Metadata for 3D City Models

Analysis of the Applicability of the ISO 19115 Standard and Possibilities for further Amendments

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1 INTRODUCTION

3D city models are becoming more and more popular in commerce and public administration. For this reason a large number of 3D city models have been created based on various methods and techniques (e.g. Zlatanova and Prosperi 2005, Abdul-Rahman et al 2006). Increasingly they are also stored in databases (e.g. Zipf and Schilling 2003). Due to the heterogenity of the methods and data sources for their creation and maintenance, special emphasis has to be laid on the documentation of the 3D models via metadata. This is a basic requirement for a successful establishment of 3D spatial data infrastructures (3D-SDI)(Tschirner & Zipf 2005, Schilling et al 2007). Metadata for the corresponding geodata is needed according to present metadata standards in order to allow the search for relevant data sets. Much research has been carried out with respect to metadata for SDIs, (e.g. Nogueras-Iso et al. 2005 as only one example of a long list). We now want to assess the applicability of the currently available metadata standards with respect to their use for describing 3D city models - as a relatively new kind of data type that will be part of future 3D-SDIs.

A study was conducted in order to find out whether the current metadata standards are suitable for 3D data. A second research topic is to develop possible amendments for a current metadata specification that fulfill the requirements for describing 3D city and landscape models. We considered mainly the standard ISO 19115 (but also Dublin Core, FGDC and CEN-TC287). For this, the individual elements of the standard were assessed critically under the aspect of sufficiency for 3D spatial data and city models. Also the question was posed if any further metadata information is needed, which is presently not included in the standard. Another question was raised about hierarchical levels. Currently metadata is mainly collected for top level of the dataset, therefore we positioned it there instead of on a feature level. The outcomes will be presented and proposals for further additions to the specifications will be discussed. For the latter the present OGC discussion paper on „CityGML“ (Groeger et al 2006) was particularly assessed - in particular regarding the question how to allow a semantic description of the structures within 3D city models.

2 APPLICABILITY OF ISO 19115 FOR 3D CITY MODELS

Metadata (data describing data) is known as structured data which describes and helps to find data sources. In the field of geodata the ISO 19115 standard is especially relevant along with its predecessors Dublin Core, CEN-TC287 and the FGDC standard, which is used in the US. These were assessed according to their application with 3D city models. This report discusses the outcomes considering the ISO 19115 standard which is especially relevant.

In the following chapters we present several examples with lists and comments of classes and attributes from ISO 19115 which seem of importance for 3D city models. These underpin the hypothesis that ISO 19115 is already partially applicable on certain aspects for describing 3D city models. In the third chapter we will discuss deficiencies and propose possibilities how amendments (e.g. extended profiles) of the standard could solve these.

The following paragraphs give positive examples of the possibilities that exist already and are useful for 3D city models:

Digital Elevation Models

The class *MD_Identification* contains the subclass *MD_DataIdentification* along with the attribute *spatialRepresentationType* and the code list *MD_SpatialRepresentationTypeCode* which reflects the way geographic information is represented and includes the values *grid* and *tin*.

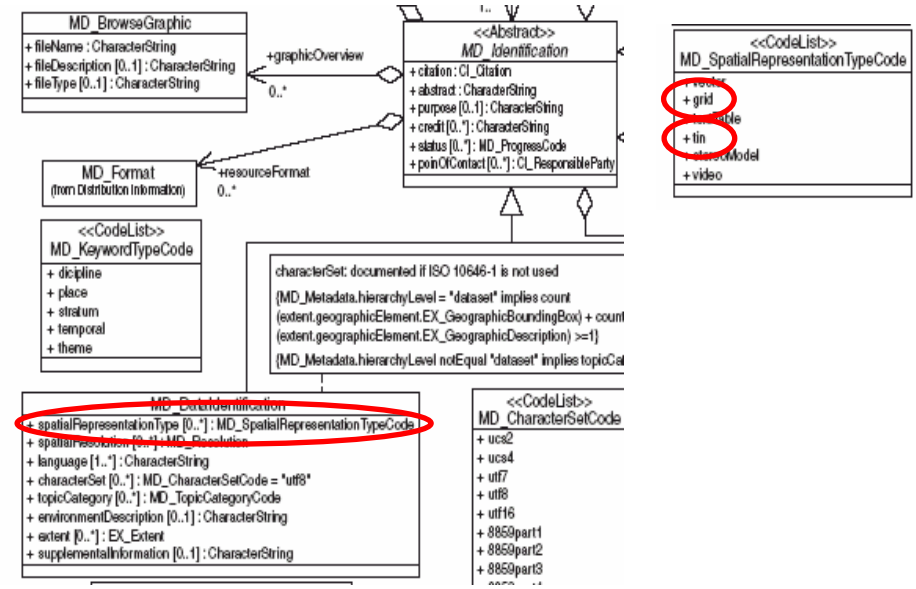

Figure 1: *SpatialRepresentationType* in ISO 19115.

