

3DCityDB-Tools plug-in for QGIS: Adding server-side support to 3DCityDB v.5.0



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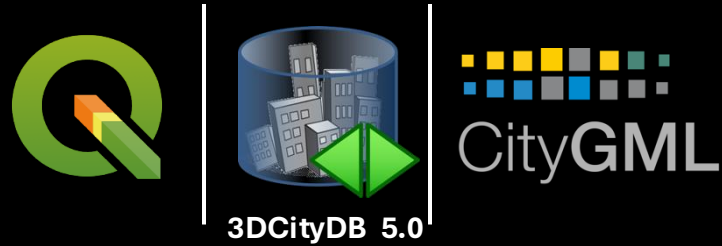
External supervisor: Zhihang Yao

Outline:

1. Introduction & Related work
2. Methodology & Implementation (part 1)
3. Methodology & Implementation (part 2)
4. Tests & Results
5. Conclusions & Future Development



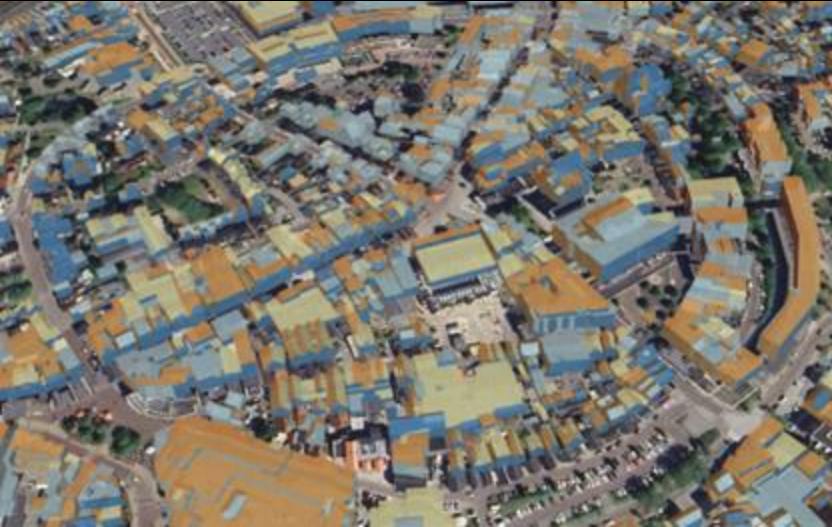
1. Introduction & Related work



3D City Models

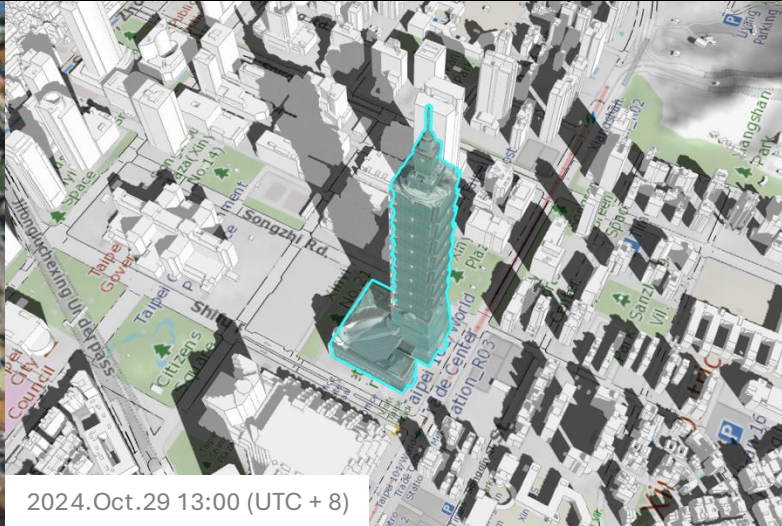
Solar Irradiance Analysis

TU Delft GEO5014 Course Assignment (2023)



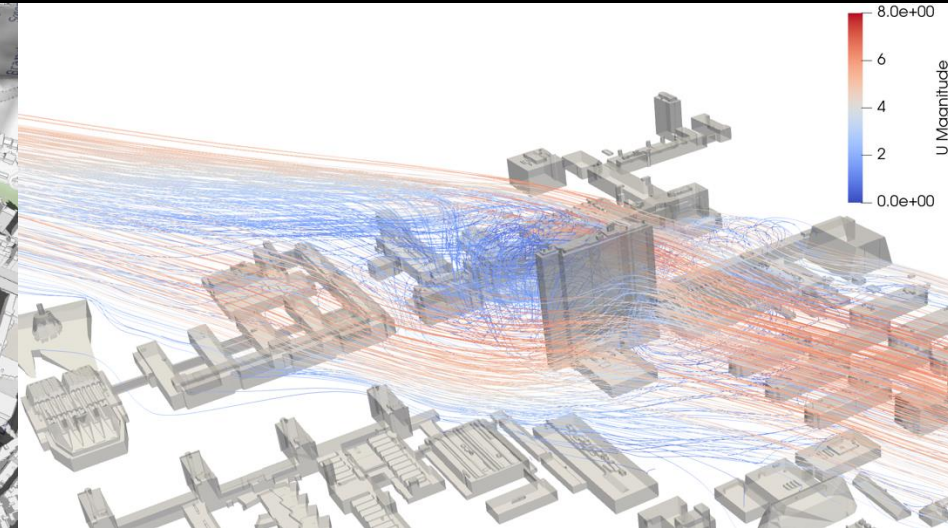
Shading Analysis

Taiwan 3D Map Online Portal Functions



Wind Speed Simulation Analysis

TU Delft GEO5015 Course Assignment (2023)

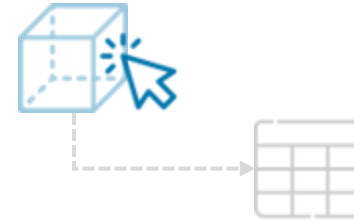


Possible Interactions with 3D City Model data from QGIS

- **Case1: checking only geometries**

- **Case2: click on one geometry to retrieve attributes**

- read-only
- read-write

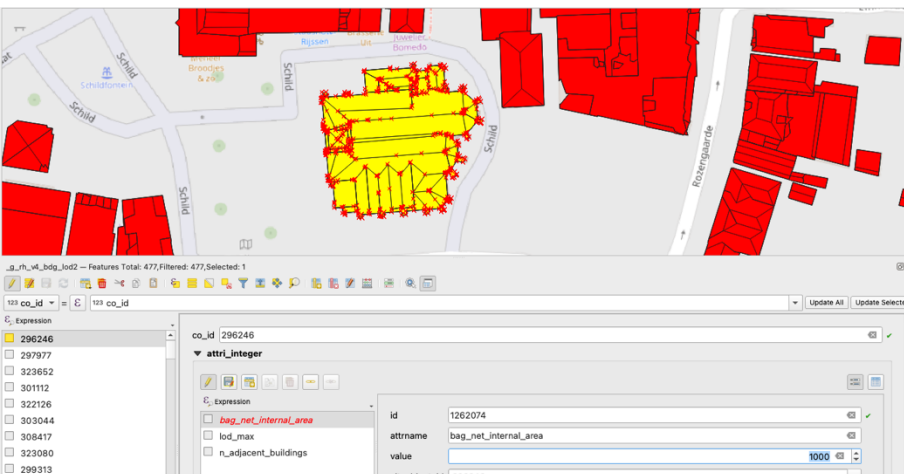
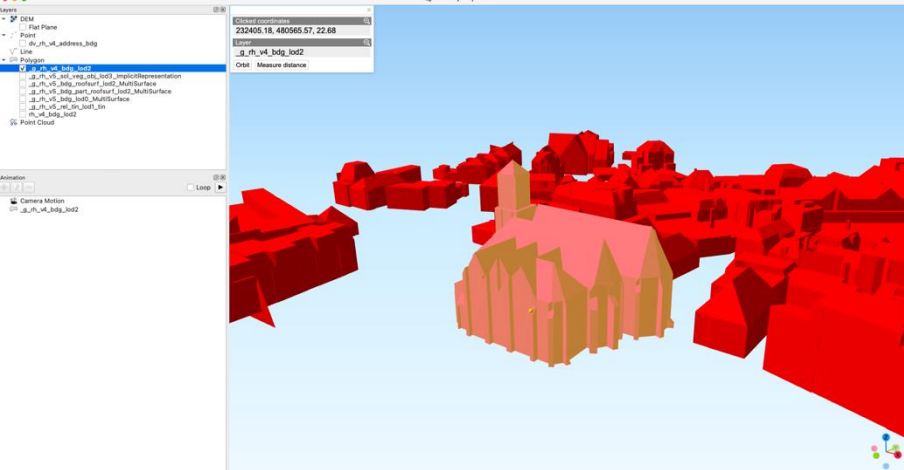


- **Case3: retrieve feature geometries with “inline” attributes**

- read-only
- read-write



- **Case4: user perform case 1-3 using GUIs**



ID	Function	CodeSpace	Usage	CodeSpace	Year of construction	Year of demolition	Roof type	CodeSpace	Height	UoM	arrays above ground/arrays below ground/height above ground	UoM
1	1150	http://www.s...	Pand in gebr...	NULL	1979	NULL	slanted	NULL	19.449 m		1	NULL
2	kantoorfunctie,woonfunctie	http://www.s...	Pand in gebr...	NULL	1973	NULL	multiple horiz...	NULL	19.783 m		2	NULL
3	winkel functie,woonfunctie	http://www.s...	Pand in gebr...	NULL	1971	NULL	slanted	NULL	22.211 m		4	NULL
4	woonfunctie	http://www.s...	Pand in gebr...	NULL	1950	NULL	slanted	NULL	17.724 m		2	NULL
5	woonfunctie	http://www.s...	Pand in gebr...	NULL	1950	NULL	slanted	NULL	17.351 m		2	NULL
6	woonfunctie,newly added function	http://www.s...	Pand in gebr...	NULL	1960	NULL	slanted	NULL	18.302 m		3	NULL
7	gezonheidszorgfunctie,kantoorL...	http://www.s...	Verbouwing...	NULL	1957	NULL	multiple horiz...	NULL	18.091 m		3	1
8	2700	http://www.s...	Pand in gebr...	NULL	1926	NULL	slanted	NULL	16.482 m		1	NULL
9	kantoorfunctie,woonfunctie	http://www.s...	Pand in gebr...	NULL	1997	NULL	slanted	NULL	22.621 m		3	0
10	woonfunctie,newly added function	http://www.s...	Pand in gebr...	NULL	1982	NULL	slanted	NULL	23.939 m		3	0

Thesis Background



3D City Database



3DCityDB-Tools
Plug-in for QGIS

Conceptual Data Model



- Standards to represent city objects

v.2.0 (2012)



v.3.0 (2021)

Fundamental changes in
data model

SQL Data Encoding



- Requires SQL skills to access the data

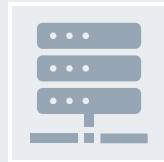
v.4.x



v.5.0

Different database
schemas

Data Interaction via GIS layers



- Intuitive data usage

v.8.x



Thesis goal

Adding support to the new
3DCityDB 5.0

Related Work - CityGML



Conceptual Data Model



- Standards to represent city objects

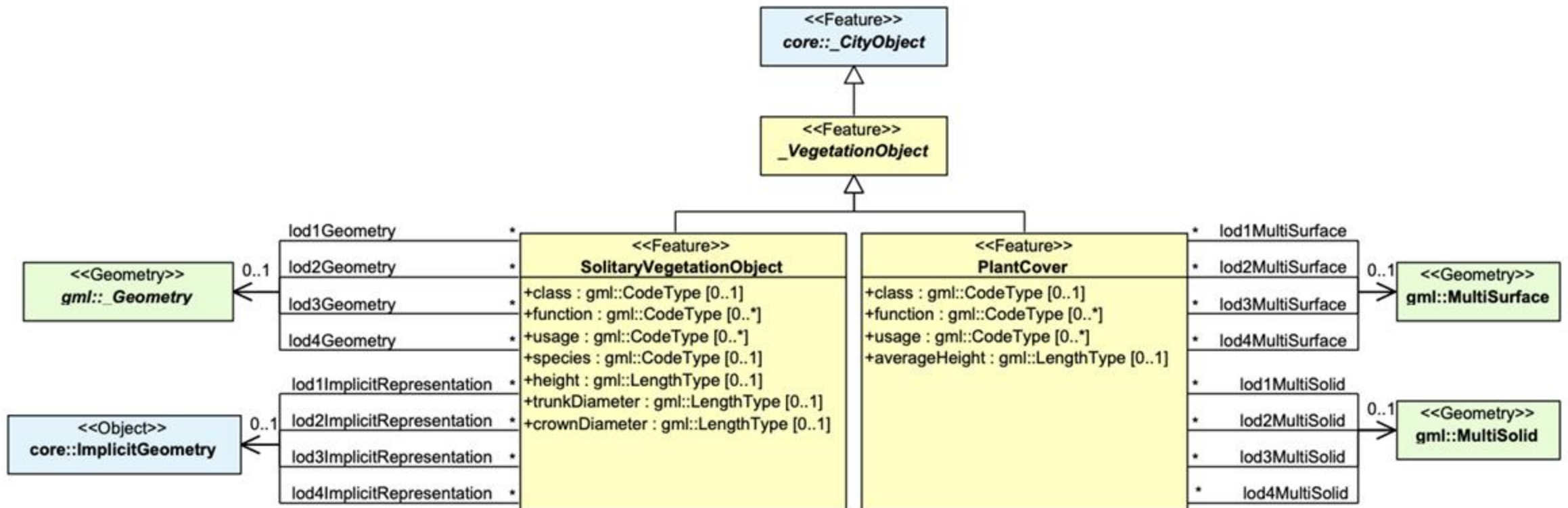
v.2.0 (2012)



v.3.0 (2021)

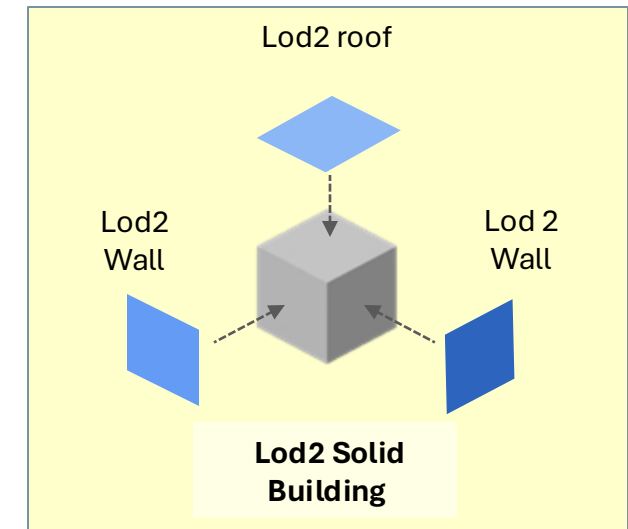
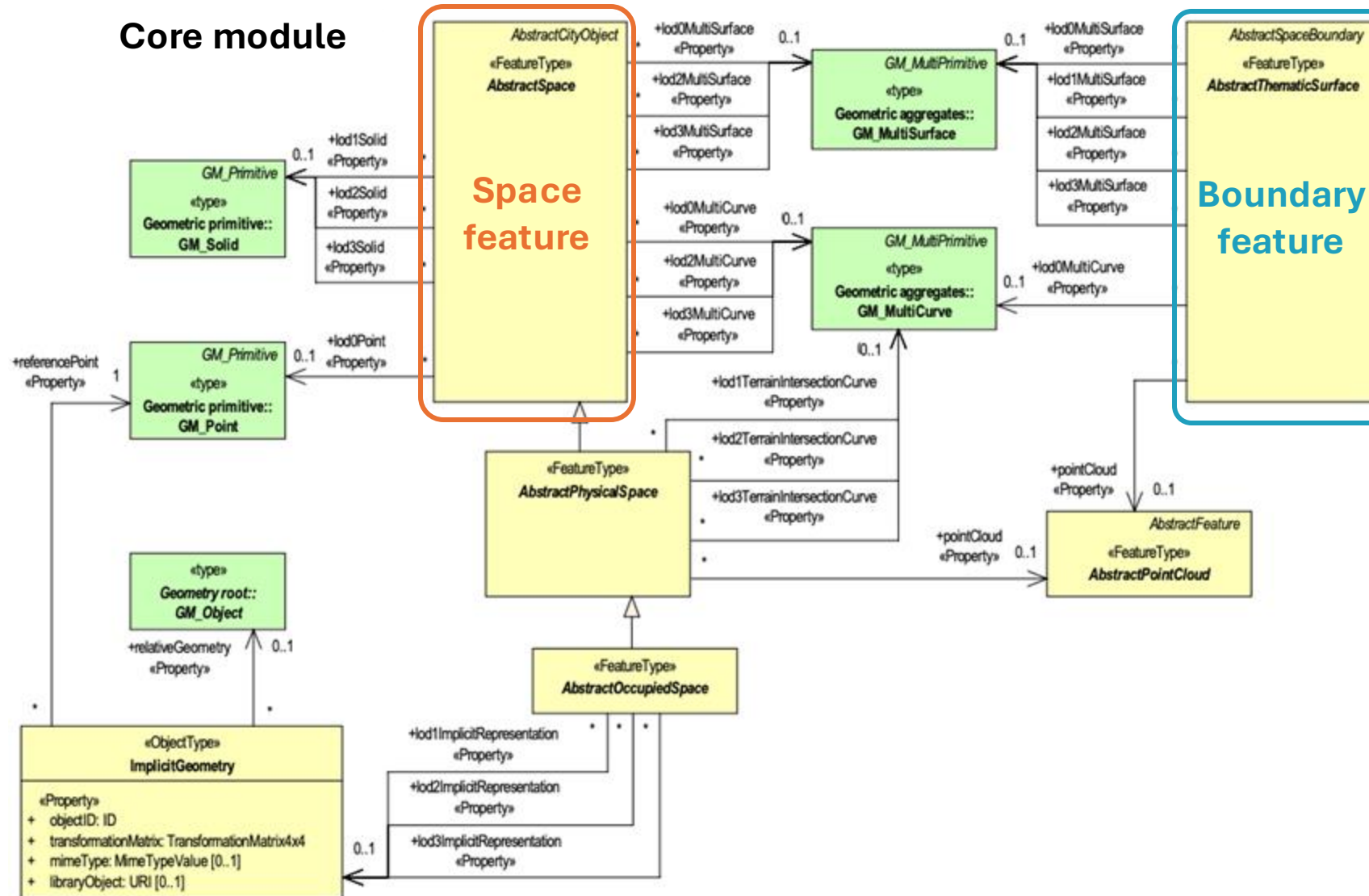
Fundamental changes in
data model

Example: Vegetation module



CityGML 2.0 Vegetation Module [Figure from Kolbe et al., (2012)]

Core module



Related Work - 3DCityDB



3D City Database

Conceptual Data Model



- Standards to represent city objects

v.2.0 (2012)



v.3.0 (2021)

