

Level of Detail in 3D city modelling

PhD research

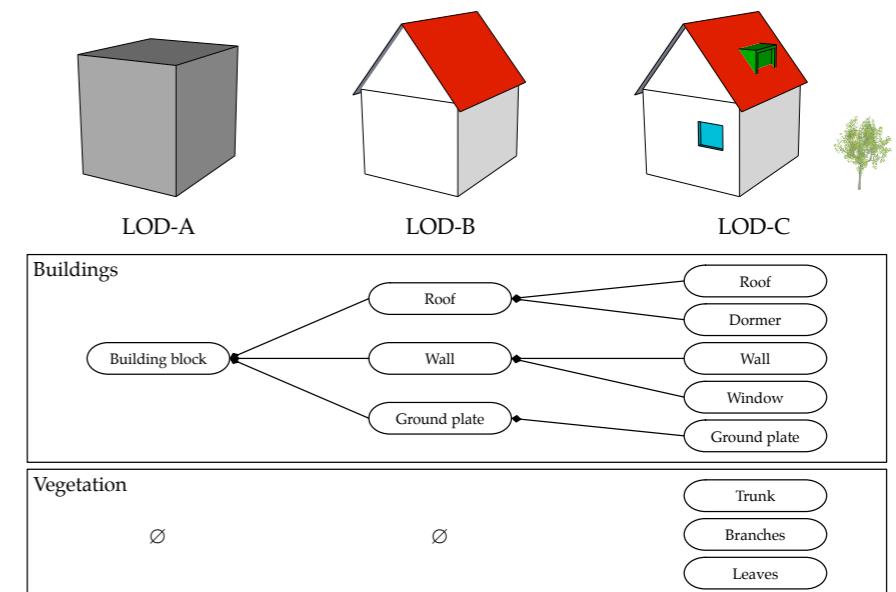
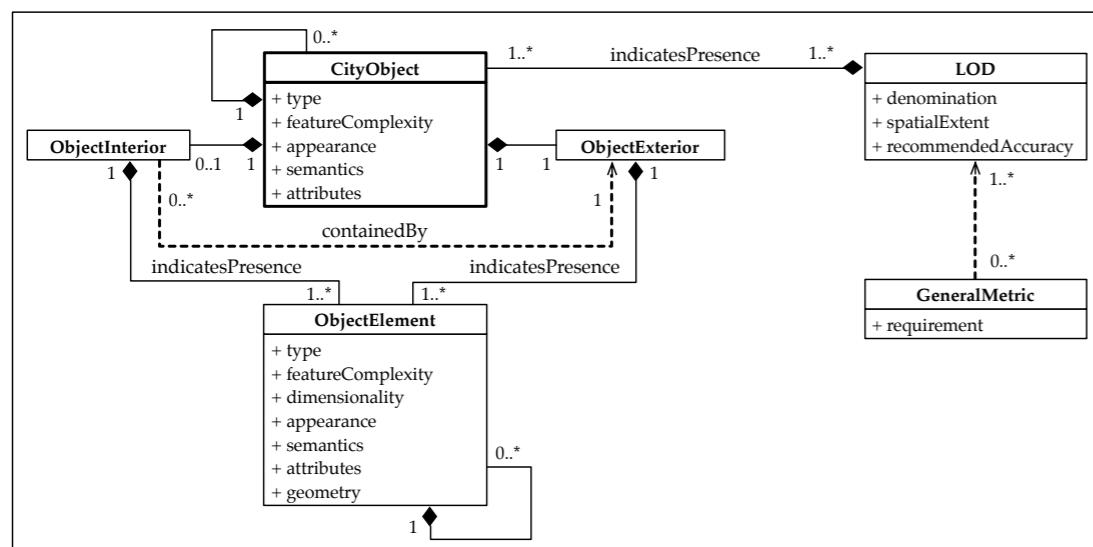
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2014-07-28
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Overview of the research

- Main aim: Improvement of the concept of LOD in 3D city modelling through a series of topics
(to be briefly presented in the next slides)
- Conducted at the Section GIS technology, TU Delft
- Supervisors: prof. dr. Jantien Stoter and dr. Hugo Ledoux
- Scheduled to end by late 2016
- Applies to 3D GIS in general, but it is focused towards CityGML, hence there is a possible contribution to CityGML 3.0

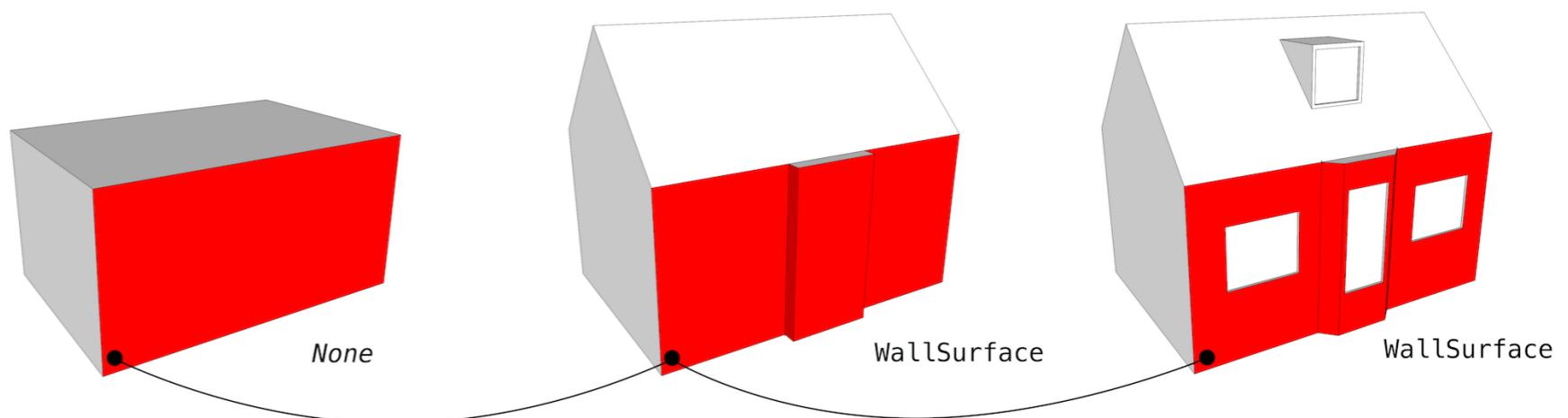
Topic 1: Formalisation of the concept

- Analysis of presently available concepts (found 26 with 79 LODs), and discussions with practitioners (+ own experience in photogrammetry, remote sensing and GIS)
- Analysis of the deficiencies in CityGML 2.0
- Output: Formalised framework for expressing the LOD of a 3D city model. Published two papers.



