Technische Universität Berlin

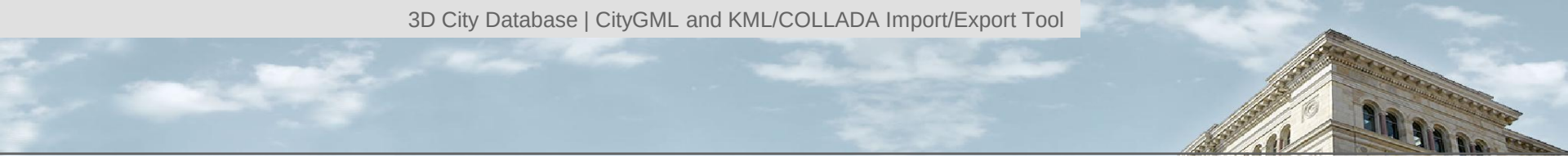
Institute for Geodesy and Geoinformation Science

Methods of GEOINFORMATION

CityGML DBMS storage
3DCityDB implementation

100% CityGML
TU Delft, March 14th, 2011

Javier Herreruela, Thomas H. Kolbe, Claus Nagel, Gerhard König
{javier.herreruela | thomas.kolbe | claus.nagel | gerhard.koenig}@tu-berlin.de
www.igg.tu-berlin.de

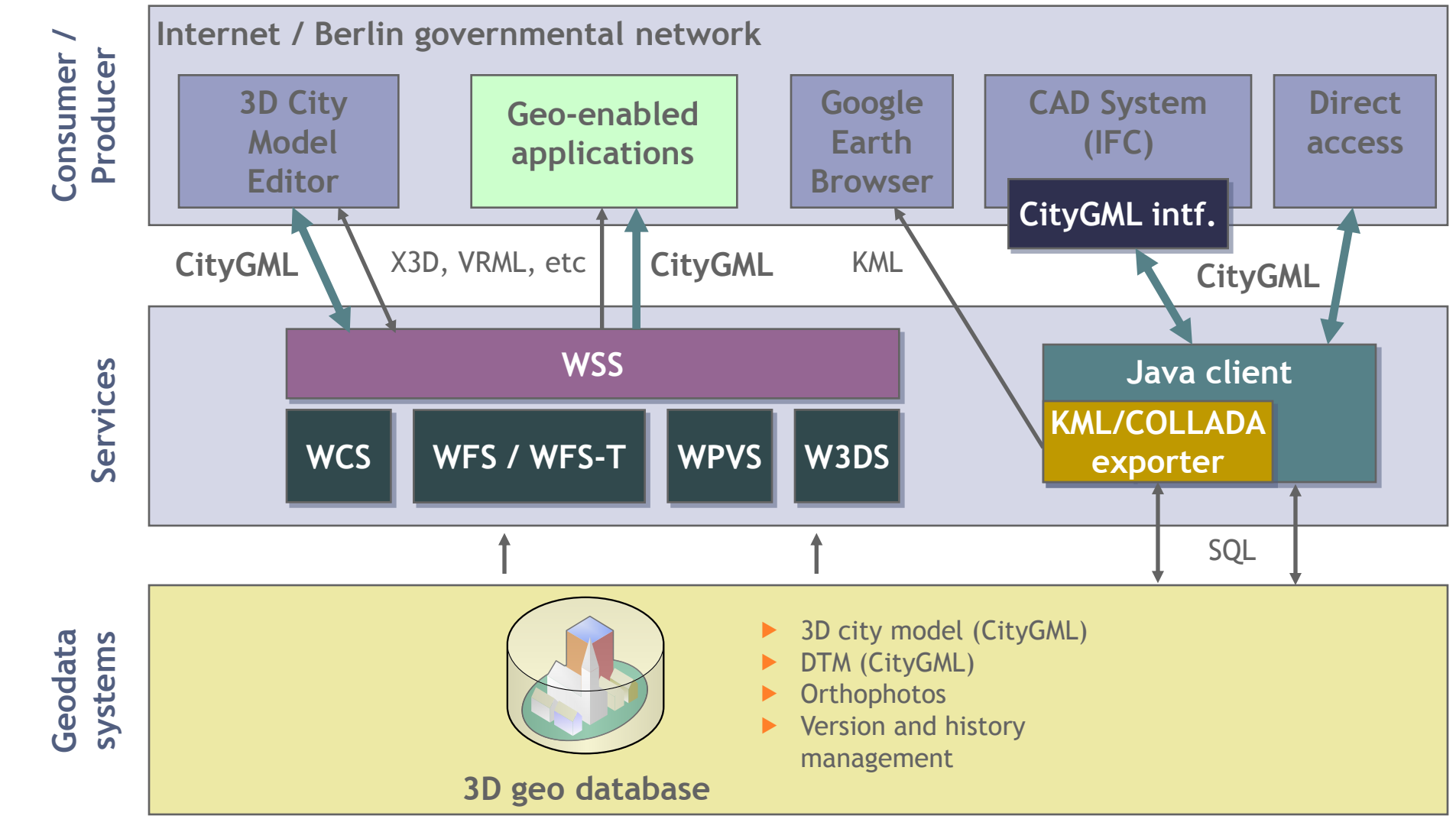


3D City Database
General Overview

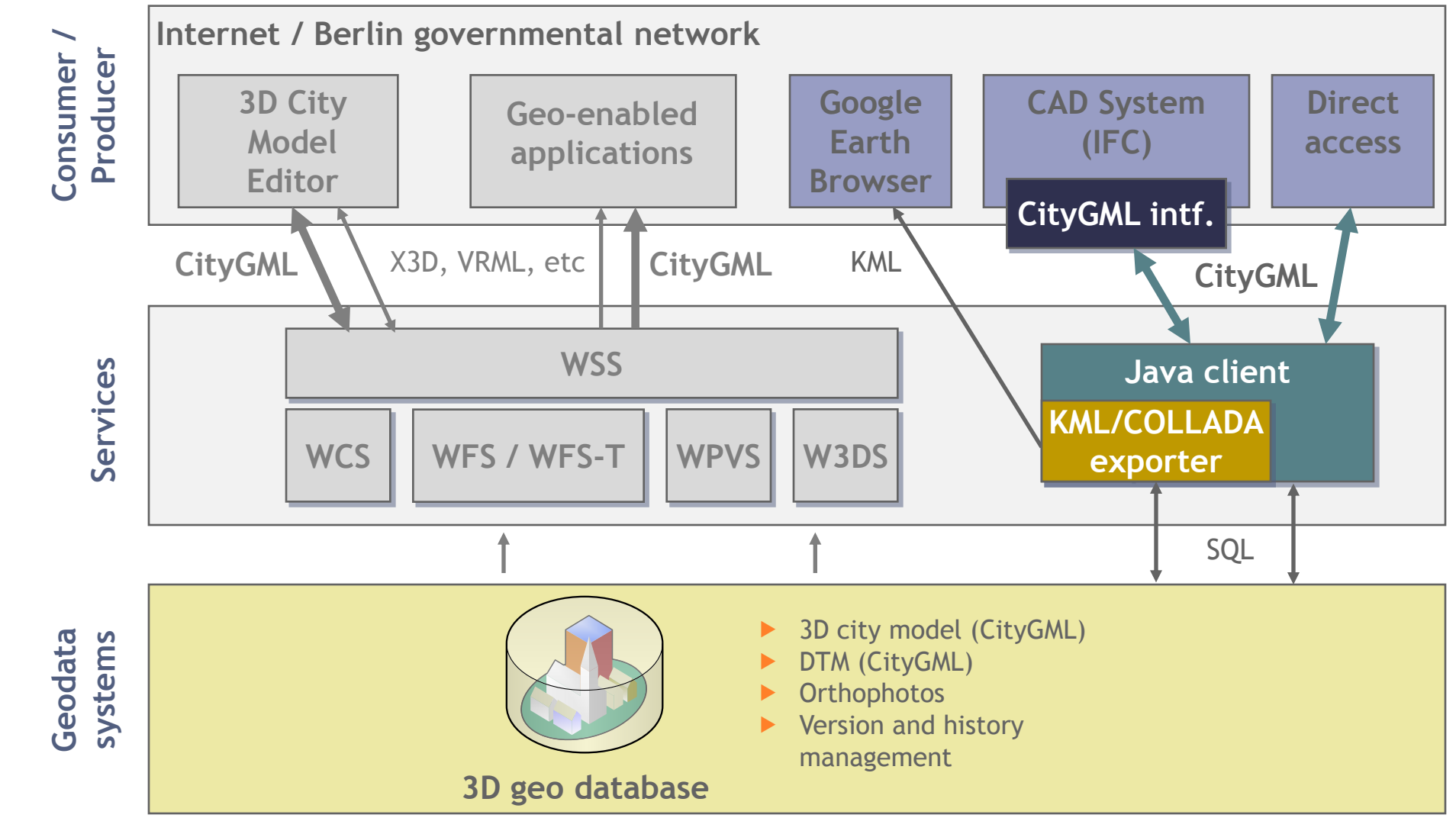
Motivation for a 3D geo database in Berlin