Fundamental changes in
data model

SQL Data Encoding



- Requires SQL skills to access the data

v.4.x

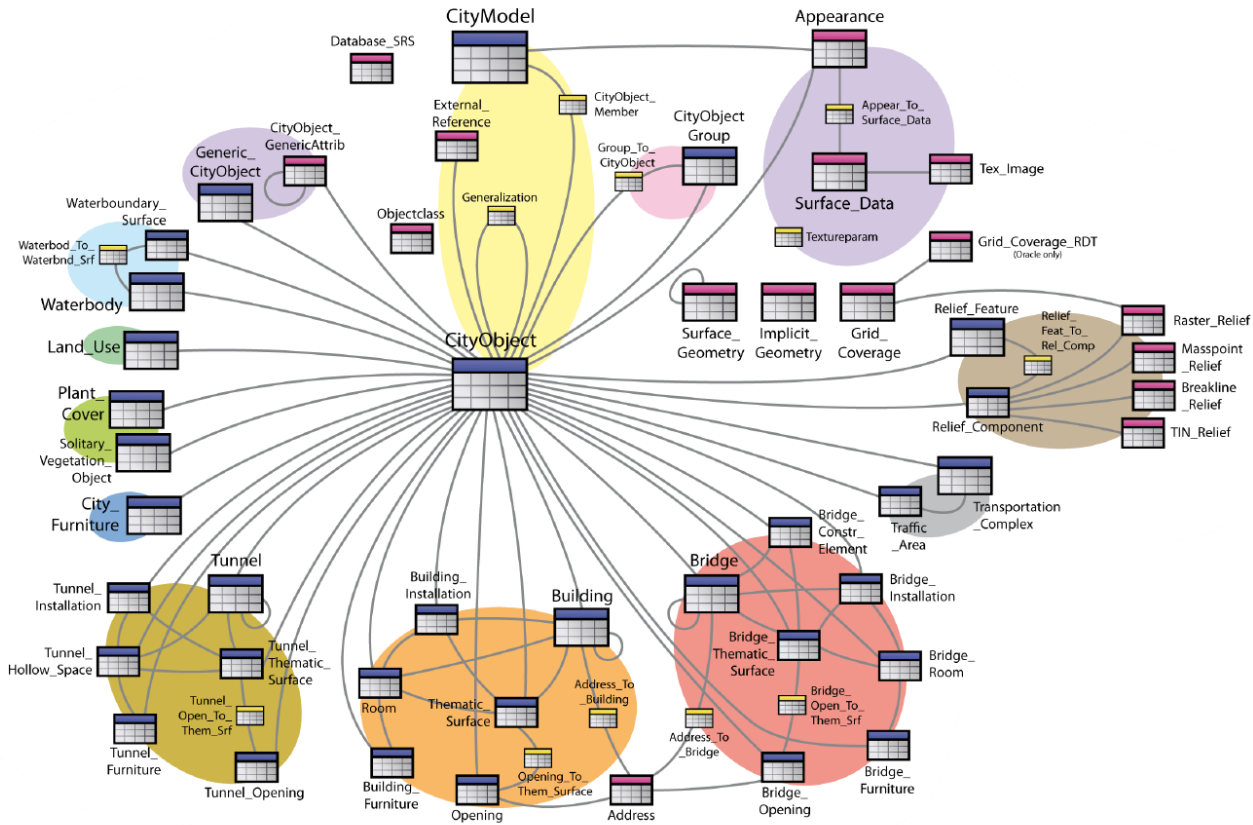


v.5.0

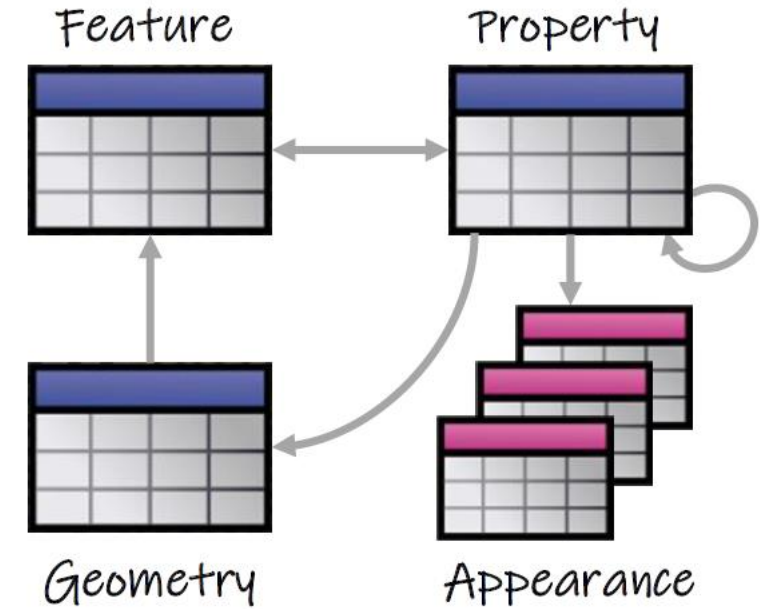
Different database
schemas



3DCityDB Versions



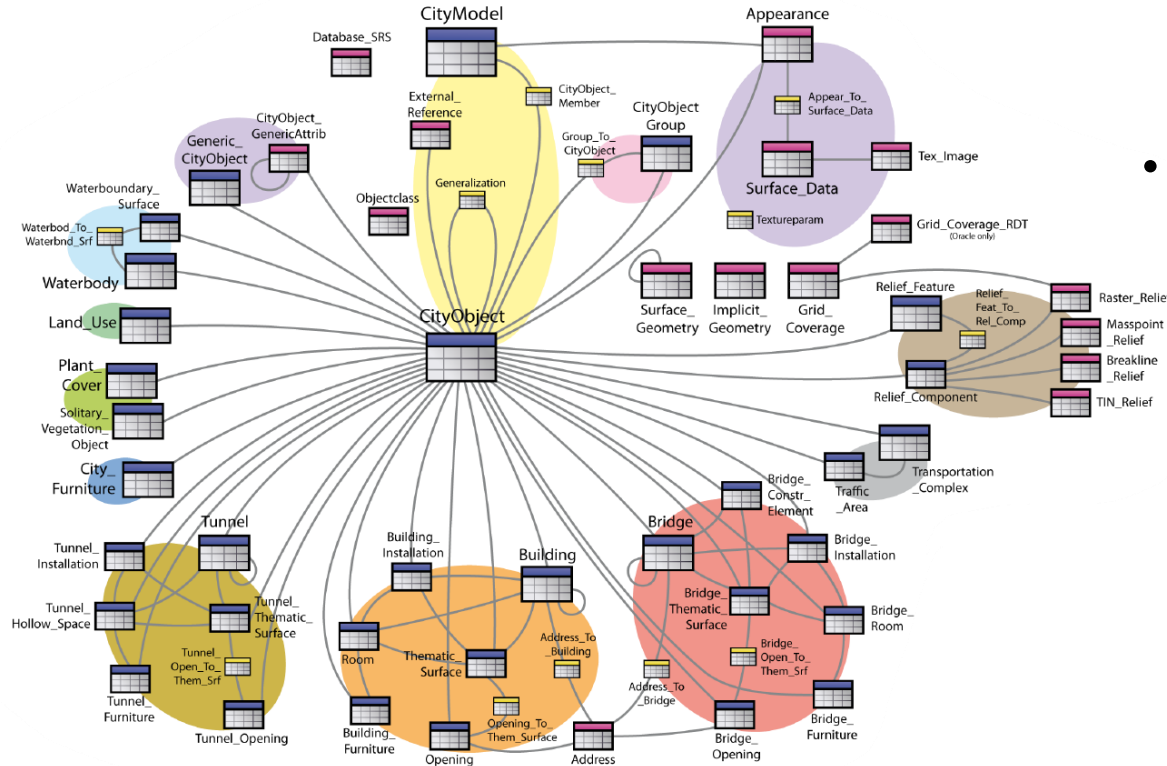
3DCityDB 4.x



3DCityDB 5.0



3DCityDB 4.x



- **Quick facts**

- 66 tables
- Standard attributes are mapped to joined tables (e.g. CITYOBJECT + BUILDING tables)
- Generic attributes are mapped to one EAV table (CITYOBJECT_GENERICATTRIB table)
- All surface geometries are decomposed into polygons

EAV: "Entity-Attribute-Value" model, or "open schema" model



Buildings mapped in 3DCityDB 4.x

- CITYOBJECT**

Attributes

	id [PK] bigint	objectclass_id integer	gmlid character varying (256)	name character varying (1000)	description character varying (4000)	envelope geometry	creation_date timestamp with time zone
1	1	26	id_box_building_26	Box building 26	This is a simple, primastic bui...	01030000A0407...	2024-06-19 14:51:28.752189+02
2	2	23	id_group_1	Ancillary buildings group	This group contains all ancill...	[null]	2024-06-19 14:51:28.757549+02

- BUILDING**

Attributes

	id [PK] bigint	objectclass_id integer	building_root_id bigint	class character varying (256)	function character varying (1000)	lod0_footprint_id bigint	lod1_solid_id bigint
1	1	26	1	[null]	[null]	1	4
2	3	26	3	habitation	residential building	35	44
3	4	26	4	traffic	hangar	18	21
4	5	26	5	habitation	residential building	41	58
5	26	26	26	[null]	[null]	145	190



Buildings mapped in 3DCityDB 4.x

- CITYOBJECT_GENERICATTRIB**

Generic attribute names

Generic attribute values

Foreign keys
feature_ID

	id [PK] bigint	root_genattrib_id bigint	attrname character varying (256)	datatype integer	strval character var	intval integer	urival character var	dateval timestamp wi	unit character var	geomval geometry	surface_geometry_id bigint	cityobject_id bigint
1	33	33	lod_max	2	[null]	0	[null]	[null]	[null]	[null]	[null]	1
2	31	31	n_adjacent_buildings	2	[null]	0	[null]	[null]	[null]	[null]	[null]	1
3	16	16	lod2_volume	6	[null]	[null]	[null]	[null]	m^3	[null]	[null]	1
4	75	75	test_integer_att_group	2	[null]	12345	[null]	[null]	[null]	[null]	[null]	2
5	77	77	test_real_att_group	3	[null]	[null]	[null]	[null]	[null]	[null]	[null]	2
6	63	63	test_measure_att_group	6	[null]	[null]	[null]	[null]	kN	[null]	[null]	2
7	73	73	test_uri_att_group	4	[null]	[null]	https://en...	[null]	[null]	[null]	[null]	2
8	81	81	test_string_att_group	1	This is a t...	[null]	[null]	[null]	[null]	[null]	[null]	2
9	79	79	test_date_att_group	5	[null]	[null]	[null]	2020-08-...	[null]	[null]	[null]	2
10	65	65	lod_max	2	[null]	2	[null]	[null]	[null]	[null]	[null]	3



Buildings mapped in 3DCityDB 4.x

- SURFACE_GEOMETRY**

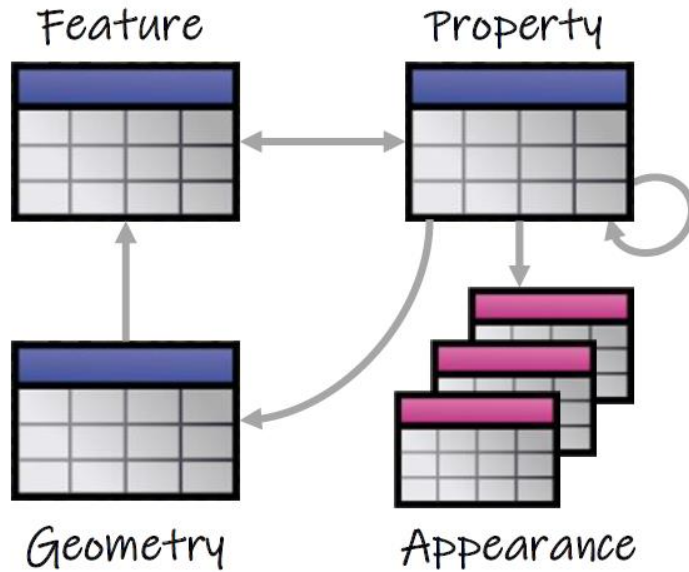
Example: 1 solid
decomposed into polygons

Foreign keys
feature_ID

	id [PK] bigint	gmlid character varying (256)	parent_id bigint	root_id bigint	is_solid numeric	solid_geometry geometry	geometry geometry	implicit_geometry geometry	cityobject_id bigint
1	1	id_lod0_MultiSurf_26	[null]	1	0	[null]	[null]	[null]	1
2	2	id_lod0_Polygon_26	1	1	0	[null]	01030000A04071000...	[null]	1
3	4	id_lod1_Solid_26	[null]	4	1	010F0000A0407100000...	[null]	[null]	1
4	5	id_lod1_CompSurf_26	4	4	0	[null]	[null]	[null]	1
5	6	id_lod1_Polygon_37	5	4	0	[null]	01030000A04071000...	[null]	1
6	7	id_lod1_Polygon_38	5	4	0	[null]	01030000A04071000...	[null]	1
7	8	id_lod1_Polygon_39	5	4	0	[null]	01030000A04071000...	[null]	1
8	9	id_lod1_Polygon_40	5	4	0	[null]	01030000A04071000...	[null]	1
9	10	id_lod1_Polygon_41	5	4	0	[null]	01030000A04071000...	[null]	1
10	11	id_lod1_Polygon_42	5	4	0	[null]	01030000A04071000...	[null]	1
11	18	id_building_3_footprint_multisurf_1	[null]	18	0	[null]	[null]	[null]	4
12	19	id_building_3_polygon_3	18	18	0	[null]	01030000A04071000...	[null]	4



3DCityDB 5.0



- **Quick facts**

- 18 Tables
- All attributes are mapped to **only one** EAV table (PROPERTY table)
- All surface geometries **NOT** decomposed into polygons

EAV: "Entity-Attribute-Value" model, or "open schema" model



Buildings mapped in 3DCityDB 5.0

- FEATURE**

	id [PK] bigint	objectclass_id integer	objectid text	identifier text	identifier_codespace text	envelope geometry	creation_date timestamp with time zone
1	1	901	id_building_09-10	[null]	[null]	01030000A040710000...	2022-03-02 01:00:00+01
2	2	902	id_buildingpart_09	[null]	[null]	01030000A040710000...	2019-11-17 01:00:00+01

- PROPERTY**

	id [PK] bigint	feature_id bigint	parent_id bigint	datatype_id integer	namespace_id integer	name text	val_int bigint	val_double double precision	val_string text
1	1	1	[null]	22	1	description	[null]	[null]	This is multi-part Building 9-10
2	2	1	[null]	14	1	name	[null]	[null]	Jabba's multi-part Palace
3	3	1	[null]	17	3	lod2_volume	[null]	2500	[null]
4	4	1	[null]	3	3	lod_max	2	[null]	[null]
5	5	1	[null]	3	3	n_adjacent_buildings	0	[null]	[null]
6	6	1	[null]	3	3	num_residents	45	[null]	[null]
7	7	1	[null]	7	8	dateOfConstruction	[null]	[null]	[null]
8	8	1	[null]	702	8	height	[null]	[null]	[null]
9	9	1	8	17	8	value	[null]	15	[null]
10	10	1	8	5	8	status	[null]	[null]	measured

Attribute names

Attribute values



Buildings mapped in 3DCityDB 5.0

- GEOMETRY_DATA**

Example: 1 solid directly
stored

Foreign keys
feature_ID

	id [PK] bigint	geometry geometry	implicit_geometry geometry	geometry_properties json	feature_id bigint
1	1	01060000A0407100000100...	[null]	{"type":8,"objectId":"id_building_9_footprint_multisurf_1",...	2
2	2	010F0000A0407100000600...	[null]	{"type":9,"objectId":"id_building_09_lod1_Solid_9","childr...	2
3	3	01060000A0407100000100...	[null]	{"type":8,"objectId":"id_building_9_roofsurface_1_lod2_g...	3
4	260	[null]	01060000800A00000001030000...	{"type":8,"objectId":"id_lod1_multisurf_tree","children":[{"t...	264

Related Work - 3DCityDB-Tools for QGIS



3D City Database



3DCityDB-Tools
Plug-in for QGIS

Conceptual Data Model



- Standards to represent city objects

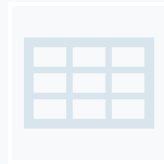
v.2.0 (2012)



v.3.0 (2021)

Fundamental changes in
data model

SQL Data Encoding



- Requires SQL skills to access the data

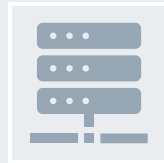
v.4.x



v.5.0

Different database
schemas

Data Interaction via GIS layers



- Intuitive data usage

v.8.x



Thesis goal

Adding support to the new
3DCityDB 5.0



(Current) 3DCityDB-Tools for QGIS

- Create “layers” that follow Simple Feature for SQL (SFS) model
 - i.e. one geometry has all attributes associated in a simple table
- Currently developed for 3DCityDB 4.x, and works only on PostgreSQL version



rh_v4_bdg_jod2 — Features Total: 29511, Filtered: 29511, Selected: 1

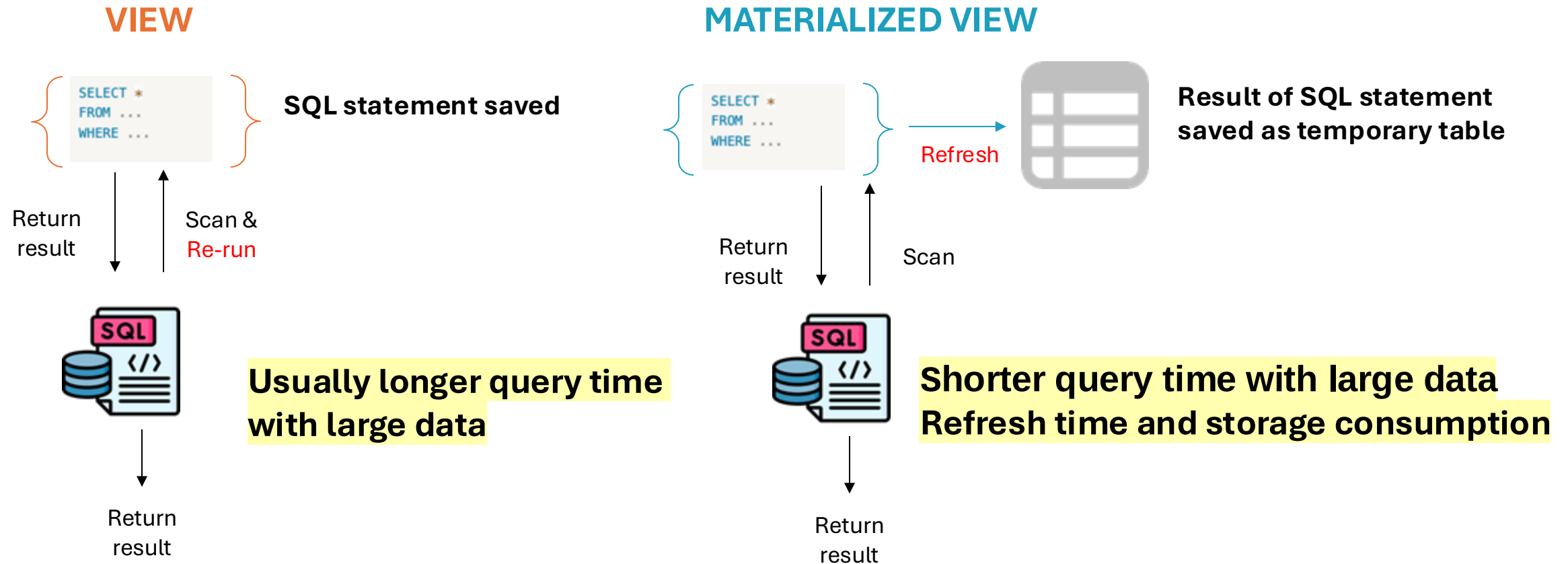
	Database ID	GML ID	GML codespace	Name	Name codespace	Description	Creation date	Termination date	Relative to terrain	Relative to
1	63465	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
2	63462	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
3	63797	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
4	63982	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
5	63473	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
6	63468	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
7	63755	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
8	64264	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
9	63751	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
10	63691	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
11	63859	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
12	64120	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
13	64487	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
14	63960	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL
15	63463	NL.IMBAG.Pa...	NULL	Building 209...	NULL	NULL	18-01-2024 11:27:09	NULL	(City)Object ...	NULL

Show All Features



SQL Views & Materialized Views (MatView)

- Current plug-in uses MatViews for geometries, and views for attributes



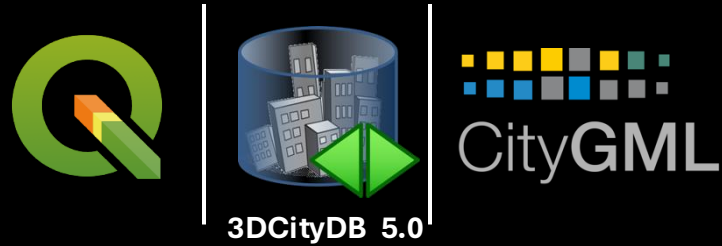
Research Questions

How does the new 3DCityDB 5.0 affect the current method of the plug-in to create layers ?

