CityGML 3.0

Tatjana Kutzner, Thomas H. Kolbe

Chair of Geoinformatics
Technical University of Munich

The 120th OGC Member Meeting

15 September 2021

The world's leading and comprehensive community of experts making location information:

- Findable
- Accessible
- Interoperable
- Reusable

City Geography Markup Language – CityGML

Application independent Geospatial Information Model
for semantic 3D city and landscape models

- comprises **different thematic areas** (buildings, vegetation, water, terrain, traffic, tunnels, bridges etc.)
- **Data model (UML) + Exchange format** (based on GML3)

CityGML represents

- 3D geometry, 3D topology, semantics, and appearance
- in 4 discrete scales (Levels of Detail, LOD)

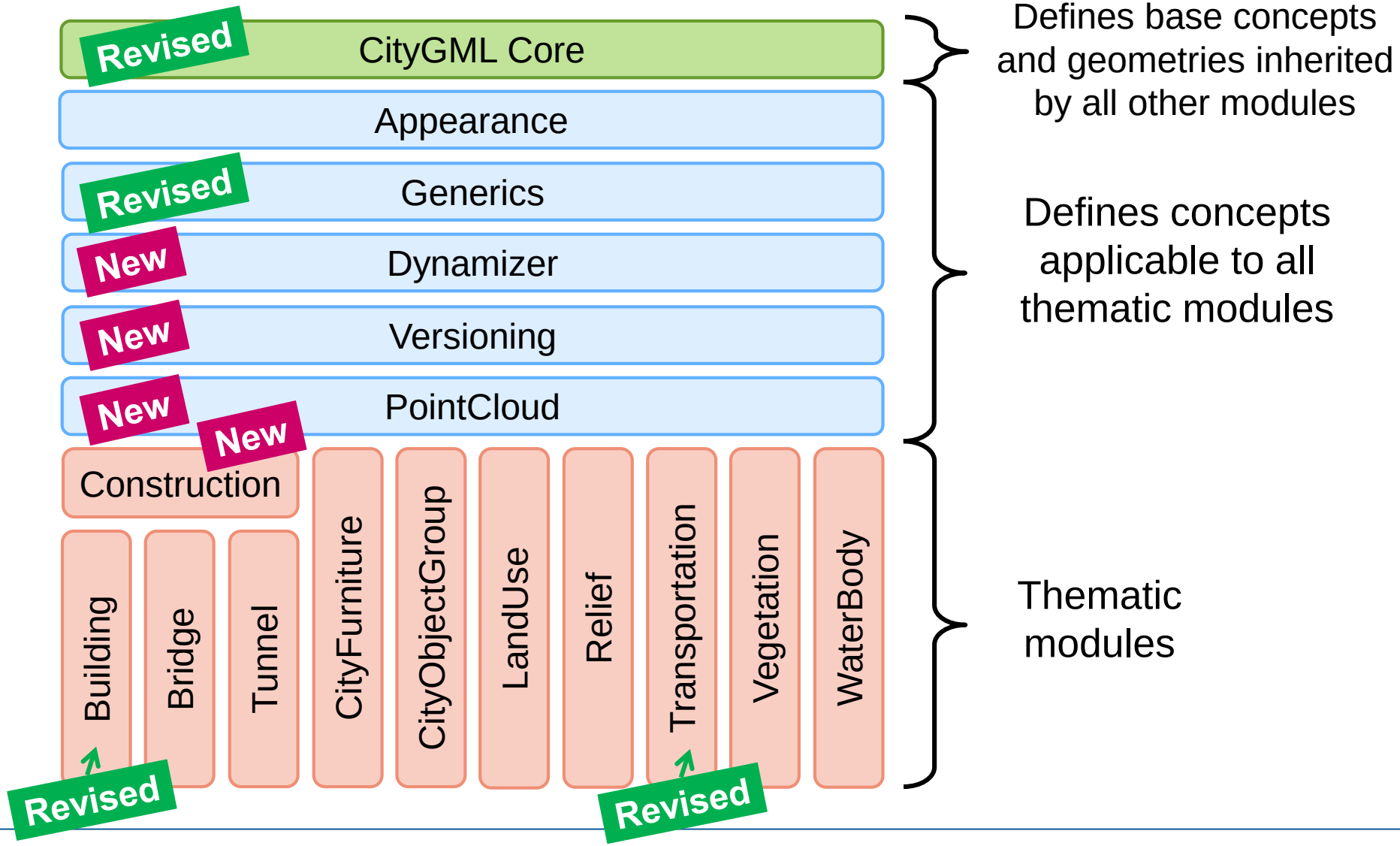
International Standard of the Open Geospatial Consortium

- Version 2.0.0 was adopted in 3/2012
- **Version 3.0 was released on 14 September 2021**