- **Repository for the official 3D city model**
  - Complete representation of city topography and landscape
  - Data from various sources (cadastre, planning, architecture, utility networks, etc.)
- **Usage of 3D city model for applications like**
  - City and Urban Planning
  - Political Issues and Consulting, Civic Participation
  - Marketing, Service, Promotion for companies
- **Basis for the Berlin 3D Spatial Data Infrastructure**
  - Access through standardized OGC Web Services, Google Earth (KML), online streaming

Berlin 3D Spatial Data Infrastructure



Berlin 3D Spatial Data Infrastructure

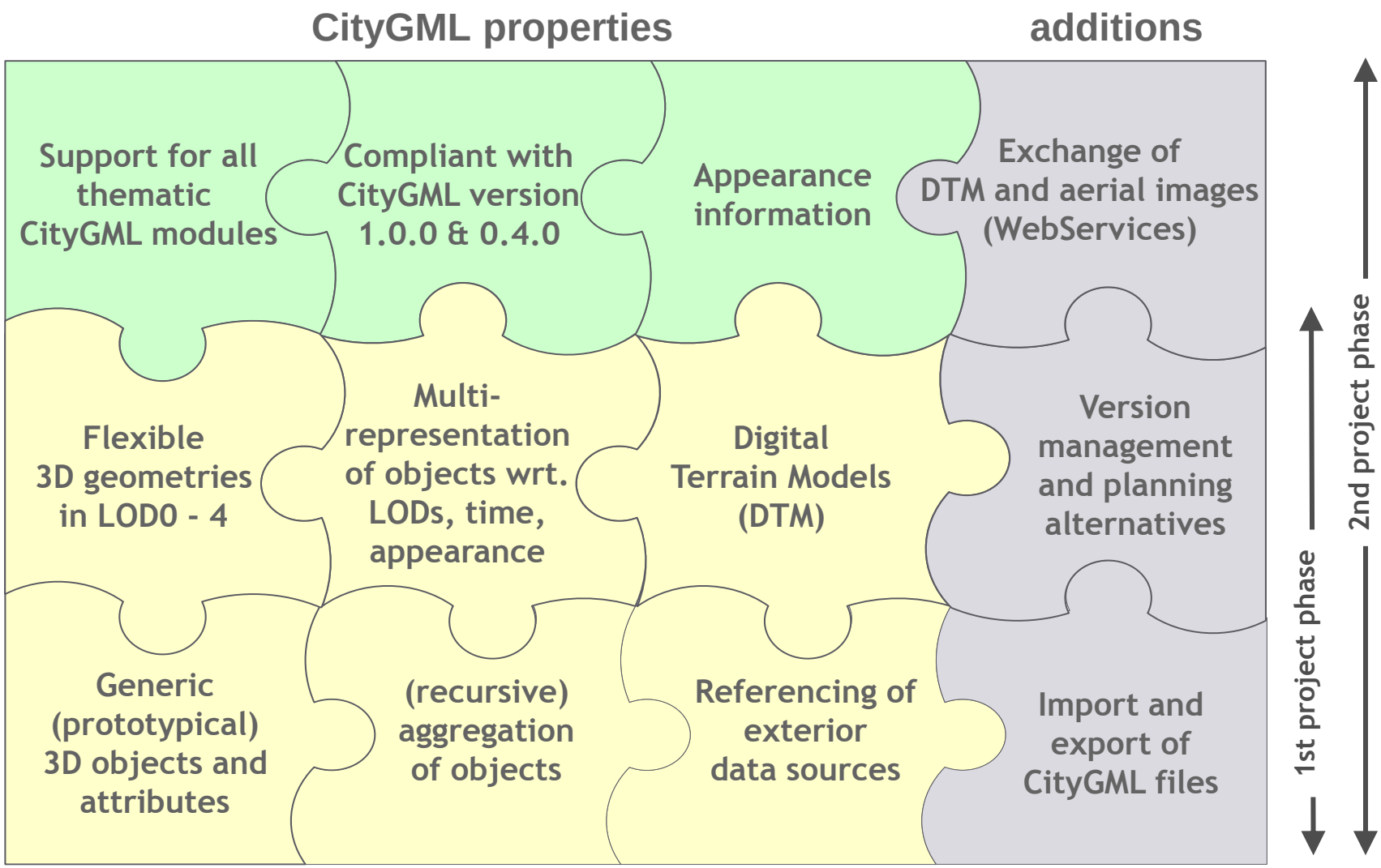


Development goals for the 3D City Database

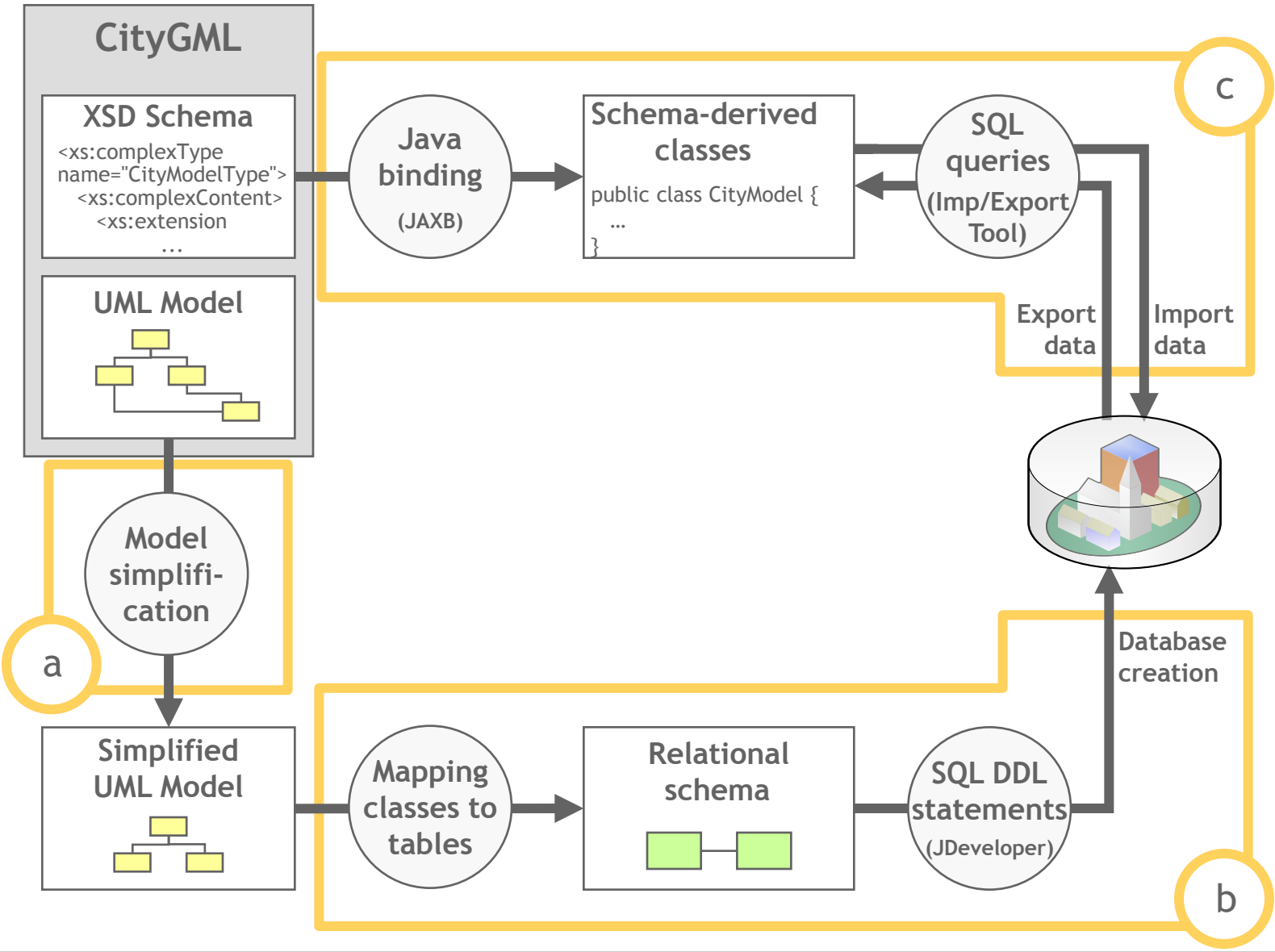
3DCityDB V2 is a **free and Open Source 3D geo database** to store, represent, and manage virtual 3D city models

- **CityGML 1.0 (and 0.4.0) compliant**
  - Support for all CityGML feature types
  - Representation of feature geometry in all 5 LODs
  - Support for CityGML's appearance model
