Modelling the legal spaces of 3D underground objects in a 3D Land Administration System

P5 presentation

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Table of contents

1. Introduction
2. Methodology
3. Results
4. Conclusion
5. Summary

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1. Introduction - background

- Urbanisation and lack of available construction land has led to an increase in the development of the underground space

- Developing the underground space can:

- help cities cope with urbanisation
- provide support for sustainable development

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1. Introduction - research motivation

- Main challenge in developing the underground space is defining and registering the Rights, Restrictions and Responsibilities (RRRs) of the underground objects

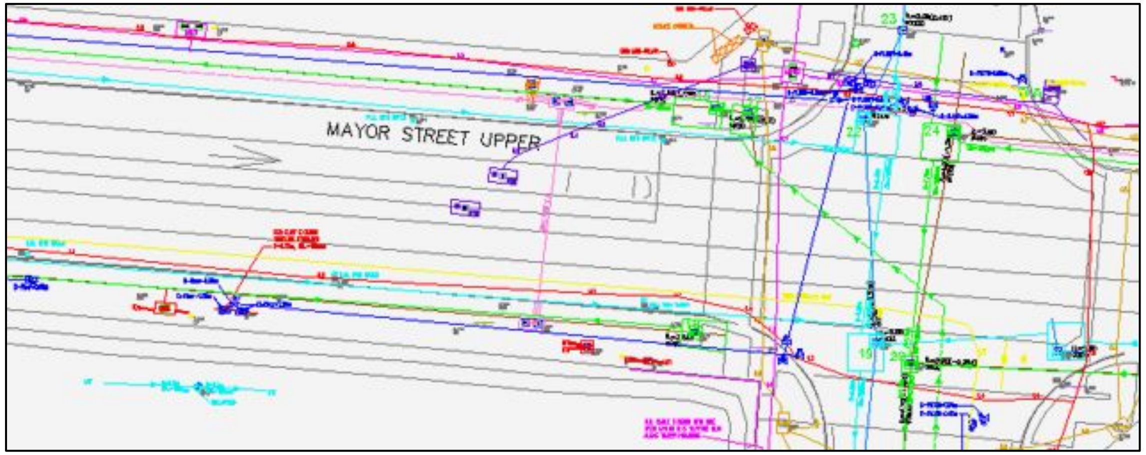
- Implementation of underground objects in Land Administration Systems (LASs) requires the use of 3D objects

- Most countries around the world use LASs where objects are registered in 2D

1. Introduction - research motivation

A 2D LAS cannot represent the 3D legal reality well:

- RRRs of underground objects (tunnels, utilities) are not easy to identify
- relations between objects below and above the surface not explicitly provided



2D model of underground utility network

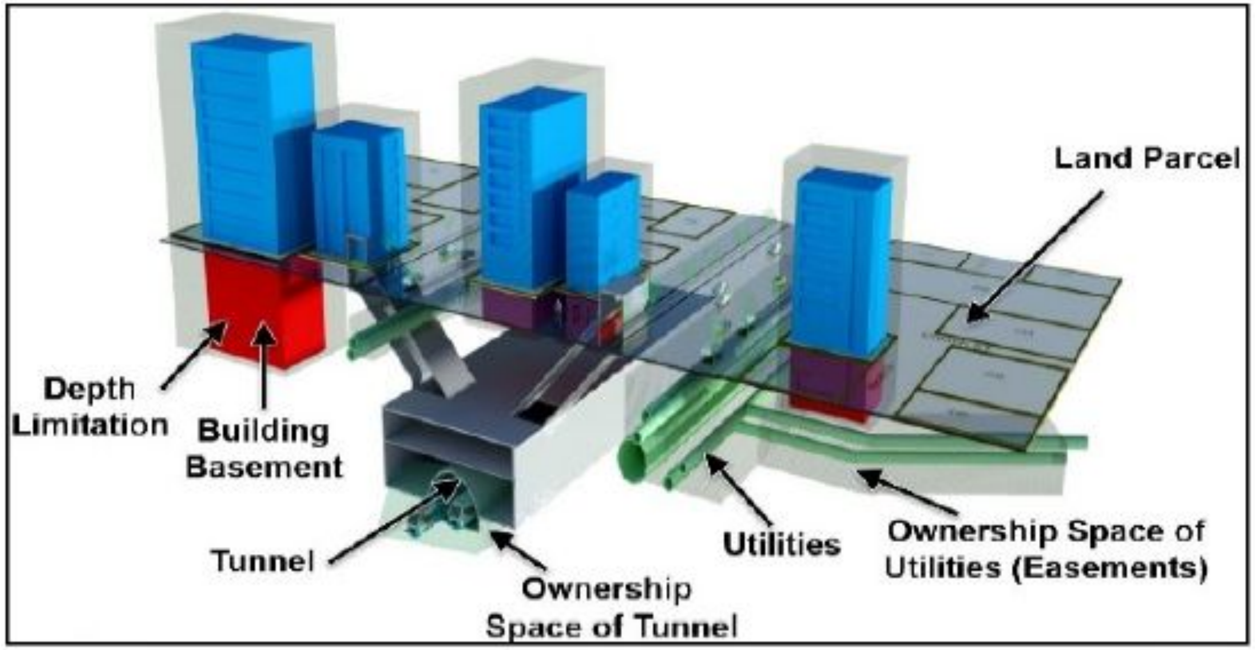
Image: https://www.indicomet.com/gpr-utility-surveys.html

1. Introduction - research motivation

- A 3D LAS, however, can clearly define the relationships between the RRRs and the 3D objects

- The registration of the objects in 3D LAS facilitates a better understanding, more efficient registration and clear visualisation of the RRRs

- 3D LAS can thereby support the development of the underground space



Schematic image of a 3D underground LAS

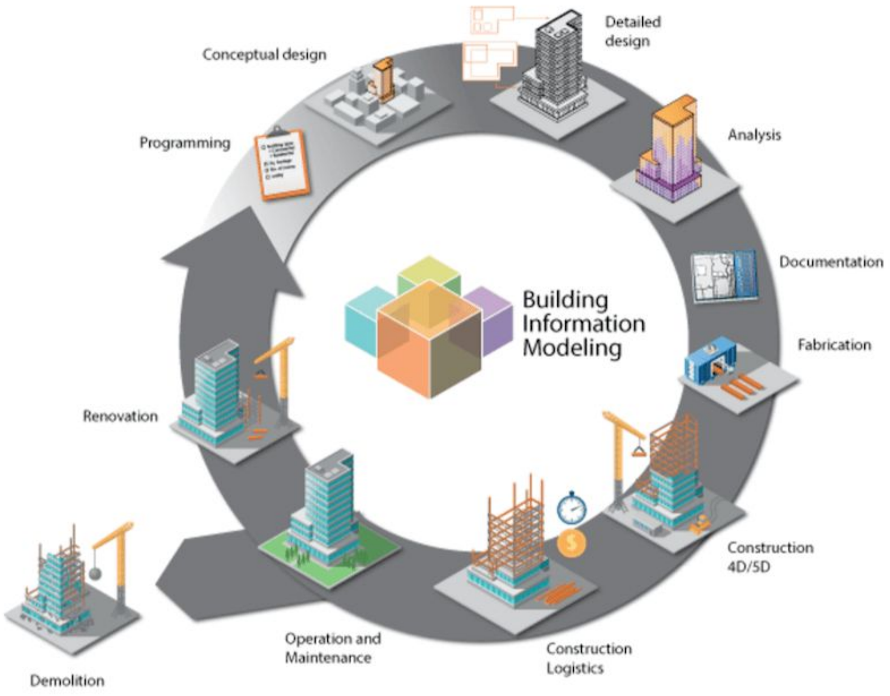
Image: Saeidian, B., Rajabifard, A., Atazadeh, B., Kalantari, M. (2021). Underground Land Administration from 2D to 3D: Critical Challenges and Future Research Directions. *Land*, 10, 1101.

1. Introduction - research motivation

- To register 3D underground objects, 3D physical data and 3D legal data are needed and integrated into one model
- For the creation, storage, exchange and visualisation of the data, standards should be used
- Standardisation of data can reduce the time and costs in processed where the data is used, making the data more understandable, interoperable and suitable for exchange

1. Introduction - research motivation

- BIM/IFC models can be used as a standard for the physical data
- Building Information Models (BIMs) comprise the semantic and geometrical information of buildings throughout the whole Life Cycle



BIM Life Cycle

Image: https://bimmda.com/en/what-is-bim

1. Introduction - research motivation

- IFC (ISO 16739-1:2018) is a open data format that makes it possible for BIMs to be exchanged without the loss of data

- The re(use) of IFC models is increasing due to a need for data exchange and interoperability across the Architecture, Engineering, Construction, Owner, Operator (AECOO) community, industry and governments.