Spatial resolution

The attribute *spatialResolution* of the subclass *MD_DataIdentification* of the class *MD_Identification* provides information on the spatial resolution of the geographic information (e.g. scale, ground resolution, grid spacing, raster resolution). This attribute is again further specified by *MD_ResolutionTypeCode* which contains the values *equivalentScale* and *distance*. *Distance* holds information about the ground resolution of the vector data, or the grid spacing of the DEM, or the raster resolution of the raster data. Giving this attribute a corresponding value, e.g. information about the grid spacing of the raster of the DEM, can also be relevant when describing a 3D city model.

BoundingBox in 3D

The subclass *MD_DataIdentification* of the class *MD_Identification* contains the attribute *extent*. For this, the data type *EX Extent* is available with the attribute *description.* This holds information about the spatial and chronological extents of the respective dataset in various ways.

In particular, the datatype *EX_Extent* has an aggregation with the abstract class *EX_GeographicExtent.* The latter has a subclass called *EX_BoundingPolygon* with the attribute *polygon*. *Polygon* is of class *GM_Object*. *GM_Object* is the main class of the ISO 19107. It defines a general model for the geometry and the topology of geographic data. Among other 3D geometries it also includes the class *GM_Solid*, with which tetrahedrons can be described. Additionally the vertical extent can be represented by *EX_VerticalExtent*.

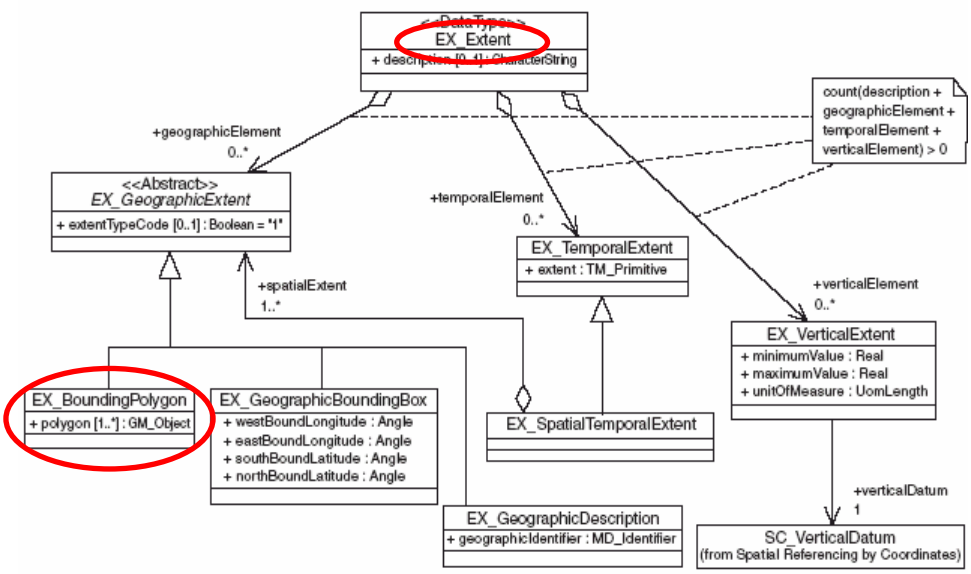

Figure 2: *GeographicExtent* in ISO 19115.

Accuracy of Location and Height

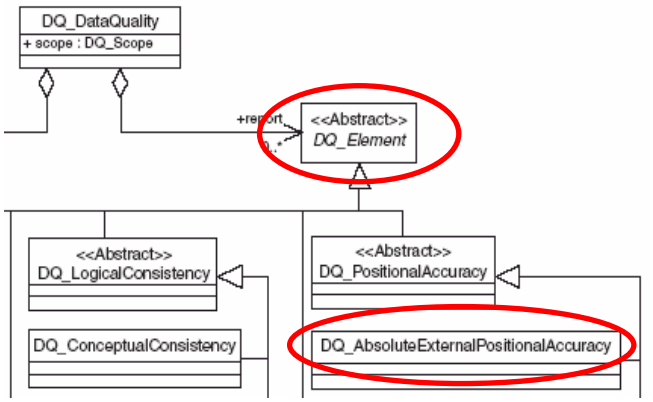

Figure 3: Position Accuracy in ISO 19115.