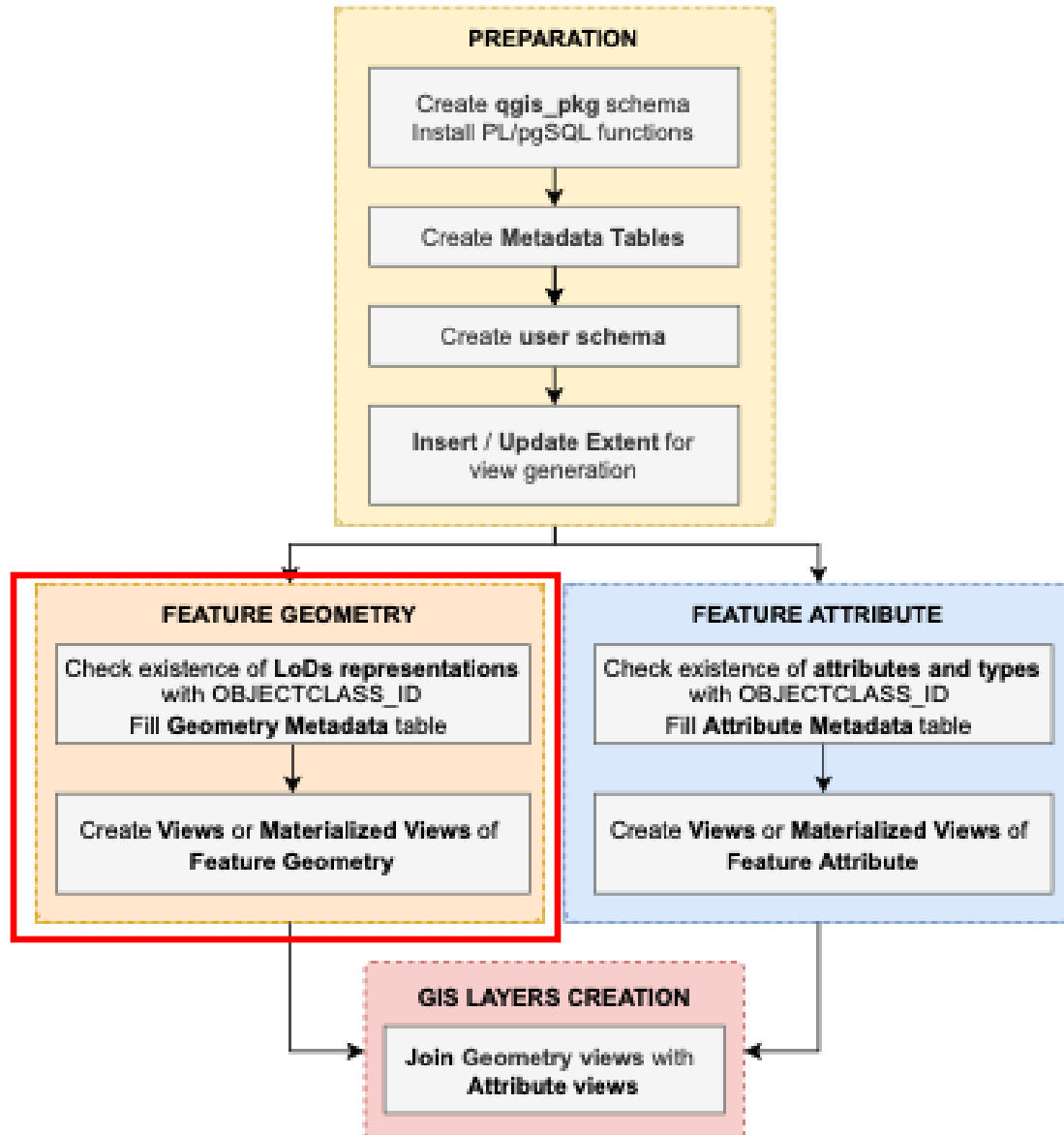
Sub-questions:

- How do the new CityGML 3.0 concepts of space, LoD affect the process ?
- With regards to **geometries**, can the same or a similar approach be reproduced ?
- With regards to **attributes**, can the same or a similar approach be reproduced ?
- How is the CityGML 2.0 data mapped to the new schema of 3DCityDB 5.0?

2.Methodology & Implementation (Part 1)



Methodology



- **Feature Geometry**

- Check existence of feature geometry representations & LoDs
- fill up metadata table
- Create (materialized) views of feature geometries

- **Feature Attribute**

- Check existence of feature attributes and “types”
- fill up metadata table
- Create (materialized) views of selected attributes

- **GIS Layer Creation**

- Join (materialized) views of feature geometries and attributes to create GIS layers

Check Existence of Geometries

Check geometry of Space feature (Building 901)

```
SELECT DISTINCT
    f.objectclass_id,
    p.name,
    p.datatype_id,
    p.name,
    p.val_lod
FROM citydb.feature AS f
    INNER JOIN citydb.property AS p ON f.id = p.feature_id
    AND f.objectclass_id = 901 ',sql_where,' --Extent selection
WHERE p.datatype_id IN (11,16)
    AND p.val_lod IS NOT NULL;
```

Check geometry of Boundary feature (Roof Surface 712)

```
SELECT DISTINCT
    f1.objectclass_id AS parent_objectclass_id,
    f2.objectclass_id,
    p2.name,
    p2.datatype_id,
    p2.name,
    p2.val_lod
FROM citydb.feature AS f1
    INNER JOIN citydb.property AS p1 ON f1.id = p1.feature_id
    AND p1.name = 'boundary' ',sql_where,'
    INNER JOIN citydb.feature AS f2 ON f2.id = p1.val_feature_id
    AND f2.objectclass_id = 712 --RoofSurface class
    INNER JOIN citydb.property AS p2 ON f2.id = p2.feature_id
    AND p2.datatype_id = 11; -- geometry property
```



Dynamically replaced by the PL/PgSQL functions

Feature Geometry Metadata

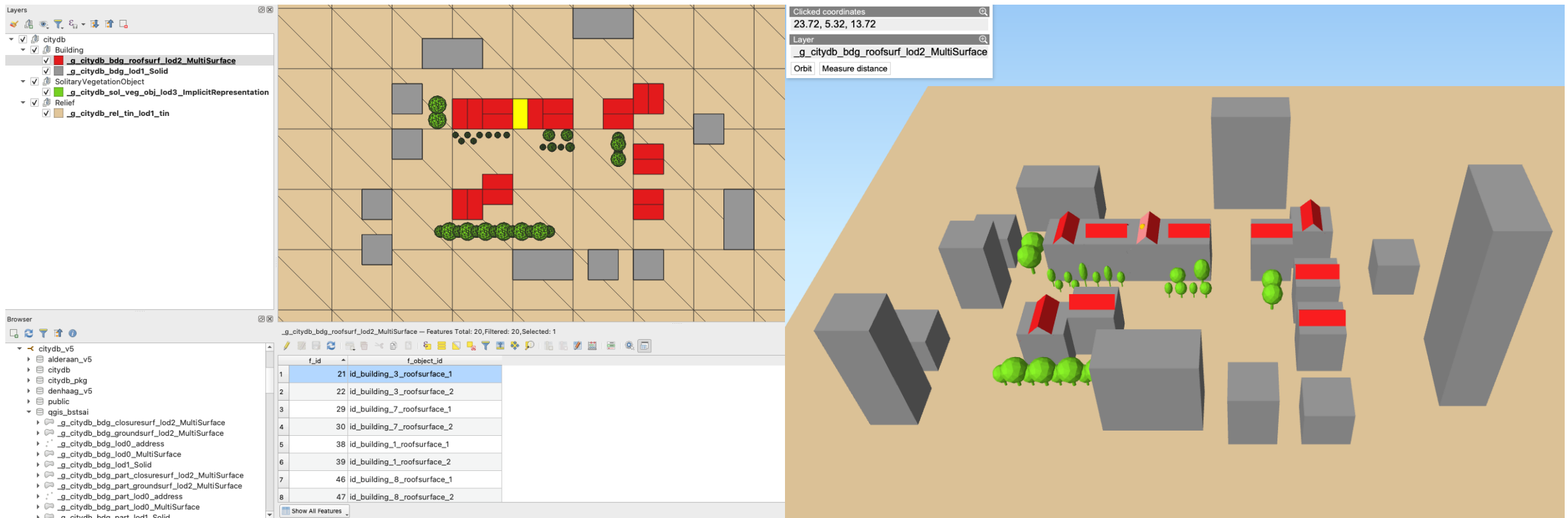
	id [PK] bigint	cdb_schema character varying	bbox_type character varying	parent_objectclass_id integer	parent_classname character varying	objectclass_id integer	classname character varying	datatype_id integer	geometry_name text	lod text	geometry_type text
13	86	citydb	db_schema	0	-	901	Building	11	lod0MultiSurface	0	MultiSurface
14	87	citydb	db_schema	0	-	901	Building	11	lod1Solid	1	Solid
15	88	citydb	db_schema	0	-	1301	SolitaryVegetationObject	16	lod1ImplicitRepresentation	1	ImplicitRepresentation
16	89	citydb	db_schema	0	-	1301	SolitaryVegetationObject	16	lod2ImplicitRepresentation	2	ImplicitRepresentation
17	90	citydb	db_schema	0	-	1301	SolitaryVegetationObject	16	lod3ImplicitRepresentation	3	ImplicitRepresentation
18	91	citydb	db_schema	0	-	902	BuildingPart	8	address	0	MultiPoint
19	92	citydb	db_schema	0	-	901	Building	8	address	0	MultiPoint
20	144	rh_v5	db_schema	901	Building	15	ClosureSurface	11	lod2MultiSurface	2	MultiSurface
21	145	rh_v5	db_schema	902	BuildingPart	15	ClosureSurface	11	lod2MultiSurface	2	MultiSurface
22	146	rh_v5	db_schema	0	-	500	ReliefFeature	3	lod	1	Envelope
23	147	rh_v5	db_schema	0	-	502	TINRelief	11	tin	1	tin
24	148	rh_v5	db_schema	901	Building	709	WallSurface	11	lod2MultiSurface	2	MultiSurface
25	149	rh_v5	db_schema	902	BuildingPart	709	WallSurface	11	lod2MultiSurface	2	MultiSurface
26	150	rh_v5	db_schema	901	Building	710	GroundSurface	11	lod2MultiSurface	2	MultiSurface
27	151	rh_v5	db_schema	902	BuildingPart	710	GroundSurface	11	lod2MultiSurface	2	MultiSurface
28	152	rh_v5	db_schema	901	Building	712	RoofSurface	11	lod2MultiSurface	2	MultiSurface
29	153	rh_v5	db_schema	902	BuildingPart	712	RoofSurface	11	lod2MultiSurface	2	MultiSurface
30	154	rh_v5	db_schema	0	-	901	Building	11	lod0MultiSurface	0	MultiSurface
31	155	rh_v5	db_schema	0	-	902	BuildingPart	11	lod0MultiSurface	0	MultiSurface
32	156	rh_v5	db_schema	0	-	1301	SolitaryVegetationObject	16	lod1ImplicitRepresentation	1	ImplicitRepresentation
33	157	rh_v5	db_schema	0	-	1301	SolitaryVegetationObject	16	lod2ImplicitRepresentation	2	ImplicitRepresentation
34	158	rh_v5	db_schema	0	-	1301	SolitaryVegetationObject	16	lod3ImplicitRepresentation	3	ImplicitRepresentation

(Parent) Classes

LoDs & geometry
representations

Visualised Geometry (Mat)Views

- When it comes to feature geometries, users can select :
 - ✓ Desired LoD
 - ✓ Desired geometry representation



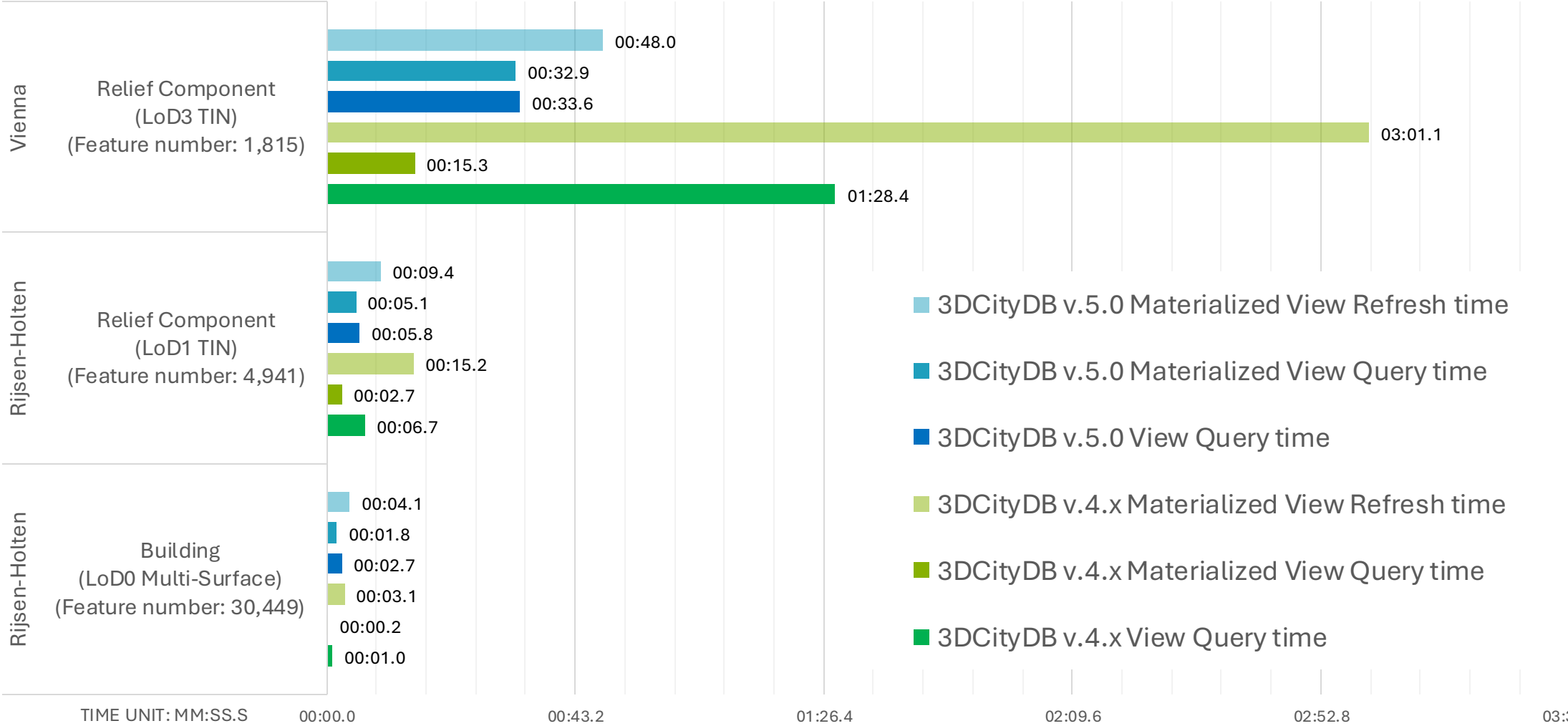
Test Datasets

Dataset (Country)	Number of Features	Database Schema Size	CityGML Modules	LoDs	CityGML Version
Alderaan (-)	273	4.3 MB	Building, Vegetation, Relief	0,1,2	2.0
Railway (-)	235	3 MB	Bridge, Building, CityFurniture, Generics, Relief, Transportation, Tunnel, Vegetation, WaterBody	3	2.0
Tokyo (JP)	39,865	84 MB	Building	0,1,2	2.0
Rijssen-Holten (NL)	827,105	3.3 GB	Building, Vegetation, Relief	2	2.0
Vienna (AT)	7,512,786	38 GB	Building, Vegetation, Relief, LandUse, Generics	1,2	2.0
FZK-Haus(-)	85	3.7 MB	Building, Construction	2	3.0
Munich Transportation(DE)	295	1.4 MB	Transportation	2	3.0
New York City Transportation(US)	7,179	19 MB	Transportation	2	3.0