Image: https://www.buildingsmart.org/buildingsmarts-technical-progress/

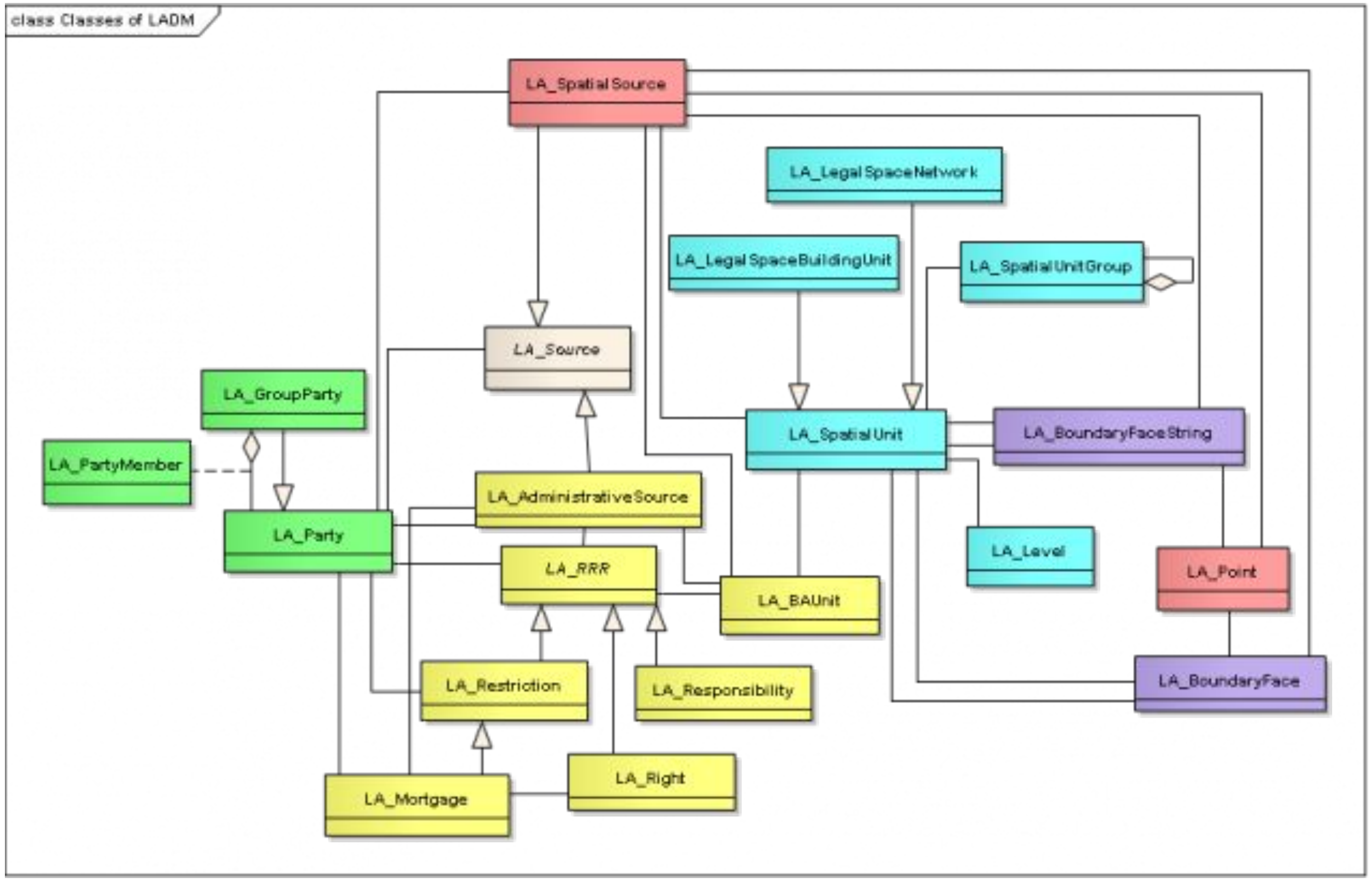
1. Introduction - research motivation

- The Land Administration Domain Model (LADM) can be used to structure the legal data in a standardised manner.

- The LADM is an international standard, that provides a formal language for describing both the spatial and non-spatial information in the land administration domain.

- Compliance with this standard leads to a more efficient LAS, where data can be exchanged and the quality of data ensured, sustained and effectively managed

1. Introduction - research motivation



LADM

Image: https://www.gim-international.com/content/article/land-administration-domain-model

1. Introduction - research motivation

- To achieve an integrated model LADM classes should be mapped to IFC entities

- Linking LADM to IFC for two scenarios:

  1. Reusing the geometry of BIM/IFC models from design for the registration of legal spaces in LASs

  2. Reusing BIM/IFC models from design to serve as a technical encoding for the exchange of data in LASs

1. Introduction - problem statement

- Other challenges: (3D) LAS vary around the world

- Different requirements for the collection, validation, registration, storing, dissemination of 3D underground (cadastral) data

1. Introduction - objective

To develop a standardised workflow in order:

- to collect, process, store, visualise, disseminate and query 3D underground data in a 3D LAS according to ISO 19152:2012 (LADM standard)
- to model the relations between underground objects and their legal spaces
- to model the relations between underground legal spaces and the 2D parcels (modelled as 3D volumetric columns) on the surface
- to connect the workflows from AECOO to 3D LAS via an IFC (ISO 16739:2018) model

1. Introduction - research question and scope

Main research question

How can the legal spaces of 3D objects below the surface be modelled in 3D Land Administration Systems based on ISO 19152:2012 in the context of reusing BIM/IFC models from design?

Scope of research

- Two types of underground objects: tunnels and utilities
- IFC 4 models of underground objects

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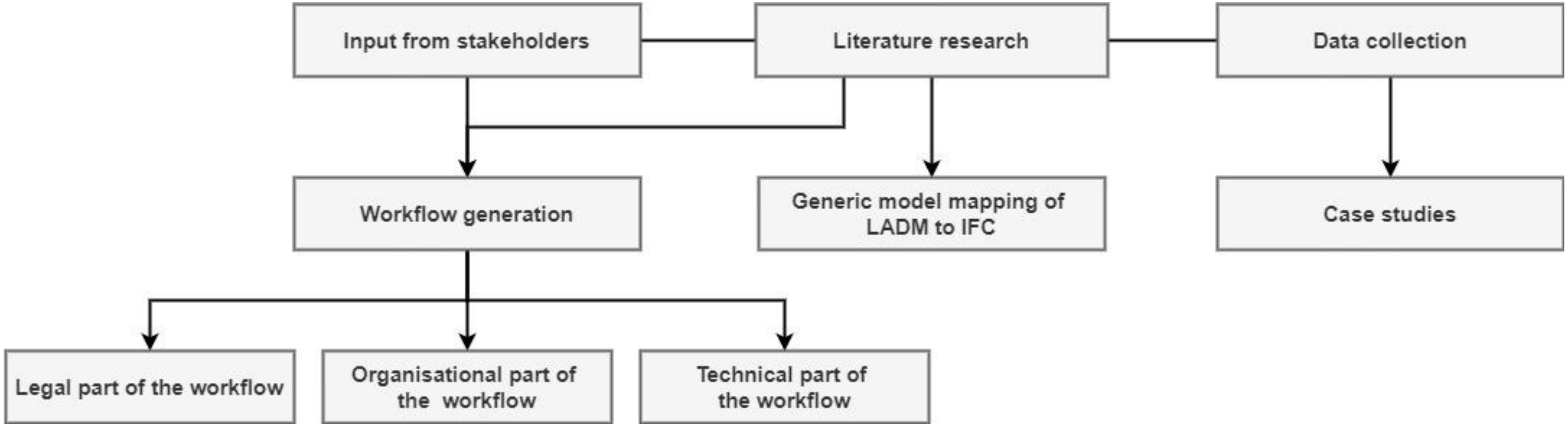
1. Introduction - relevance

- Research done in implementation of LADM in a 3D LAS with the use of IFC models (Broekhuizen, 2021)
- For objects above the surface (office buildings, apartment complexes)
- RRRs of objects on the surface can easily be determined by applying the legal information from the enriched BIM/IFC model.
- No research done for objects below the surface

Enriched BIM/IFC model visualised in 3D geospatial visualisation platform (Broekhuizen, 2021)

2. Methodology



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2. Methodology - data collection

Count of data formats of provided datasets per organisation

		Data formats							
		IFC 2x3	IFC 4	DWG	CityGML	SHP	GPKG	RVT	NWD
Code	**Name of organisation**								
D	Municipality of Almere						2		
D	Municipality of Amsterdam	2		1					
D	Municipality of Groningen				2				
D	Municipality of Rotterdam			10					
D	Province of Gelderland							1	
D	Province of Groningen	1							
D	Province of North-Holland					2			
D	National agency Rijkswaterstaat	3		6					5
D	Water company PWN					1			
S	Canton of Basel		1						
S	National agency Swisstopo		3						
E	Ballast-Nedam								1
E	Prisma Groep	1							
E	Skanska UK	2							

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2. Methodology - data collection

Categorisation of the collected objects based on the IFC type

	Data formats	
	IFC 2x3	IFC 4
Type of object		
Tunnel	3	
Utilities / (part of a) utility network		3
Bridge	1	1
Petrochemical pipes	1	
Underpass	2	
Building	1	
Surroundings	1	