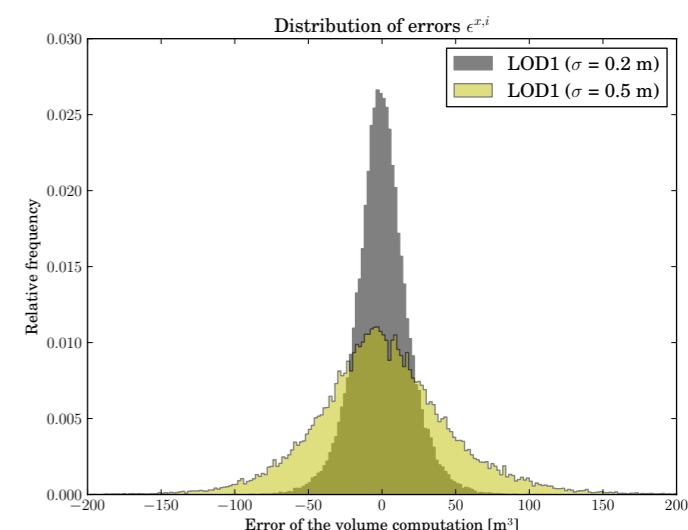
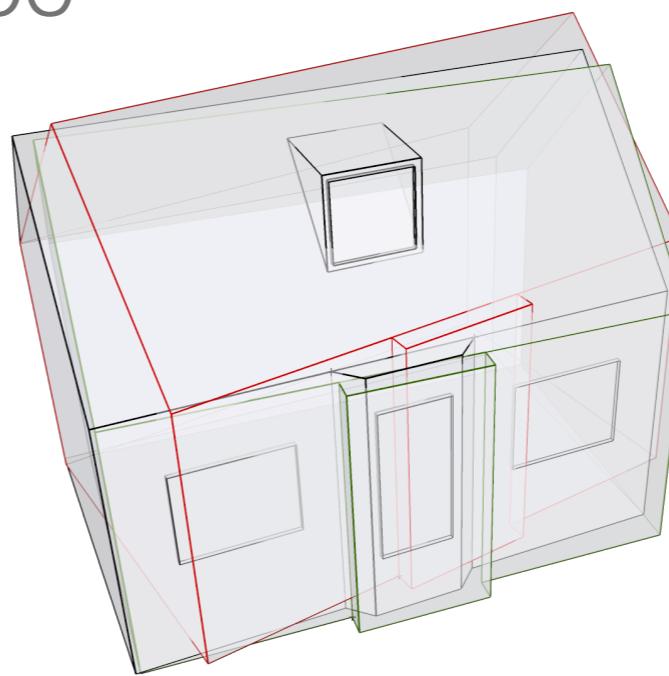
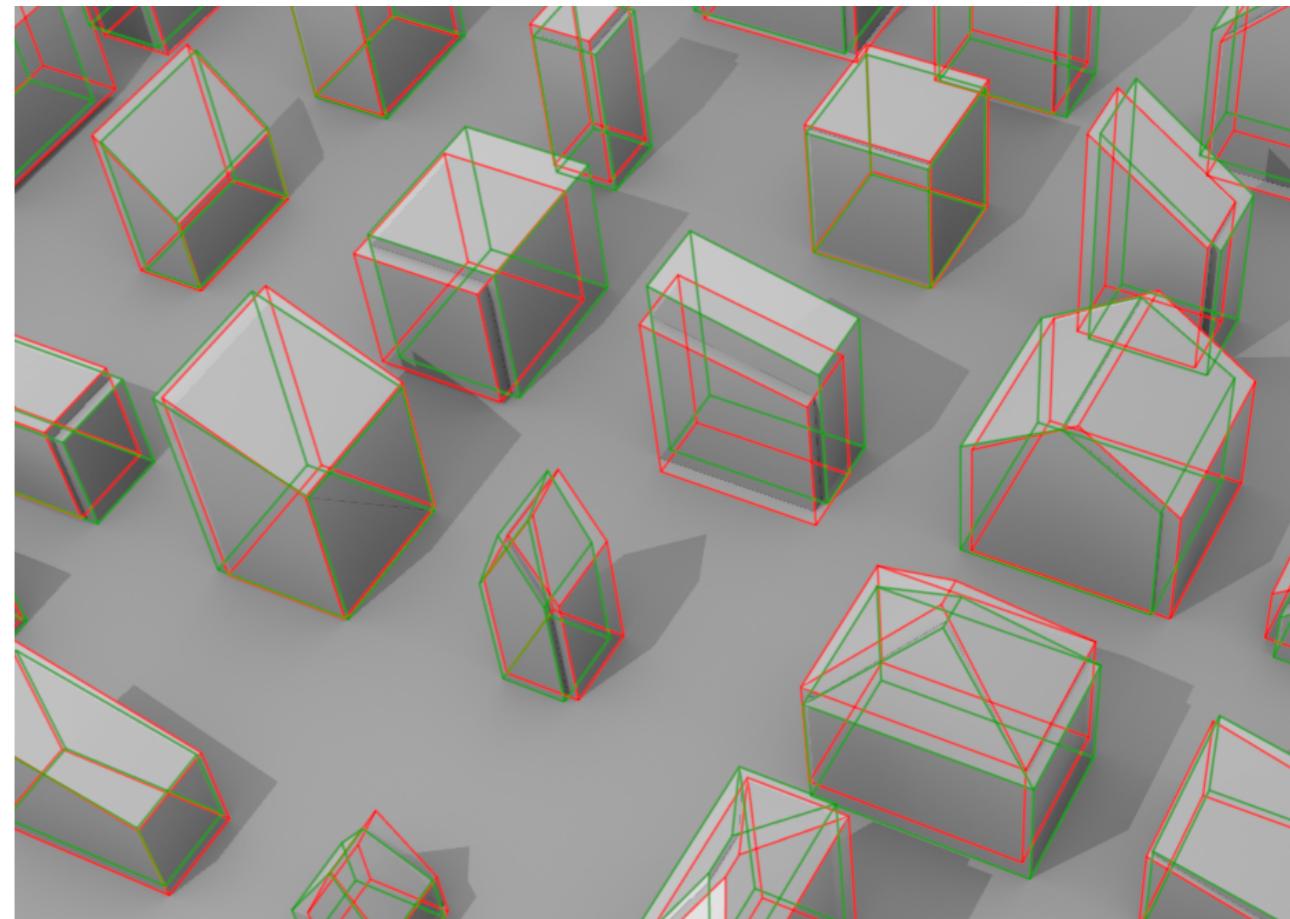
Topic 2: LOD management

- Currently it is not clear when to switch between LODs as it is the case in computer graphics
- LODs are linked, but more work could be done
- Aim: Translate the related concepts from computer graphics to 3D city modelling
- Work in progress



Topic 3: Error propagation in 3D GIS

- Investigating the propagation of uncertainty in the input data to the uncertainty in the output of a (3D) GIS operation
- Related to LOD: investigates whether accuracy should be a part of the LOD specifications



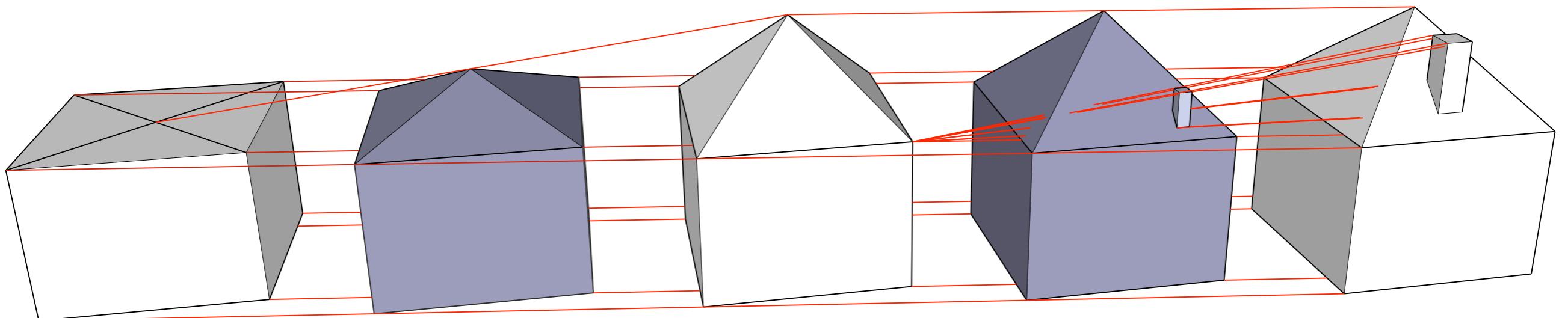
Topic 4: Geometric references and other concepts

- Each LOD has a number of variants, that are not regarded in the metadata in CityGML
- E.g. top block in LOD1 has more than a few possibilities
- Experiments of the effect of using different variants within an application



Topic 5: 4D integration (3D space + scale)

- Integration of the LODs as a 4th spatial dimension
- Generation of intermediary LODs by *slicing* the 4D model
- Continuous LODs
- Continuation of the work 2D+scale (vario-scale project)