(-) Artificial datasets

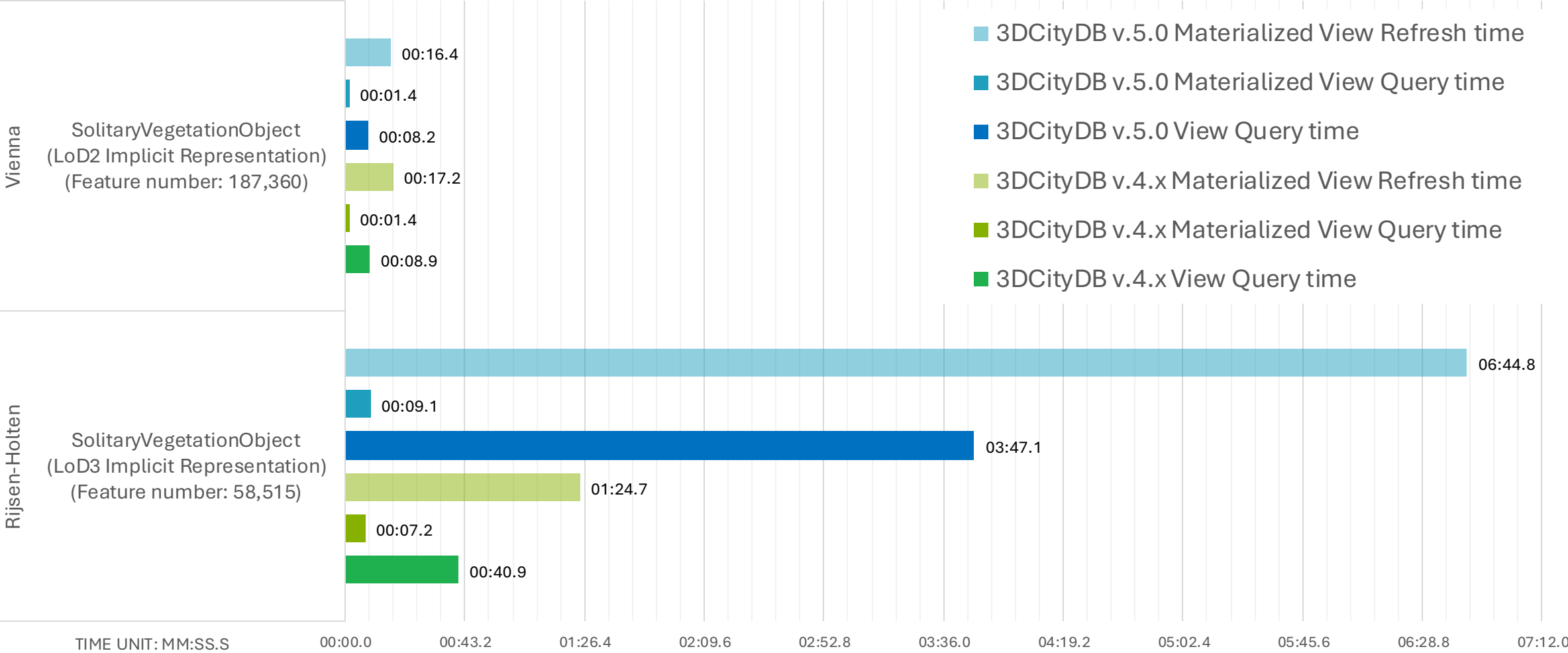
Choice of View or MatView for Geometries

Space & Relief Component features with geometries (Buildings, TINs) TIN: Triangulated irregular network



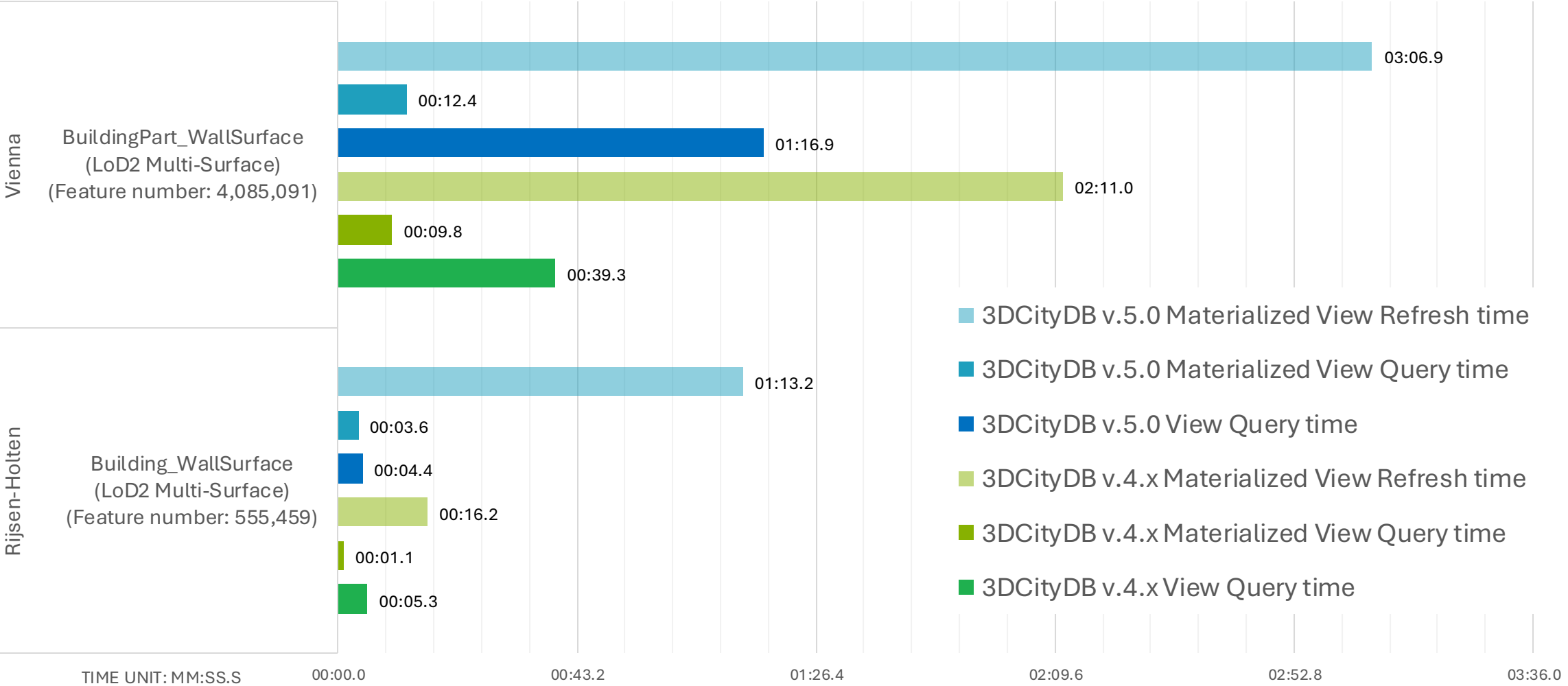
Choice of View or MatView for Geometries

Space features with implicit geometries (Trees)



Choice of View or MatView for Geometries

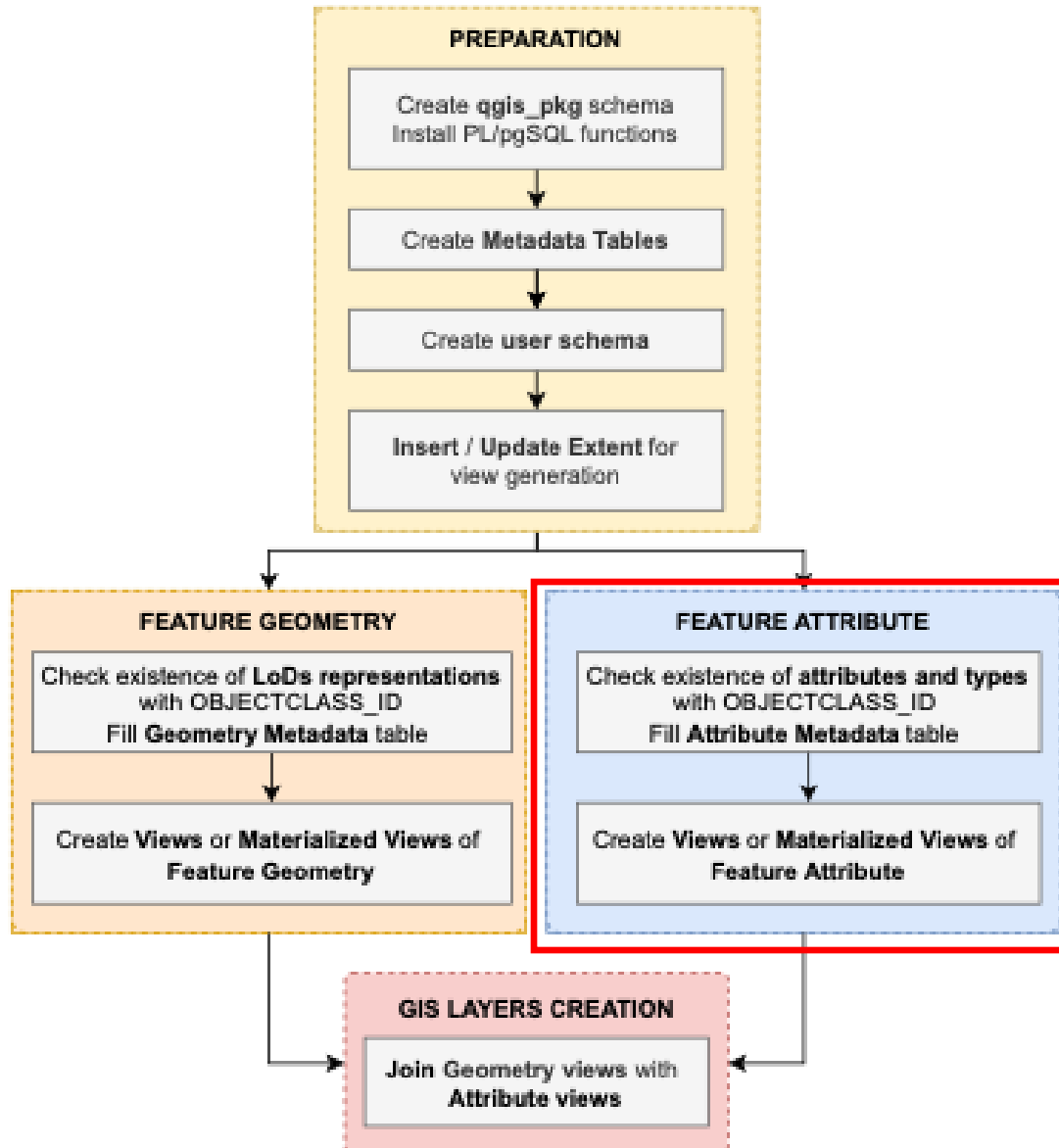
Boundary features with geometries (Building walls)



Feature Geometry: Results

- **When it comes to feature geometries, it is not necessary to create materialized views for all representations**
 - Optional with space geometries (different from implicit representations)
 - Still needed for implicit representation, and boundary geometries
 - It is still reasonable to use materialized views for accessing geometries
- **In the server-side plug-in of this research, users can select**
 - Desired geometry representation
 - Desired LoD

Methodology



- **Feature Geometry**

- Check existence of feature geometry representations & LoDs
- fill up metadata table
- Create (materialized) views of feature geometries

- **Feature Attribute**

- Check existence of feature attributes and “types”
- fill up metadata table
- Create (materialized) views of selected attributes

- **GIS Layer Creation**

- Join (materialized) views of feature geometries and attributes to create GIS layers

Check Feature Attributes

- **Check whether attributes are:**
 - Type: “Inline” or “Nested”
 - Multiplicity: [0..1] “single” / [0..*] “multiple”



- **4 possible classes:**
 - Class 1 - “Inline-Single”
 - Class 2 - “Inline-Multiple”,
 - Class 3 - “Nested-Single”
 - Class 4 - “Nested-Multiple”



- **Flatten (i.e. "linearise") attributes depending on their classes**

Check Existence and Classify Attributes

Check “Inline” feature attributes (Building 901)

```
SELECT
    ARRAY_AGG(DISTINCT p.name)
FROM citydb.feature AS f
    INNER JOIN citydb.property AS p ON (f.id = p.feature_id
        AND f.objectclass_id = 901 ',sql_where,')
WHERE p.parent_id IS NULL
    -- Filter irrelevant attribute data types and Nested attribute
    AND p.datatype_id NOT IN
        (8, 9, 10, 11, 16, ',nested_attri_ids,');
```

Check “Nested” feature attributes (Building 901)

```
SELECT
    ARRAY_AGG(ARRAY[p_attri, attri]) AS nested_attribute_set
FROM(
    SELECT DISTINCT p.name AS p_attri, p1.name AS attri
    FROM citydb.feature AS f
        INNER JOIN citydb.property AS p ON f.id = p.feature_id
        AND f.objectclass_id = 901
        -- Filter on parent attribute
        AND p.datatype_id NOT IN (8, 9, 10, 11, 16) ',sql_where,'
        -- Join the child attributes and filter out the Inline attributes
        INNER JOIN citydb.property AS p1 ON p.id = p1.parent_id
    ORDER BY p.name, p1.name
) AS nested_attribute;
```

 Dynamically replaced by the PL/PostgreSQL functions

Feature Attribute Metadata

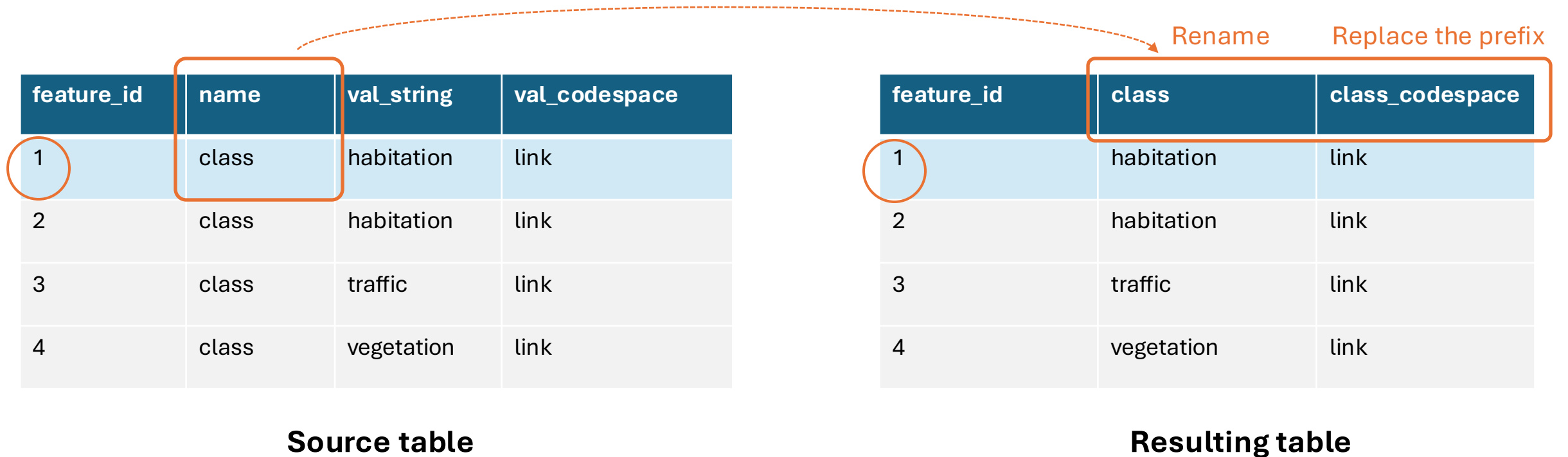
	id [PK] bigint	cdb_schema character varying	bbox_type character varying	objectclass_id integer	classname character varying	parent_attribute_name character varying	parent_attribute_typename character varying	attribute_name character varying	attribute_typename character varying	is_nested boolean	is_multiple boolean
1	1	alderaan	db_schema	502	TINRelief	-	-	description	StringOrRef	false	false
2	2	alderaan	db_schema	502	TINRelief	-	-	lod	Integer	false	false
3	3	alderaan	db_schema	502	TINRelief	-	-	name	Code	false	false
4	4	alderaan	db_schema	902	BuildingPart	-	-	class	Code	false	false
5	5	alderaan	db_schema	902	BuildingPart	-	-	dateOfConstruction	Timestamp	false	false
6	6	alderaan	db_schema	902	BuildingPart	-	-	description	StringOrRef	false	false
7	7	alderaan	db_schema	902	BuildingPart	-	-	function	Code	false	false
8	8	alderaan	db_schema	902	BuildingPart	-	-	lod_max	Integer	false	false
9	9	alderaan	db_schema	902	BuildingPart	-	-	n_adjacent_buildings	Integer	false	false
10	10	alderaan	db_schema	902	BuildingPart	-	-	name	Code	false	false
11	11	alderaan	db_schema	902	BuildingPart	-	-	roofType	Code	false	false
12	12	alderaan	db_schema	902	BuildingPart	-	-	storeyHeightsAboveGround	MeasureOrNilReasonList	false	false
13	13	alderaan	db_schema	902	BuildingPart	-	-	storeysAboveGround	Integer	false	false
14	14	alderaan	db_schema	902	BuildingPart	-	-	storeysBelowGround	Integer	false	false
15	15	alderaan	db_schema	902	BuildingPart	height	Height	highReference	Code	true	false
16	16	alderaan	db_schema	902	BuildingPart	height	Height	lowReference	Code	true	false
17	17	alderaan	db_schema	902	BuildingPart	height	Height	status	String	true	false
18	18	alderaan	db_schema	902	BuildingPart	height	Height	value	Measure	true	false
19	19	alderaan	db_schema	15	ClosureSurface	-	-	list_adjacent_buildings	String	false	false

Classes

Existing attributes

“Inline” / Simple /
“Nested” Multiple

Class 1 - “Inline-Single” Attributes



Class 1 - “Inline-Single” Attributes

- PROPERTY table, before

	id [PK] bigint	feature_id bigint	parent_id bigint	datatype_id integer	name text	val_string text	val_codespace text
1	13	1	[null]	14	class	habitation	http://www.sig3d.org/codelists/s...
2	138	20	[null]	14	class	habitation	http://www.sig3d.org/codelists/s...
3	197	29	[null]	14	class	habitation	http://www.sig3d.org/codelists/s...

- ..After flattening

	f_id bigint	class text	class_codespace text
1	1	habitation	http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_class.x...
2	20	habitation	http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_class.x...
3	29	habitation	http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_class.x...

Class 2 - “Inline-Multiple” Attributes

Source table				Resulting table				
feature_id	name	val_string	val_codespace	feature_id	function_1	function_codespace_1	function_2	function_codespace_2
1	function	residential	link	1	residential	link	hostel	link
1	function	hostel	link	2	hospital	link	NULL	NULL
2	function	hospital	link	3	residential	link	NULL	NULL
3	function	residential	link		Multiplicity 1		Multiplicity 2	

Rename

Replace the prefix

Class 2 - “Inline-Multiple” Attributes

- PROPERTY table, before

	id [PK] bigint	feature_id bigint	parent_id bigint	datatype_id integer	name text	val_string text	val_codespace text
1	14	1	[null]	14	function	residential building	http://www.sig3d.org/codelists/...
2	139	20	[null]	14	function	residential building	http://www.sig3d.org/codelists/...
3	198	29	[null]	14	function	residential building	http://www.sig3d.org/codelists/...
4	272	30	[null]	14	function	youth hostel	http://www.sig3d.org/codelists/...
5	271	30	[null]	14	function	residential building	http://www.sig3d.org/codelists/...