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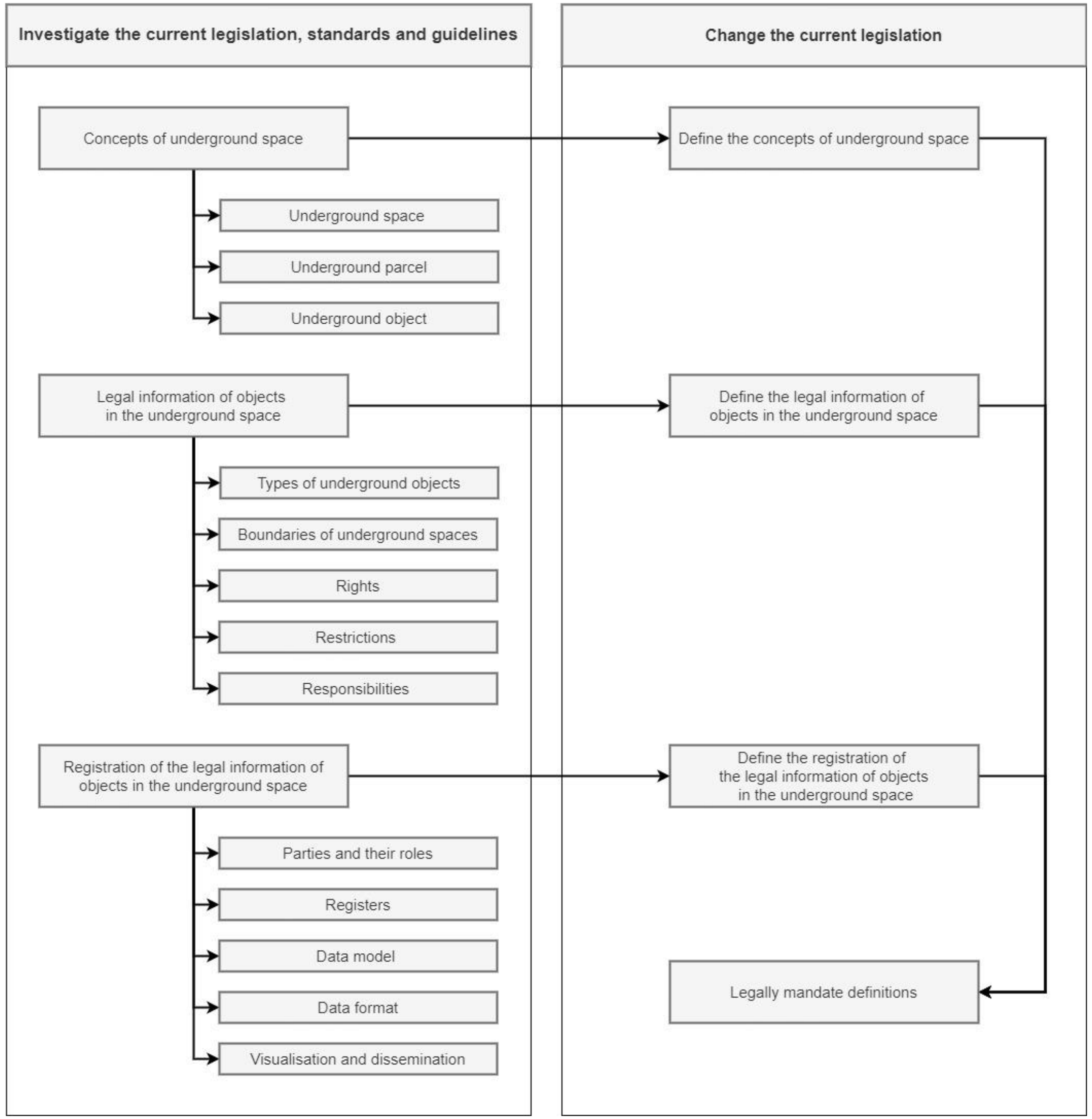
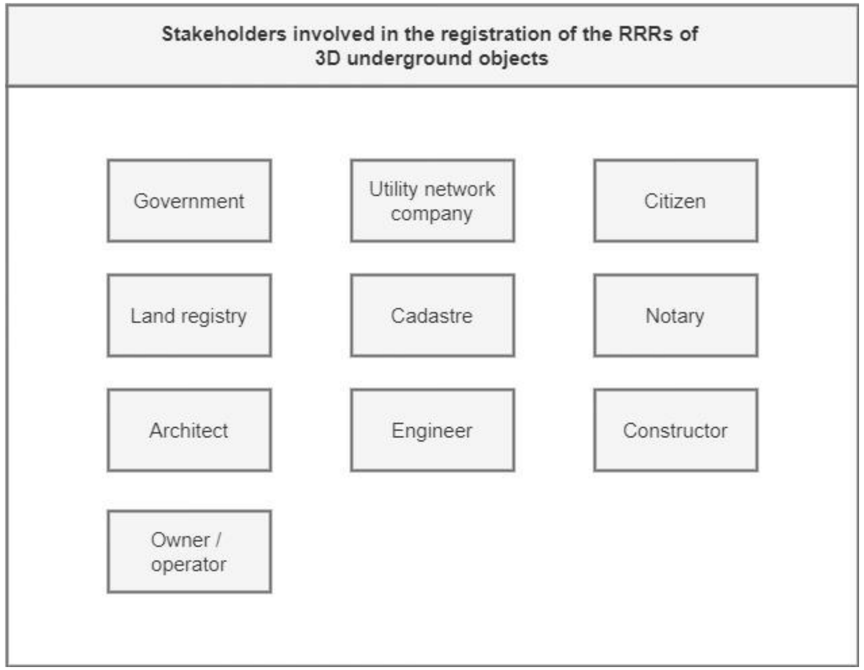
2. Methodology - legal workflow



2. Methodology - organisational workflow



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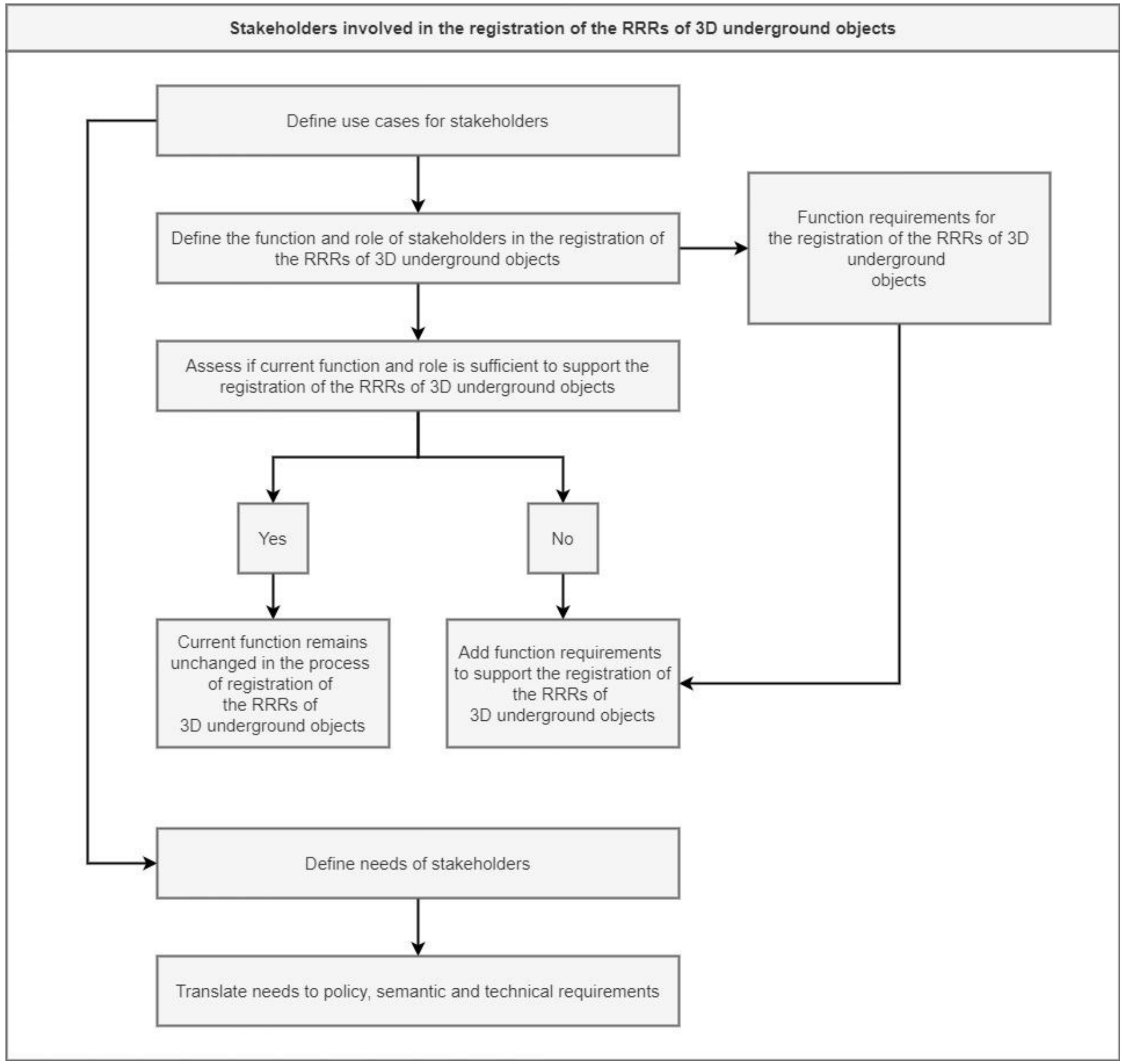
2. Methodology - organisational workflow