- **Relational database schema for Oracle 10g R2 Spatial or higher**
  - Spatial data types and advanced processing of spatial data
  - Efficient storage and management of raster data
  - Sustainability through Workspace Manager (Version and History Management)
  - Connection possibilities to commercial GIS
- **Open Source** and released under the terms of the **LGPLv3**
  - Developed by IGG, TU Berlin in cooperation with IGG, Univ. of Bonn, lat/lon and 3DGeo (now: Autodesk)
  - direct 3DCityDB support in Autodesk LandXPlorer Professional
  - current developments are also supported by VirtualCitySystems

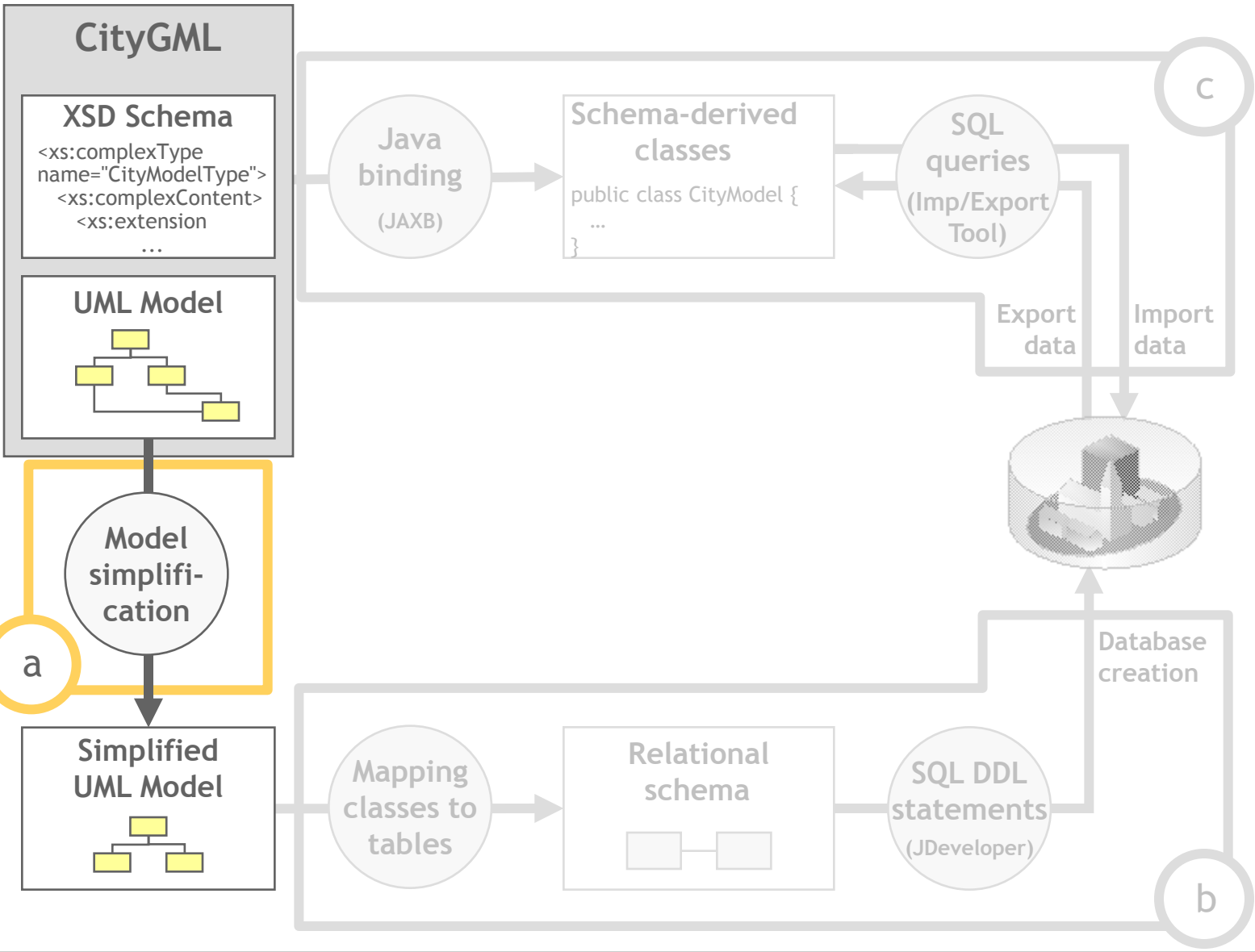
Functionality of the 3D City Database



Development cycle of the 3D City Database



Development cycle of the 3D City Database



Simplifications of CityGML's data model

- CityGML = Application independent Geospatial Information Model
  - Thematic model covers a broad range of application fields
  - Complex aggregations/relations within thematic modules
  - Comparable situation on the geometry level (GML3)