The class *DQ_DataQuality* with its subclass *DQ_Element*, *DQ_PositionalAccuracy* and *DQ_AbsoluteExternalPositionalAccuracy* give information about the accuracy of the location and the height. These are also important aspects of 3D city models.

3D-object geometries

The class *MD_SpatialRepresentation* contains the subclass *MD_VectorSpatialRepresentation* with the attribute *geometricObjects* and the data type *MD_GeometricObjects*.

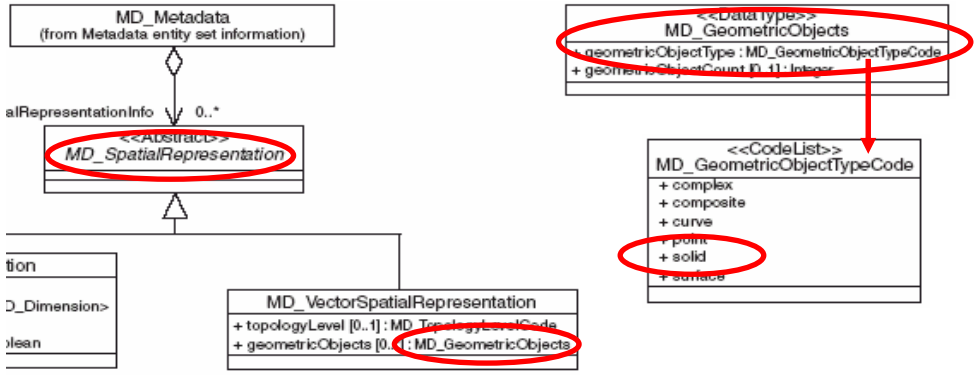

Figure 4: 3D Geometric Objects in ISO 19115.

The object *geometry* itself (*MD_GeometricObjects*) also contains attributes such as *geometricObjectType.* This specifies the geometry type of the objects according to a code list called *MD_GeometricObjectTypeCode*. In particular also the value *solid* is included there .

3D-Topology Support

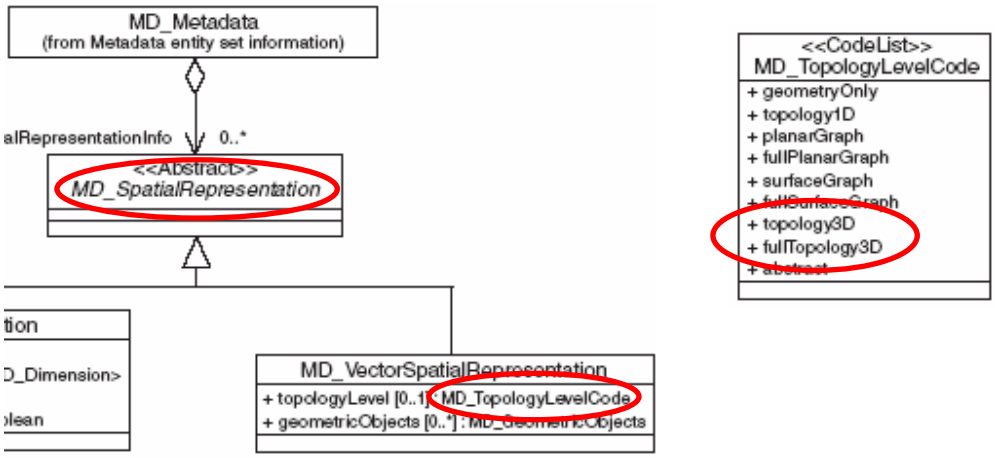

Figure 5: 3D-Topology in ISO 19115.

The class *MD_SpatialRepresentation* includes the subclass *MD_VectorSpatialRepresentation* with the attribute *topologyLevel* and the code-list *MD_TopologyLevelCode*. That describes the type of topological relation and includes among others values like *topology3D* and *fullTopology3D.* So the existence of 3D topology can already be derived from ISO 19115.