- .. After flattening

	f_id bigint	function_1 text	function_codespace_1 text	function_2 text	function_codespace_2 text
1	1	residential building	http://www.sig3d.org/codelists/...	[null]	[null]
2	20	residential building	http://www.sig3d.org/codelists/...	[null]	[null]
3	29	residential building	http://www.sig3d.org/codelists/...	[null]	[null]
4	30	residential building	http://www.sig3d.org/codelists/...	youth hostel	http://www.sig3d.org/codelists/...

Class 3 - “Nested-Single” Attributes

Rename to parent & child
attribute name combinations

attrib_id	feature_id	parent_id	name	val_string	val_double	val_uom
8	1	NULL	height	NULL	NULL	NULL
9	1	8	value	NULL	15	m
10	1	8	status	measured	NULL	NULL
11	1	8	lowReference	lowest GroundPoint	NULL	NULL
11	1	8	highReference	highest RoofEdge	NULL	NULL

Source table

feature_id	height_value	height_value_UoM	height_status	height_low Reference	height_high Reference
1	15	m	measured	lowest GroundPoint	highest RoofEdge

Resulting table

Class 3 - “Nested-Single” Attributes

- PROPERTY table, before

	id [PK] bigint	feature_id bigint	parent_id bigint	datatype_id integer	name text	val_string text	val_double double precision	val_uom text
1	5	1	[null]	702	height	[null]	[null]	[null]
2	6	1	5	17	value	[null]	21.5	m
3	7	1	5	5	status	measured	[null]	[null]
4	8	1	5	14	lowReference	lowestGroundPoint	[null]	[null]
5	9	1	5	14	highReference	highestRoofEdge	[null]	[null]

- ..After flattening

	f_id bigint	height_status text	height_highReference text	height_lowReference text	height_value double precision	height_value_UoM text
1	1	measured	highestRoofEdge	lowestGroundPoint	21.5	m
2	42	measured	highestRoofEdge	lowestGroundPoint	26.7	m
3	155	measured	highestRoofEdge	lowestGroundPoint	12.4	m

Class 4 - “Nested-Multiple” Attributes

Class 3 rename strategy

attrib_id	feature_id	parent_id	name	val_string	val_double	val_uom
8	1	NULL	height	NULL	NULL	NULL
9	1	8	value	NULL	15	m
10	1	8	status	measured	NULL	NULL
11	1	8	lowReference	lowest GroundPoint	NULL	NULL
11	1	8	highReference	highest RoofEdge	NULL	NULL

2nd height entry

Source table

feature_id	height_value_1	height_UoM_1	height_status_1	height_lowReference_1	height_highReference_1
1	15	m	measured	lowest GroundPoint	highest RoofEdge

Multiplicity 1

Multiplicity 2

Resulting table

Class 4 - “Nested-Multiple” Attributes

- PROPERTY table, before

	id bigint	feature_id bigint	parent_id bigint	datatype_id integer	name text	val_string text	val_double double precision	val_uom text
16	260	30	[null]	702	height	[null]	[null]	[null]
17	261	30	260	17	value	[null]	15	m
18	262	30	260	5	status	measured	[null]	[null]
19	263	30	260	14	lowReference	lowestGroundPoint	[null]	[null]
20	264	30	260	14	highReference	highestRoofEdge	[null]	[null]
21	265	30	[null]	702	height	[null]	[null]	[null]
22	266	30	265	17	value	[null]	49.21	ft
23	267	30	265	5	status	measured	[null]	[null]
24	268	30	265	14	lowReference	lowestGroundPoint	[null]	[null]
25	269	30	265	14	highReference	highestRoofEdge	[null]	[null]

Class 4 - “Nested-Multiple” Attributes

- ..After flattening

	f_id bigint	height_highReference_1 text	height_lowReference_1 text	height_status_1 text	height_value_1 double precision	height_value_UoM_1 text	height_highReference_2 text	height_lowReference_2 text	height_status_2 text	height_value_2 double precision	height_value_UoM_2 text
1	1	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
2	20	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
3	29	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
4	30	highestRoofEdge	lowestGroundPoint	measured	15	m	highestRoofEdge	lowestGroundPoint	measured	49.21	ft
5	46	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]

Feature Attribute: Results

citydb_av_i_901_description — Features Total: 22, Filtered: 22, Selected: 1

f_id	description
1	This is multi-part Building 9-10
2	45 This is Building 8
3	28 This is Building 7
4	90 This is Building 6
5	54 This is Building 5
6	63 This is Building 4
7	20 This is Building 3
8	72 This is Building 2
9	105 This is Building 12
10	82 This is Building 11
11	37 This is Building 1

Class 1 - Inline-Single
Building - “description”

citydb_av_i_901_function — Features Total: 11, Filtered: 11, Selected: 1

f_id	function_1	function_codespace_1	function_2	function_codespace_2	function_3	function_codespace_3
1	residential building	http://www.sig3d.org/codelists/...	NULL	NULL	NULL	NULL
2	20 hangar	http://www.sig3d.org/codelists/...	NULL	NULL	NULL	NULL
3	28 residential building	http://www.sig3d.org/codelists/...	NULL	NULL	NULL	NULL
4	37 residential building	http://www.sig3d.org/codelists/...	youth hostel	http://www.sig3d.org/cod...	NULL	NULL
5	45 residential building	http://www.sig3d.org/codelists/...	NULL	NULL	NULL	NULL
6	54 hospital	http://www.sig3d.org/codelists/...	NULL	NULL	NULL	NULL
7	63 residential building	http://www.sig3d.org/codelists/...	NULL	NULL	NULL	NULL
8	72 residential building	http://www.sig3d.org/codelists/...	hostel	http://www.sig3d.org/cod...	youth hostel	http://www.sig3d.org/codelist...
9	82 residential building	http://www.sig3d.org/codelists/...	NULL	NULL	NULL	NULL
10	90 residential building	http://www.sig3d.org/codelists/...	NULL	NULL	NULL	NULL
11	105 residential building	http://www.sig3d.org/codelists/...	NULL	NULL	NULL	NULL

Class 2 - Inline-Multiple
Building - “function”

Feature Attribute: Results

qgis_bstsai./japan_v5/postgres@PostgreSQL 15

Query Query History

```
1 SELECT *
2 FROM qgis_bstsai."citydb_amv_n_901_土砂災害警戒区域"
3 ORDER BY f_id
```

土砂災害警戒区域: Landslide Disaster Warning Area (parent attribute)

- 区域区分: Zone type (child attribute. code 1: designated ; code 2: specially designated)
- 現象区分: Phenomenon type (child attribute. code 1: steep slope failure)

Data Output Messages Notifications

	f_id bigint	土砂災害警戒区域_区域区分 text	土砂災害警戒区域_現象区分 text
1	1	1	1
2	1	1	1
3	2086	1	1
4	4401	1	1
5	4562	1	1
6	4805	2	1
7	7381	1	1
8	10149	1	1
9	10622	1	1
10	11090	2	1

Class 3 - Nested-Single
Building – “土砂災害警戒区域
(Landslide Disaster Warning Area)”

qgis_bstsai./citydb_v5/postgres@PostgreSQL 15

Query Query History

```
1 SELECT *
2 FROM qgis_bstsai.citydb_amv_n_901_height
3 ORDER BY f_id
```

Data Output Messages Notifications

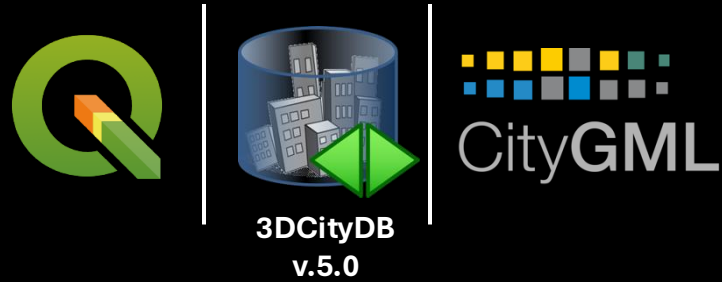
	f_id bigint	height_highReference_1 text	height_lowReference_1 text	height_status_1 text	height_value_1 double precision	height_value_UoM_1 text	height_highReference_2 text	height_lowReference_2 text	height_status_2 text	height_value_2 double precision	height_value_UoM_2 text
1	1	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
2	20	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
3	28	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
4	37	highestRoofEdge	lowestGroundPoint	measured	15	m	highestRoofEdge	lowestGroundPoint	measured	49.21	ft
5	45	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
6	54	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
7	63	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
8	72	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
9	82	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
10	90	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]
11	105	highestRoofEdge	lowestGroundPoint	measured	15	m	[null]	[null]	[null]	[null]	[null]

Class 4 - Nested-Multiple
Building – “height”

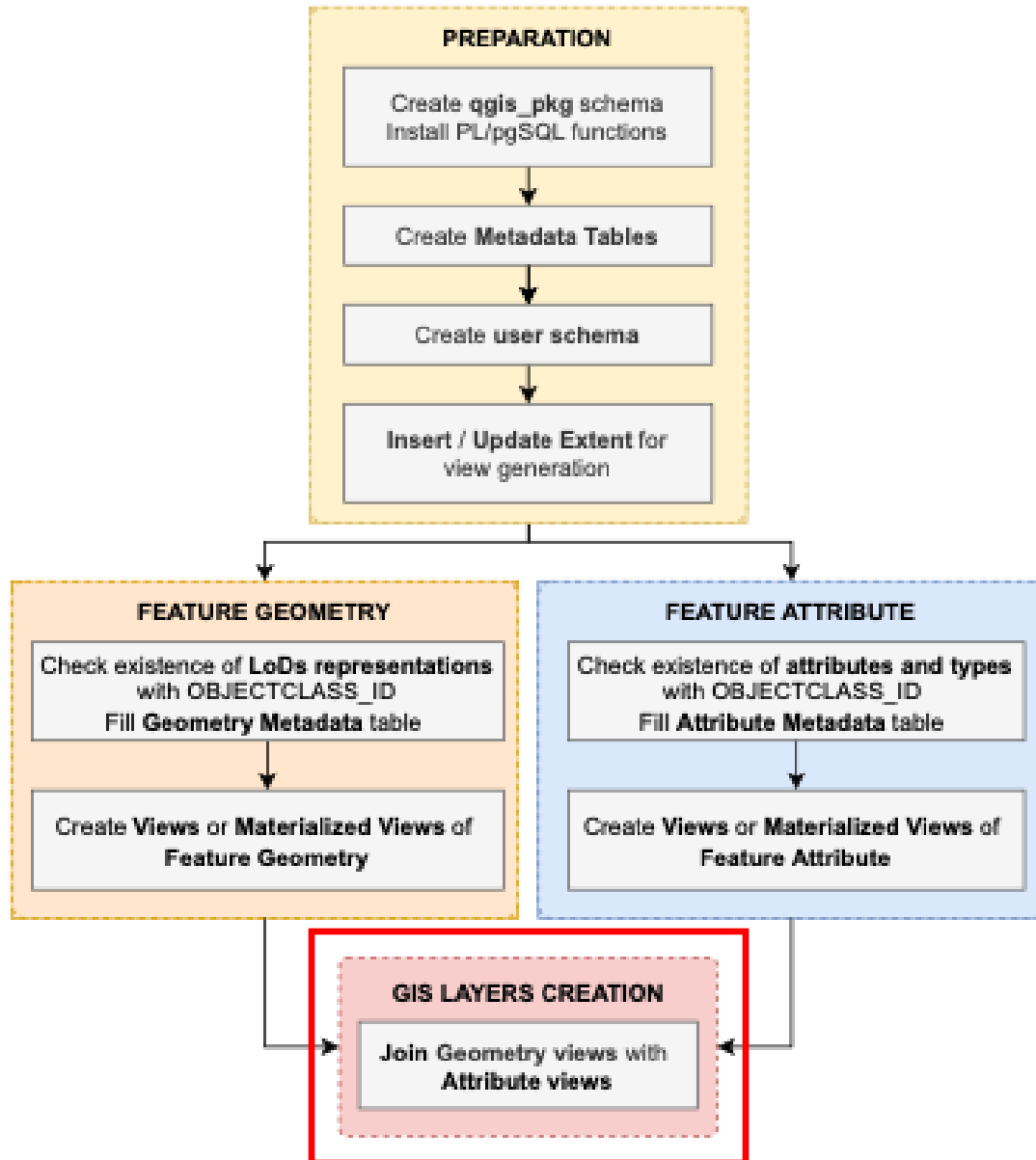
Feature Attribute: Results

- When it comes to **feature attributes**, the structure of PROPERTY table in 3DCityDB 5.0 makes attribute flattening more challenging
- 4 classes of attributes correspond to 4 linearising strategies
- In the server-side plug-in of this research
 - Users can select which attributes to link with geometries
 - Generic attributes are treated as “standard” attributes
 - Attribute names in other characters (e.g., kanji in Japanese) can be used as column names, too

3. Methodology & Implementation (Part 2)



Methodology



- **Feature Geometry**

- Check existence of feature geometry representations & LoDs
- fill up metadata table
- Create (materialized) views of feature geometries

- **Feature Attribute**

- Check existence of feature attributes and “types”
- fill up metadata table
- Create (materialized) views of selected attributes

- **GIS Layer Creation**

- Join (materialized) views of feature geometries and attributes to create GIS layers
- Store information for layer generation

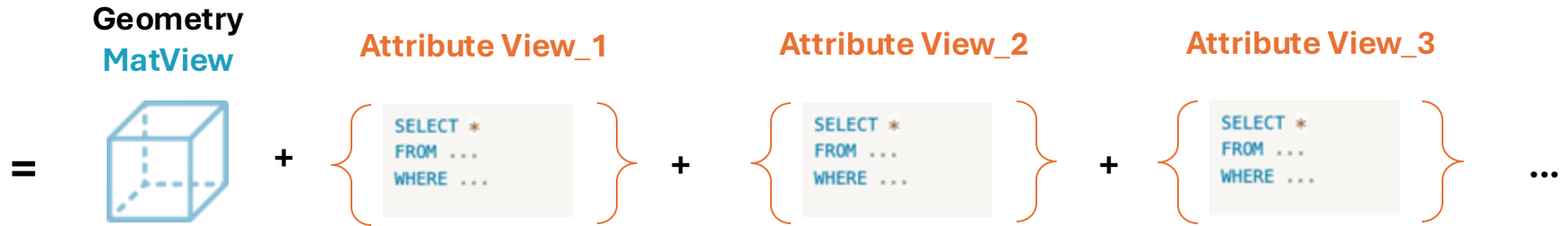
GIS Layer Creation Approaches



Approach_1

View

multiple left JOINS



Approach_2

Materialized View

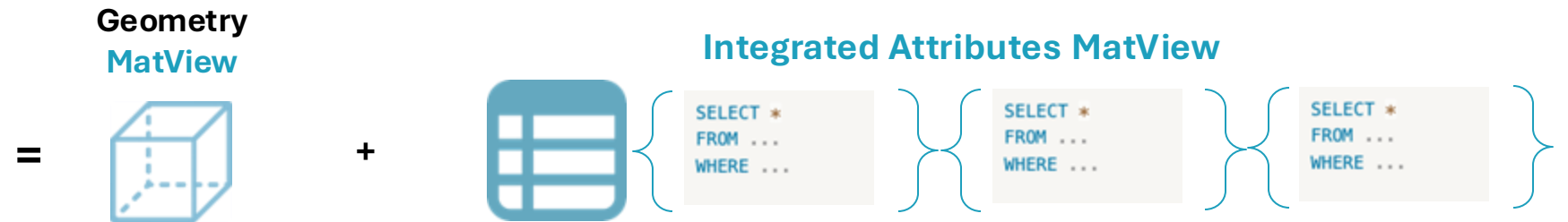
multiple left JOINS



Approach_3

Materialized View

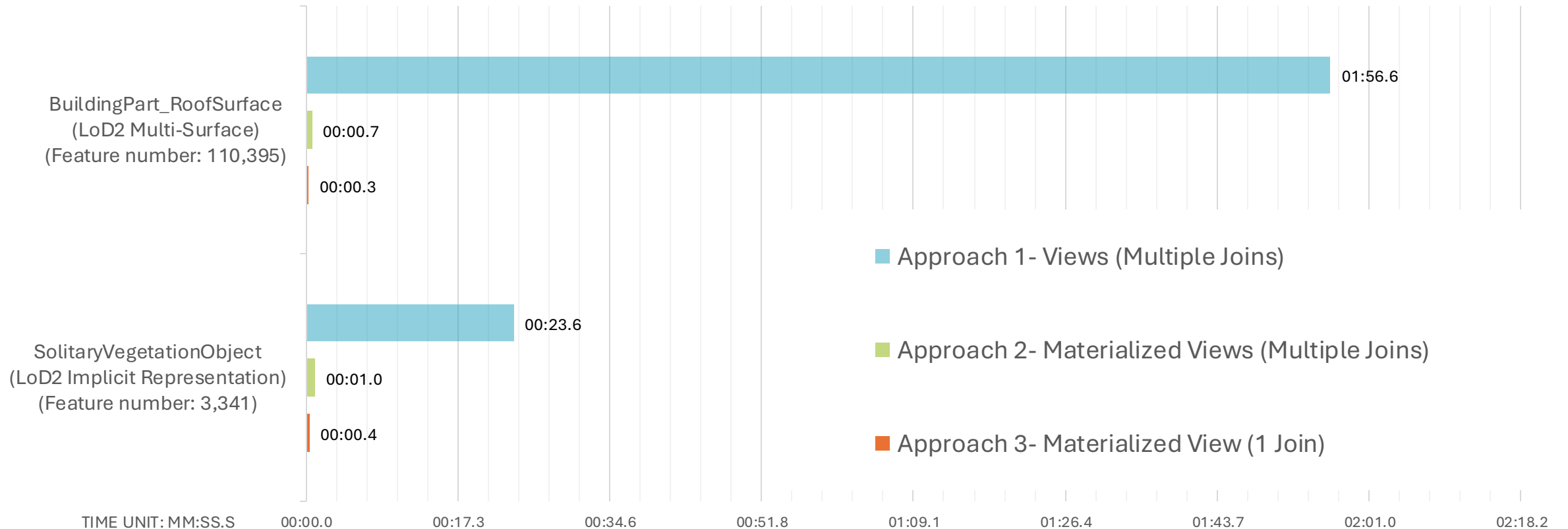
just 1 left JOINS



Choice for GIS Layer Creation approaches

- Timewise, **Approach 3** is the most suitable option: just one JOIN + MatViews

Query Time of the GIS Layers (Vienna dataset)



GIS Layer Creation Query Templates

Integrate selected feature attributes

```
SELECT
    COALESCE(a1.f_id, a2.f_id, ...) AS f_id,
    a1.',qi_a1_col_name_2,',
    a2.',qi_a2_col_name_2,',
    a2.',qi_a2_col_name_3,',
    ...
FROM ('.',ql_collect_flatten_attri_1_SQL,') AS a1
FULL JOIN ('.',ql_collect_flatten_attri_2_SQL,') AS a2
    ON COALESCE(a1.f_id) = a2.f_id
FULL JOIN ('.',ql_collect_flatten_attri_3_SQL,') AS a3
    ON COALESCE(a1.f_id, a2.f_id) = a3.f_id
...
```