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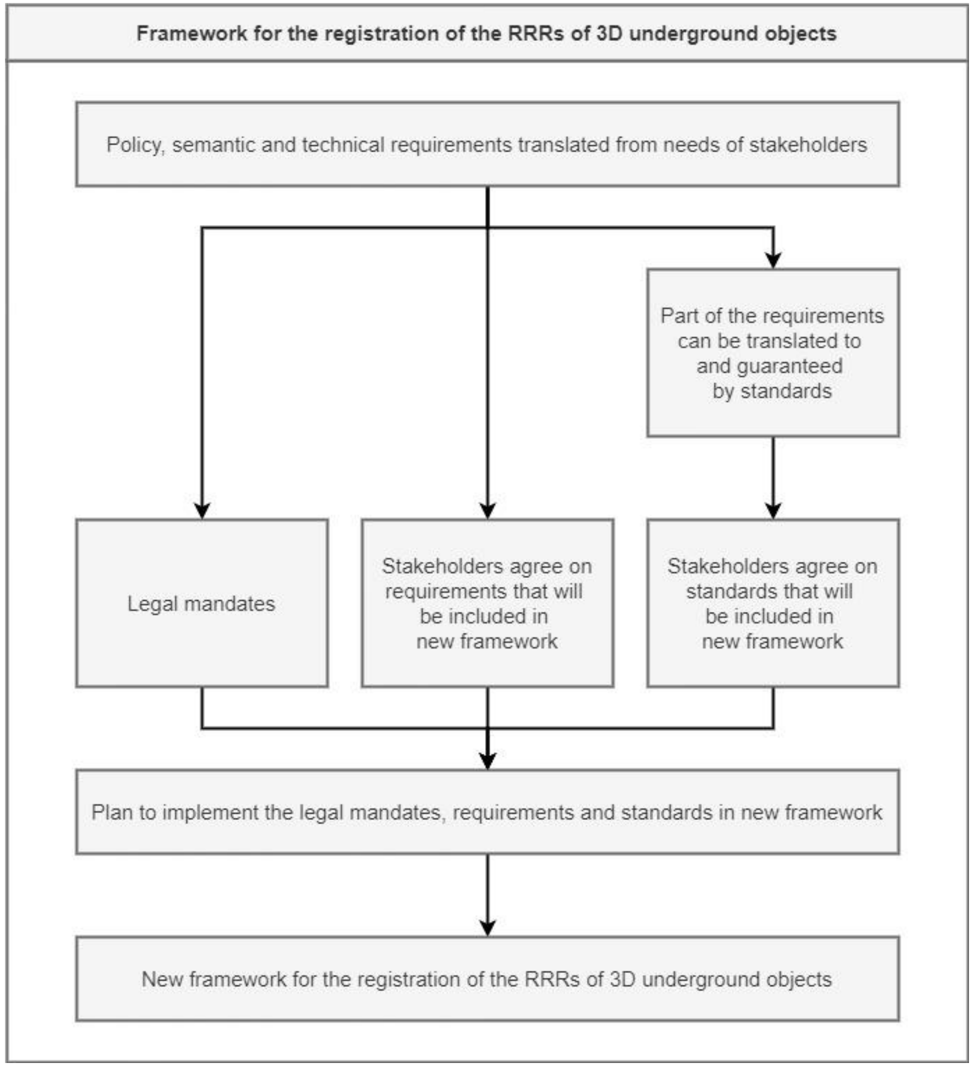
2. Methodology - organisational workflow



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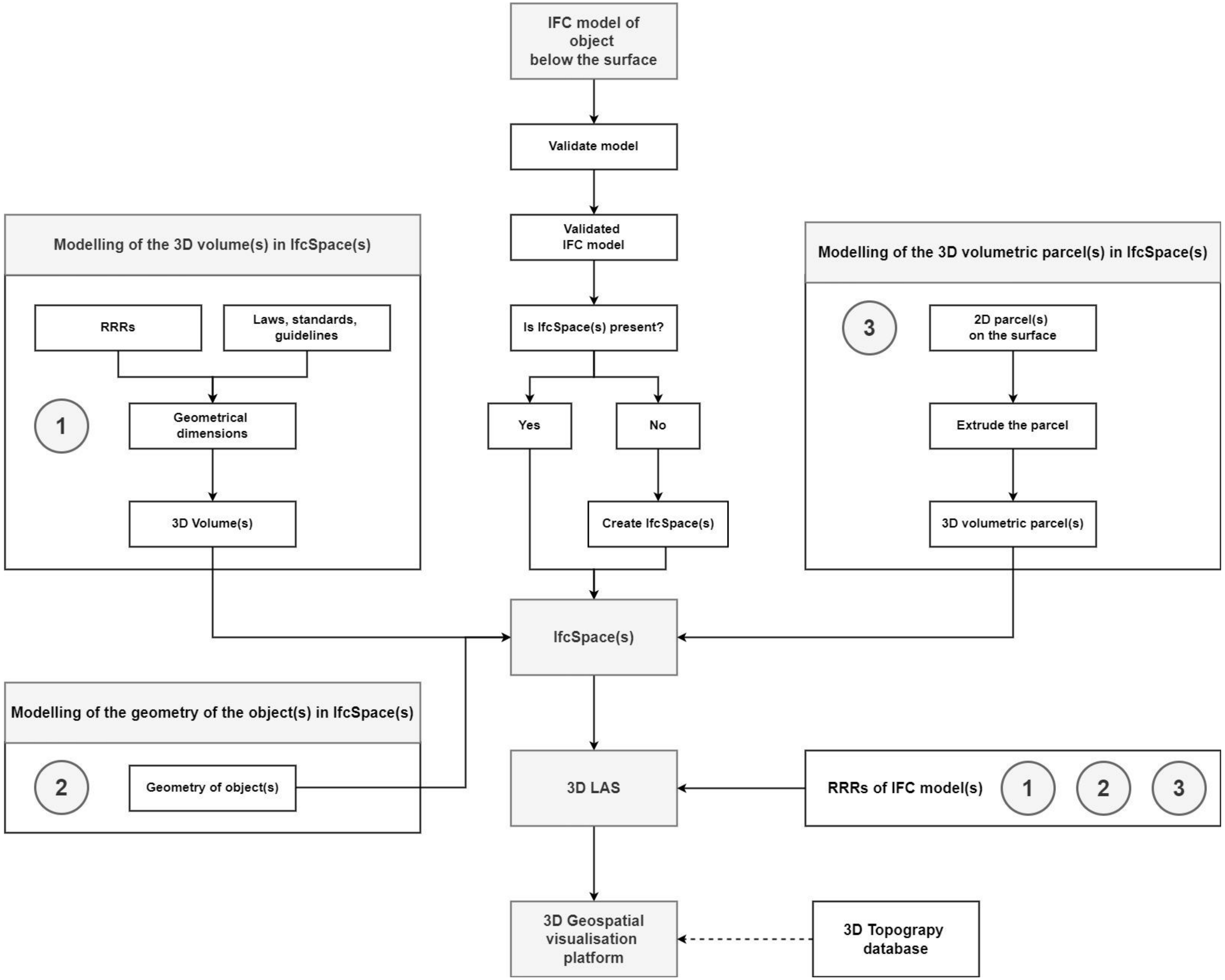
2. Methodology - technical workflow