3 PROPOSALS FOR AN AMENDMENT OF ISO 19115 BASED ON CITYGML AND OWN SUGGESTIONS

In the following sections we present an overview of possible further amendments (classes, attributes, attribute values) of ISO 19115 in respect to 3D city models. This can improve the possibility to “search and find” specific 3D city models with particular properties through the use of metadata catalogues. We were especially inspired by CityGML. CityGML is a general semantic

information model for representing 3D city objects. CityGML defines classes and relationships for relevant topographic objects in city-models, including geometric, topological, semantic, and visual characteristics. The base class of all objects is *CityObject*. All other objects inherit the *CityObject* characteristics.

We define the following classes and we think that these seem adequate for extending ISO 19115 beyond its current status in order to support 3D city models in a better way.

Level of Detail

In general three dimensional city- and regional models are available in different levels of detail (LoD). Usually these are being generated or created from various sources which often are independent of each other. In many cases only data with little detail is available for the whole area. Vice versa only small parts of the city are represented in high detail such as individual architectural highlights. CityGML currently proposes five LoD´s, beginning with the lowest resolution of LoD 0 up to the highest resolution of LoD 4. These LoD´s regard both geometry and thematic differentiation.

LoD 1 – 3 correspond with the respective detail levels described in current literature, while LoD 0 and 4 are additions suggested by CityGML. LoD 0 is defined as regional model which mainly consists of a DEM together with satellite image/aerial photos or a map if applicable. Both of these are available in LoD2, while LoD3 denotes architectural models with detailed wall and roof structures. LoD4 contains additional interior structures for buildings. Each LoD has criteria about accuracies and minimal dimensions of objects. The classification into five LoDs can be used to evaluate and compare the quality of the 3D city models. .

This results in the following possibility for further extending ISO 19115: The subclass *MD_DataIdentification* of the class *MD_Identification* receives the new attribute *levelOfDetail*. An integer value between 0 and 4 is allocated to this, in order to annotate the level of detail (see Fig. 6). This information should possibly added to a featureLevel, but as the specification only includes top level metadata, we positioned it there as a means to allow finding datasets that are of a specific LoD.

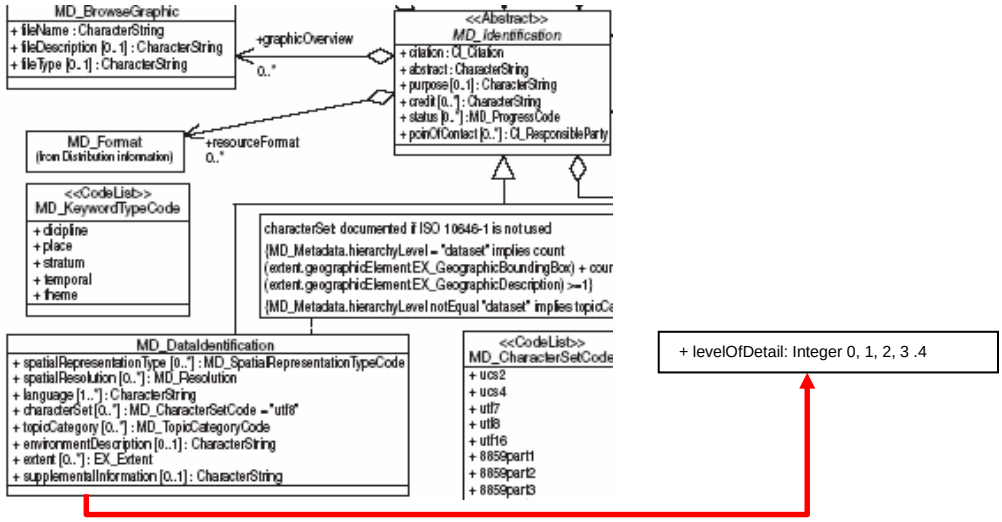

Figure 6: Proposal for extension of ISO 19115: *levelOfDetail*.

DEM

A DEM is essential as a basis for most 3D city models, and can serve as a spatial reference for other features. For this reason there should be information about the raster accuracy regarding the raster width, resp. information about which type of elevation model is being used. As mentioned above, *tin* and *grid* are already included. The following extensions of the specification seem desirable: *massPoints* and *breakLines* should be added in the code list *MD_SpatialRepresentationTypeCode* for the attribute *spatialRepresentationType* of the *MD_DataIdentification* class in order to describe more accurately which elevation information was used for the DEM creation.

Semantic object classes

It may be reasonable to further specify extensions to ISO 19115 concerning 3D city models so that the semantic description of the object classes can also be included in the metadata. This way for example the following questions could be answered:

- Find a 3D city model that has traffic lights
- Find a 3D city model with floor plan information of buildings within the cadastral area
- Find a 3D city model that has LoD 1
- Find a 3D city model that has textured buildings
- etc.