- Analysis of the requirements for the Berlin geo database:
  A simplified schema is already sufficient

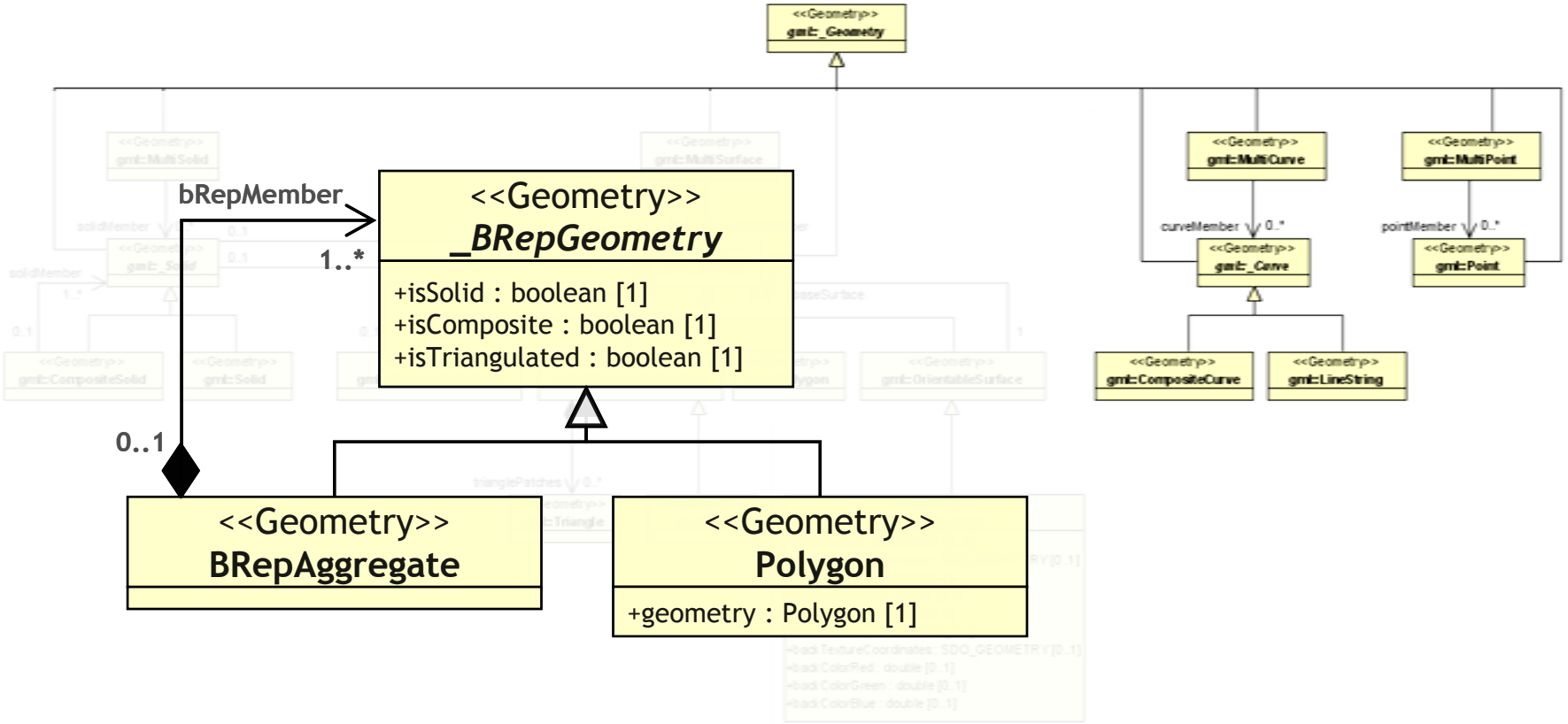
- Adaption of CityGML's data model
  - Simplification where possible → but still **99% compliant to CityGML**
  - Less number of database tables → simpler relational schema
  - Allows for more efficient querying/processing of database content

Examples for model simplification

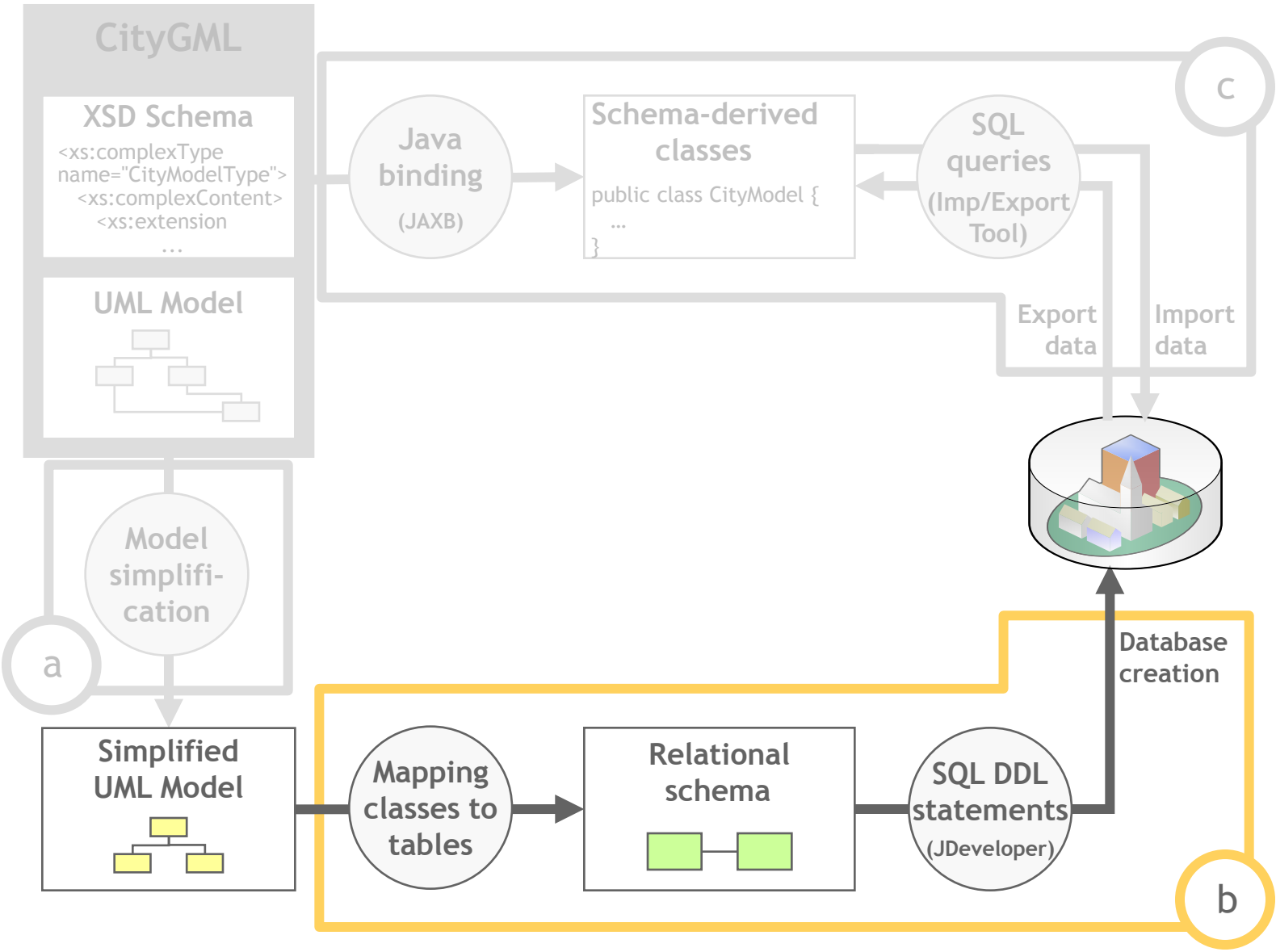
- Multiplicities of attributes — **0..* → 0..1**
- Cardinalities of associations (and also type of associations) — **n:m → 1:n resp. n:1**; **aggregation → composition**
- Recursive aggregations — **parent-id und root-id**
- Conversion of data types — **gml:CodeType, app:Color → String**; **GML geometry → SDO_GEOMETRY**
- Project specific classes and attributes — **Orthophotos, Address information, Metadata**