Characteristics of CityGML 3.0

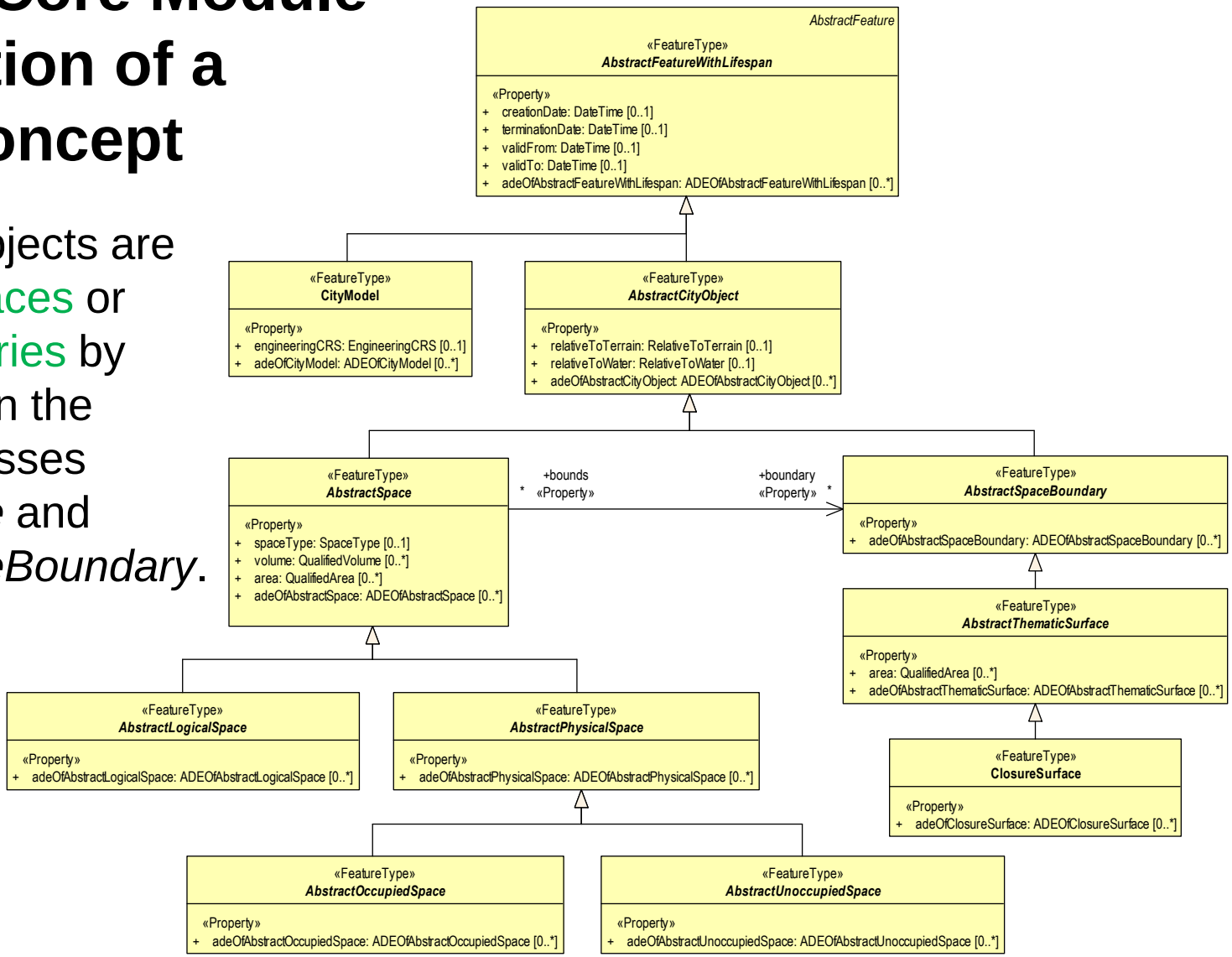
- **New and revised modules**: Improved support for using 3D city models in urban planning, simulations and analyses; IoT; Smart Cities
- **Less redundancy**: Concepts used in several modules are integrated and provided centrally via inheritance
- All city objects are based on **two new central concepts**: Spaces and SpaceBoundaries, all geometries are associated with them
- **Better interoperability** with other standards (IndoorGML, IFC, RDF, LADM, INSPIRE)
- **Model-driven approach**: ISO-compliant UML model + automatic derivation of exchange formats
  - At least two specifications: - CityGML 3.0 Conceptual Model specification
    - CityGML 3.0 GML Implementation specification
- **Backwards compatibility** with CityGML 1.0 and 2.0

CityGML 3.0 Module Overview

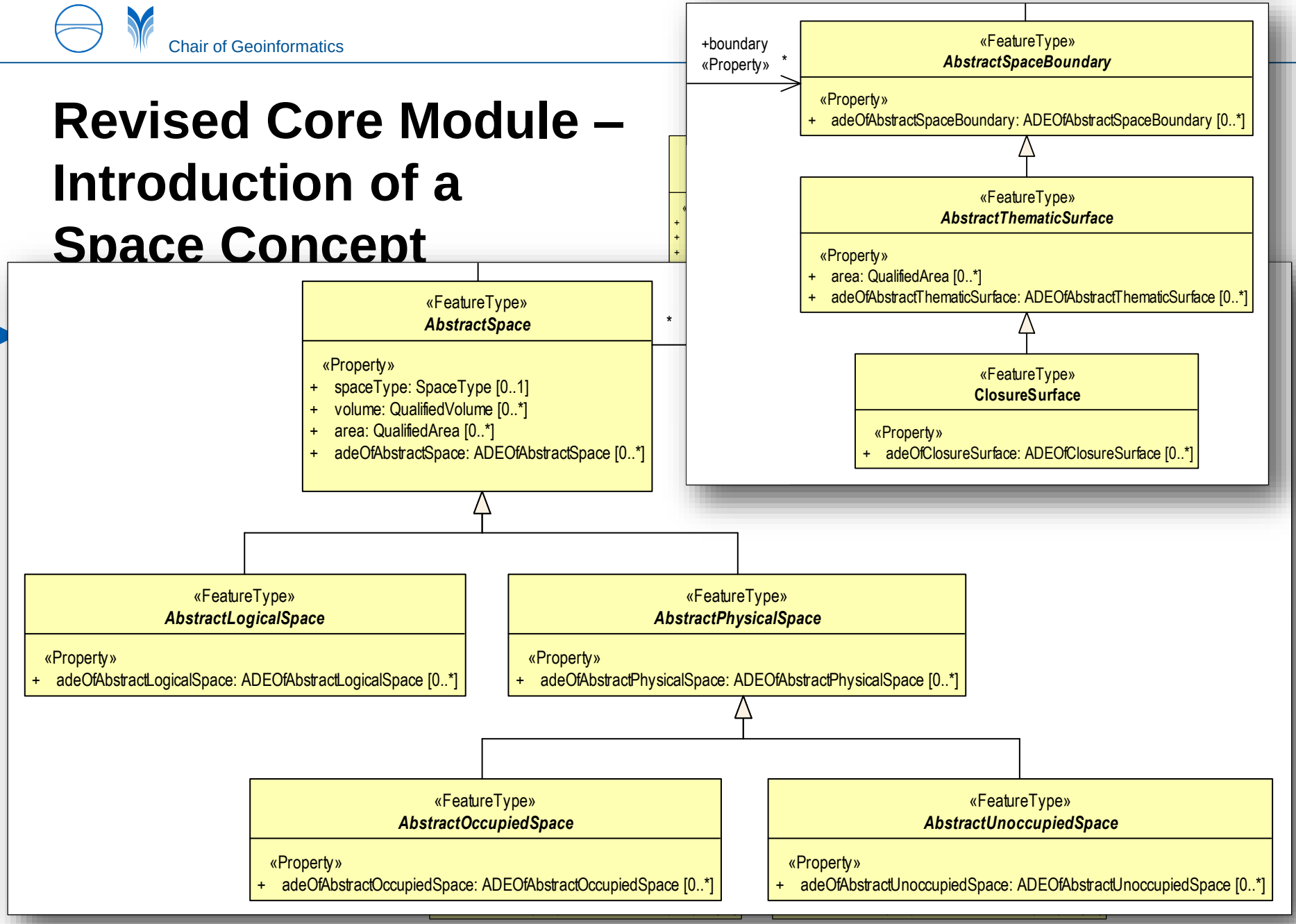


Revised Core Module – Introduction of a Space Concept

- All thematic objects are now either spaces or space boundaries by basing them on the two pivotal classes *AbstractSpace* and *AbstractSpaceBoundary*.