CityGML already includes detailed semantic structures for the various possibly included objects and object parts. Table 1 gives an example of a functional typing of buildings taken from CityGML.

BuildingFunctionCode (small excerpt)			
1000	residential building	1780	heat plant
1010	tenement	1790	pumping station
1020	hostel	1800	building for disposal
1030	residential- and administration building	1810	building for effluent disposal
1040	residential- and office building	1820	building for filter plant
1050	residential- and business building	1830	toilet
1060	residential- and plant building	1840	rubbish bunker
1070	agrarian- and forestry building	1850	building for garbage incineration
1080	residential- and commercial building	1860	building for abatement disposal
1090	forester's house	1870	building for agrarian and forestry

Table 1: *BuildingFunctionCode* according to CityGML (small subset from a large number of types).

Similar classes are available in CityGML for many different other object types (Fig. 7). Based on this, further options for extending the ISO 19115 are discussed. These are mentioned briefly below. Another possibility would be to link the metadata with an online object catalogue on the web as discussed in the outlook.

It was also discussed how to handle metadata that would better fit to feature levels (as it is discussed with aggregations in CityGML). But as more detailed objects are often stored separately instead of putting LoD4-Elements together with LoD-1 buildings. Therefore we placed it on to the top level, like e.g. *processOf-BuildingHeight*.

For the first draft we derive the new classes *MD_Building, MD_Water, MD_Street, MD_Plant* and *MD_CityFurniture* from CityGML and put them under the subclass of *MD_CityModelDescription* under *MD_ContentInformation*. This addition seemed meaningful because information that can be saved under the class *MD_ContentInformation* describes a data set.

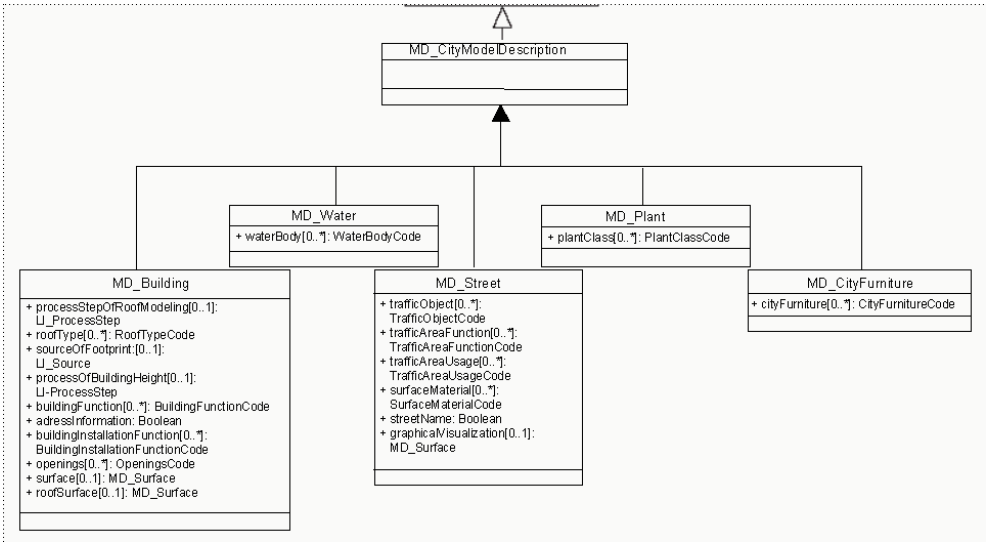

Figure 7: Possible amendment of ISO 19115 through elements derived from CityGML and own proposals.

We also suggest a number of other classes and attributes which are shown in the table below in order to give a short overview: All attributes written in italic style are defined by us. All other attributes resp. the code lists were taken from Annex A of the CityGML discussion paper.