Simplifications of CityGML's geometry model

- CityGML is implemented as GML3 application schema
  - Only a subset of GML3 geometry classes is supported (straight lines, planar surfaces)

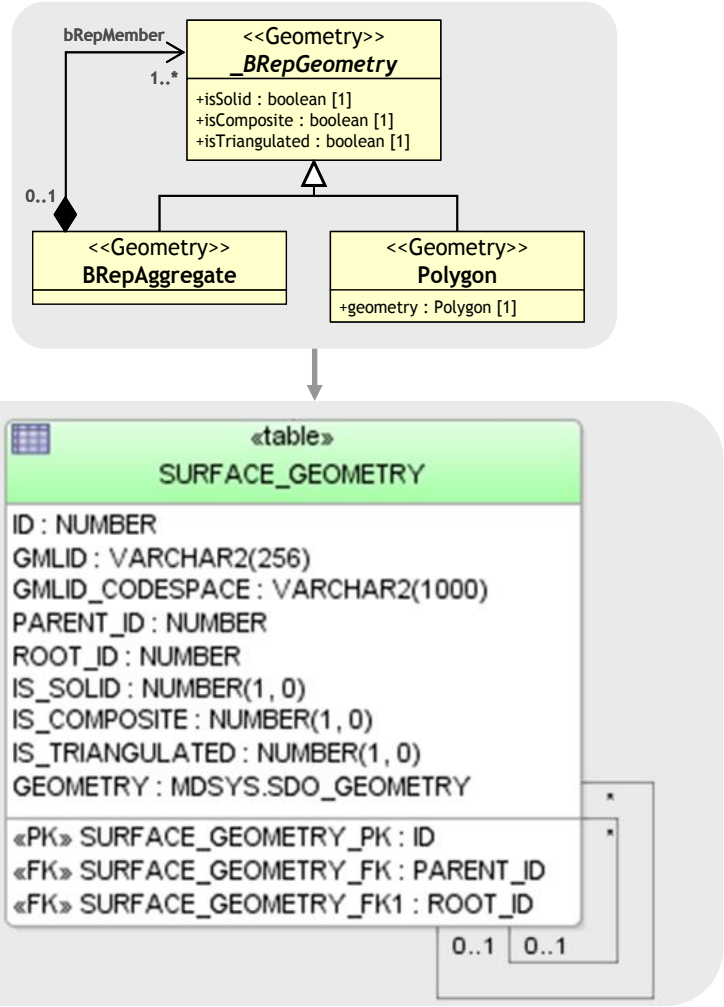


Derivation of the relational database schema



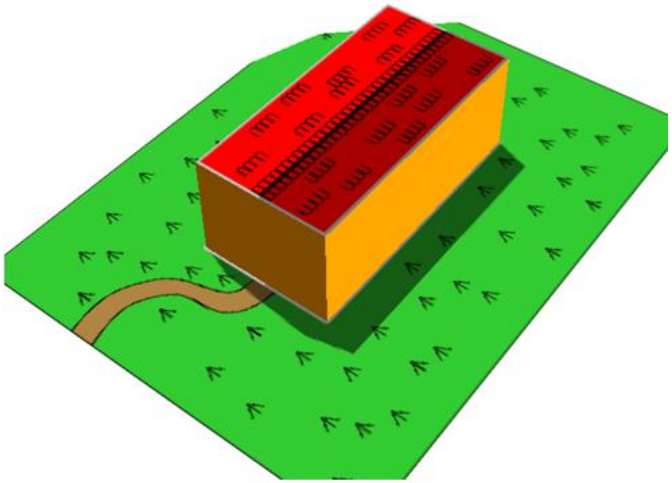
Derivation of the relational database schema

- Realisation of geometry model



GML3 Geometry	isSolid	isComposite	isTriangulated	Oracle Geometry
Polygon, Triangle, Rectangle	0	0	0	SDO_GEOMETRY
MultiSurface	0	0	0	NULL
Composite Surface	0	1	0	NULL
Triangulated Surface	0	0	1	NULL
Solid	1	0	0	NULL
MultiSolid	0	0	0	NULL
Composite Solid	1	1	0	NULL

Geometry representation

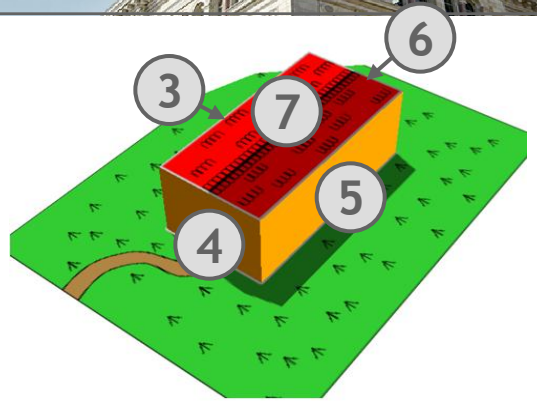


LOD1 building with appearance information

Representation in 3D geo database?

Geometry representation

```
<bldg:lod1Solid>
 <gml:Solid>
  <gml:exterior>
   <gml:CompositeSurface gml:id="lod1Surface">
    <gml:surfaceMember>
     <gml:Polygon gml:id="Left1">
      <gml:exterior>
       <gml:LinearRing gml:id="LeftRing1">
        <gml:posList srsDimension="3"> 0.0 0.0 0.0 10.0
         0.0 0.0 10.0 0.0 4.0 0.0 0.0 4.0 0.0 0.0 0.0
        </gml:posList>
       </gml:LinearRing>
      </gml:exterior>
     </gml:Polygon>
    </gml:surfaceMember>
    ...
    <gml:surfaceMember>
     <gml:Polygon gml:id="Roof1">
      <gml:exterior>
       <gml:LinearRing gml:id="RoofRing
        <gml:posList srsDimension="3">
         0.0 4.0 10.0 5.0 4.0 0.0 5.0 4
        </gml:posList>
       </gml:LinearRing>
      </gml:exterior>
     </gml:Polygon>
    </gml:surfaceMember>
   </gml:CompositeSurface>
  </gml:exterior>
 </gml:Solid>
</bldg:lod1Solid>
```

