	51.7	134.4
858-11	Road	858-11-1	US	SMG	FO	34.8	90.4
821	Building site	821-0-1	US (Exit)	Private land	SS	80.4	208.9
858-29	Road	858-29-1	US	SMG	FO	200.5	521.4
858-30	Road	858-30-1	US	SMG	FO	565.5	1470.3
858-28	Road	858-28-1	US	SMG	FO	51.8	134.6
858-32	Road	858-32-1	US	SMG	FO	10.6	27.5
858-27	Road	858-27-1	US	SMG	FO	24.1	62.6
1373	Road	1373-0-2	SP	SMG	FO	382.4	1567.9
1377	Road	1377-0-2	SP	SMG	FO	348.8	1429.9
858	Road	858-0-2	SP	SMG	FO	198.0	811.6
858-1	Road	858-1-2	SP	SMG	FO	205.7	843.3
858-4	Road	858-4-2	SP	SMG	FO	2544.9	10434.2

US: Underground Shopping Mall
SP: Subway Station Platform
SMG: Seoul Metropolitan Government
FO: Full Rights of Ownership
SS: Sectional Superficies

Development of 3D Underground Cadastral System with Indoor Mapping for As-Built BIM: A Case Study of Gangnam Subway Station in Korea

- ## Proposed Method
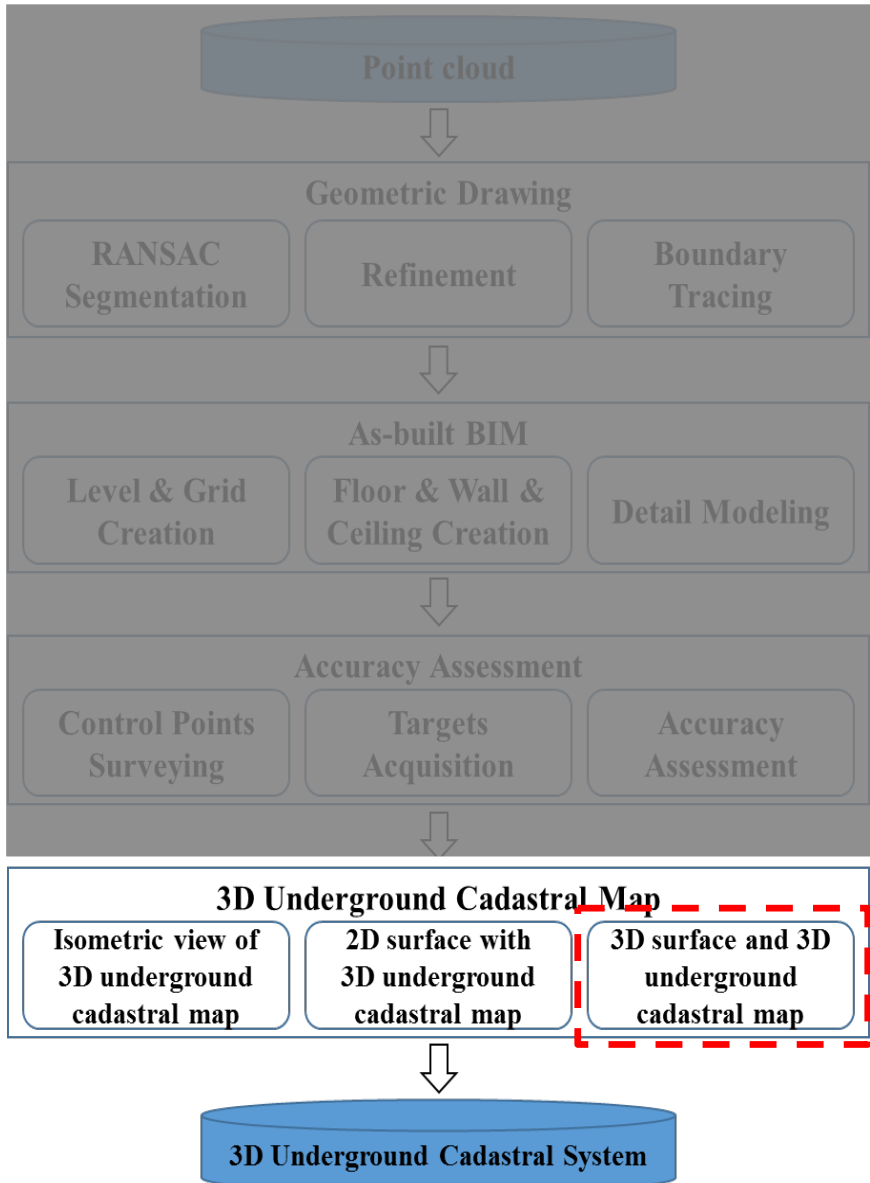
- ## Application & Results

Conclusion
& Future works

Conclusion & Future works

Registration framework of 3D underground parcel

- Proposed the registration framework of 3D underground parcel that provides a comprehensive approach by creating new terminology of underground parcel and maps.

- Further research, especially, legal aspects will be needed to meet the requirement of protection of the ownership and other related rights, restriction and responsibility.
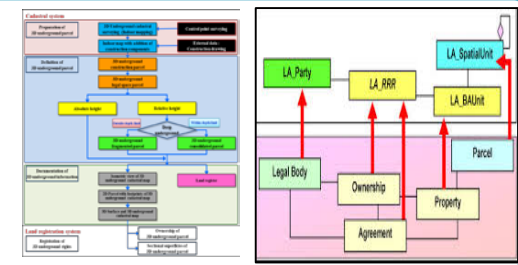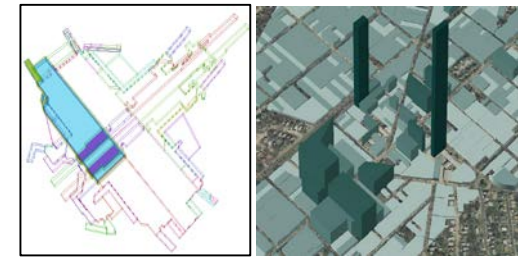
Korean 3D underground cadastral data model

- Proposed standards for registration of spatial information of 3D underground parcel, and it enhances the compatibility of 3D underground cadastral data.

- Further research, extend the value of 3D underground cadastral data model for working with other land management sector such as city planning system and real-estate system.
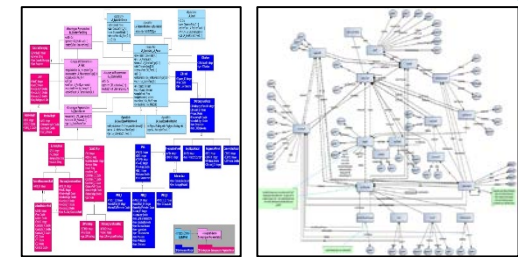
3D underground cadastral mapping

- Proposed the possibility for implementing 3D underground cadastral system based on indoor mapping for as-built BIM by terrestrial laser scanning data.

- Further research, full 3D cadastral system is needed to improve the usability and potential value of the 3D land information system.

Thank you