CityGML 2.0 LOD concept

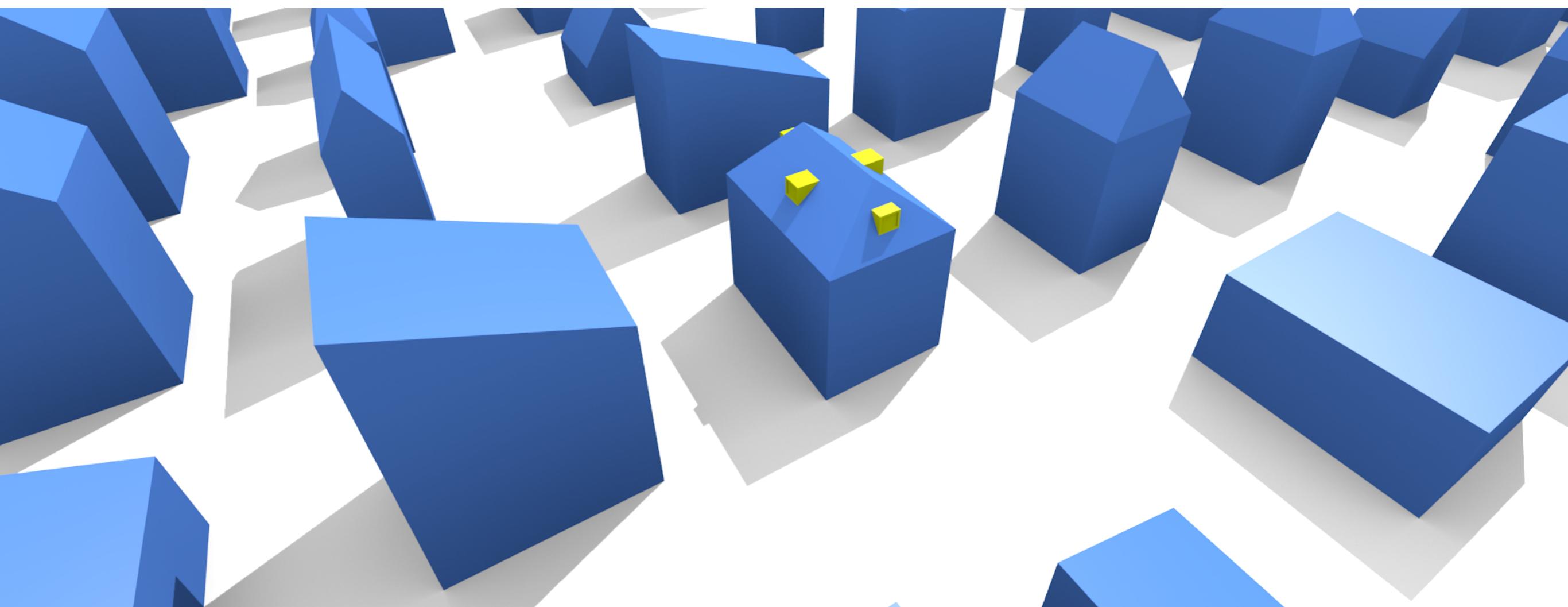
Issues and our view

Main issues with the concept from our perspective

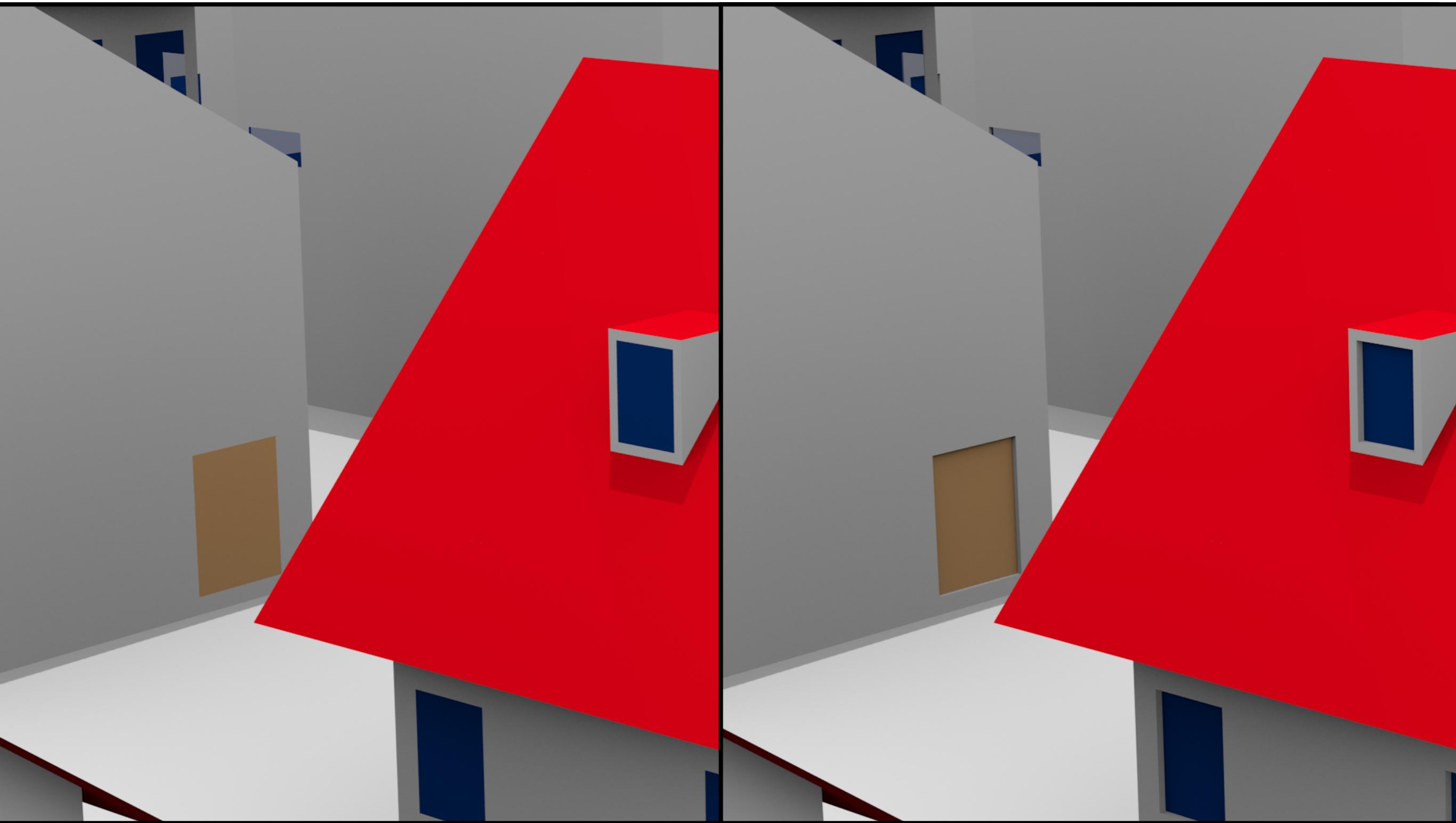
- Practitioners use the LOD concept as in computer graphics: to describe (communicate) the complexity of the model that has to be acquired. The complexity of the geometry is in the focus, and in practice the LOD is synonymous to it.
- CityGML has a different intention. And the supposed complexity of each LOD is described only narratively and briefly.
- The number of possible representations is higher than the current 5 LODs. Two problems: not possible to precisely specify all forms with 5 LODs, and not possible to store more than 5 LODs
- Some specific issues that we have identified are presented in the continuation, with some of the work that has been done from our side.

Issue #1: Specification not precise, and ambiguous

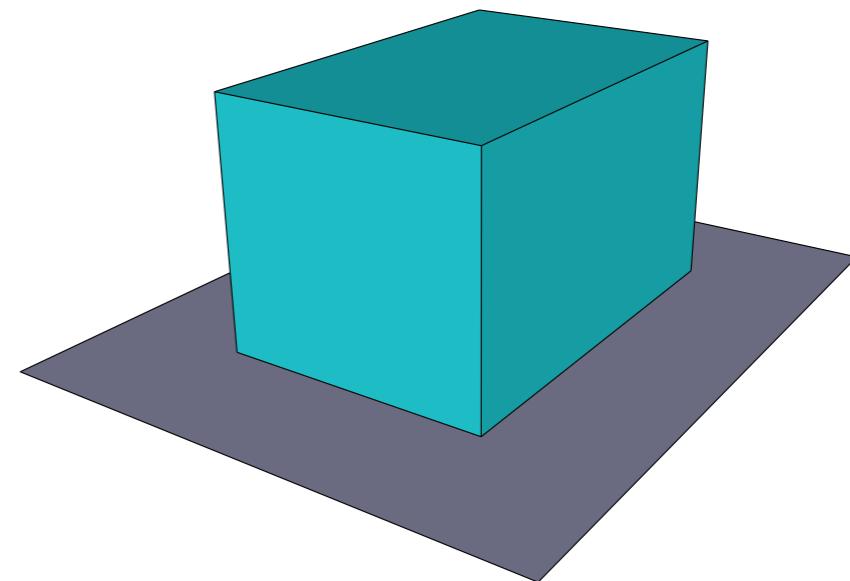
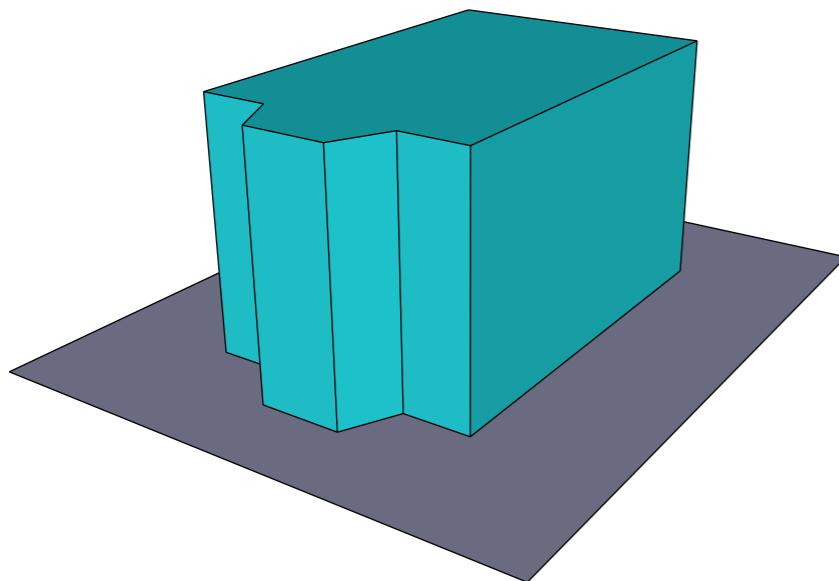
- Most practitioners find the issue in the specification of the LODs, i.e. its lack. It is not clear what has to be modelled and how well.
E.g. whether an LOD2 should contain dormers or not