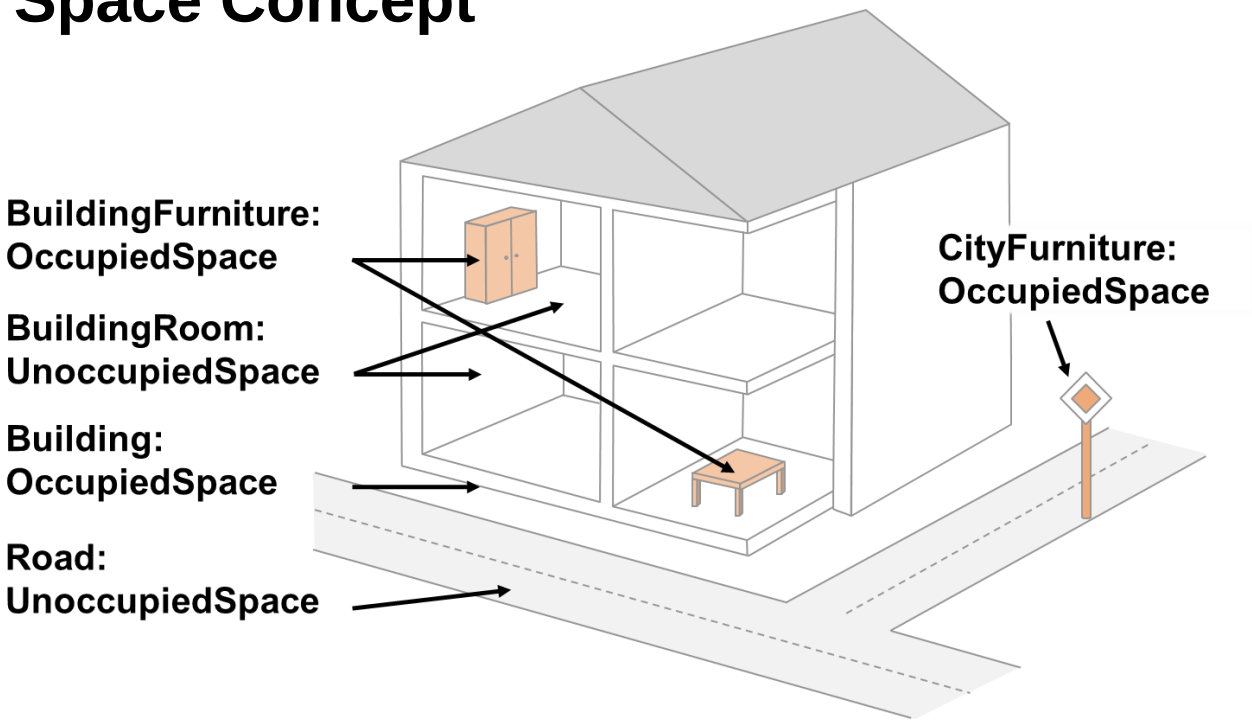


Revised Core Module – Introduction of a Space Concept



Advantages of the Space Concept

- Supports the **analysis of navigable spaces** (e.g. to generate IndoorGML data from CityGML)

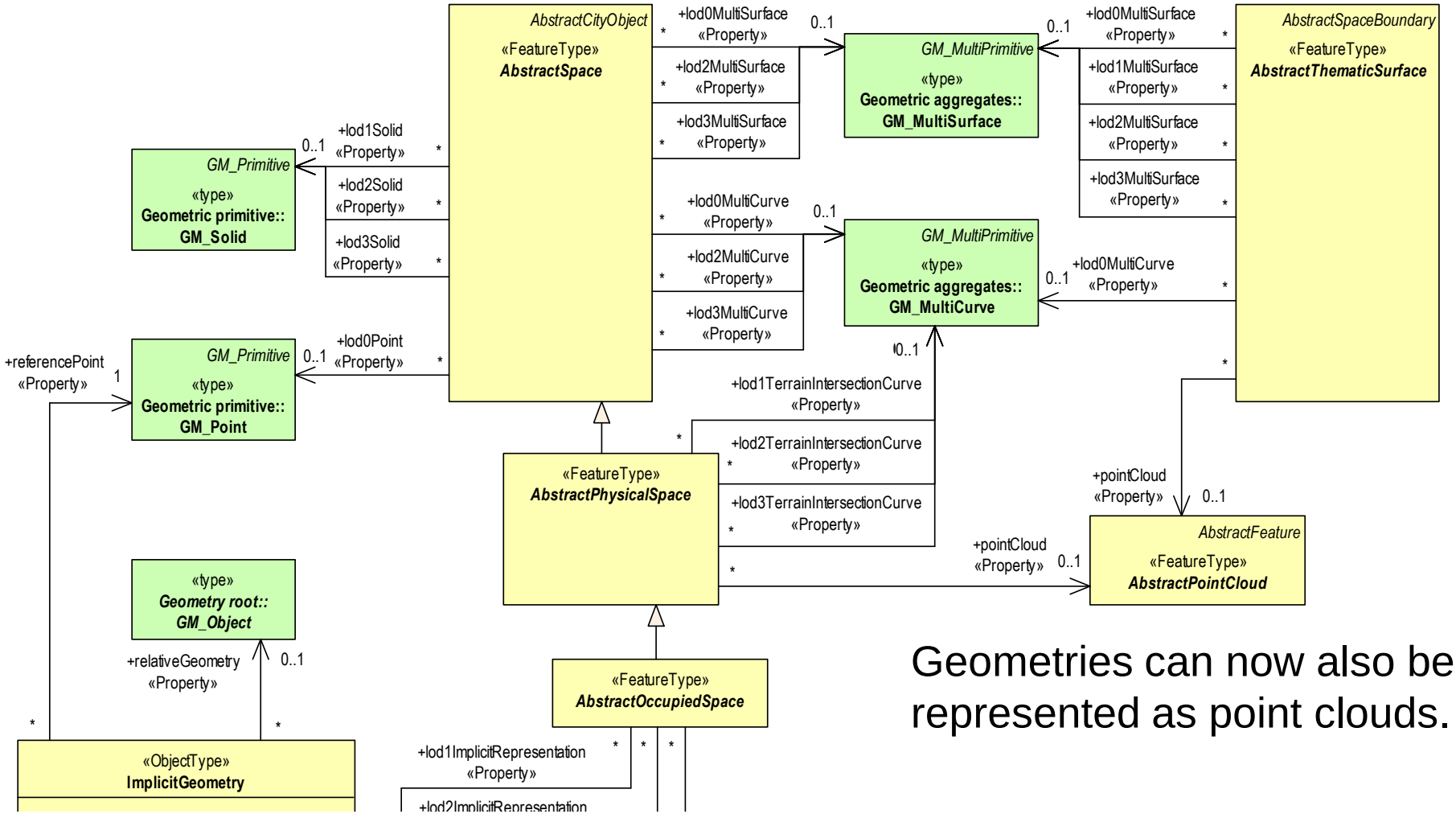


- Supports the **expression of explicit topological, geometrical, and thematic relations** between
  spaces and spaces, spaces and space boundaries, and space boundaries and space boundaries

- Practitioners and developers do not see much of the space concept, because the space and space boundary classes are just abstract classes. **Only elements representing objects from concrete subclasses** such as Building, BuildingRoom, or TrafficSpace **will appear in CityGML files**.