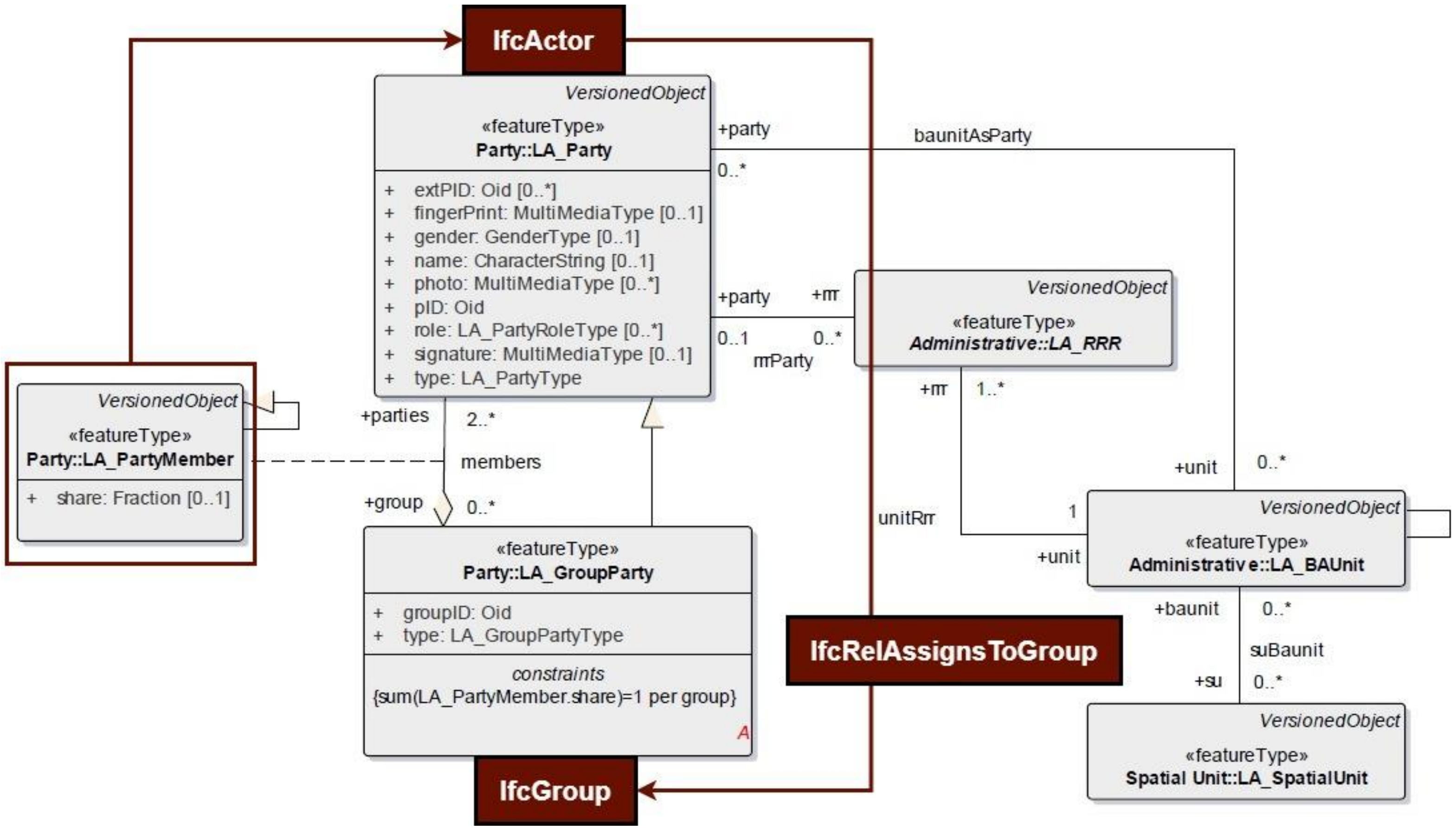


3. Results - mapping LADM classes to IFC entities

- Revised model from LADM up until October 2021 is used (ISO/TC 211)
- IFC 4 version is used
- Previous version IFC 2x3 and upcoming version IFC 4x3 will also be evaluated
- No difference in entities with regards to entities used for mapping LADM classes to IFC entities for IFC 2x3
- For IFC 4x3, main difference was that IfcBuildingElementProxy was deprecated

3. Results - mapping LADM classes to IFC entities

Party Package
(TC/211, 2021)



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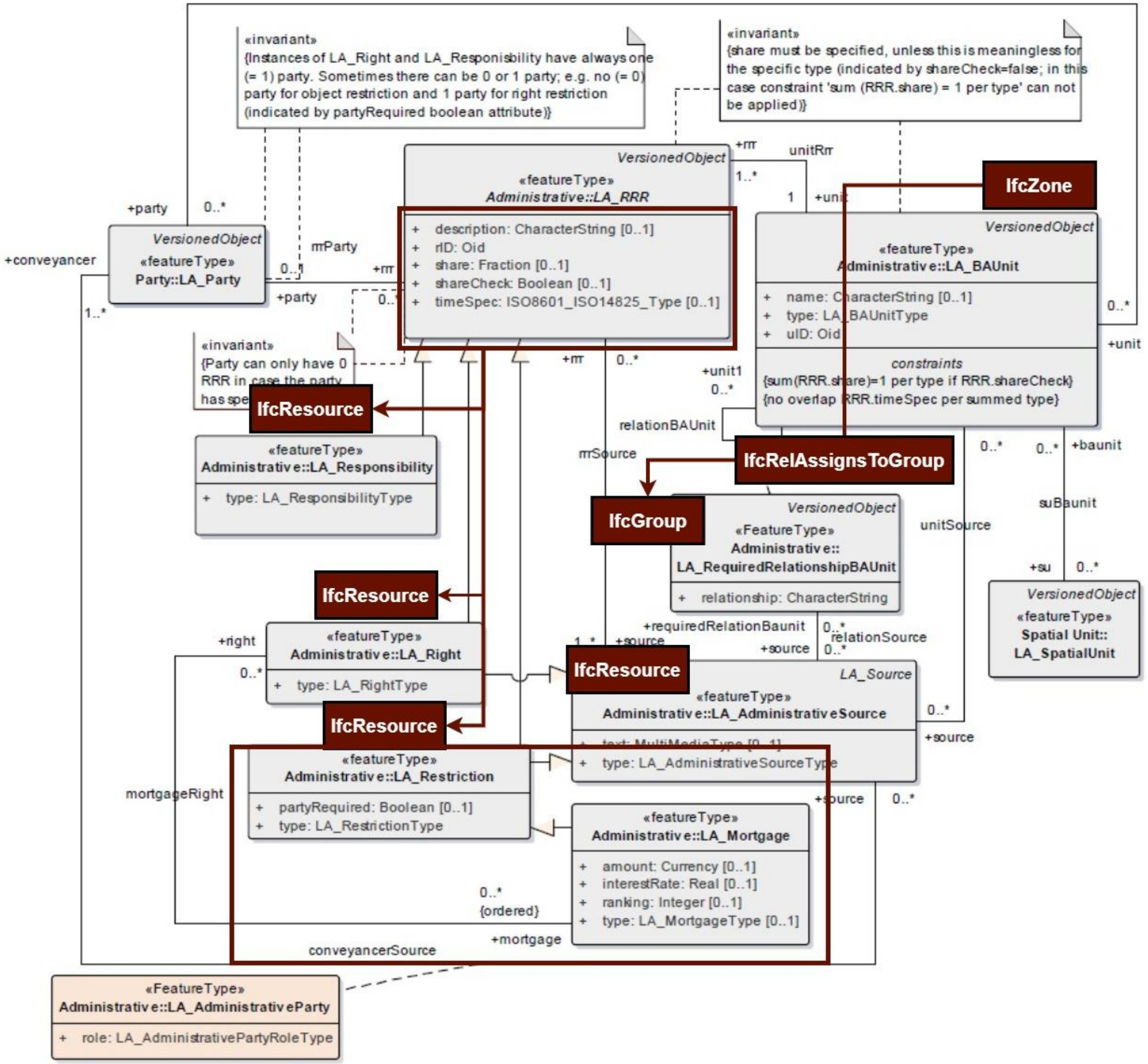
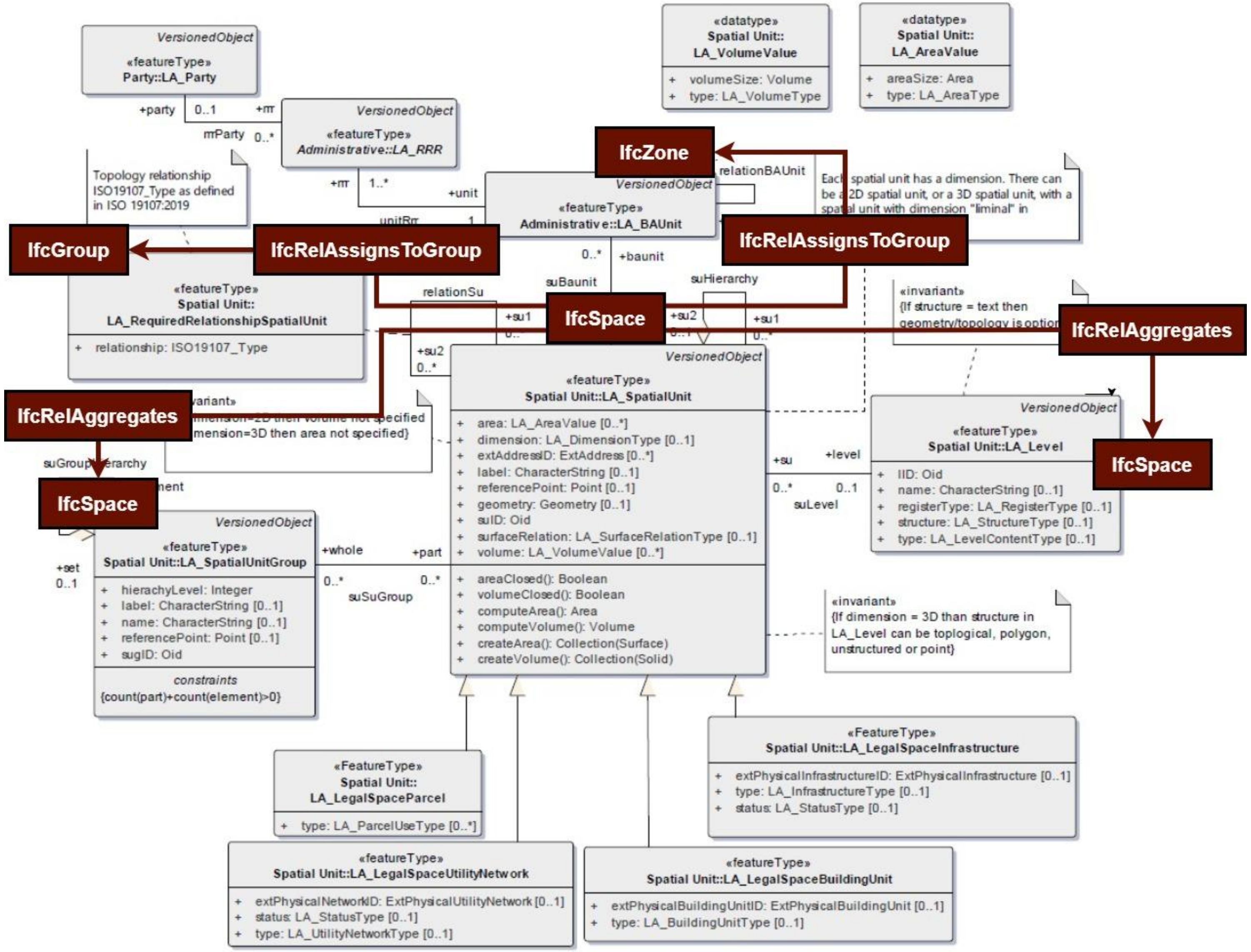
3. Results - mapping LADM classes to IFC entities

Administrative Package
(ISO/TC 211, 2021)