(cont...) same applies to LOD3



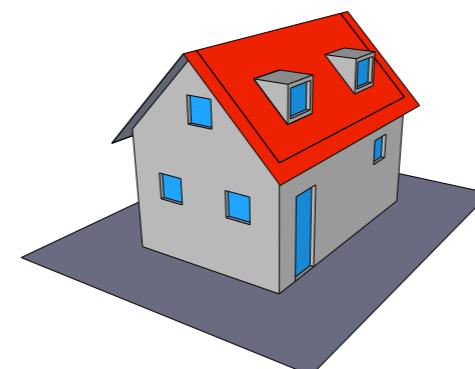
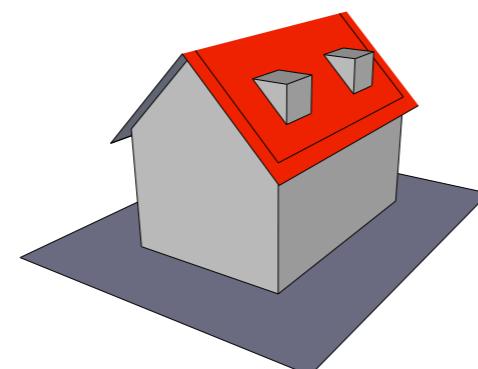
(cont...) but also already in LOD1



Both are valid LOD1 models, but they
considerably deviate in the complexity (and price)

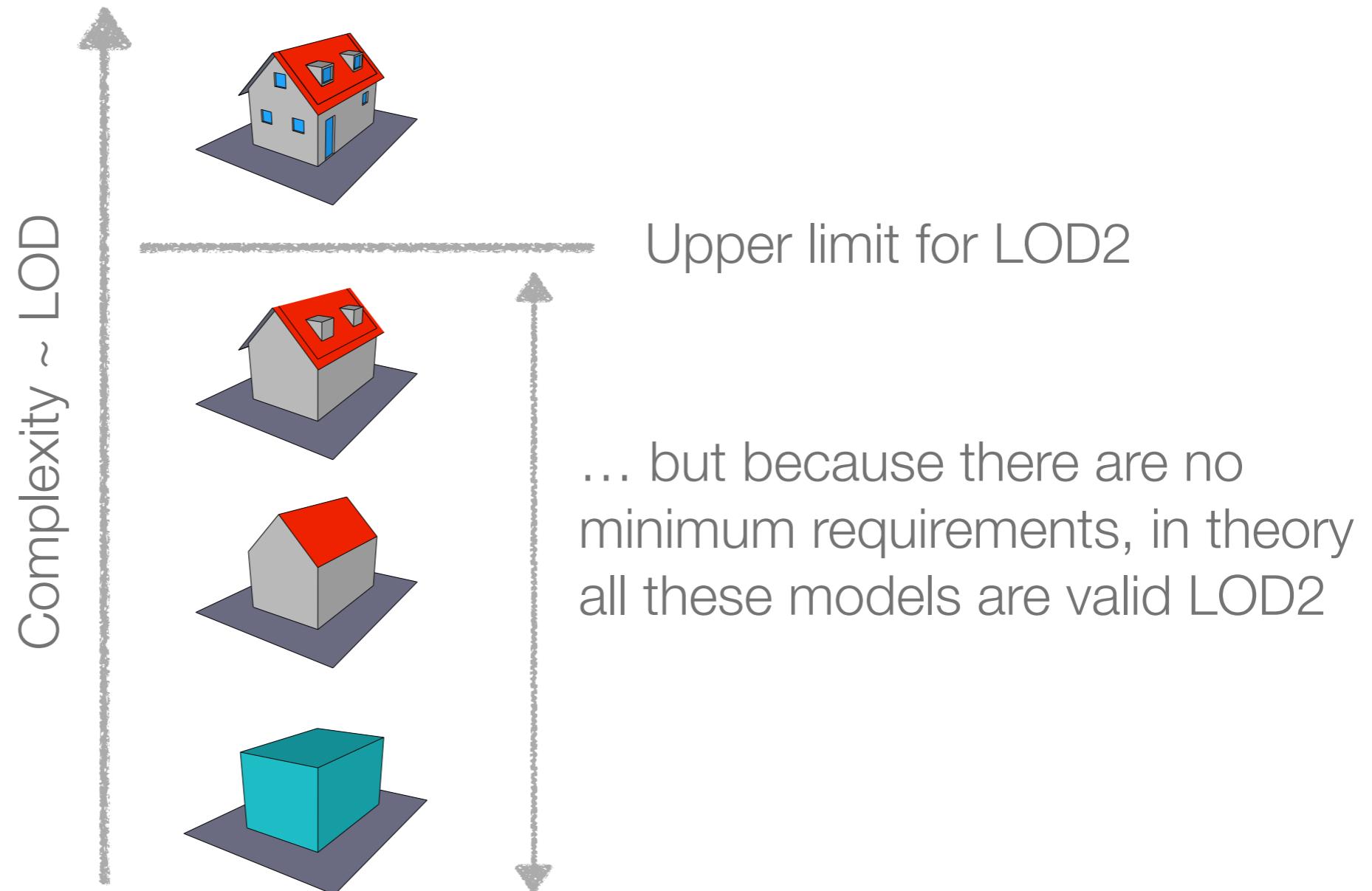
Issue #2: Upper boundaries, rather than requirements

- The main rationale of the level of detail concept in CityGML is that it imposes “upper” limits for the LODs (constraints), rather than (“lower”) requirements
- For instance, for an LOD2 there are no minimum requirements, but there is a constraint that it cannot contain openings (“upper limit”)
- LOD3 example: both models below are a valid LOD3



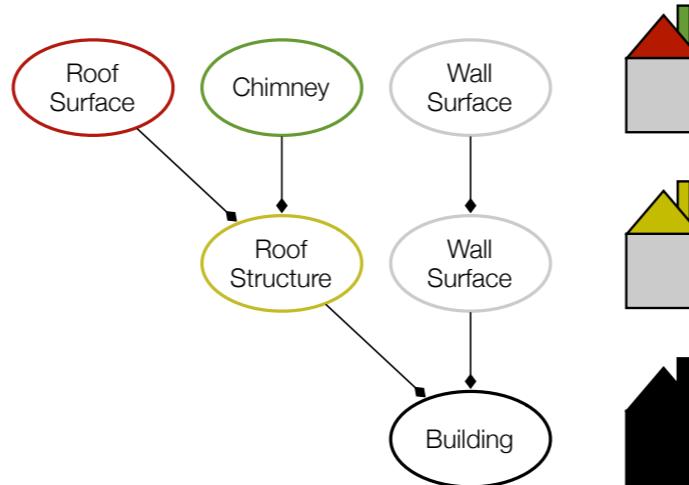
(cont...)