 Dynamically replaced by the PL/PgSQL functions

Create GIS layer using approach 3

```
SELECT
    g.f_id,
    g.f_object_id,
    g.geom,
    -----
    -- Dynamically extended part
    -- The first column a.f_id is not selected
    a.',qi_a_col_name_2,',
    a.',qi_a_col_name_3,',
    a.',qi_a_col_name_4,',
    ...
    -----
FROM citydb.',qi_geometry_materialized_view_name,' AS g
LEFT JOIN citydb.',qi_attri_table,' AS a ON g.f_id = a.f_id
```

Layer Creation Metadata

	id [PK] bigint	cdb_schema character varying	feature_type character varying	parent_classname character varying	classname character varying	lod character	geometry_type character varying	layer_name character varying	gv_name character varying	inline_attris character varying[]	nested_attris character varying[]	is_matview boolean	is_all_attris boolean	is_joins boolean	av_table_name character varying	av_join_names character varying	n_features integer	creation_date timestamp with time zone
1	1	alderaan	Relief	[null]	ReliefFeature	lod1	Envelope	"=Imv_alderaa...	"_g_alderaan_f...	{description,lod,n...	[null]	true	true	false	"_amv_alderaa...	[null]	1	2024-10-15 09:26...
2	2	alderaan	Relief	[null]	TINRelief	lod1	tin	"=Imv_alderaa...	"_g_alderaan_f...	{description,lod,n...	[null]	true	true	false	"_amv_alderaa...	[null]	120	2024-10-15 09:26...
3	3	alderaan	Building	[null]	Building	lod0	MultiSurface	"=Imv_alderaa...	"_g_alderaan_b...	{class,dateOfCon...	{height}	true	true	false	"_amv_alderaa...	[null]	21	2024-10-15 09:26...
4	4	alderaan	Building	[null]	Building	lod1	Solid	"=Imv_alderaa...	"_g_alderaan_b...	{class,dateOfCon...	{height}	true	true	false	"_amv_alderaa...	[null]	21	2024-10-15 09:26...
5	5	alderaan	Building	[null]	BuildingPart	lod0	MultiSurface	"=Imv_alderaa...	"_g_alderaan_b...	{class,dateOfCon...	{height}	true	true	false	"_amv_alderaa...	[null]	2	2024-10-15 09:26...
6	6	alderaan	Building	[null]	BuildingPart	lod1	Solid	"=Imv_alderaa...	"_g_alderaan_b...	{class,dateOfCon...	{height}	true	true	false	"_amv_alderaa...	[null]	2	2024-10-15 09:26...
7	7	alderaan	Vegetation	[null]	SolitaryVeget...	lod1	ImplicitRepr...	"=Imv_alderaa...	"_g_alderaan_s...	{crownDiameter,h...	[null]	true	true	false	"_amv_alderaa...	[null]	33	2024-10-15 09:26...
8	8	alderaan	Vegetation	[null]	SolitaryVeget...	lod2	ImplicitRepr...	"=Imv_alderaa...	"_g_alderaan_s...	{crownDiameter,h...	[null]	true	true	false	"_amv_alderaa...	[null]	33	2024-10-15 09:26...
9	9	alderaan	Vegetation	[null]	SolitaryVeget...	lod3	ImplicitRepr...	"=Imv_alderaa...	"_g_alderaan_s...	{crownDiameter,h...	[null]	true	true	false	"_amv_alderaa...	[null]	33	2024-10-15 09:26...
10	10	alderaan	Core	Building	ClosureSurface	lod2	MultiSurface	"=Imv_alderaa...	"_g_alderaan_b...	{list_adjacent_buil...	{relatedTo}	true	true	false	"_amv_alderaa...	[null]	10	2024-10-15 09:26...
11	11	alderaan	Construction	Building	WallSurface	lod2	MultiSurface	"=Imv_alderaa...	"_g_alderaan_b...	{description,name}	[null]	true	true	false	"_amv_alderaa...	[null]	37	2024-10-15 09:26...
12	12	alderaan	Construction	Building	GroundSurface	lod2	MultiSurface	"=Imv_alderaa...	"_g_alderaan_b...	{description,name}	[null]	true	true	false	"_amv_alderaa...	[null]	10	2024-10-15 09:26...
13	13	alderaan	Construction	Building	RoofSurface	lod2	MultiSurface	"=Imv_alderaa...	"_g_alderaan_b...	{description,name...	[null]	true	true	false	"_amv_alderaa...	[null]	20	2024-10-15 09:26...
14	14	alderaan	Core	BuildingPart	ClosureSurface	lod2	MultiSurface	"=Imv_alderaa...	"_g_alderaan_b...	{list_adjacent_buil...	{relatedTo}	true	true	false	"_amv_alderaa...	[null]	2	2024-10-15 09:26...
15	15	alderaan	Construction	BuildingPart	WallSurface	lod2	MultiSurface	"=Imv_alderaa...	"_g_alderaan_b...	{description,name}	[null]	true	true	false	"_amv_alderaa...	[null]	8	2024-10-15 09:26...
16	16	alderaan	Construction	BuildingPart	GroundSurface	lod2	MultiSurface	"=Imv_alderaa...	"_g_alderaan_b...	{description,name}	[null]	true	true	false	"_amv_alderaa...	[null]	2	2024-10-15 09:26...
17	17	alderaan	Construction	BuildingPart	RoofSurface	lod2	MultiSurface	"=Imv_alderaa...	"_g_alderaan_b...	{description,name...	[null]	true	true	false	"_amv_alderaa...	[null]	4	2024-10-15 09:26...
18	18	rh	Relief	[null]	ReliefFeature	lod1	Envelope	"=Imv_rh_rel_f...	"_g_rh_rel_feat...	{description,lod,n...	[null]	true	true	false	"_amv_rh_Reli...	[null]	1	2024-10-15 09:26...
19	19	rh	Relief	[null]	TINRelief	lod1	tin	"=Imv_rh_rel_t...	"_g_rh_rel_tin_l...	{lod,name}	[null]	true	true	false	"_amv_rh_TIN...	[null]	9	2024-10-15 09:26...
20	20	rh	Building	[null]	Building	lod0	MultiSurface	"=Imv_rh_bdg...	"_g_rh_bdg_lod...	{3dbag_tile,bag_n...	{height}	true	true	false	"_amv_rh_Buil...	[null]	493	2024-10-15 09:26...
21	21	rh	Building	[null]	BuildingPart	lod0	MultiSurface	"=Imv_rh_bdg...	"_g_rh_bdg_par...	{building_type,cla...	[null]	true	true	false	"_amv_rh_Buil...	[null]	3	2024-10-15 09:26...
22	22	rh	Vegetation	[null]	SolitaryVeget...	lod1	ImplicitRepr...	"=Imv_rh_sol_...	"_g_rh_sol_veg...	{crownDiameter,h...	[null]	true	true	false	"_amv_rh_Solit...	[null]	622	2024-10-15 09:26...
23	23	rh	Vegetation	[null]	SolitaryVeget...	lod2	ImplicitRepr...	"=Imv_rh_sol_...	"_g_rh_sol_veg...	{crownDiameter,h...	[null]	true	true	false	"_amv_rh_Solit...	[null]	622	2024-10-15 09:26...

(Parent)
Classes

LoDs &
Geometries

"Inline" & "Nested"
Attributes selected

Created GIS Layers

Layers

- ✓ Railway
 - ✓ =lmv_railway_v5_doorsurf_lod3_MSurf_attri_table
 - ✓ =lmv_railway_v5_bdg_groundsurf_lod3_MSurf_attri_table
 - ✓ =lmv_railway_v5_bdg_lod3_MCurve_attri_table
 - ✓ =lmv_railway_v5_bdg_outer_ceilingurf_lod3_MSurf_attri_table
 - ✓ =lmv_railway_v5_bdg_outer_floorsurf_lod3_MSurf_attri_table
 - ✓ =lmv_railway_v5_bdg_roofsurf_lod3_MSurf_attri_table
 - ✓ =lmv_railway_v5_bdg_lod3_TerrainC_attri_table
 - ✓ =lmv_railway_v5_bdg_wallsurf_lod3_MSurf_attri_table
 - ✓ =lmv_railway_v5_bdg_inst_lod3_MSurf_attri_table
 - ✓ =lmv_railway_v5_windowsurf_lod3_MSurf_attri_table
- ✓ Building
 - ✓ =lmv_railway_v5_city_frn_lod3_MSurf_attri_table
 - ✓ =lmv_railway_v5_gen_occupied_space_lod3_MSurf_attri_table
 - ✓ =lmv_railway_v5_trn_railway_lod3_MSurf_attri_table
- ✓ Tunnel
- ✓ =lmv_railway_v5_sol_veg_obj_lod3_ImplicitR_attri_table
- ✓ WaterBody
- ✓ Relief
- citydb

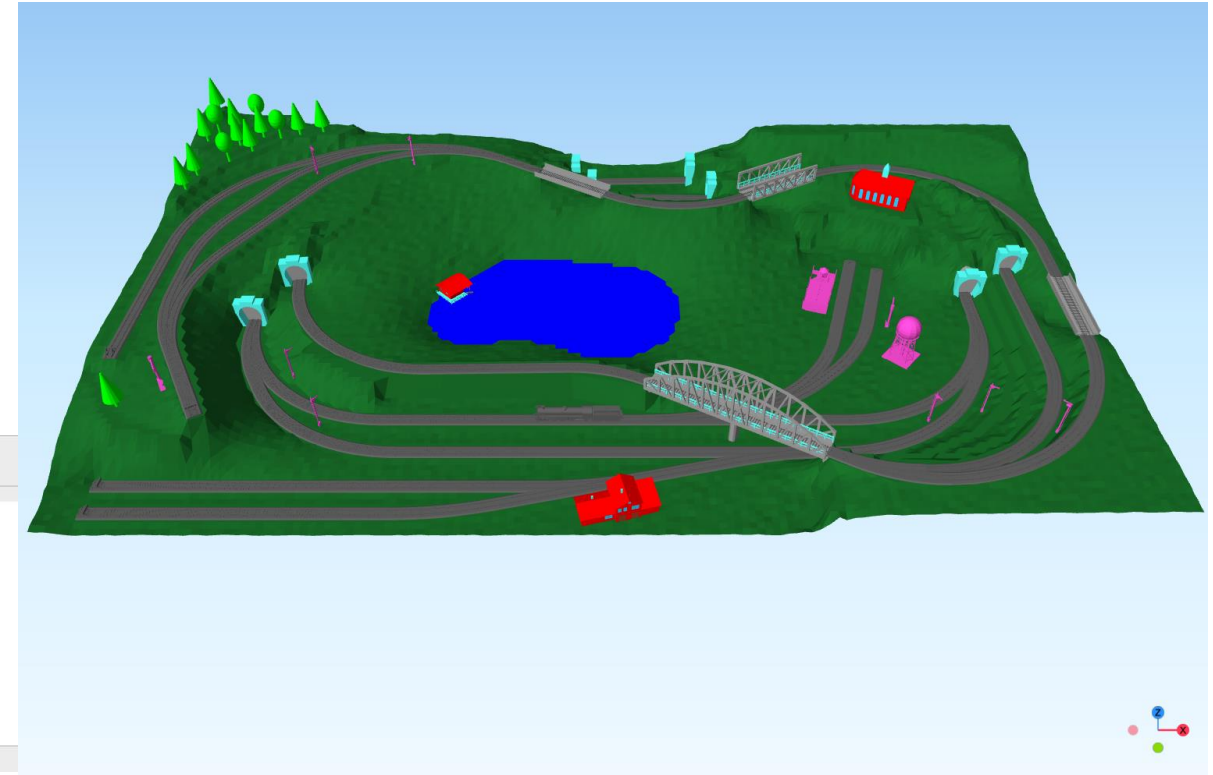
Browser

- PostgreSQL
 - citydb_v4
 - citydb_v5
 - alderaan_v5
 - citydb
 - citydb_pkg
 - denhaag_v5
 - public
 - qgis_btsai
 - =lmv_citydb_bdg_closuresurf_lod2_MSurf_attri_table
 - =lmv_citydb_bdg_groundsurf_lod2_MSurf_attri_table
 - =lmv_citydb_bdg_lod0_MSurf_attri_table
 - =lmv_citydb_bdg_lod0_Unknown_attri_table
 - =lmv_citydb_bdg_lod1_Solid_attri_table
 - =lmv_citydb_bdg_part_closuresurf_lod2_MSurf_attri_table
 - =lmv_citydb_bdg_part_groundsurf_lod2_MSurf_attri_table
 - =lmv_citydb_bdg_part_lod0_MSurf_attri_table

=lmv_railway_v5_bdg_roofsurf_lod3_MSurf_attri_table — Features Total: 8, Filtered: 8, Selected: 0

f_id	f_object_id	Name	relativeToTerrain	relativeToWater	
1	97	ID_6d63969e-15d2-4f2e-90a2-35edec8d221b	Roof 1	entirelyAboveTerrain	NULL
2	102	ID_a5076d2c-2fb6-4137-848a-b0c994b5054c	Roof 2	entirelyAboveTerrain	NULL
3	107	ID_87b62137-28fe-4231-a47e-025fd7c35c9	Roof 3	entirelyAboveTerrain	NULL
4	149	ID_17bda456-193e-45c2-b9c7-9ed49b790b22	Roof 1	entirelyAboveTerrain	NULL
5	152	ID_ddecbbcd-40a6-4080-9252-18de8a1c5d62	Roof 2	entirelyAboveTerrain	NULL
6	154	ID_42b3c0ee-2f71-4145-a317-1e81e121f7d2	Roof 3	entirelyAboveTerrain	NULL
7	168	ID_c1f7e1b5-adc7-4e72-bf23-b2b31dcc0368	Roof 1	NULL	substantiallyAboveWate...
8	169	ID_b55bf68b-a39d-427e-8565-80ef45397693	Roof 2	NULL	substantiallyAboveWate...

Show All Features

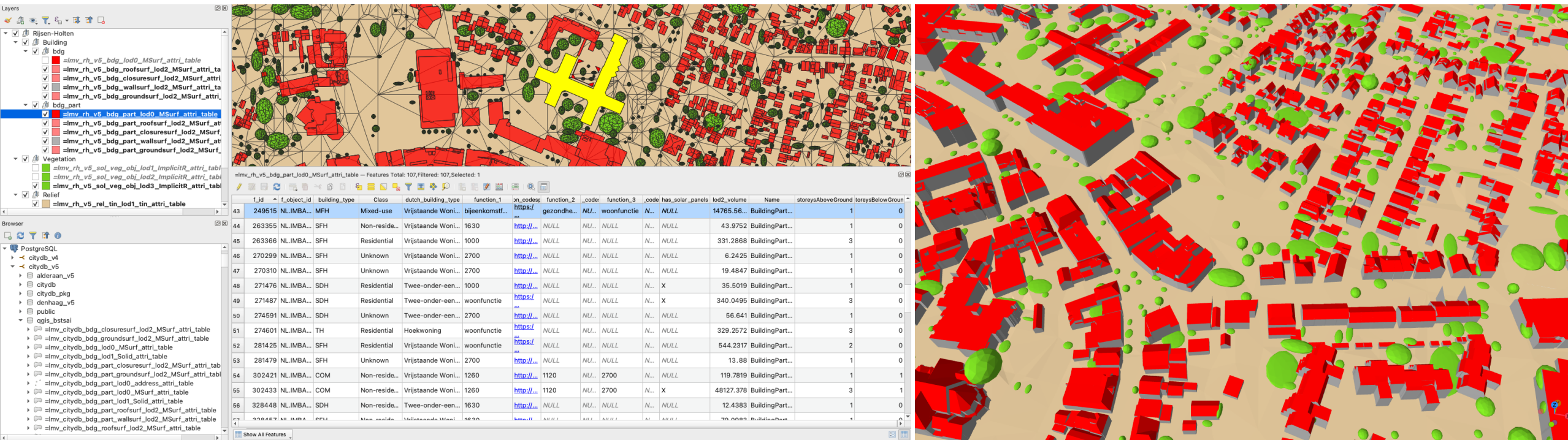


4. Tests & Results



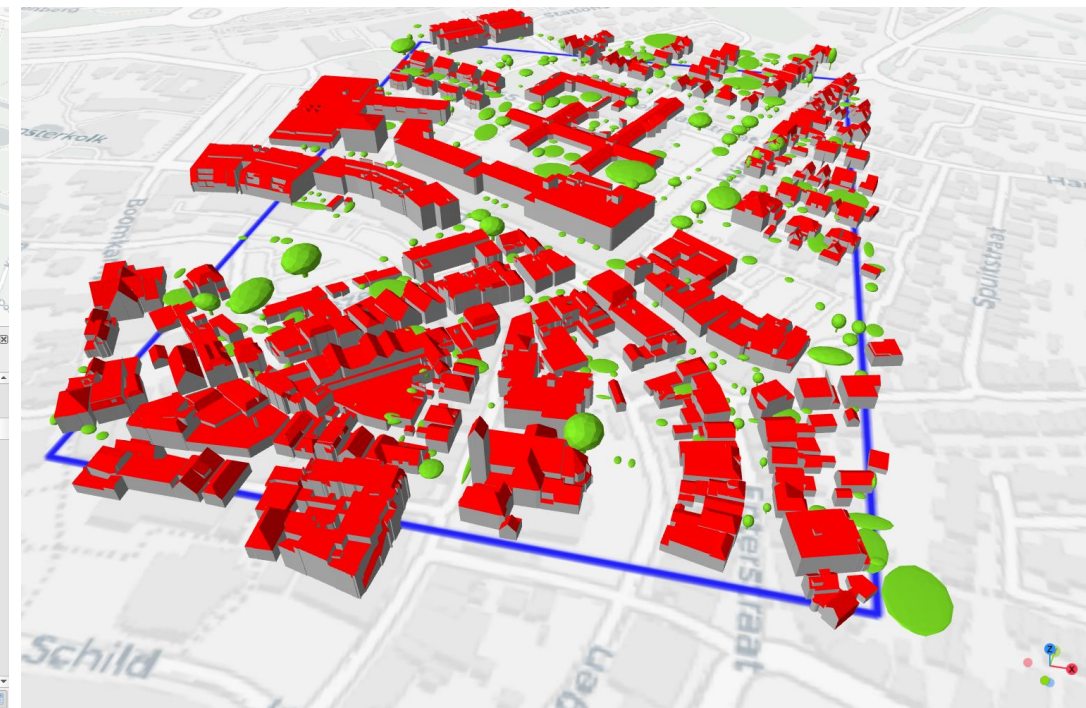
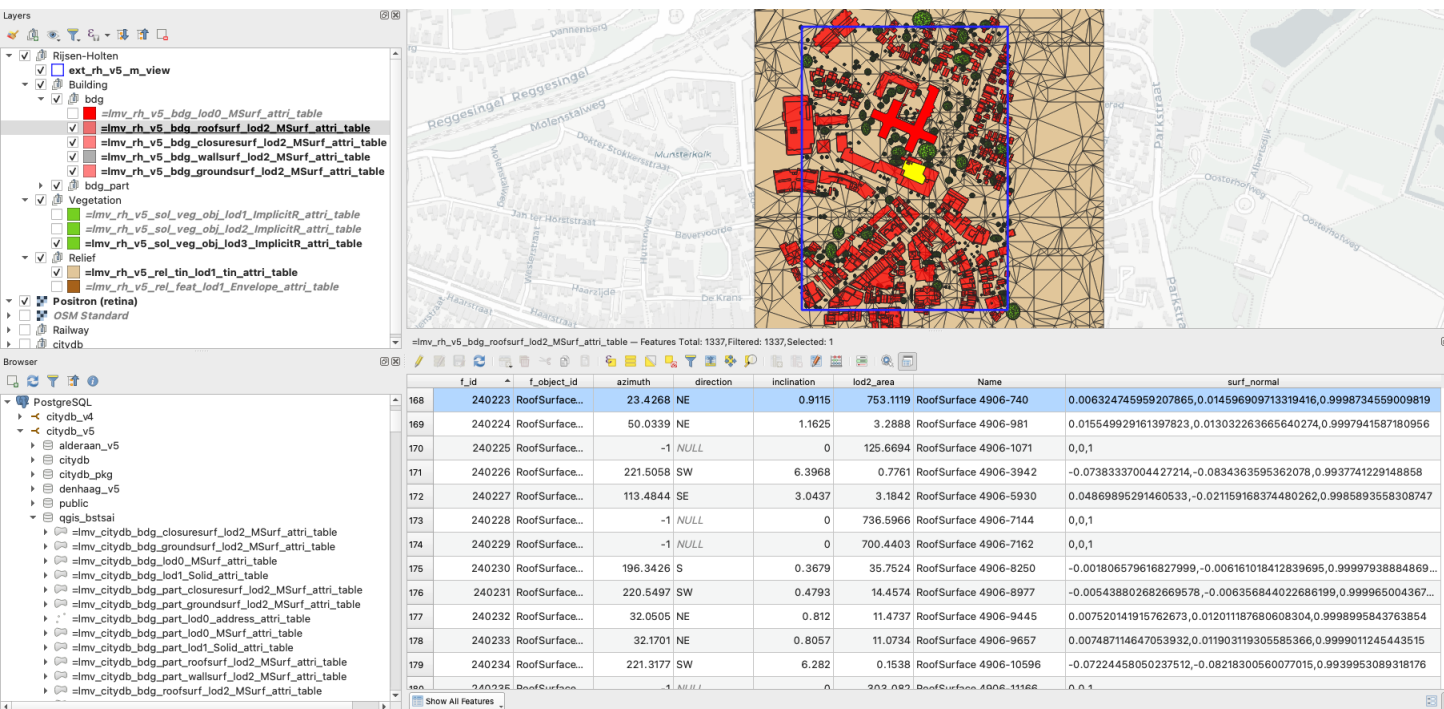
Results