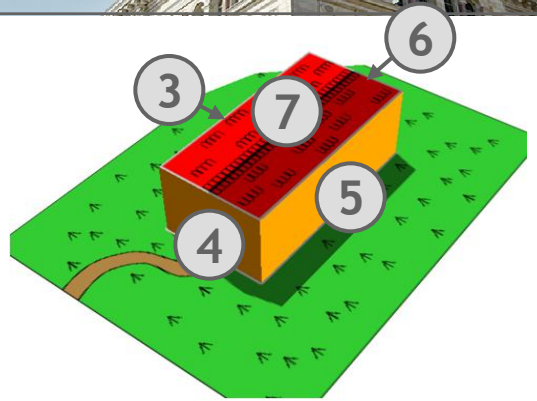


SURFACE_GEOMETRY

ID	GMLID	PARENT_ID	ROOT_ID	IS_SOLID	IS_COMPOSITE	GEOMETRY
1	UUID		1	1	0	
2	lod1Surface	1	1	0	1	
3	Left1	2	1	0	0	SDO_GEOMETRY
4	Front1	2	1	0	0	SDO_GEOMETRY
5	Right1	2	1	0	0	SDO_GEOMETRY
6	Back1	2	1	0	0	SDO_GEOMETRY
7	Roof1	2	1	0	0	SDO_GEOMETRY

Geometry representation

```
<bldg:lod1Solid>
 <gml:Solid>
  <gml:exterior>
   <gml:CompositeSurface gml:id="lod1Surface">
    <gml:surfaceMember>
     <gml:Polygon gml:id="Left1">
      <gml:exterior>
       <gml:LinearRing gml:id="LeftRing1">
        <gml:posList srsDimension="3"> 0.0 0.0 0.0 10.0
         0.0 0.0 10.0 0.0 4.0 0.0 0.0 4.0 0.0 0.0 0.0
        </gml:posList>
       </gml:LinearRing>
      </gml:exterior>
     </gml:Polygon>
    </gml:surfaceMember>
    ...
    <gml:surfaceMember>
     <gml:Polygon gml:id="Roof1">
      <gml:exterior>
       <gml:LinearRing gml:id="RoofRing
        <gml:posList srsDimension="3">
         0.0 4.0 10.0 5.0 4.0 0.0 5.0 4
        </gml:posList>
       </gml:LinearRing>
      </gml:exterior>
     </gml:Polygon>
    </gml:surfaceMember>
   </gml:CompositeSurface>
  </gml:exterior>
 </gml:Solid>
</bldg:lod1Solid>
```

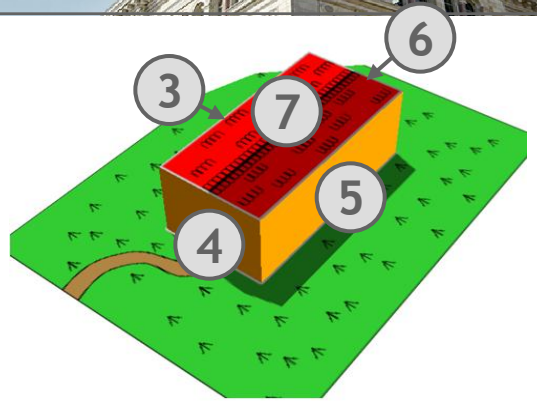


SURFACE_GEOMETRY

ID	GMLID	PARENT_ID	ROOT_ID	IS_SOLID	IS_COMPOSITE	GEOMETRY
1	UUID		1	1	0	
2	lod1Surface	1	1	0	1	
3	Left1	2	1	0	0	SDO_GEOMETRY
4	Front1	2	1	0	0	SDO_GEOMETRY
5	Right1	2	1	0	0	SDO_GEOMETRY
6	Back1	2	1	0	0	SDO_GEOMETRY
7	Roof1	2	1	0	0	SDO_GEOMETRY

Geometry representation

```
<bldg:lod1Solid>
 <gml:Solid>
  <gml:exterior>
   <gml:CompositeSurface gml:id="lod1Surface">
    <gml:surfaceMember>
     <gml:Polygon gml:id="Left1">
      <gml:exterior>
       <gml:LinearRing gml:id="LeftRing1">
        <gml:posList srsDimension="3"> 0.0 0.0 0.0 10.0
         0.0 0.0 10.0 0.0 4.0 0.0 0.0 4.0 0.0 0.0 0.0
        </gml:posList>
       </gml:LinearRing>
      </gml:exterior>
     </gml:Polygon>
    </gml:surfaceMember>
    ...
    <gml:surfaceMember>
     <gml:Polygon gml:id="Roof1">
      <gml:exterior>
       <gml:LinearRing gml:id="RoofRing
        <gml:posList srsDimension="3">
         0.0 4.0 10.0 5.0 4.0 0.0 5.0 4
        </gml:posList>
       </gml:LinearRing>
      </gml:exterior>
     </gml:Polygon>
    </gml:surfaceMember>
   </gml:CompositeSurface>
  </gml:exterior>
 </gml:Solid>
</bldg:lod1Solid>
```

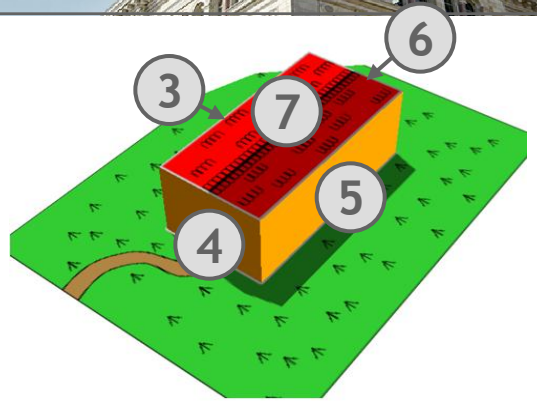


SURFACE_GEOMETRY

ID	GMLID	PARENT_ID	ROOT_ID	IS_SOLID	IS_COMPOSITE	GEOMETRY
1	UUID		1	1	0	
2	lod1Surface	1	1	0	1	
3	Left1	2	1	0	0	SDO_GEOMETRY
4	Front1	2	1	0	0	SDO_GEOMETRY
5	Right1	2	1	0	0	SDO_GEOMETRY
6	Back1	2	1	0	0	SDO_GEOMETRY
7	Roof1	2	1	0	0	SDO_GEOMETRY

Geometry representation

```
<bldg:lod1Solid>
 <gml:Solid>
  <gml:exterior>
   <gml:CompositeSurface gml:id="lod1Surface">
    <gml:surfaceMember>
     <gml:Polygon gml:id="Left1">
      <gml:exterior>
       <gml:LinearRing gml:id="LeftRing1">
        <gml:posList srsDimension="3"> 0.0 0.0 0.0 10.0
         0.0 0.0 10.0 0.0 4.0 0.0 0.0 4.0 0.0 0.0 0.0
        </gml:posList>
       </gml:LinearRing>
      </gml:exterior>
     </gml:Polygon>
    </gml:surfaceMember>
    ...
    <gml:surfaceMember>
     <gml:Polygon gml:id="Roof1">
      <gml:exterior>
       <gml:LinearRing gml:id="RoofRing
        <gml:posList srsDimension="3">
         0.0 4.0 10.0 5.0 4.0 0.0 5.0 4
        </gml:posList>
       </gml:LinearRing>
      </gml:exterior>
     </gml:Polygon>
    </gml:surfaceMember>
   </gml:CompositeSurface>
  </gml:exterior>
 </gml:Solid>
</bldg:lod1Solid>
```