- The complexity of the models is not prescribed, it is rather implied. Consequence: it's possible to store a coarse model in any higher LOD, diminishing the purpose of the LOD concept



Issue #3: One-dimensional concept and decoupling metrics

- The semantics might not be important for some producers and users, but CityGML basically enforces it
- No proper way to convey an LOD of a model that is geometrically rich but without semantics. Need for separating the “driving” metrics, e.g. geometry and semantics, with separate levels



- Best explained in paper Löwner, M.-O. et al. (2013) *

* New Concepts for Structuring 3D City Models – an Extended Level of Detail Concept for CityGML Buildings. Lecture Notes in Computer Science. Proceedings of the 13th International Conference Computational Science and Its Applications – ICCSA 2013.
http://link.springer.com/chapter/10.1007/978-3-642-39646-5_34

(cont...) Issue #3

- Consequence: the below model is highly detailed but it is not an LOD3 since it contains no highly detailed semantics



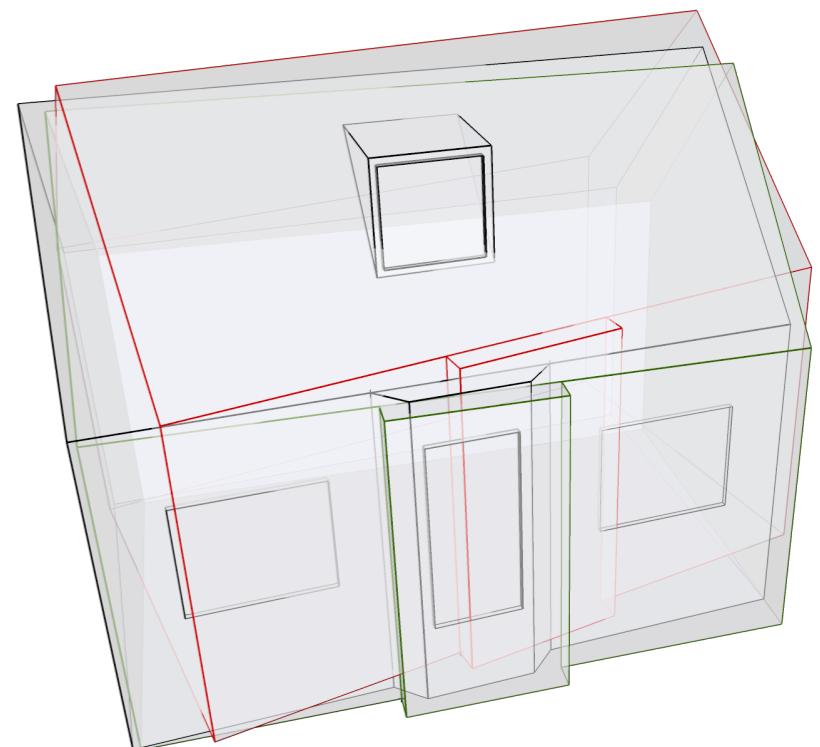
Issue #4: Texture not regarded

- Appearance properties are not found in the specifications
- Texture is expensive to acquire, so practitioners understandably regard it as one of the main points within the complexity of the models
- Example of a proprietary LOD concept (Blom3D™): the three LODs differ only in their appearance—a logic that varies from CityGML



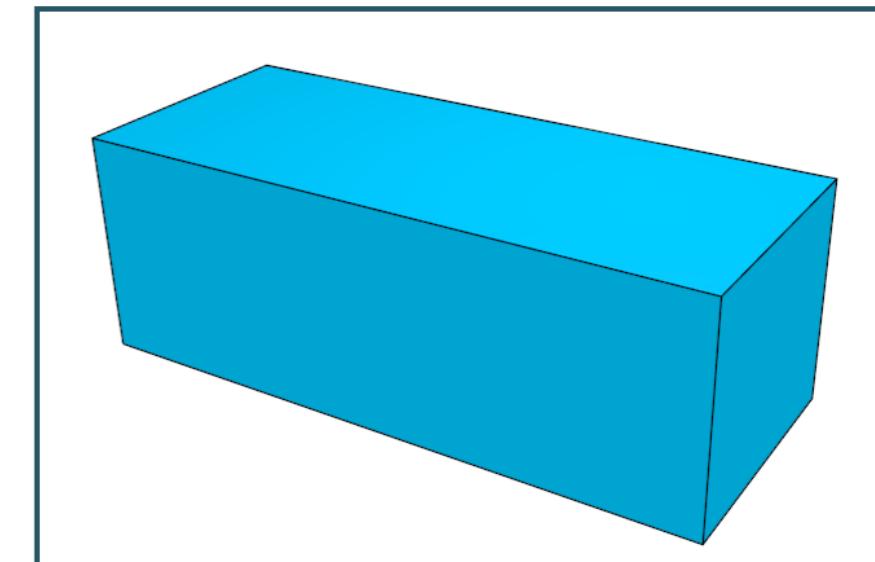
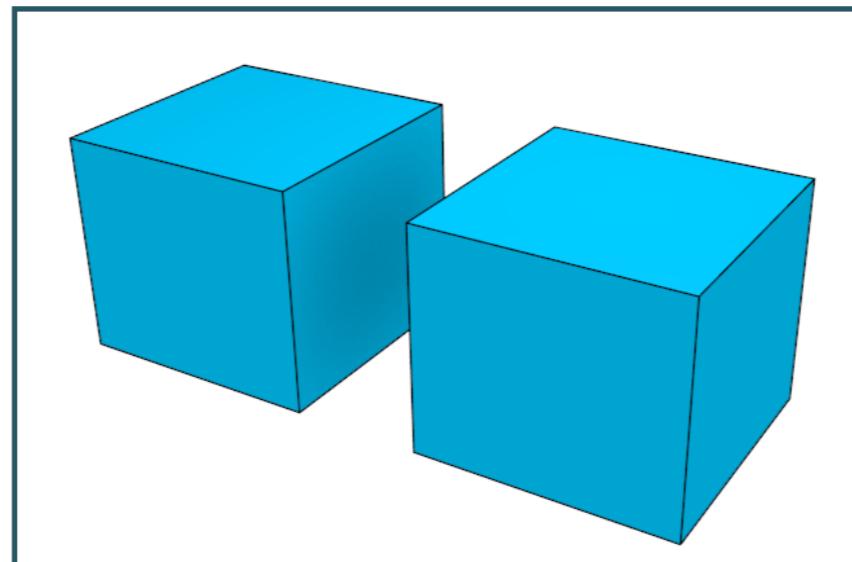
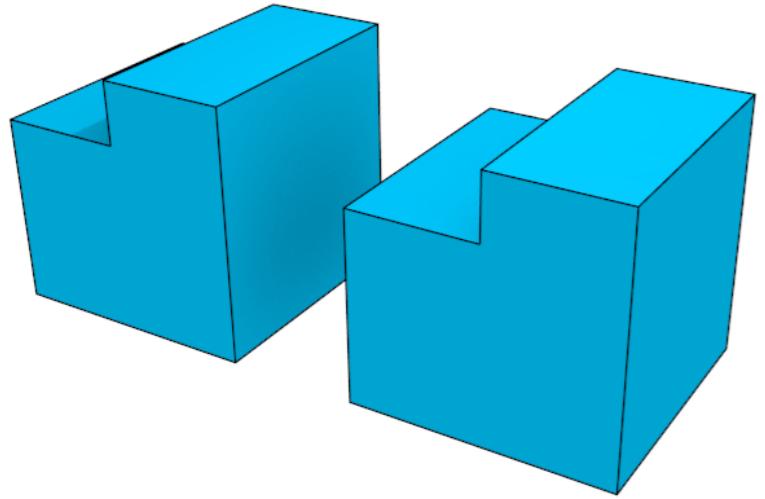
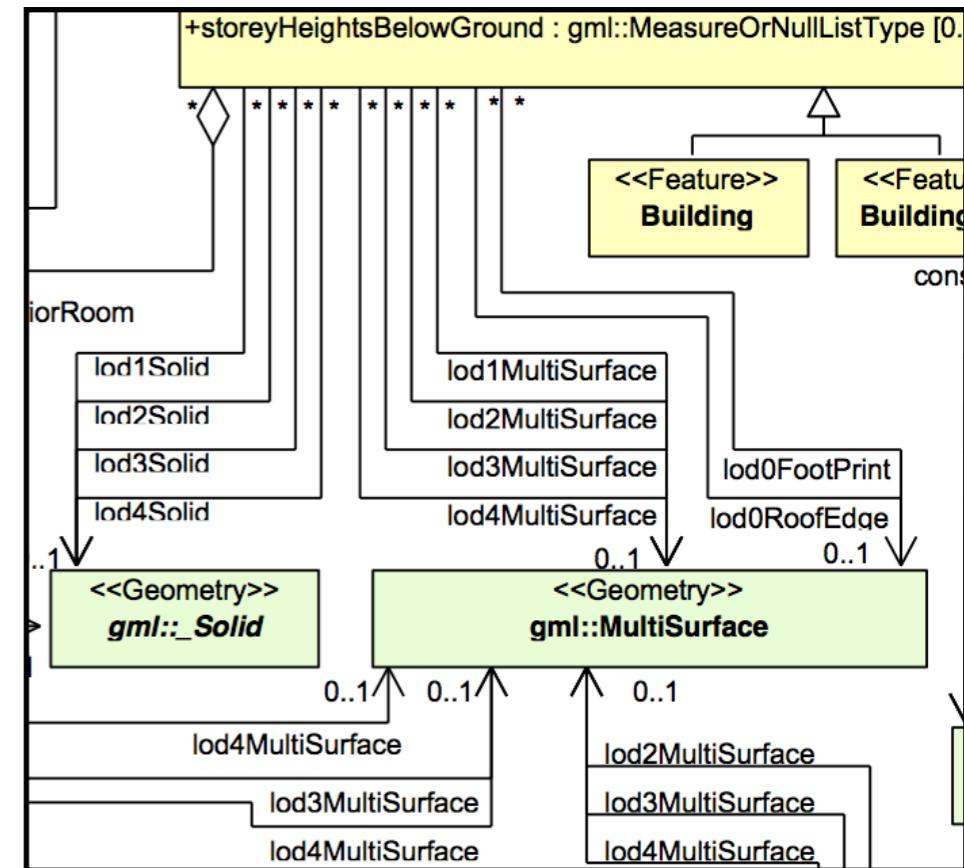
Issue #5: Accuracy requirements per LOD