- Rijsen-Holten dataset (CityGML 2.0) – full schema extents



Results

- Rijssen-Holten dataset (CityGML 2.0) – user-selected extents

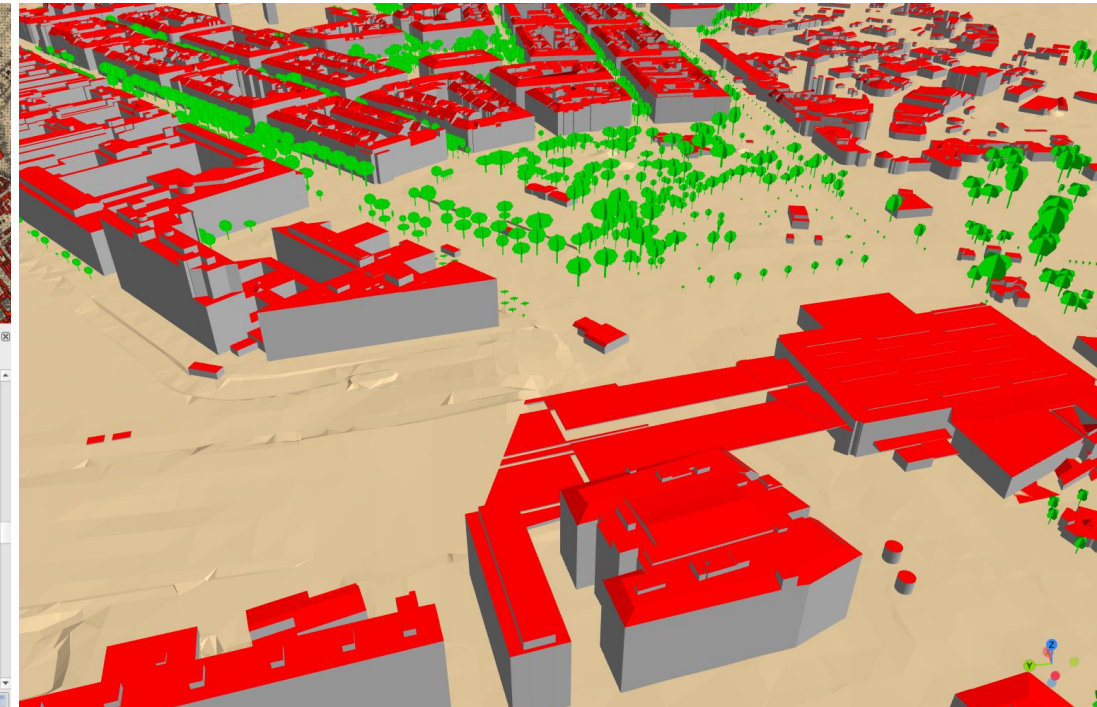


Results

- Vienna dataset (CityGML 2.0)– full schema extent

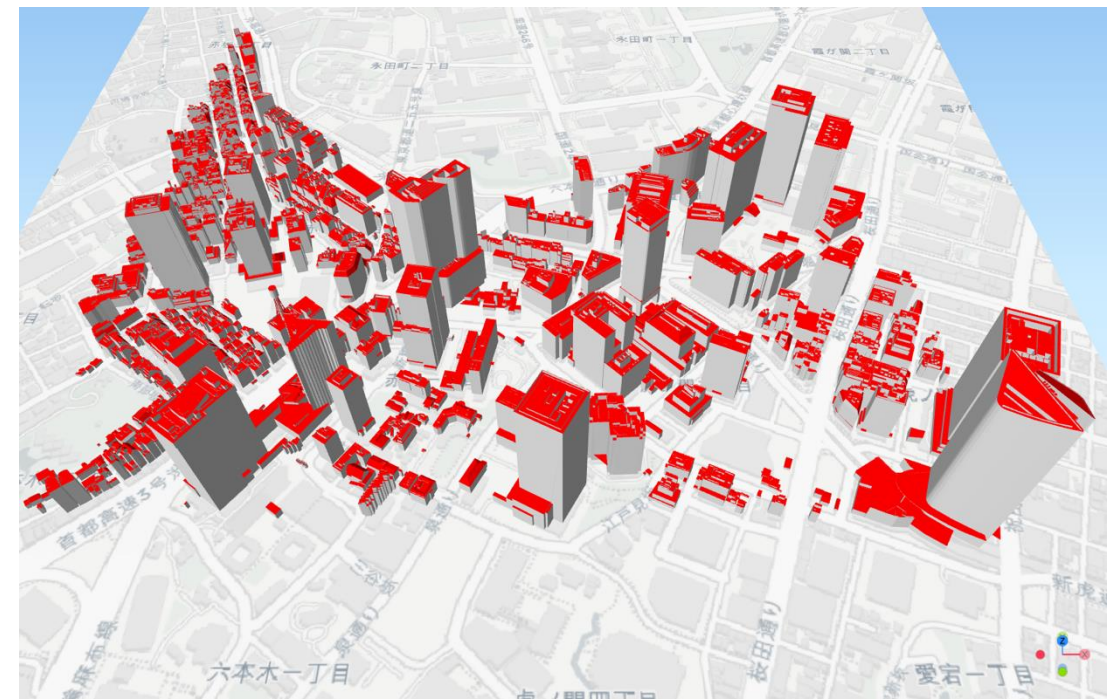
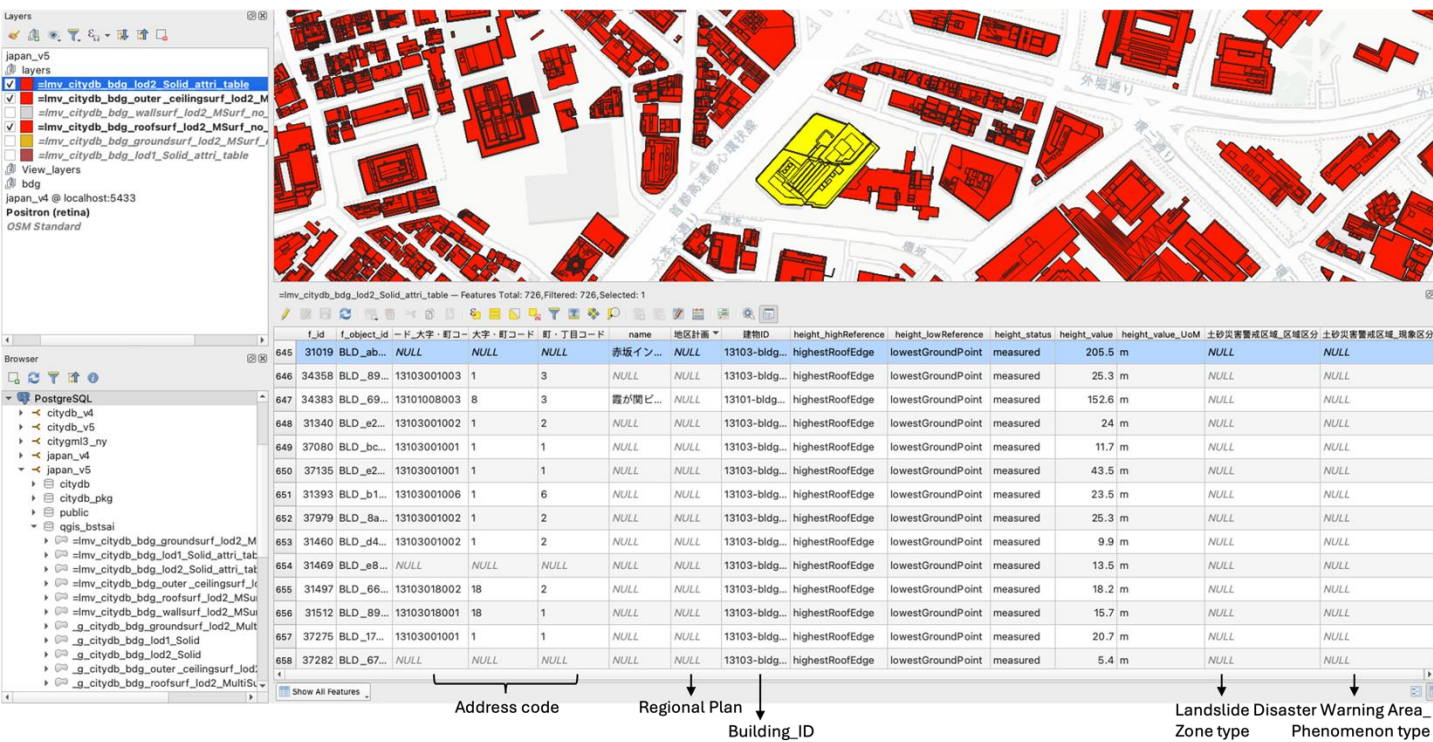
The screenshot displays a GIS application interface. The main map area shows a 2D aerial view of a city with a yellow highlighted polygon. The Layers panel on the left lists various data layers, including 'vienna_v5' and 'OSM Standard'. The Browser panel at the bottom left shows a tree view of the data structure. The data table at the bottom right displays the following information:

f_id	f_object_id	Dachneigung	Dachorientierung	Flaeche	FlaecheUUID	
153925	4599664	UUID_LOD2_514691-5cb7...	90.0	-1.0	29063.94	56d0b828-d996-499c-ae42-488b0bc6865a
153926	4601588	UUID_LOD2_008119-de98...	87.1	342.52	31.63	0a82a2b0-6210-4a39-8fdc-1bfbb4a05c09
153927	4601589	UUID_LOD2_008119-de98...	87.1	162.52	31.63	d2bed6cf-6b49-4169-a7d6-c2f828fdda7b
153928	4601596	UUID_LOD2_A33600-f73e...	90.0	-1.0	31.73	144c1892-b654-401c-a909-3d5208574917
153929	4601603	UUID_LOD2_503700-1cd7...	90.0	-1.0	197.08	10b52c85-0de1-46ca-8d15-223a1dbf30fd
153930	4601655	UUID_LOD2_A00440-75bf...	90.0	-1.0	36.94	0e3161d4-4169-4641-8765-03a4fba40bbe
153931	4601662	UUID_LOD2_006488-c127...	55.66	274.07	52.56	00c3797b-2197-495e-8250-a5e63bcc54e4
153932	4601663	UUID_LOD2_006488-c127...	55.66	94.07	52.51	153c3377-db5f-4706-bb57-a6ef5e95f810
153933	4601664	UUID_LOD2_006488-c127...	57.63	184.11	368.6	bee14169-fa9f-470e-b45a-add5c2973dc7
153934	4601665	UUID_LOD2_006488-c127...	57.63	4.11	373.74	cd13a220-3ded-4dba-8a6e-958b25a6490c
153935	4601711	UUID_LOD2_008123-3584...	53.62	170.75	172.97	dc4e4349-3a5f-4293-8294-28630c1c62d9
153936	4601712	UUID_LOD2_008123-3584...	54.74	260.75	128.78	2488dc8b-7912-4720-923b-c8d00ef8e859
153937	4601713	UUID_LOD2_008123-3584...	57.21	350.78	124.78	ac20e153-fa45-4d02-94fb-ba7d7f388d5c



Results

- Tokyo dataset (CityGML 2.0) – full schema extent

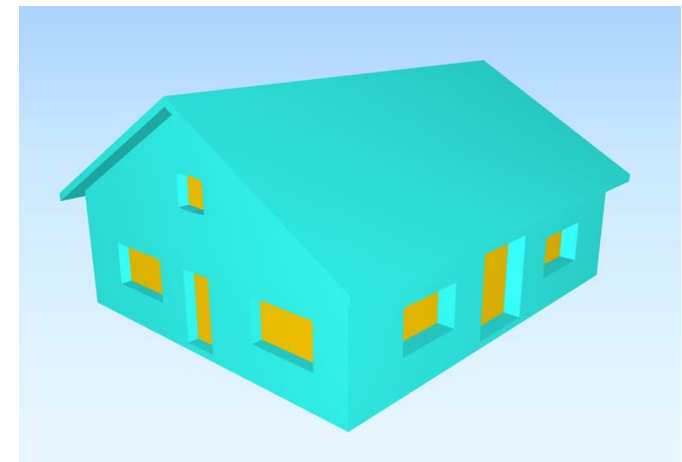
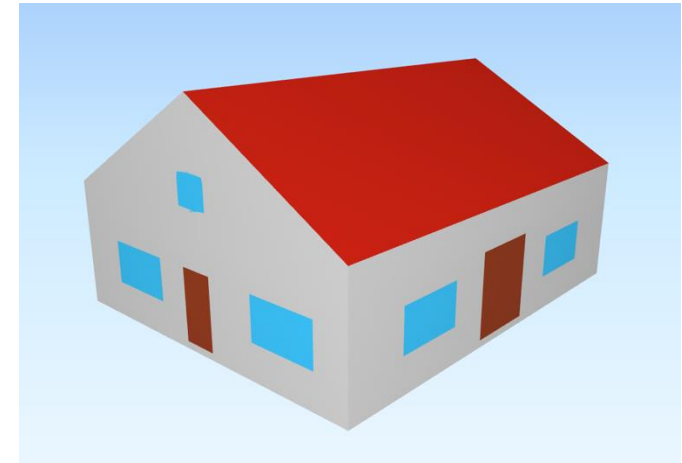


Results

- FZK Haus dataset (CityGML 3.0) – full schema extent

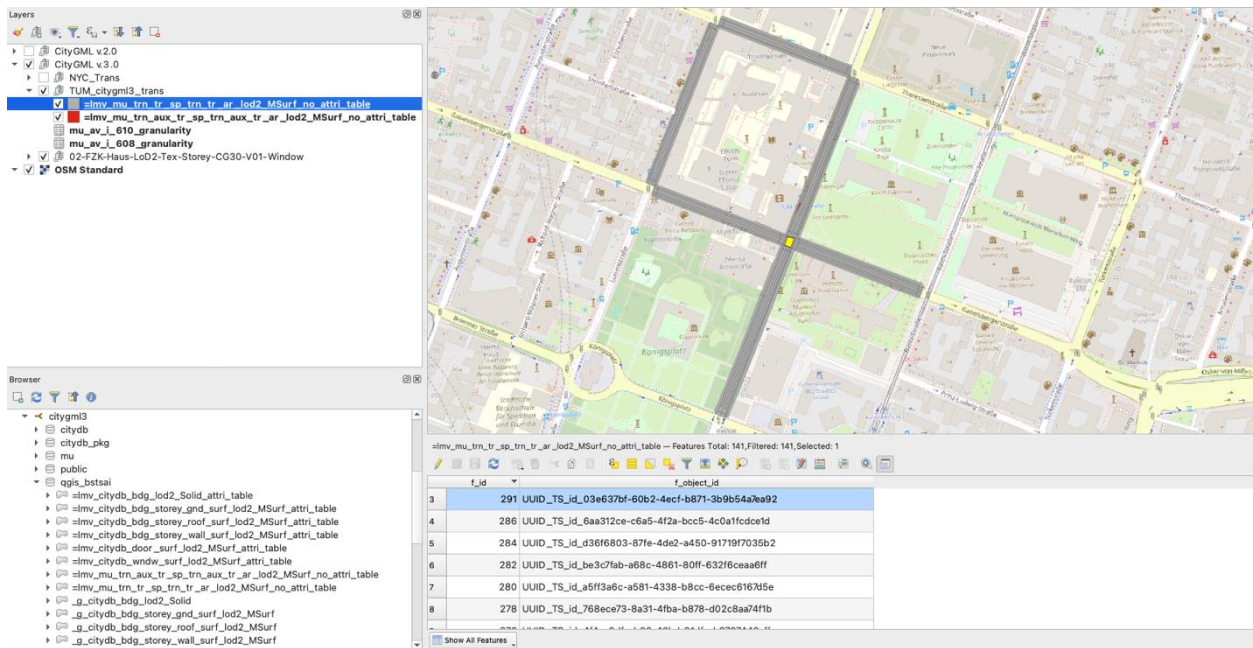
The screenshot displays a GIS application window. The main view shows a 3D model of a building with a red roof and yellow walls. The Layers panel on the left lists several layers, including CityGML v.2.0, CityGML v.3.0, TUM_citygml3_trans, and 02-FZK-Haus-LoD2-TeX-Storey-CG30-V01-Window. The Browser panel at the bottom left shows a tree structure of the data, including citygml3, citydb, citydb_pkg, mu, public, and qgis_bstsa. The data table at the bottom right shows the following data:

f_id	f_object_id	name
1	20 ID_cd67bfa5...	Second Floor / Roof North
2	21 ID_b415e52...	Second Floor / Roof South