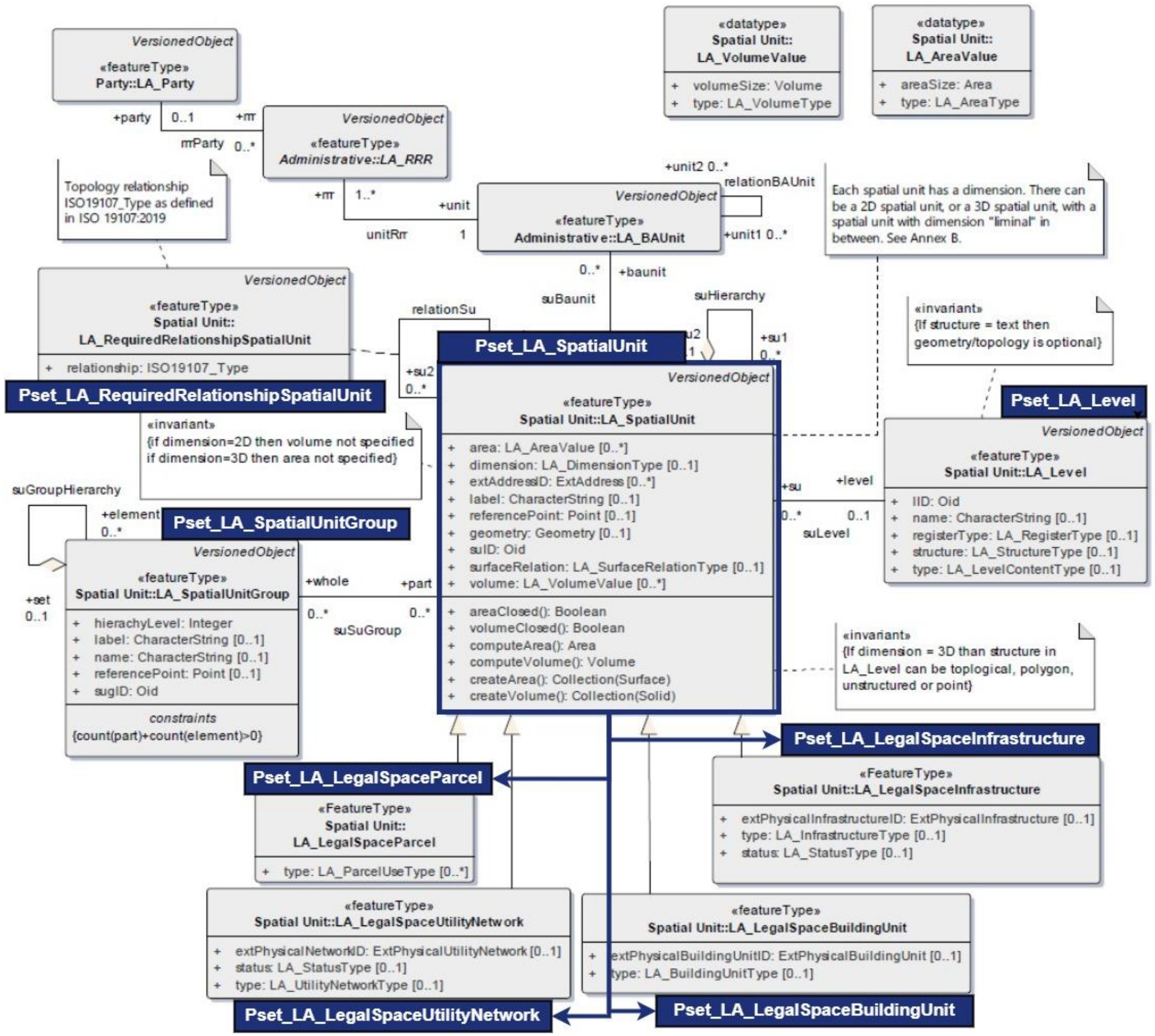
3. Results - mapping LADM classes to IFC entities

Spatial Package
(ISO/TC 211, 2021)



3. Results - mapping LADM classes to IFC entities

Spatial Package



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3. Results - mapping LADM classes to IFC entities

Spatial Package:

Pset_LA_LegalSpaceUtilityNetwork

LADM information			Pset_LA_LegalSpaceUtilityNetwork (of IfcSpace)		
LADM Attribute name	**LADM Type**	**LADM codeList**	**IFC Attribute name**	**IFC Data Type**	**Description**
extPhysicalUtilityNetworkID	ExtPhysicalUtilityNetwork	-	extPhysicalUtilityNetworkID	IfcGloballyUniqueID	Identifier of the physical description of the utility network
status	LA_StatusType	inUse outOfUse planned	status	IfcLabel	Status of the utility network
type	LA_UtilityNetworkType	chemicals electricity gas heating oil telecommunication water	type	IfcLabel	Type of the utility network

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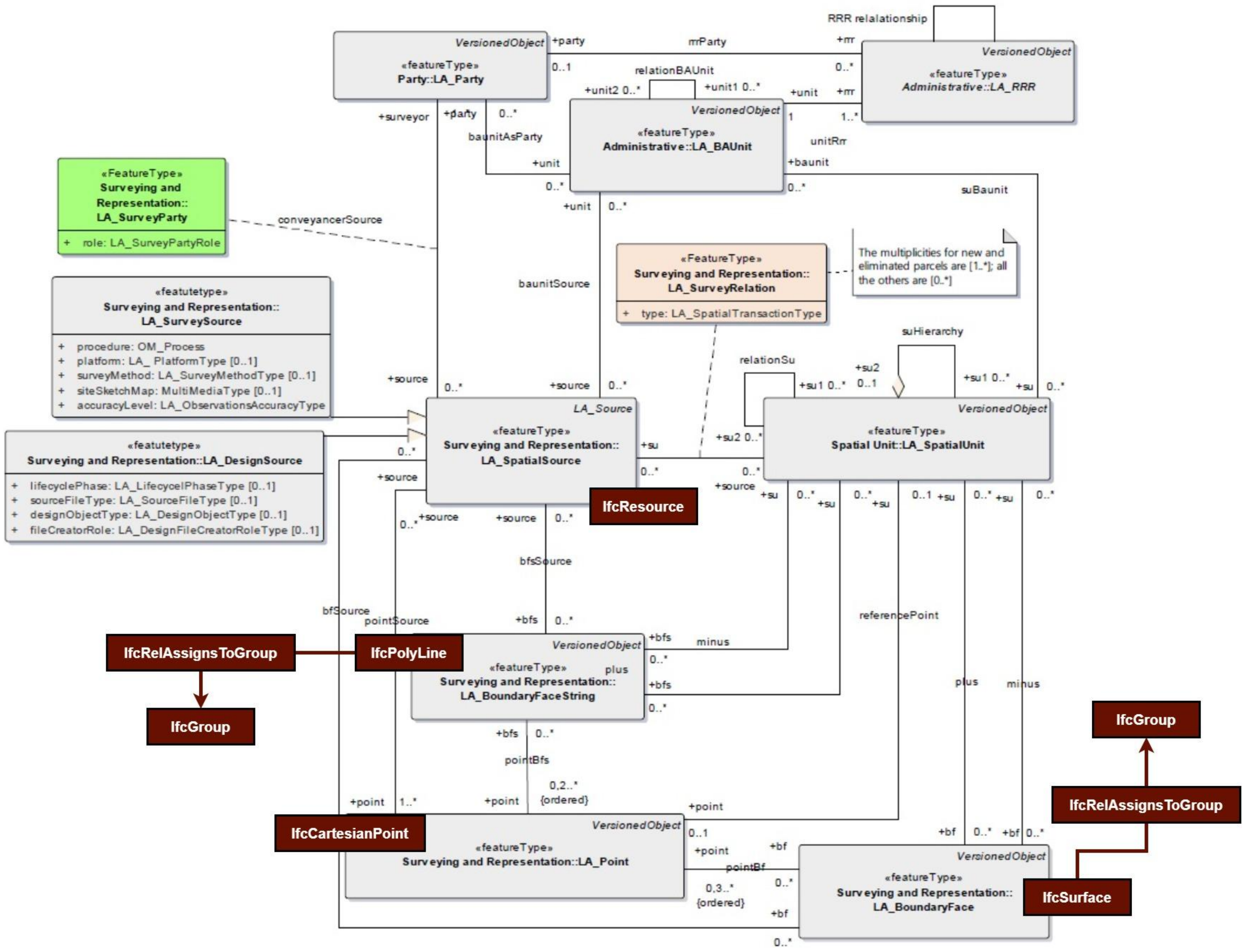
3. Results - mapping LADM classes to IFC entities

Surveying and Representations subpackage (ISO/TC 211, 2021)



3. Case studies - sewage pipes in Almere

The legal spaces were modelled through the following steps:

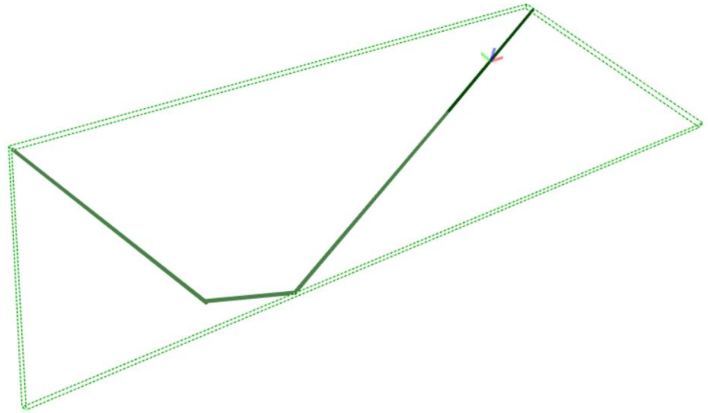
1. Select pipe segments from the sewage network
2. Convert the pipe segments to IFC models
3. Select the parcels under which the pipe segments lie
4. Convert the parcels to an IFC model
5. Store the pipe segments and the parcels in the 3D DBMS
6. Add the RRRs to the 3D DBMS
7. Write the data from the 3D DBMS to Cesium 3D Tiles
8. Visualise the Cesium 3D Tiles