- The accuracy of the geometry is part of the LOD specification in CityGML. However, this might not be a good solution, as:
 - this is more relevant for an application and the required quality of its output, rather than the input model and its LOD
 - two models of the same LOD may be of different accuracy. Example (green and red are two models of the same LOD with different positional accuracy; the black model is the ground truth)



Issue #6: Cardinality of LODs

- Rigid concept with a 1:1 relation
- The following 3 models are all LOD1, but only one can be stored



Issue #7: Geometric references

- Vertical (top/bottom), and horizontal (footprint/roof edge) references not noted in the metadata
- Further variants of LOD1 (related to the previous issue)

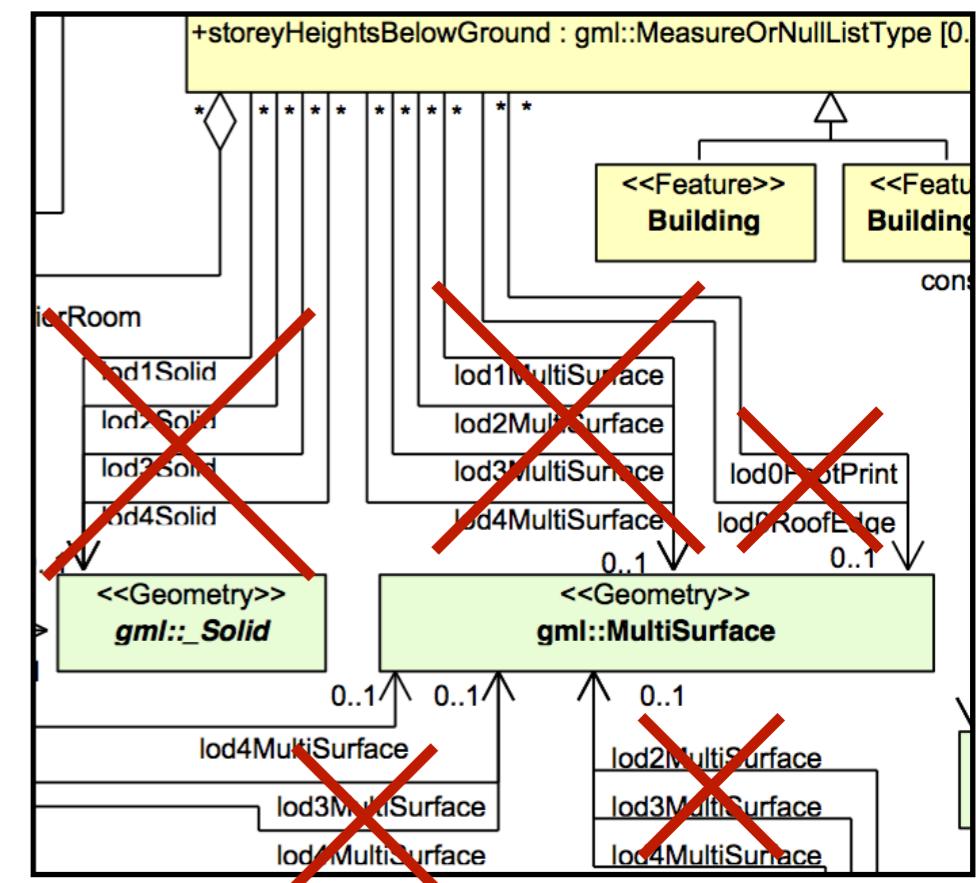


Work that has been done at TU Delft

- We focused on our view of the LOD concept as the specification of the complexity of the 3D models (industry perspective, but also from computer graphics)
- Understanding that it conflicts with the current purpose and intention of the LOD concept in CityGML
- A few proposals in the continuation

0. Main proposal

- Abolish the LOD concept in its current rigid form
- Extensibility and customisation:
Allow custom LODs with custom specifications
- Retain the “old” LOD references as a general guideline and refine them
- Use the INSPIRE geometric references to describe models in the metadata



0. Main proposal

```
<bldg:Building>
```

```
  <bldg:representation lod:name="lod3">
```

```
    <bldg:boundedBy>
```

```
    . . .
```

```
  <bldg:representation lod:name="lod-high">
```

```
    <bldg:boundedBy>
```

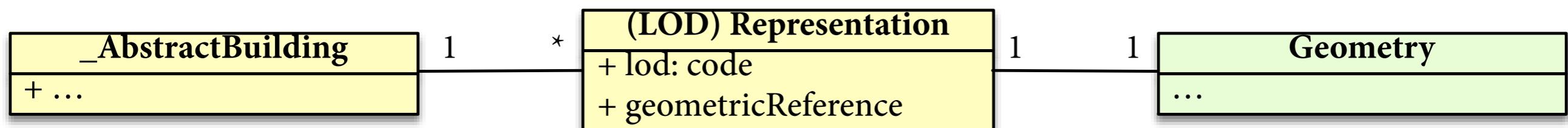
```
    . . .
```

```
  <bldg:representation lod:name="block_model"
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```
    verticalGeometryReference3DTop="topOfConstruction">
```

```
    <bldg:solid>
```

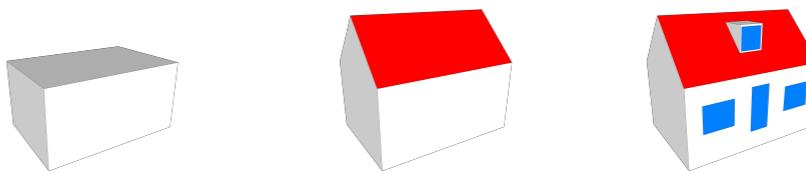
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    . . .
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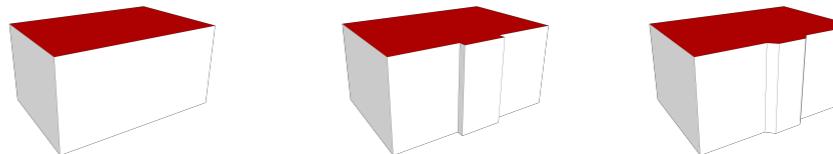
1. Decomposition of the concept (framework)