Name	Description / Interpretation
MD_CityModel-Description	3D city model information
Name	Description / Interpretation
MD_Building	Building information
processOf_ RoofModeling	Information about the creation process of the roofs such as laser scanning, digitizing, of photogrammetry. The ISO 19115 metadata model includes the class *LI_ProcessStep* (subclass of *DQ_DataQuality* and *LI_Lineage*), which gives information about the development process and also gives output about the creation process through the attribute *description*.
roofType	Information about the type of roofs
sourceOfFootprint	Information about the source of the footprint such as cadastre data, architectural model. ISO19115 Metadata model has a class called *LI_Source* (Subclass of *DQ_DataQuality* and *LI_Lineage*) with the attribute *description*, which gives a detailed description of the data source.
processOf-BuildingHeight	Description of the building height detection process such as measured height (e.g. from ALKIS), calculated height from the number of storys. The ISO19115 Metadata model includes the *LI_ProcessStep* class (subclass of *DQ_DataQuality* and *LI_Lineage*), which gives information about the development process and has the attribute *description*, which informs about the creation process.
buildingFunction	Information about the function of the building
addressInformation	Information availability about owner of the building and his postal address: “yes” or “no“
BuildingInstallation Function	Information about building element(s) which characterize the building´s outer appearance
openings	Information about the type of opening in an outer or inner wall
surface	Information about the surface of the building´s facade
roofSurface	Information about the surface of the roof

Name	Description / Interpretation
MD_Water	Information about a body of water
waterBody	Information about the type of water body
Name	Description / Interpretation
MD_Street	Information about streets
trafficObject	Information about traffic objects
trafficAreaFunction	Function of traffic areas
trafficAreaUsage	Usage of the traffic area
surfaceMaterial	Information about the surface material of the traffic area
streetName	Information about the existence of street names: "yes" or "no"
Graphical-Visualization	Information about the *graphical visualization* of the traffic area
Name	Description / Interpretation
MD_Plant	Information about the plant object
plantClass	Information about the class of plants (e.g. shrub, high plants, grasses)
Name	Description / Interpretation
MD_CityFurniture	Information about the city furniture
cityFurnitureCode	Information about the used city furniture
Name	Description / Interpretation
MD_Surface	General information about the surface of an object or objects
surfaceStyle Type	Specification of the surface of an object: Each surface can either have a color with lighting information or a texture.
MD_Resolution	Information about the spatial resolution resp. the quality (texture) of the geographic information. *MD_Resolution* is a class included in ISO19115.
textureType	Information about the texture type: Was the texture specifically and individually made for a certain object, or is the texture of a sort which is typical for a certain geo object and can be applied on multiple objects?

Table 2: Further proposals for extension of ISO 19115.

If none of the values in the code list can be allocated then the attribute value „other" can be applied and the user can use free text entry (CharacterString) in order to describe his/her data.

4 DISCUSSION AND OUTLOOK

As of now, there is no online object catalogue available for CityGML from which attribute values could be derived. If the catalog resp. the code lists from CityGML were available online as an object catalogue, the information we put under the *MD_ContentInformation* class would not be necessary directly in the metadata profile. Instead, a reference to the internet catalogue could be given. This can be done by the allocation of the respective attribute *featureTypes* and *featureCatalogueCitation* of the class *MD_FeatureCatalogueDescription* (see: *MD_ContentInformation).* The additional attribute *featureCatalogueCitation* delivers bibliographical information concerning the implemented object type catalogue (title, short name, date, edition). This information can be in form of a Web-Link if an object catalogue is available on the internet. Another attribute is *featureTypes* which should include a list of object types, if possible as a link to the according part of the catalogue if it is available online.

We see this work as first step towards a further discussion on the needs of future 3D-SDI – in particular for 3D city models. Current SDI developments focus on 2D spatial data, but it is clear, that in the long run a similar development is necessary for 3D data. SDI need metadata catalogues in order

to fulfill their promises. Therefore we conducted this first analysis on the possibilities and deficiencies of current metadata standards as ISO19115 with respect to 3D city models. We found that a range of basic attributes in ISO 19115 can already be used for this purpose. We found several possible issues that need to be discussed if and how these missing information could also be incorporated in metadata catalogues. We also presented possible ways how these missing elements could be added to ISO 19115. We are aware that these are only proposals which might lead to further discussions.

Another major problem we are aware of is, that actually filling in all these additional elements is laborious and double work might be needed. One solution for this problem might be to automatically generate the extended ISO 19115 metadata from out of the CityGML file and therefore avoid duplication of work. Yet another option might be to store the list of object classes in an online catalogue and only link to this resource. It is also clear that today still most 3D city models lack most of such information. Some hope for the better may be justified if CityGML or similar standardized semantic descriptions for city models are used more frequently, as this allows at least developing a common semantic model for the objects that are part of the city model. This can be incorporated into the metadata standard either directly or via online object catalogues. We are aware that is not our task to amend an ISO standard with the above mentioned elements and that there are other possibilities. But it is important to further discuss this as it is an important topic for the future.

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