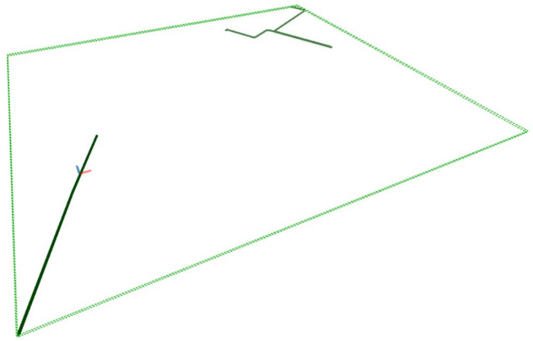
3. Case studies - sewage pipes

1. Select pipe segments from the sewage network

3. Case studies - sewage pipes

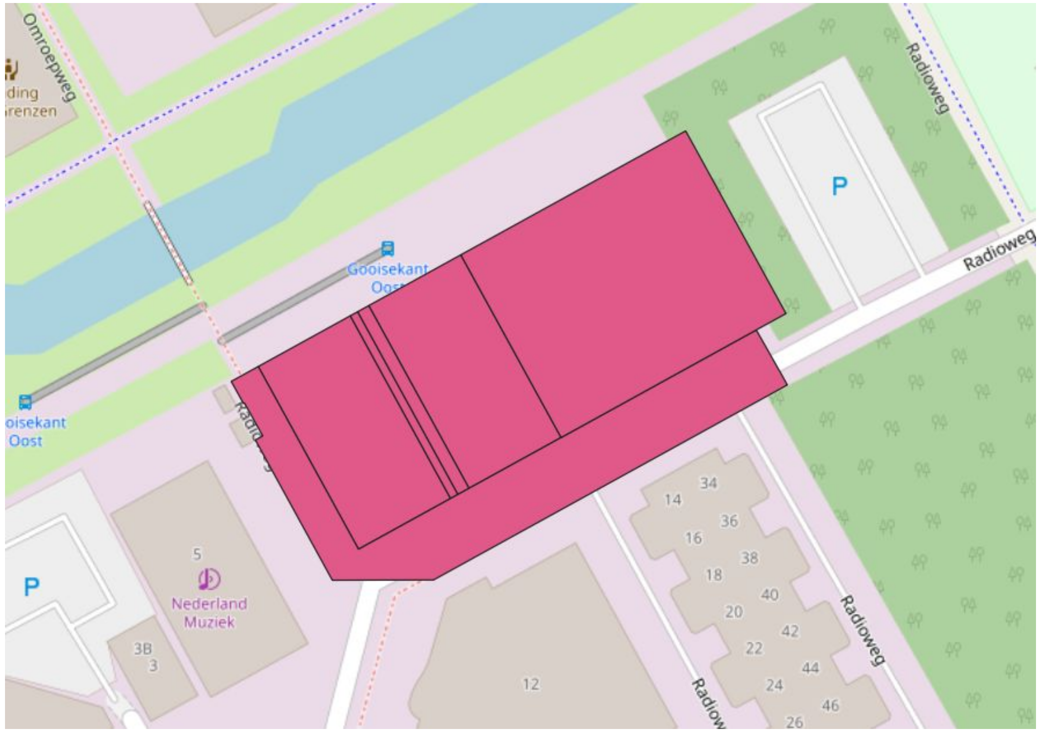
2. Convert the pipe segments to IFC models





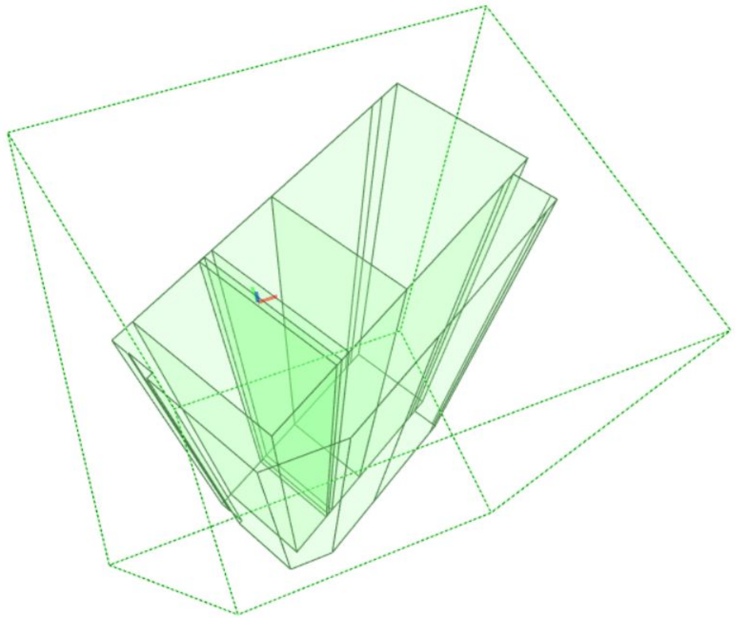
3. Case studies - sewage pipes

3. Select the parcels under which the pipe segments lie



3. Case studies - sewage pipes

4. Convert the parcels to an IFC model



3. Case studies - sewage pipes

5. Store the pipe segments and the parcels in the 3D DBMS

6. Add the RRRs to the 3D DBMS

```
UPDATE parcels_almere
SET Party = 'Rijnhomij B.V.', Rights = 'Ownership', Restrictions = 'Obligation to consent (Liander N.V.)'
WHERE name = '3147';
```

case_almere/postgres@PostgreSQL 13

Query Editor | Query History

```
SELECT *
FROM parcels_almere_view
```

Data Output | Explain | Messages | Notifications

	globalid character (22)	name text	description text	longname text	party character varying	rights character varying	restrictions character varying	responsibilities character varying
1	UrMng2RIQrSniLsYJIpVow	3557	[null]	[null]	Municipality of Almere	Ownership	[null]	[null]
2	U1tRGLiKRASFJlsdgvQ6_A	3805	[null]	[null]	MO Holding B.V.	Ownership	Right of Superficies (Liander N.V.)	[null]
3	1o9aU9AoS7OPY$nNo2Dfmg	3147	[null]	[null]	Rijnhomij B.V.	Ownership	Obligation to consent (Liander N.V.)	[null]
4	mai0mKi2R$awtElXyIpGhQ	3148	[null]	[null]	Rijnhomij B.V.	Ownership	Obligation to consent (Liander N.V.)	[null]
5	qIOu7sZIQHWGCUXTZSxFAg	3303	[null]	[null]	Rijnhomij B.V.	Ownership	Obligation to consent (Liander N.V.)	[null]
6	GhTNBaU4S6OeOOnh6VhKyg	3302	[null]	[null]	G.N. Wijngaard B.V.	Ownership	Obligation to consent (Liander N.V.)	[null]

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3. Case studies - sewage pipes

7. Write the data from the 3D DBMS to Cesium 3D Tiles

8. Visualise the Cesium 3D Tiles

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3. Case studies - Heinenoordtunnel

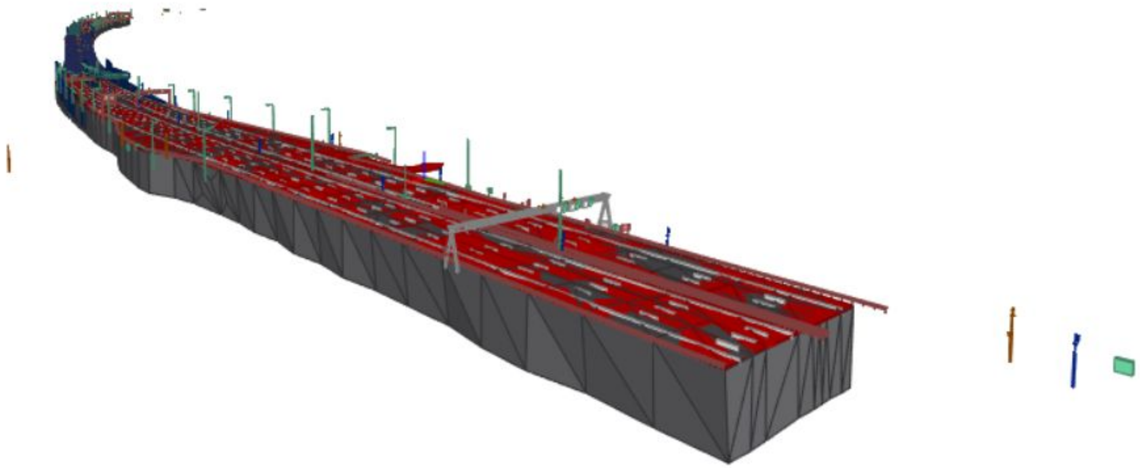
The legal spaces were modelled through the following steps:

1. Simplify the IFC model of the tunnel
2. Select the parcels under which the tunnel lies
3. Convert the parcels to an IFC model
4. Store the simplified IFC model and the parcell in the 3D DBMS
5. Add the RRRs to the 3D DBMS
6. Write the data from the 3D DBMS to Cesium 3D Tiles
7. Visualise the Cesium 3D Tiles