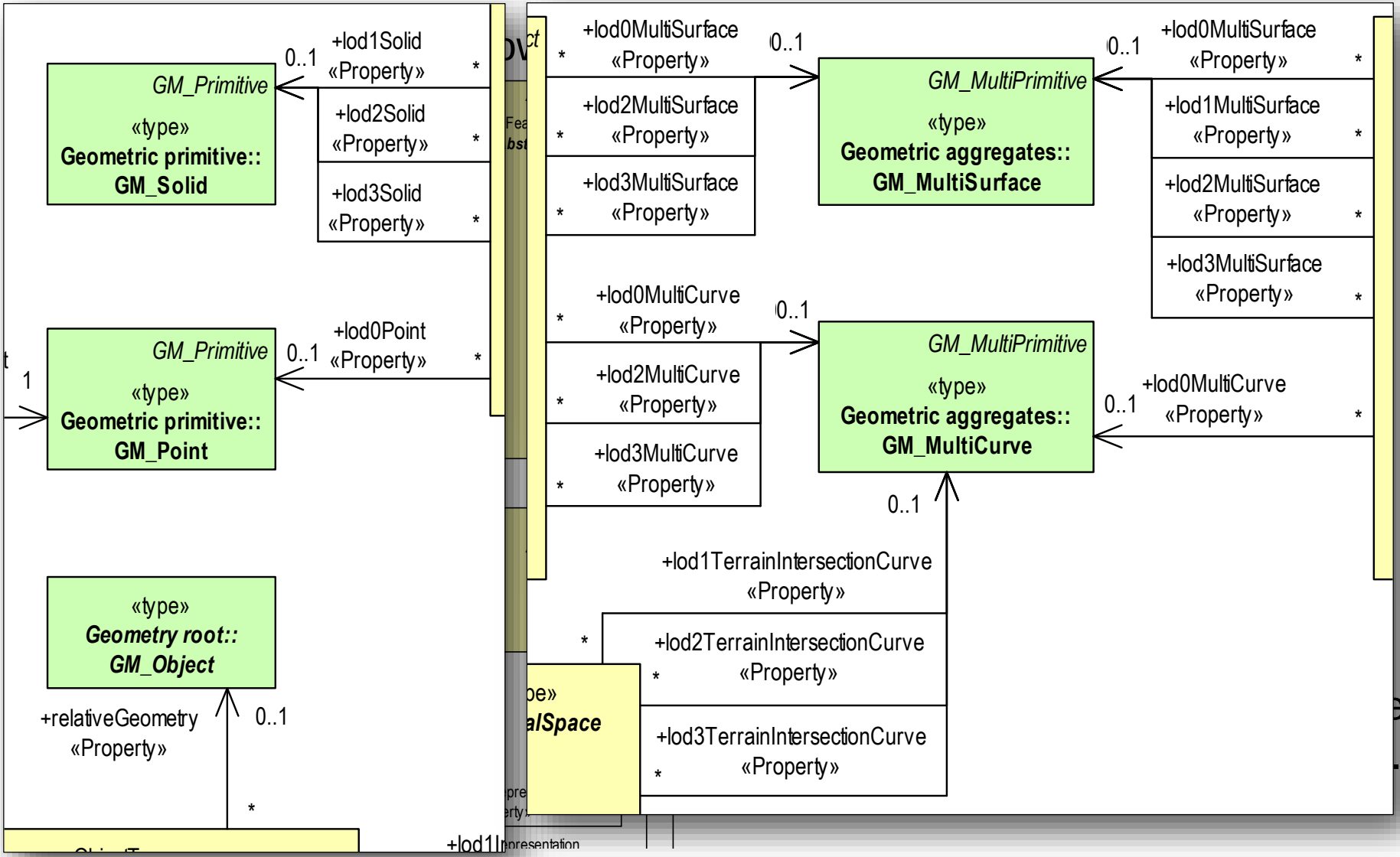
Revised Core Module – Geometry and LOD Concept

- The LOD concept is now part of the Core module → less redundancy

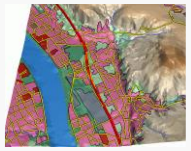


Geometries can now also be represented as point clouds.

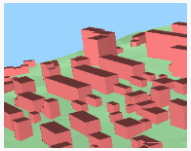
Revised Core Module – Geometry and LOD Concept



New LOD concept: 4 levels of details



LOD0 – Regional, landscape model **+ interior**
- 2.5D Digital terrain model



LOD1 – City, regional model
- Prismatic buildings without roof structures **+ interior**

LOD2 – City districts, site model
- Simple buildings with detailed roof structures **+ interior**

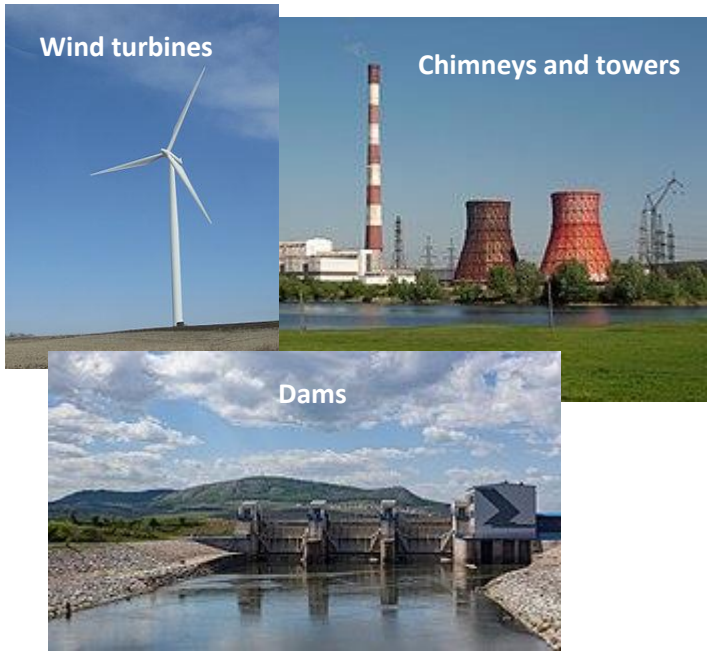
LOD3 – Architectural models (exterior) **+ interior**
- Detailed architectural models