- The LOD of a model can be decomposed into six metrics

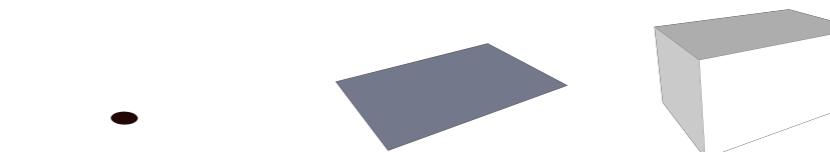
1. Presence of features



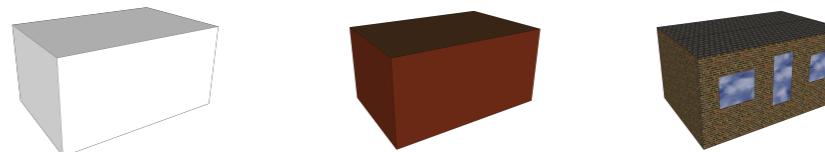
2. Feature complexity



3. Dimensionality



4. Appearance



5. Semantics



Top
Walls
Ground

6. Attributes

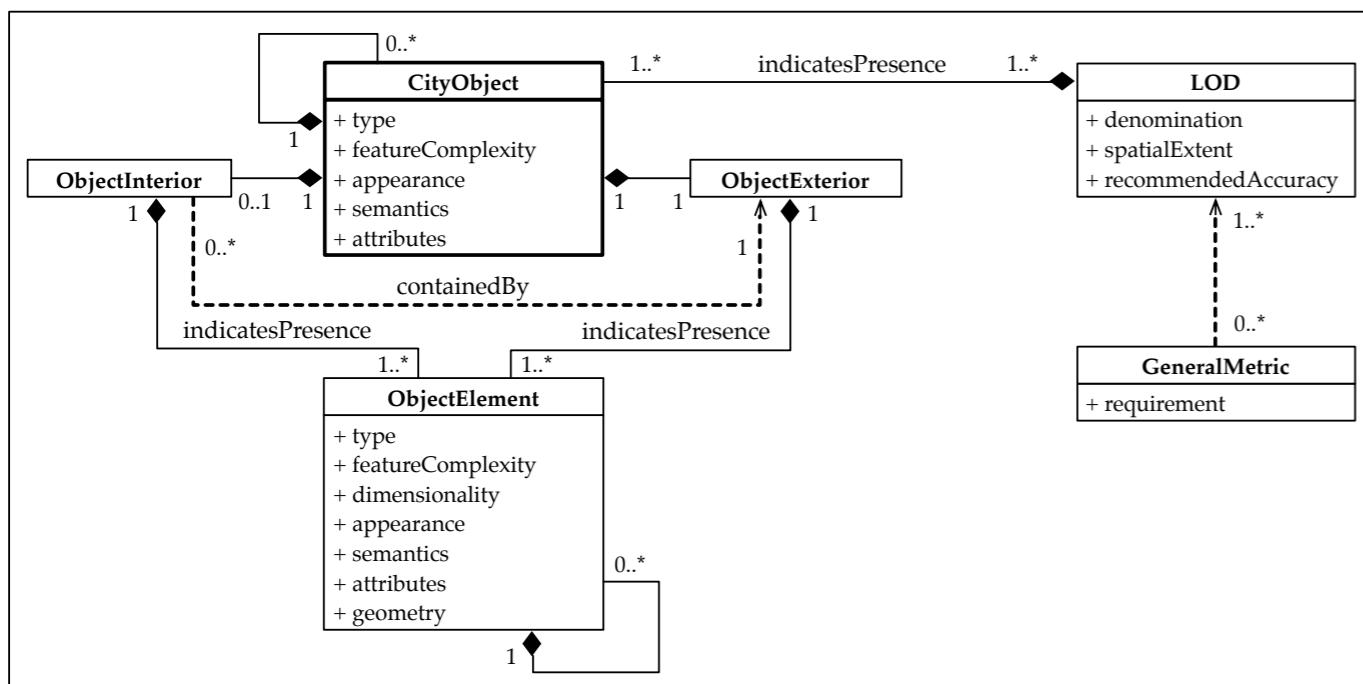
<constructed>"2005"
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LOD (orthogonal metrics that can be combined) →

2. Specifications (expressing each LOD)

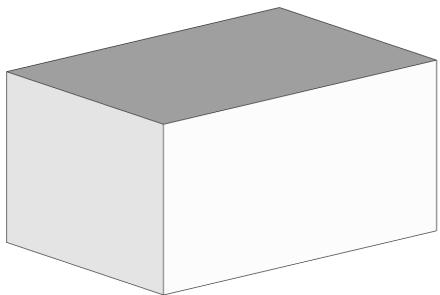
- How to unambiguously express what to acquire, how well, etc.
- UML, and table form. Each LOD can uniquely be specified with it.



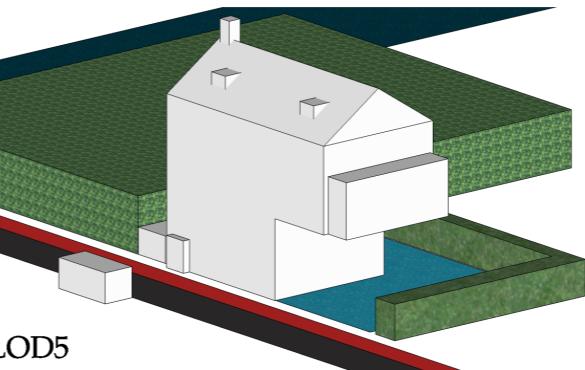
General metrics	3D City Model LOD specification				LOD i			
	Object	Feat. C.	Attributes	Elements	Feat. C.	Dim.	Appearance	Attributes
Feature complexity				0.4 m				
Appearance resolution				0.3 m/px				
Semantics				Yes, full spatio-semantic coherence				
City objects and elements	Object	Feat. C.	Attributes	Elements	Feat. C.	Dim.	Appearance	Attributes
	Buildings		+ Occupancy + EnergyRating	Wall		2		+ Material
				Roof	0.2 m	3		None
				Roof.Dormer	0.2 m	3		None
				Chimney	0.2 m	3		None
				Balcony		3		None
				Pier		3		None
				Opening		2		None
	Interior							
Roads			+ RoadUse	Storey		3	None	+ Use
				Traffic area- Cars		2	Black	+ SpeedLimit
				Traffic area- Bicycles		2	Red	None
Street lights	1 m	+ PowerConsumption	Pole		3	None		None

Example of a finer series of LODs

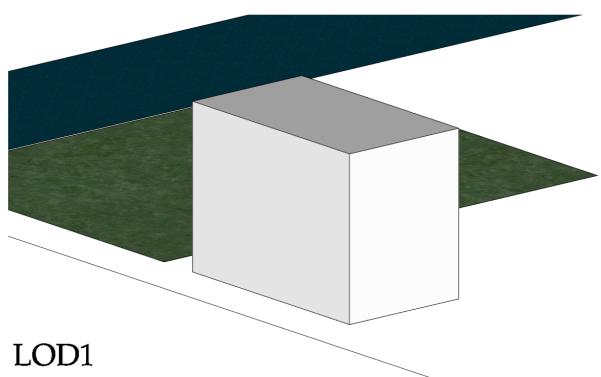
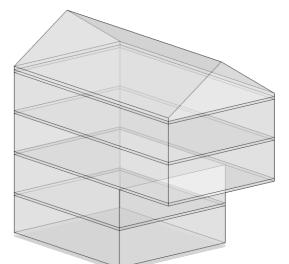
- 10 discrete LODs that are finely specified thanks to this specification
- Example of the realisation of the framework rather than a proposal for CityGML
- This example also shows the number of LODs that cannot be accomplished within the standard 5 LODs, hence it is crucial to allow extensibility and flexibility of the LOD concept in CityGML



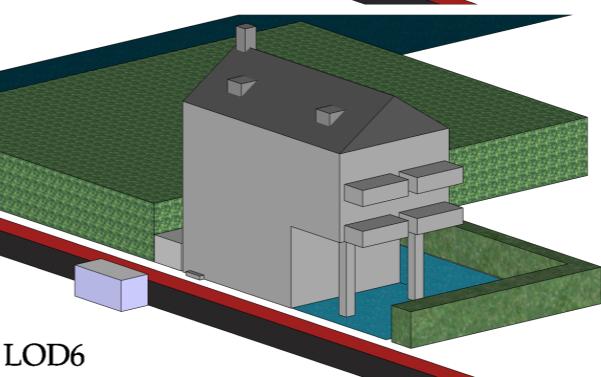
LOD0



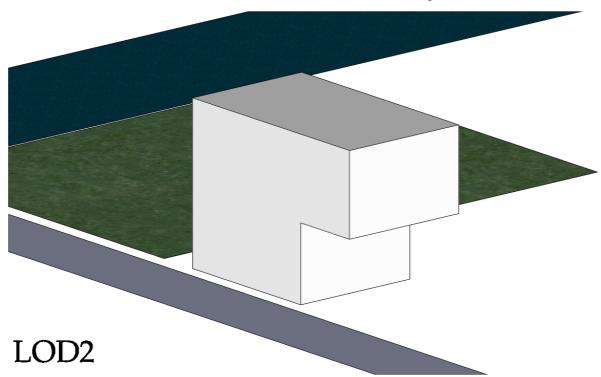
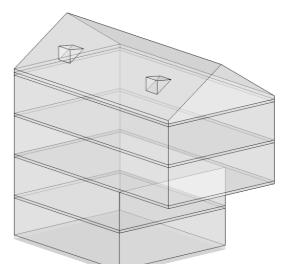
LOD5



LOD1



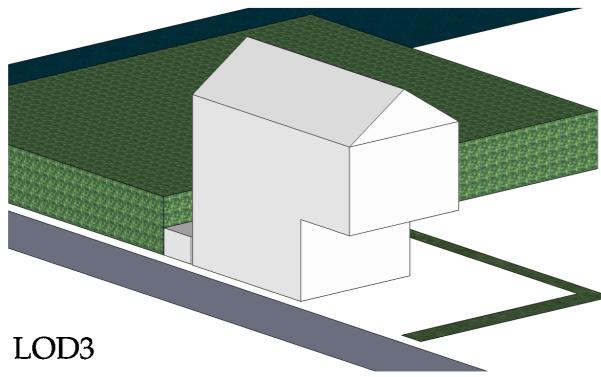
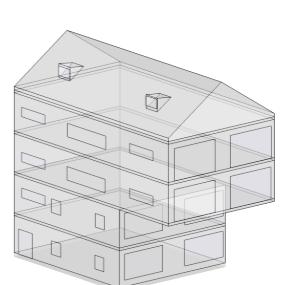
LOD6