SURFACE_GEOMETRY

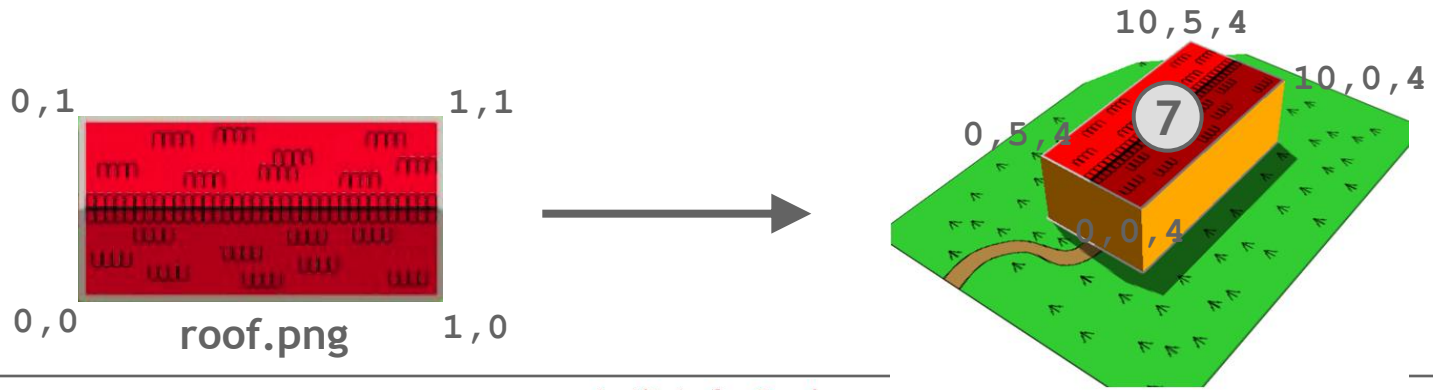
ID	GMLID	PARENT_ID	ROOT_ID	IS_SOLID	IS_COMPOSITE	GEOMETRY
1	UUID		1	1	0	
2	lod1Surface	1	1	0	1	
3	Left1	2	1	0	0	SDO_GEOMETRY
4	Front1	2	1	0	0	SDO_GEOMETRY
5	Right1	2	1	0	0	SDO_GEOMETRY
6	Back1	2	1	0	0	SDO_GEOMETRY
7	Roof1	2	1	0	0	SDO_GEOMETRY

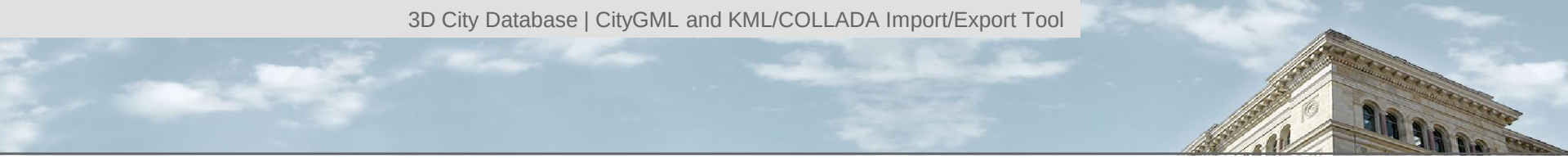
Assignment of surface appearances

```
<app:appearanceMember>
 <app:Appearance>
  <app:theme>Summer</app:theme>
   …
  <app:surfaceDataMember>
   <app:ParameterizedTexture gml:id="roofTexture">
    <app:imageURI>roof.png</app:imageURI>
    <app:wrapMode>wrap</app:wrapMode>
    <app:target uri="#Roof1">
     <app:TexCoordList>
      <app:textureCoordinates ring="#RoofRing1">
       0.0 0.0 1.0 0.0 1.0 1.0 0.0 1.0 0.0 0.0
      </app:textureCoordinates>
     </app:TexCoordList>
    </app:target>
   </app:ParameterizedTexture>
  </app:surfaceDataMember>
  …
 </app:Appearance>
</app:appearanceMember>
```

TEXTUREPARAM

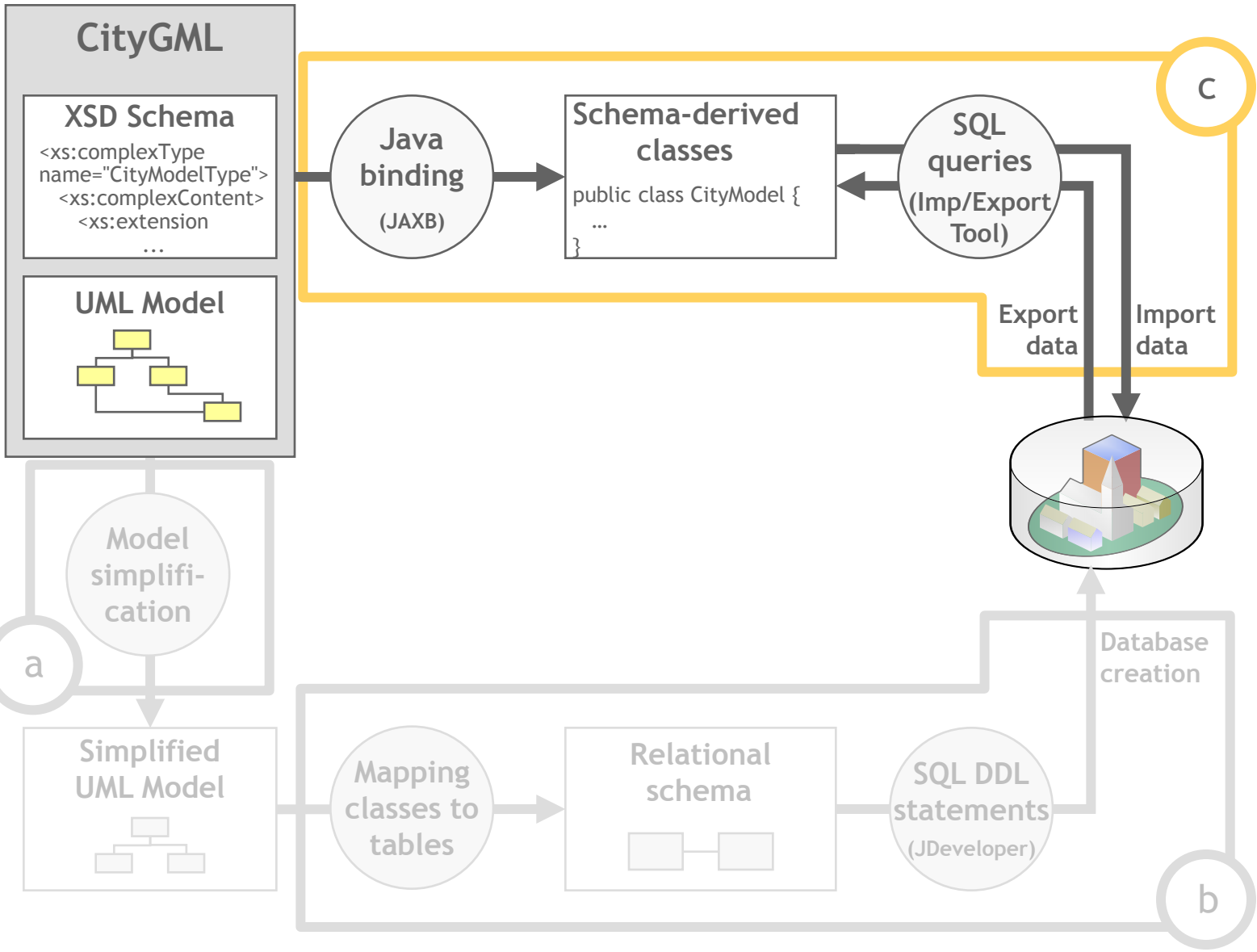
SURFACE_GEOMETRY_ID	IS_TEXTURE_PARAMETRIZATION	WORLD_TO_TEXTURE	TEXTURE_COORDINATES	SURFACE_DATA_ID
7	1	-	0.0 0.0 1.0 0.0 1.0 1.0 0.0 1.0 0.0 0.0	x
…				