LOD4 – Architectural models (interior)
- "Walkable" architectural models

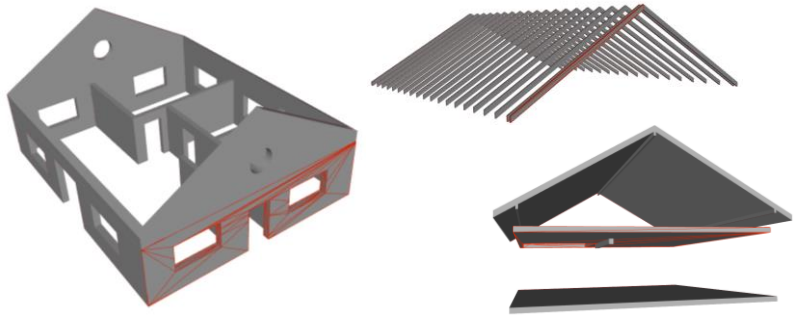
- CityGML 3.0 allows for representing the interior of buildings, tunnels and bridges in LODs 0-3 as well.
  → E.g., the exterior can now be modelled in LOD1, whereas the interior is represented in LOD2 or 3
- Supports the use of 3D city models in applications which require detailed representations of the indoor, but not necessarily of the outdoor, e.g. indoor navigation and energy applications.

Improved representation of constructions

- Better representation of constructions that are neither buildings, tunnels, nor bridges (“**other constructions**”)

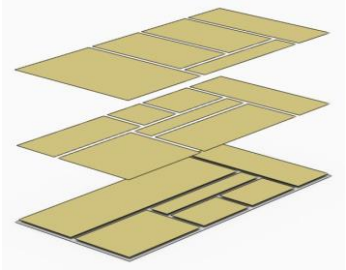


- Improved **BIM/GIS interoperability**
  - IFC objects can be converted to CityGML 3.0 BuildingConstructiveElements

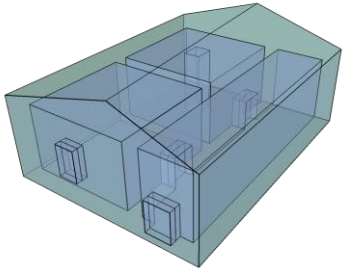


- **Revised LOD concept**
  - Allows for indoor modelling in different LODs

LOD0 Floor plans



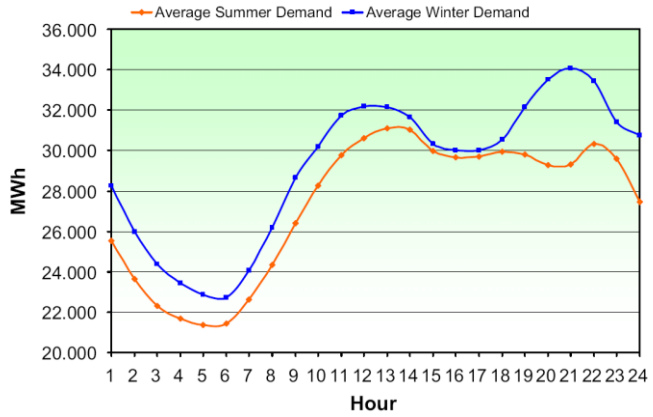
LOD1 Rooms
LOD2 Building



- Billwhittaker at English Wikipedia (https://commons.wikimedia.org/wiki/File:Wind_turbine_walnut_iowa.jpg), „Wind turbine walnut iowa“, https://creativecommons.org/licenses/by-sa/3.0/legalcode
- Tadeáš Bednarz (https://commons.wikimedia.org/wiki/File:Nové_Mlýny_Reservoir_-_Dam_2020_07.jpg), https://creativecommons.org/licenses/by-sa/4.0/legalcode
- Chimney_and_two_hiperboloide_cooling_towers_on_Kharkov.JPG: Victor Vizu derivative work: kaвstn Disk/Cat (https://commons.wikimedia.org/wiki/File:Chimney_and_two_hiperboloide_cooling_towers_on_Kharkov-CN.jpg), „Chimney and two hiperboloide cooling towers on Kharkov-CN“, https://creativecommons.org/licenses/by-sa/3.0/legalcode
- Löwner, M. O., Gröger, G., Benner, J., Biljecki, F., & Nagel, C. (2016). Proposal for a new LOD and multi-representation concept for CityGML. ISPRS Annals of Photogramm. Remote Sens. Spatial Inf. Sci., IV-2/W1, 3–12. http://doi.org/10.5194/isprs-annals-IV-2-W1-3-2016

Changes in the context of semantic 3D city models – Highly dynamic changes

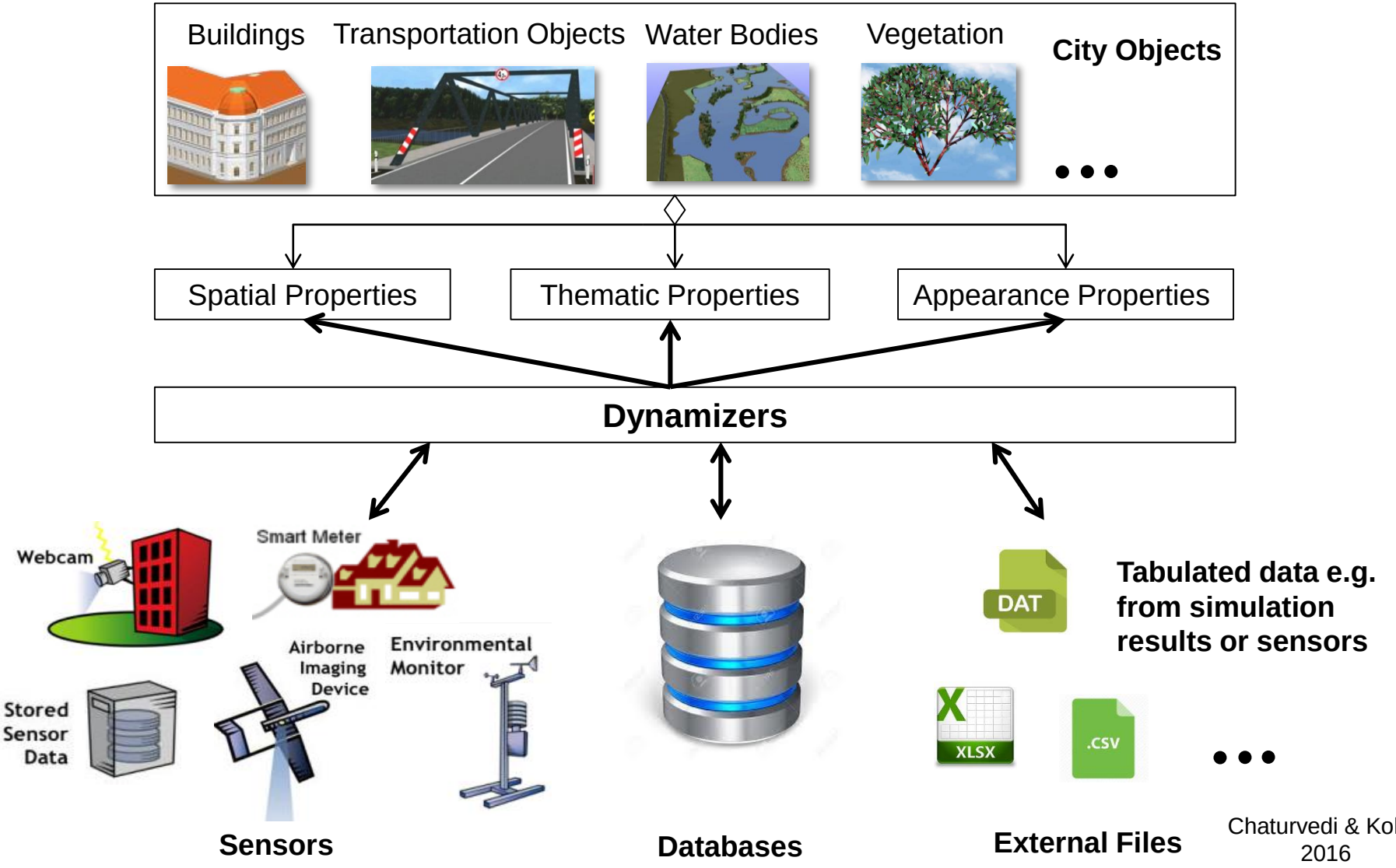
- **Variations of spatial properties**: change of a feature's geometry, both in respect to shape and to location (e.g. moving objects)
- **Variations of thematic attributes**: changes of physical quantities like energy demands, temperatures, solar irradiation
- **Appearance**: e.g. raster images showing air quality
- **Variations with respect to sensor or real-time data**