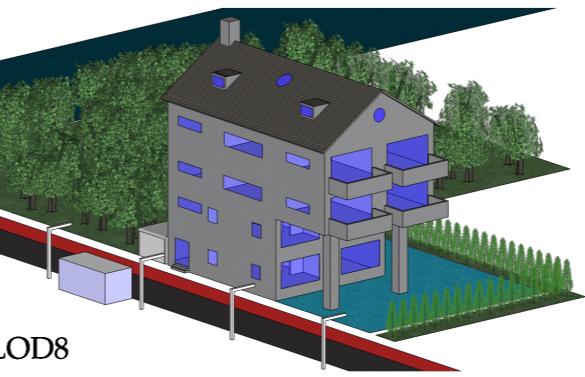
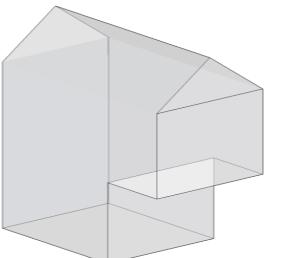
LOD2



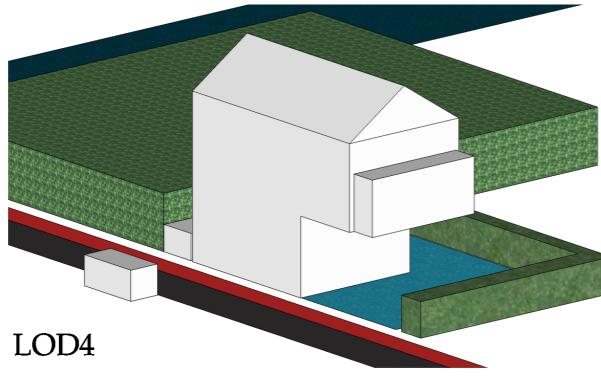
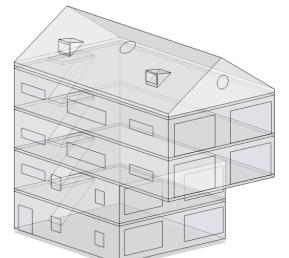
LOD7



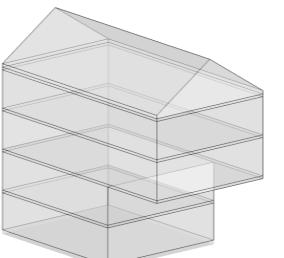
LOD3



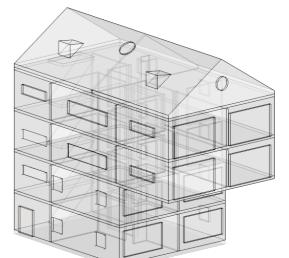
LOD8



LOD4

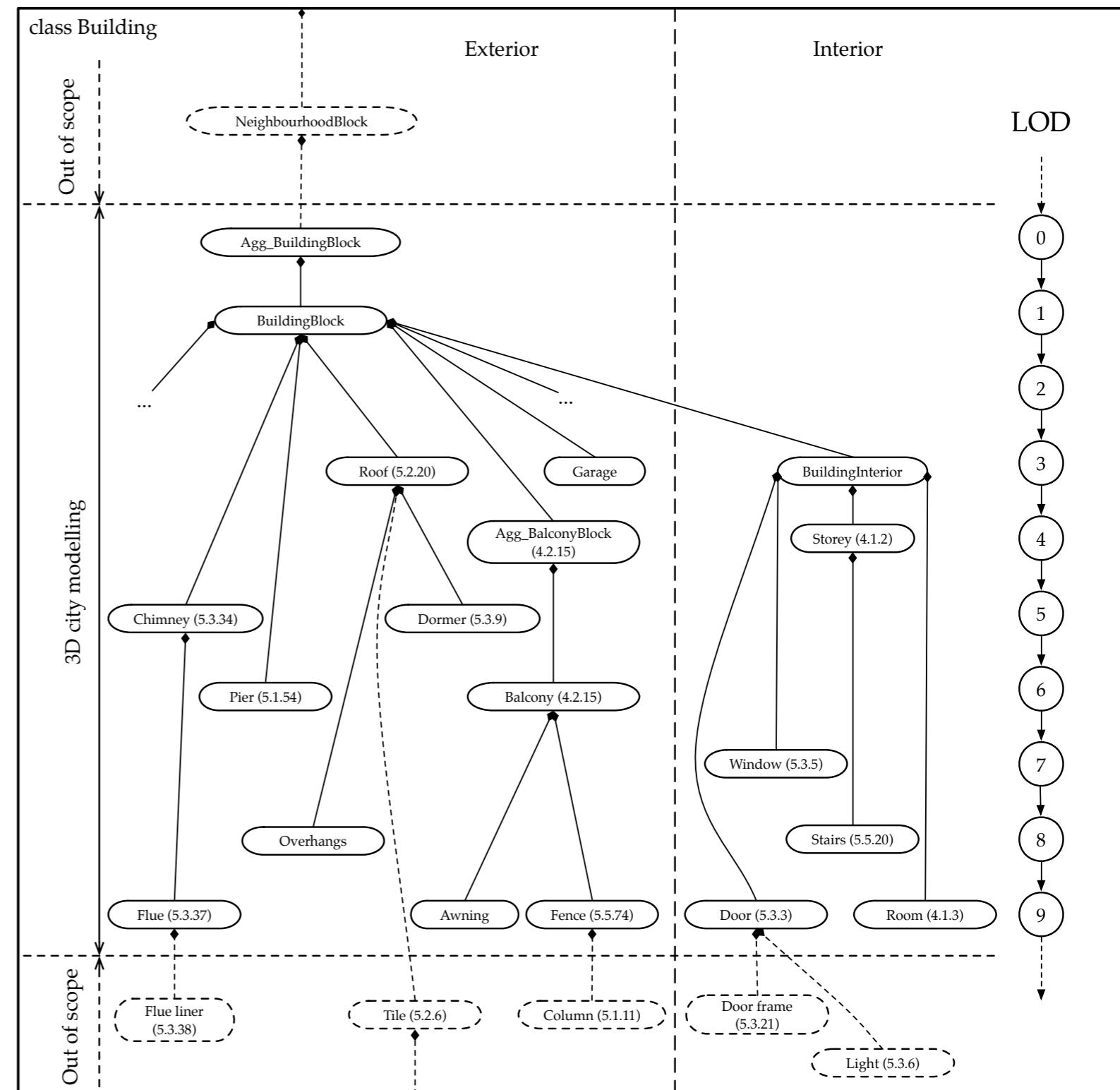


LOD9



(cont...)

- With a list of features that has to be acquired in each LOD

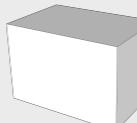


Application of the framework to CityGML

- Use this framework to refine current LODs (LOD1, LOD2, ...) by specifying them better and/or create subgroups and variants
- Use it also to help users define their own LODs
- Two-fold advantage: both refined and flexible to new representations

Five template LODs of CityGML for guideline

- Beside better description, help the users by extending them and defining their variants

	LOD 1 family		
Description	Block model with no texture, and limited semantics		
Feature complexity	> 0.3 m		
	LOD 1.0	LOD 1.1	LOD 1.2
Description	Basic block model	Multi block model	Extruded fine footprint
Aggregation	Allowed	Allowed	Not allowed
Roofs	Flat	Flat	Flat
Feature complexity	0.5 m	0.3 m	0.3 m
Example			

Further reading

- Journal paper (framework)

Formalisation of the level of detail in 3D city modelling

Computers, Environment and Urban Systems

vol. 48, November 2014, pp. 1-15.

<http://dx.doi.org/10.1016/j.compenvurbsys.2014.05.004>

- Conference paper (analysis)

Revisiting the concept of level of detail in 3D city modelling

Proceedings of the ISPRS 8th 3DGeoInfo Conference

November 2013

<http://dx.doi.org/10.5194/isprsaannals-II-2-W1-63-2013>

Acknowledgements

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Nederlandse Organisatie voor Wetenschappelijk Onderzoek

Further information:

<http://www.gdmc.nl/biljecki>