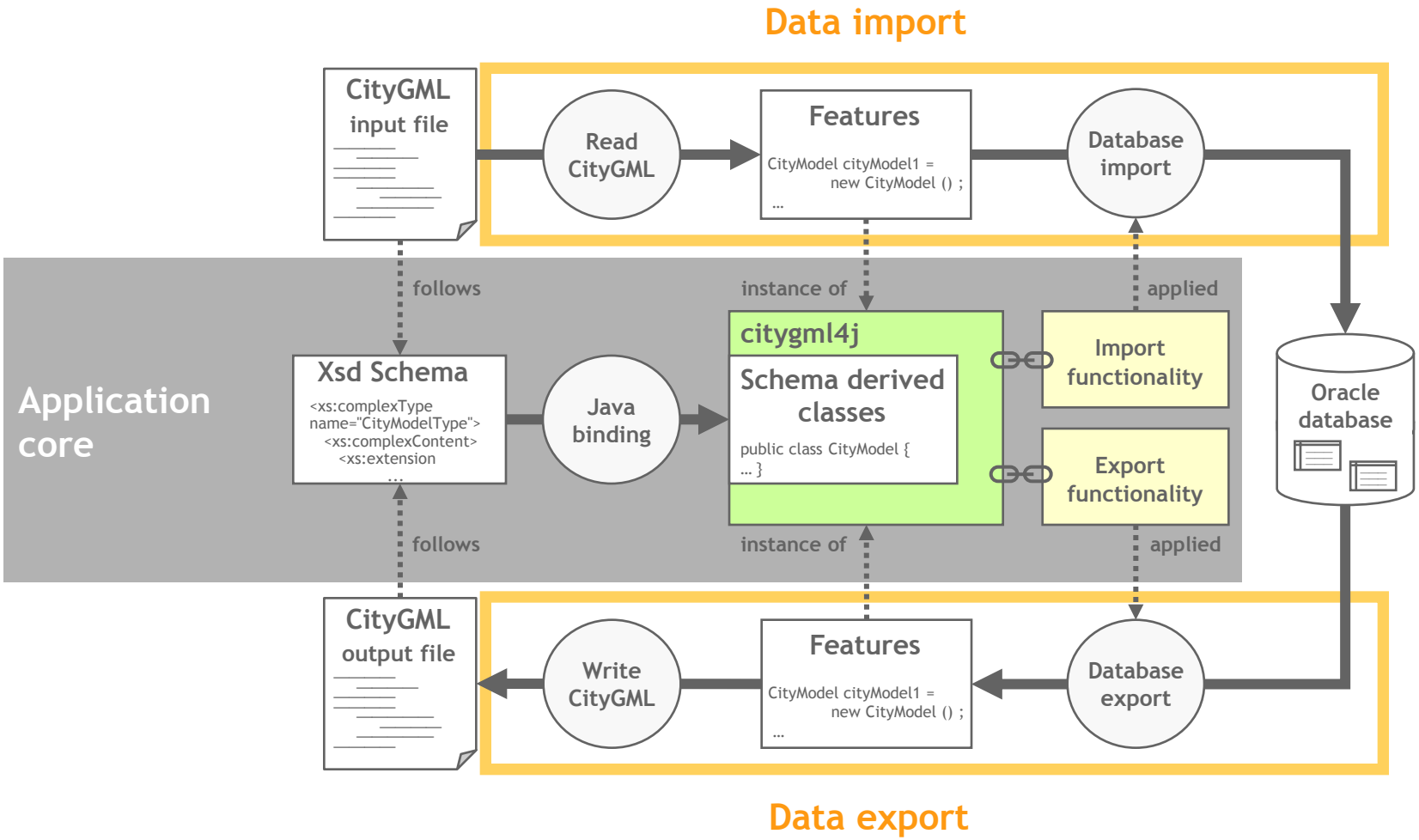


3D City Database
CityGML Import/Export Tool

Creation of an Import/Export Tool



Creation of an Import/Export Tool : Overview



(Some) Characteristics of the Import/Export Tool

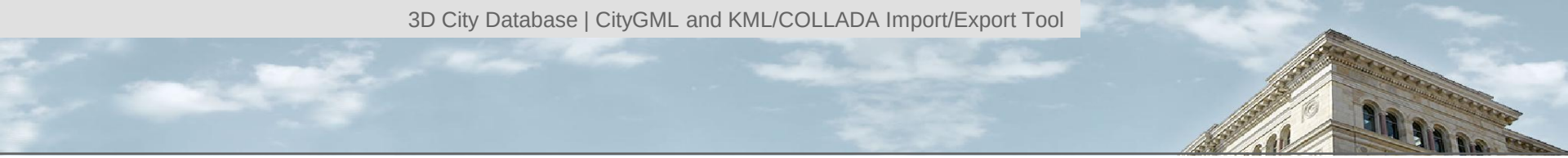
- Support for CityGML files of arbitrary size (>>4GB)
- Concurrency of data processing through multithreading
  - High performance on standard platforms
- Matching functionality
  - Identify and merge corresponding representations of the same building object within the database
- Support for XLink references (also within BRep geometries)
- Filter options enable user-defined import and export
  - GML ID, GML name
  - Bundled import and export for data tiling (classified by IDs or Bounding Boxes)
  - Selection of object classes

Performance data

- All tests executed on an Intel® Xeon® QuadCore, Win7 64-Bit, 12 GB RAM.
- 3DCityDB Server: 2 Intel® Xeon® QuadCore, Enterprise Linux RedHat (Kernel: 2.6.18) , 32 GB RAM, 4 SAS disks (146 GB) and 16 SSD disks (64GB), Oracle 10.2.0.4.0

City Model	Size in GB	LoDs	Import time without Textures
Cologne	7.71	LoD1	37 Min
Berlin	6.23	LoD2, LoD3	20 Min

City Model	Size in GB	LoDs	Export time without Textures
Cologne	7.71	LoD1	12 Min
Berlin	6.23	LoD2, LoD3	8 Min



3D City Database
Import/Export Tool Demo

What is available?

http://opportunity.bv.tu-berlin.de/software

- **3D City Database (current version 2.0.3)**
  - Oracle SQL scripts and PL/SQL functions
  - Comprehensive documentation
- **3D City Database Import/Export Tool (current version 1.2.2)**
  - Executable Java binaries
  - Complete source code
  - Comprehensive documentation
  - **KML/COLLADA exporter to be released in 2nd quarter 2011**
- **citygml4j (current version 1.0)**
  - Java class library and API for reading and writing CityGML datasets
  - Library files for Java5 and Java6
  - Source code, comprehensive documentation, tutorials