Source:C. García-Ascanio and C. Maté, "Electric power demand forecasting using interval time series: A comparison between VAR and iMLP,"*Energy Policy*

Source: MOREL M., GESQUIÈRE G., "Managing Temporal Change of Cities with CityGML". In UDMV (2014)

Dynamizers link Feature Properties with Timeseries Data



New Dynamizer module – Example Scenario

CityGML object

```
<bldg:WallSurface gml:id = "UUID_01_WS_1">
     <gen:doubleAttribute name = "globalRadMonth">
          <gen:value = xxx />
     </gen:doubleAttribute>
  </Building>
```

One dynamic attribute which changes with time

Replacing dynamic attributes using XPath

Simulation Results

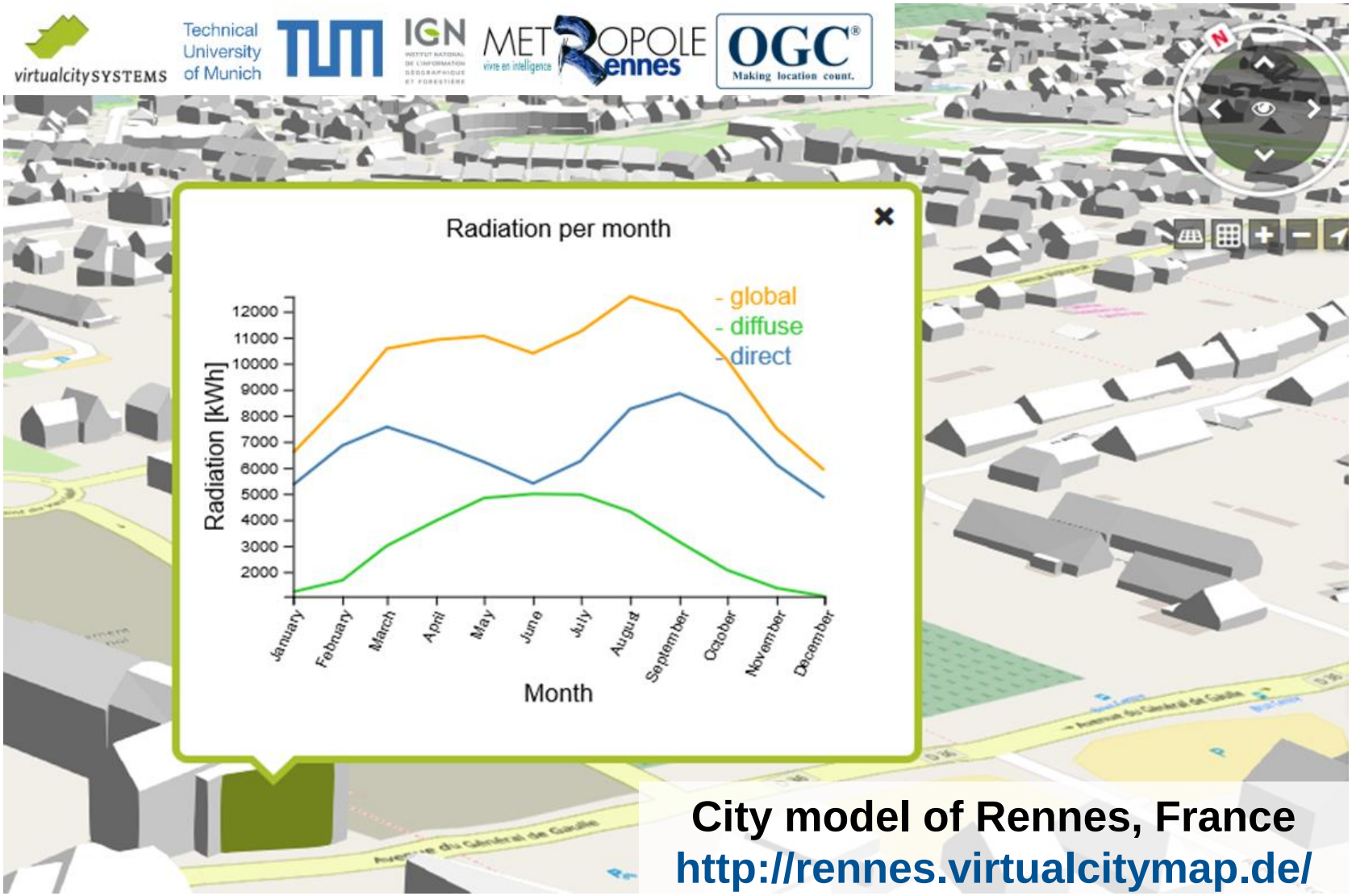
Month	Global Radiation
JAN-15	4293.446
FEB-15	5563.502
MAR-15	7010.33
. . .	. . .
DEC-15	4010.239

```
<cityObjectMember>
  <dyn:Dynamizer>
    <dyn:attributeRef> //bldg:WallSurface [@gml:id = 'UUID_01_WS_1']
                       /doubleAttribute[@name = 'globalRadMonth']
                       /gen:value
    </dyn:attributeRef>
    <dyn:startTime> 2015-01-01T00:00:00Z </dyn:startTime>
    <dyn:endTime> 2015-12-31T00:00:00Z </dyn:endTime>
    <dyn:dynamicData>.. </dyn:dynamicData>
  </dyn:Dynamizer>
</cityObjectMember>
```