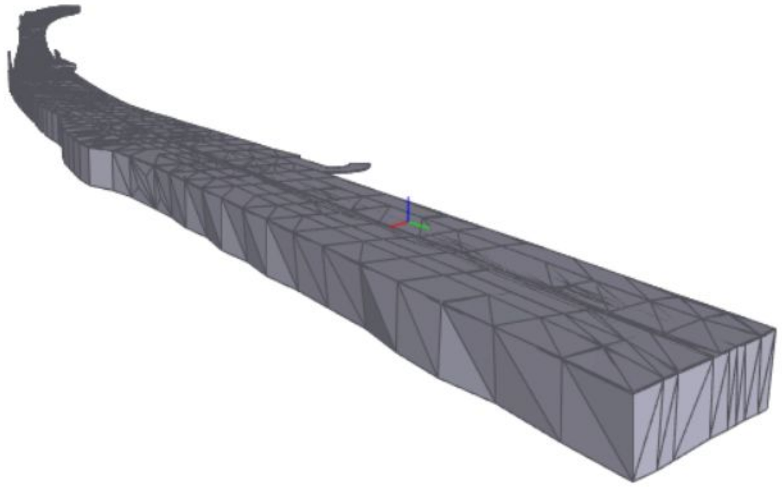
Only step 1 and 7 are presented in the following two slides.

3. Case studies - Heinenoordtunnel

1. Simplify the IFC model of the tunnel



IFC model Heinenoordtunnel



Simplified IFC model Heinenoordtunnel

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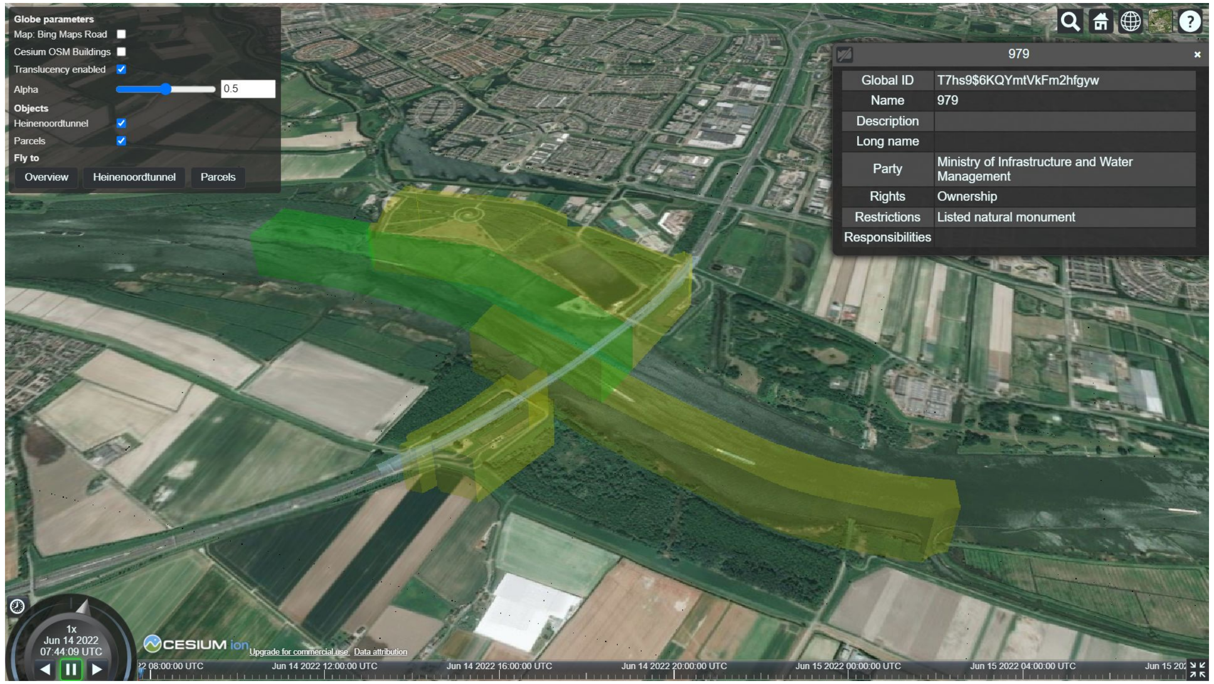
3. Case studies - Heinenoordtunnel

7. Visualise the Cesium 3D Tiles



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4. Conclusions - research question

Main research question

How can the legal spaces of 3D objects below the surface be modelled in 3D Land Administration Systems based on ISO 19152:2012 in the context of reusing BIM/IFC models from design?

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4. Conclusions - research question

Sub-question

1. Which 3D underground objects are there and how are they currently modelled in LAS?

- Utilities (gas, water, electricity, sewage, drainage, waste management
- Petrochemical installations
- Tunnels
- Cellars
- Parking garages

Most LASs model underground objects in 2D.

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4. Conclusions - research question

Sub-question

2. How does the current legislation in the Netherlands support the registration of 3D underground objects in LASs and how can the legislation be improved?

- Current legislation facilitates, but does not support the registration of 3D underground objects
- Amendments need to be made to the Dutch law
- Investigate current standards and guidelines
- Use standards and guidelines as blueprint for amendments to the law (or new law)

4. Conclusions - research question

Sub-question

3. Who are the stakeholders in registering the 3D objects below the surface in LASs?

- governmental organisations
- land registry organisations
- cadastral organisations
- utility network companies
- notaries
- architects
- engineers
- constructors
- owners / operators
- citizens

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4. Conclusions - research question

Sub-question

4. What are the requirements (technical and semantic) to register BIM/IFC models of 3D objects below the surface?

- The data should be complete
- The depth values of the 3D underground objects should be included in the data
- The data should be accurate

4. Conclusions - research question

Sub-question

4. What are the requirements (technical and semantic) to register BIM/IFC models of 3D objects below the surface?

- The data should be correctly georeferenced
- The data should be geometrically valid
- IfcSpace should be used to store the legal spaces
- The legal spaces should have unique IDs

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4. Conclusions - research question

<u>Sub-question</u>

4. What are the requirements (technical and semantic) to register BIM/IFC models of 3D objects below the surface?

- There should be no overlap between the legal spaces
- The same semantics should be used throughout the whole process of registering 3D underground objects
- There should be sufficient metadata
- All versions of the data should be stored

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4. Conclusions - research question

Sub-question

5. How can the legal spaces of 3D objects below the surface be efficiently stored, visualised and disseminated?

The BIM/IFC models of 3D underground objects:

- are enriched with legal information
- structured according to the LADM
- stored in a spatial database

4. Conclusions - research question

Sub-question

5. How can the legal spaces of 3D objects below the surface be efficiently stored, visualised and disseminated?

- where in one table the legal information is stored and in a respective table the physical information is stored
- can best be visualised on a 3D geospatial visualisation platform
- where querying is supported

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4. Conclusions - research question

<u>Sub-question</u>

6. How can the effectiveness of the proposed workflow be evaluated?

All workflows:
- Working group
- Consisting of stakeholders and legal, organisational and technical experts

Technical workflow
- Through case studies (in this research)

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4. Conclusions - case studies

Case study 1: sewage system in Almere

- A legal space does not always have to be made separate from the existing (or potential) legal spaces (2D parcels extruded to 3D volumetric parcels)
- Existing (or potential) legal spaces are adequate enough to describe the RRRs of other objects present in these legal spaces
- The technical workflow supports the use of 2D parcels that are extruded to 3D volumetric parcels and modelled in IfcSpace

4. Conclusions - case studies

<u>Case study 2: Heinenoordtunnel</u>

- A legal space does not always have to be made separate from the existing (or potential) legal spaces (2D parcels extruded to 3D volumetric parcels)

- Existing (or potential) legal spaces are adequate enough to describe the RRRs of other objects present in these legal spaces

- The technical workflow supports the use of 2D parcels that are extruded to 3D volumetric parcels and modelled in IfcSpace

4. Conclusions - discussion

- Lack of usable and publishable IFC 4 models of 3D underground objects
- Application of the research to countries other than the Netherlands

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4. Conclusions - recommendations

- Use international open standards
- Georeferencing: LoGeoRef method proposed by Clemen et al., 2019.
- IfcFacilityPart as an alternative for IfcBuildingElementProxy

4. Conclusions - future work

- More case studies with IFC models of different underground objects in countries other than the Netherlands
- Use entities other than IfcSpace to store RRRs of underground objects
- Attach the RRRs of underground objects to the (geometrical primitives of the) objects
- Map the operations of the LADM classes to IFC entities

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4. Conclusions - future work

- IFC models can be used to update the registration of the legal information of the objects
- IFC models can be extended with LADM classes for better exchange of data
- IFC models can serve as a technical encoding for the LADM data exchange

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Summary

- More research in defining the RRRs of underground objects and mandating the registration of the RRRs of underground objects
  → Legal workflow

- More involvement of stakeholders and also implementing their requirements
  → Organisational workflow

- 3D volumetric parcels are sufficient to describe the RRRs of underground objects
  → Technical workflow

References

Broekhuizen, M. (2021). *BIM/IFC files as input for 3D Land Administration Systems* (Master's thesis, TU Delft, Delft, The Netherlands).
Retrieved from: https://studenttheses.uu.nl/handle/20.500.12932/390.

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Thank you for your attention