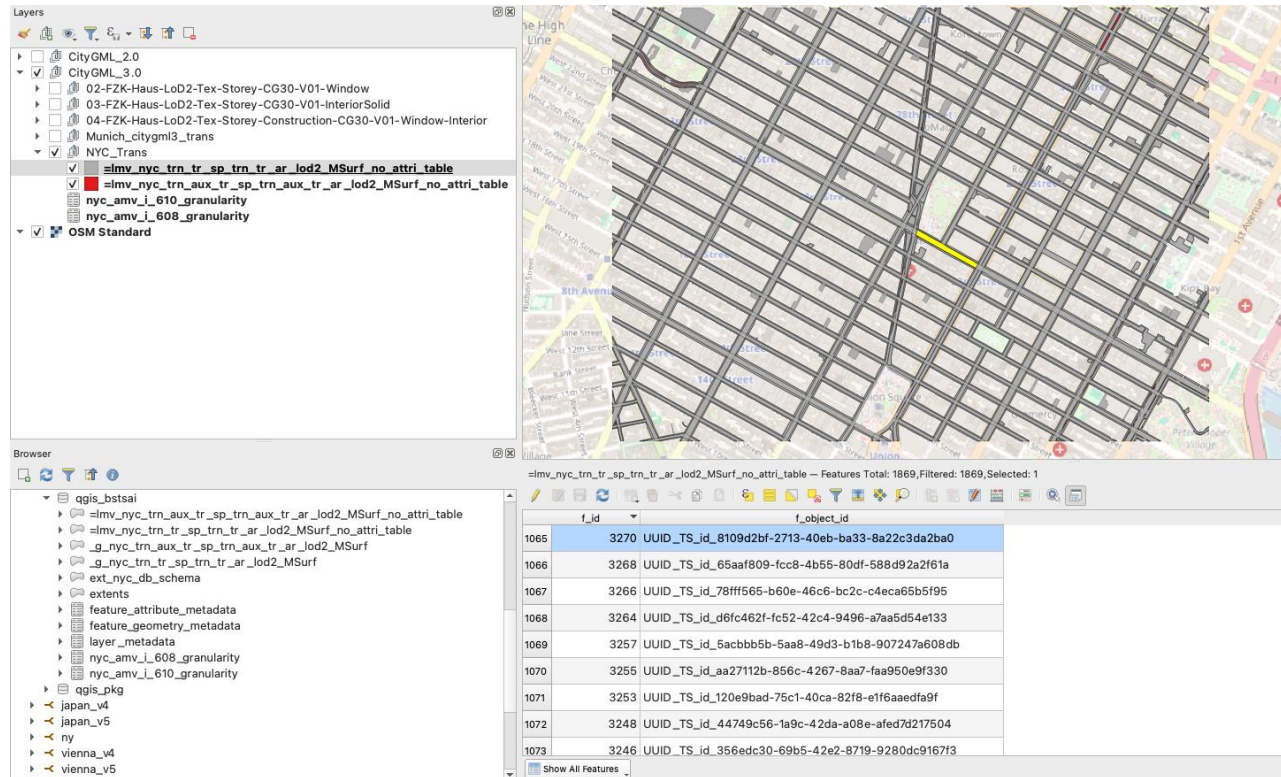
Results

- **Munich transportation dataset (CityGML 3.0) – full schema extent**



Results

- New York City transportation dataset (CityGML 3.0) – full schema extent



5. Conclusions & Future Development



Answers to Research Questions

How does the new 3DCityDB affects the current method of the plug-in to create layers?

Answers to Research Questions

For geometries:

- How do the new CityGML 3.0 concepts of space, LoD affect the process ?
- Can the same or a similar approach be reproduced ?
 - The CityGML 3.0 Core module simplifies management of geometry representations and LoDs
 - Users can select their desired feature LoD and geometry representation for creating GIS layers
 - Materialized views are still preferable with implicit geometries and space-boundary classes

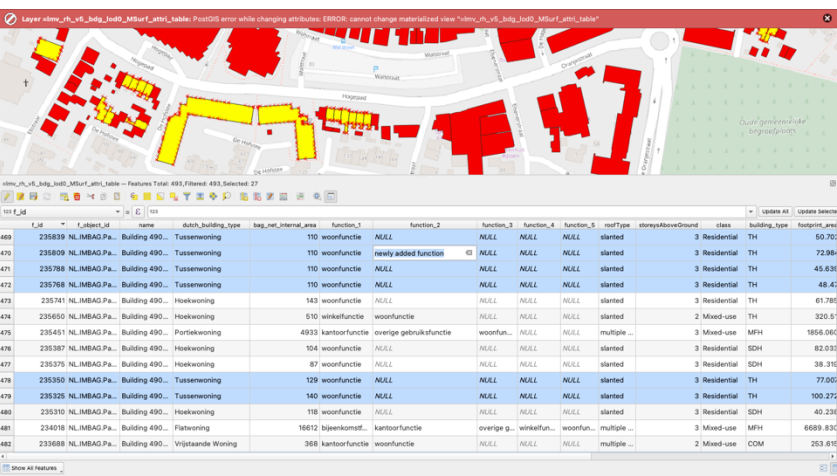
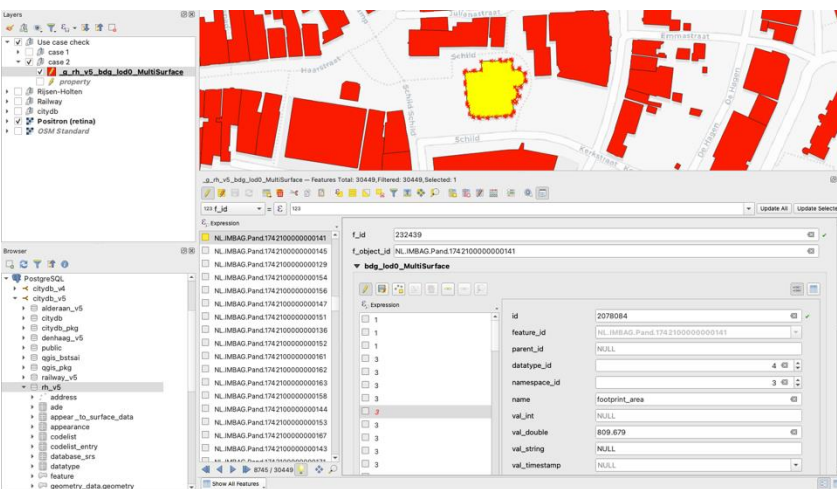
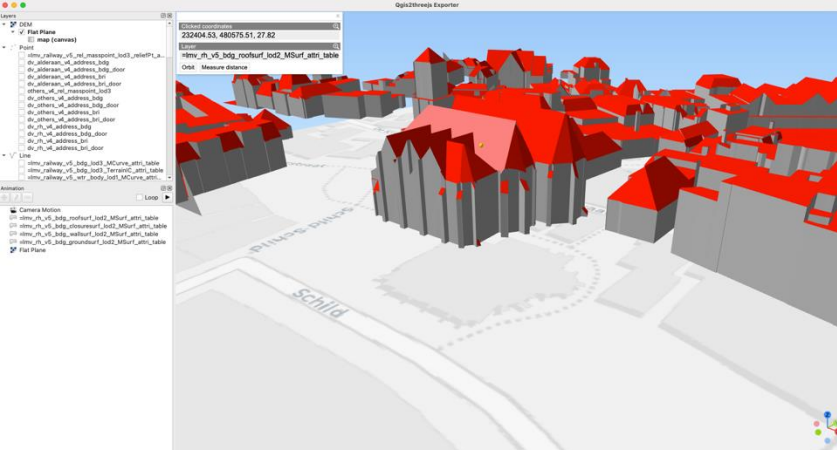
Answers to Research Questions

For attributes:

- Can the same or a similar approach be reproduced ?
 - **No!!** Since all attributes are stored following the EAV model within 3DCityDB 5.0. They require different strategies for flattening depending on one of the four classes.
 - **But:** The current new approach should simplify future management of ADE-related attributes
 - Attribute materialized views are preferable to offer better user experience.

Answers to Research Questions

- **How is the CityGML 2.0 data mapped to the new schema of 3DCityDB 5.0?**
 - CityGML 2.0 data is mapped automatically to CityGML 3.0 upon import into 3DCityDB 5.0
 - Certain properties from CityGML 2.0 cannot be directly mapped are marked as “deprecated” (e.g. RoofEdge geometry)
 - In the implementation of this research, the deprecated properties are displayed in the metadata check but are excluded during view creation



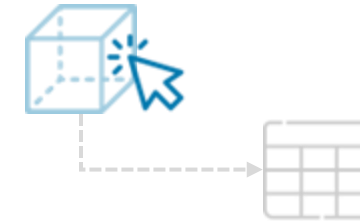
Use Cases Check & Limitations

- ✓ • Case1: checking feature geometries

- Case2: click on feature geometry to access attributes

- ✓ ○ read-only

- ✓ ○ read-write



- Case3: access feature geometry and linked attributes

- ✓ ○ read-only

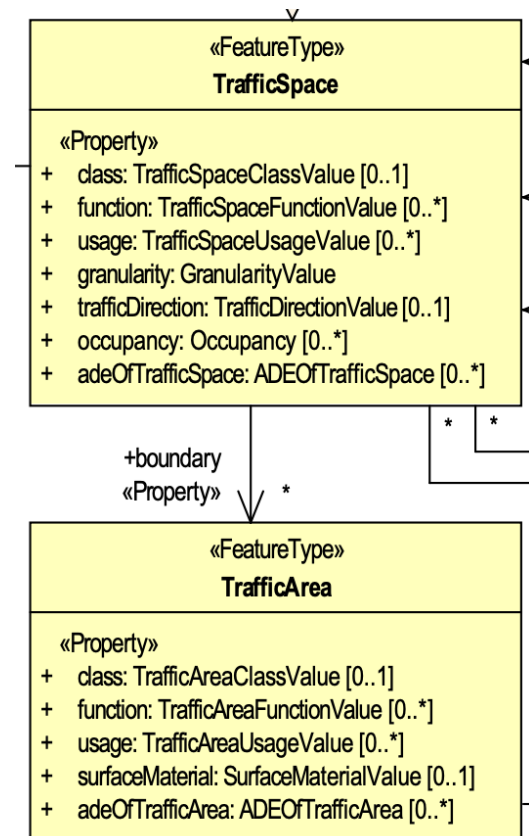
- ✗ ○ read-write



- ✗ • Case4: user perform case 1-3 using GUIs

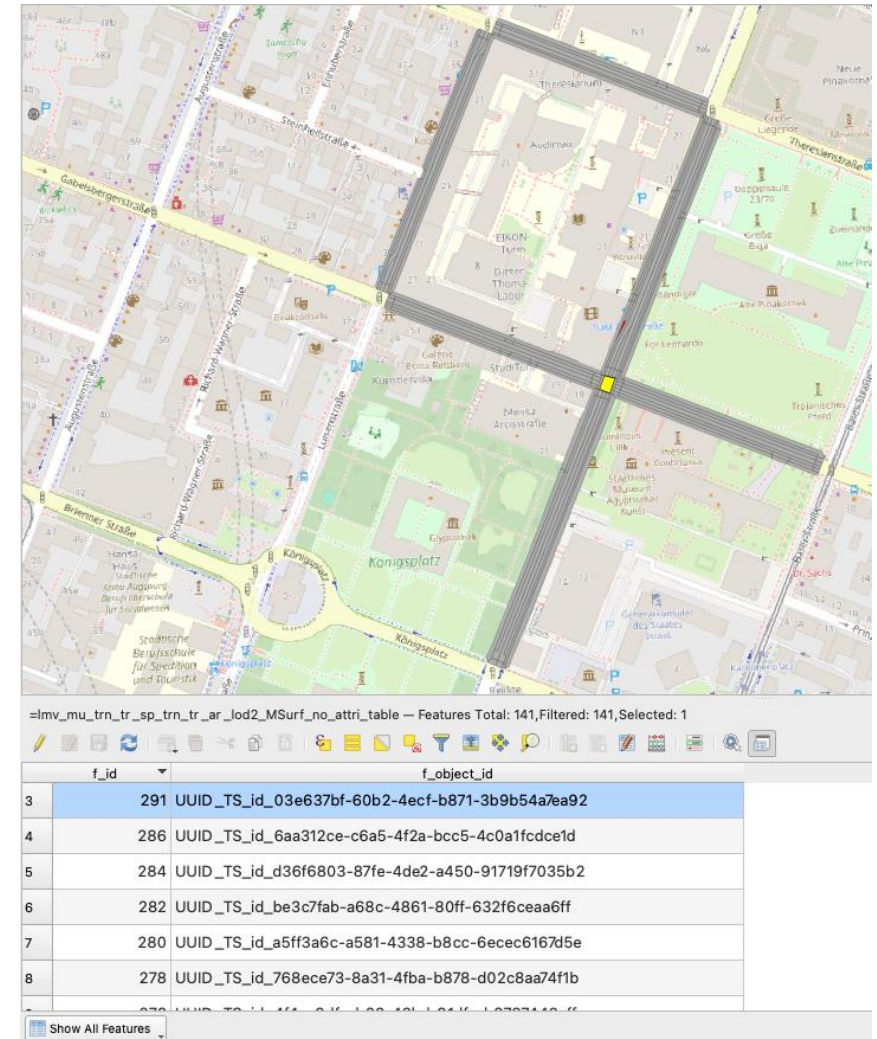
Limitations

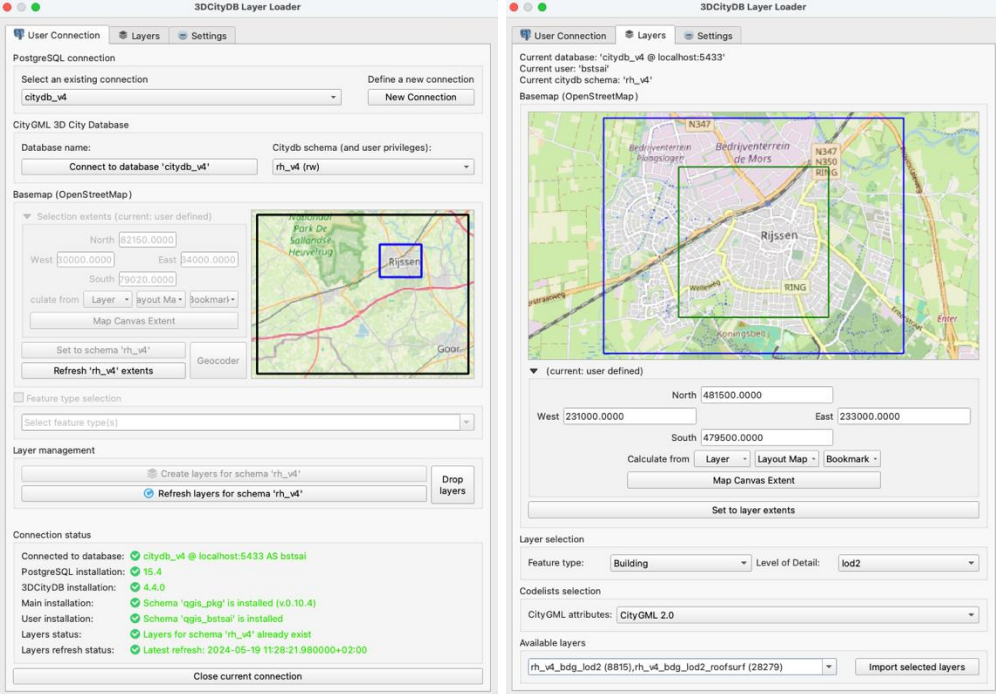
- At the moment, features without their "own" geometry representations cannot be viewed via GIS layers



- Space Feature**
 - No own geometries

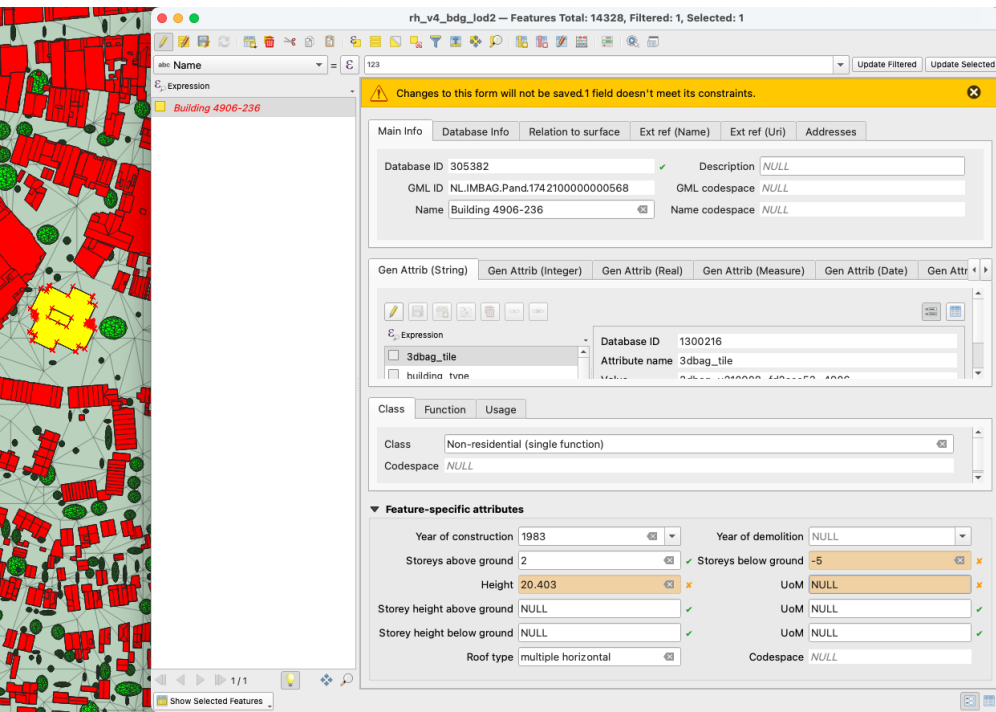
- Boundary Feature**
 - lod2 Multi-Surface





Future Development

- **Add Read-write capabilities for use case 3-2**
 - Rethinking of the strengths/weaknesses of materialised views?
 - Role of IVM (Incremental View Maintenance) package in PostgreSQL?
- **Adaptation of the plug-in client side**
 - Modify “Layer Loader” to enable geometries and attribute selection
 - Use the metadata table (on layer generation) as the connecting point between PostgreSQL server-side (this work) and the new to-be-updated client-side in QGIS



**Create GIS layers from the data
stored within 3DCityDB v.5.0
Demo**



Thank you for your attention



3DCityDB 5.0



CityGML