Dynamizer

Respresenting data in standardized ways, such as OGC TimeseriesML, OGC Observations & Measurements

Dynamizer in OGC Future City Pilot Phase 1



City model of Rennes, France
http://rennes.virtualcitymap.de/

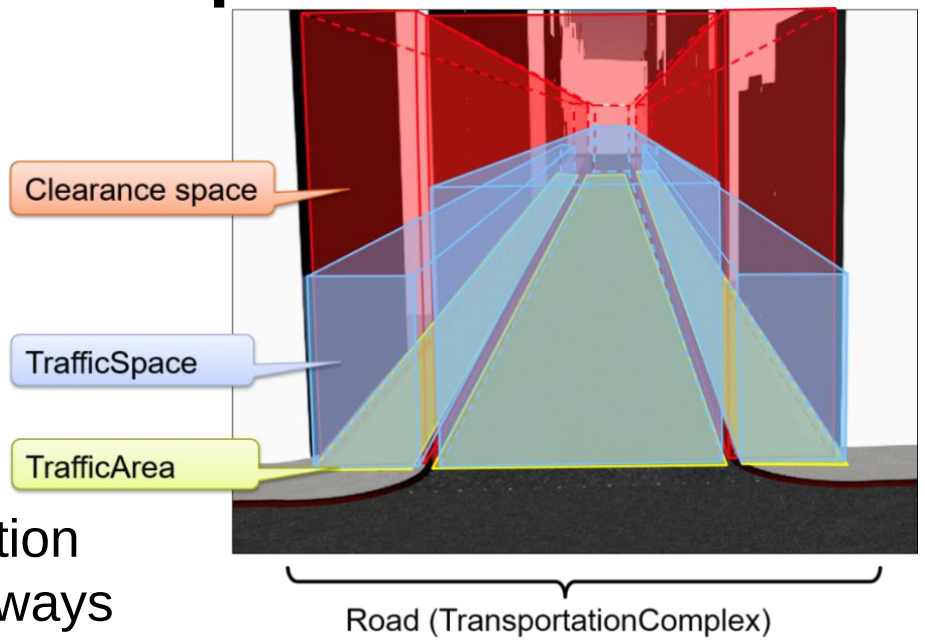
Changes in the context of semantic 3D city models

- **Slower changes**
  - History or evolution of cities/city models
  - Change of feature‘s geometry over time
  - Managing parallel or alternative versions over time
- New **Versioning Module:**
  - Explicit modeling of changes
  - Snapshots of city models at a specific point in time
  - All objects can have bitemporal lifespan data (date of creation / termination, valid from / valid to).
  - Multiple versions of city objects can be represented within one city model data set.

Image Source: www.pinterest.com

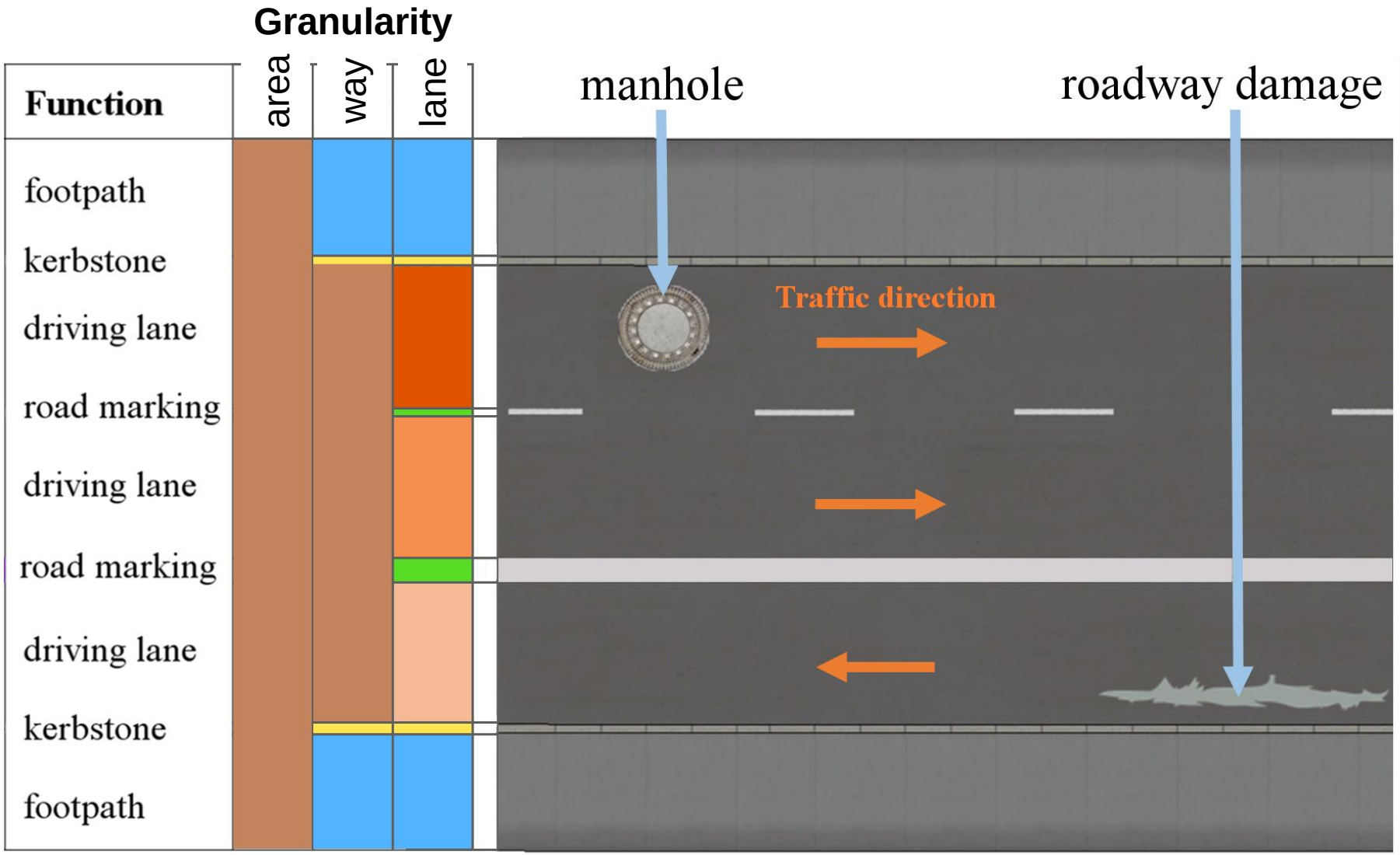
Changes in the CityGML Transportation Module

- Usage of the space concept
- Introduction of clearance space
- Introduction of waterways
- Introduction of (road) markings and holes
- Thematic separation of transportation objects like roads, railways, waterways into sections and intersections



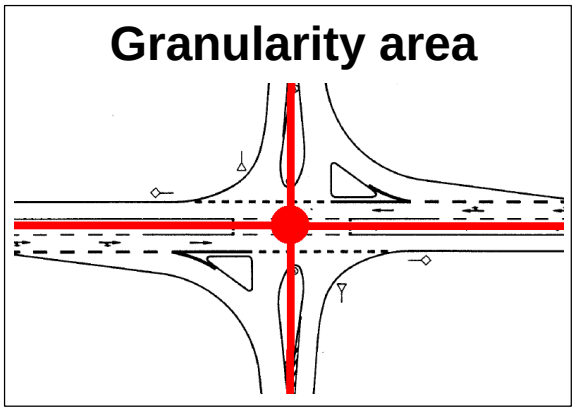
- Introduction of three granularities: area, way, lane
  - all transportation objects (roads, railways, waterways, tracks) can be represented in three granularities: area, way, lane
  - graph + areal representations for all three granularities
  - data on ‘lane’ granularity usable for traffic & training simulations

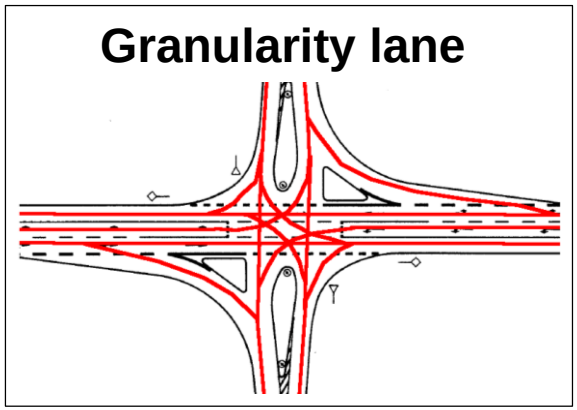
Street Space Modelling in three Granularities



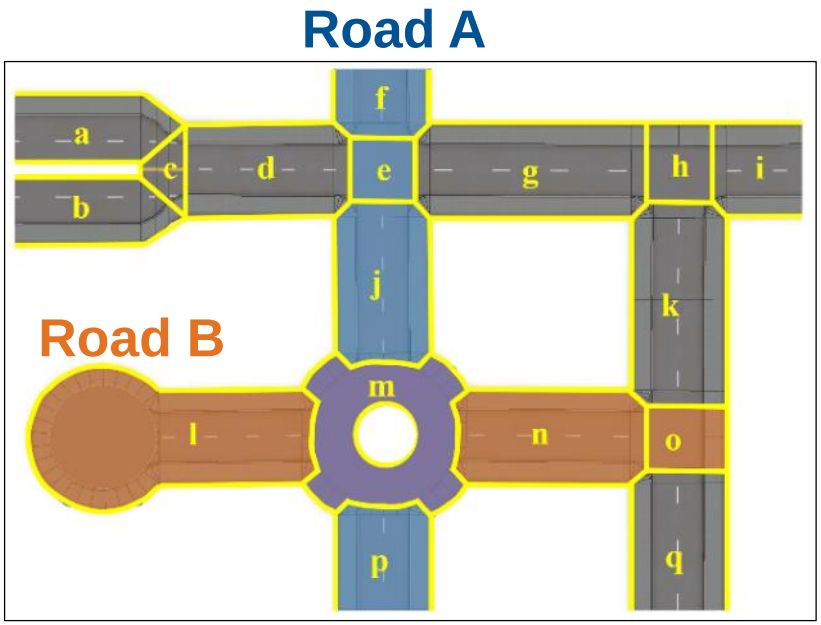
Revised Transportation module

- Introduction of linear / graph representation in multiple levels of granularity





- Segmentation of transportation objects into sections / intersections
  - One section per road / railway / waterway segment, dead end, …
  - Intersections belong to multiple transportation objects
    → Non-redundant geometries
    → Linking concept



Beil & Kolbe, 2020

Conclusions

- The new version CityGML 3.0 improves the use of 3D city models in different areas of application (urban planning, energy simulations, environmental simulations, traffic analyses, autonomous driving, Smart Cities, …)
  - Representation of dynamic data and linkage with Internet-of-Things (IoT)
- The new LOD concept allows for more flexibility in representing the interior and exterior of city objects + representing objects as point clouds
- The revised Core module and the new Construction module provide
  - better interoperability with other standards (IndoorGML, IFC, RDF, LADM, INSPIRE)
  - simplification of geometry handling
  - improved representation of physical and logical objects
- State-of-the art UML model generation including ISO-compliance + automatic derivation of exchange formats

Resources

CityGML 3.0 UML Diagrams:

- https://github.com/opengeospatial/CityGML-3.0CM

CityGML 3.0 XML Schema Files:

- https://github.com/opengeospatial/CityGML-3.0Encodings

Test data sets:

- Various test data sets that have been created by mapping publicly available CityGML 2.0 data sets to CityGML 3.0 (e.g. Rotterdam, Helsinki, KIT-Railway): https://1drv.ms/u/s!Ag_9VT-F89-7jlqoc77pjKmG-8VP?e=G551gC
- Test data sets for the Transportation module: https://github.com/tum-gis/citygml3.0-transportation-examples
- A test data set that makes use of the newly introduced class "BuildingConstructiveElement": https://github.com/tum-gis/ifc-to-citygml3

First Prototype Implementations and Tools

- All software tools that are able to read and process generic GML 3 application schemas can work directly with CityGML 3 application schemas as well
  - (e.g. FME, HALE, GDAL, Interactive Instruments WFS, Deegree, GALDOS WFS, CPA SupportGIS, FZKViewer)
- CityGML 3.0 was implemented and tested in practice at the OGC CityGML 3.0 Hackathon in June 2019 in London and at the CityGML Challenge in October 2019 in Manchester
- The Open Source Java API citygml4j has been ported by Claus Nagel for CityGML 3.0: github.com/clausnagel/citygml4j-devel
- Open Source Conversion Tool CityGML 2.0 → CityGML 3.0 (currently Building, CityFurniture & Appearance modules only): https://github.com/tum-gis/citygml2-to-citygml3
- IFC → CityGML 3.0 FME Workspace: https://github.com/tum-gis/ifc-to-citygml3