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OGC® OWS-6 UTDS-CityGML Implementation Profile

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Preface

Suggested additions, changes, and comments on this draft report are welcome and encouraged. Such suggestions may be submitted by email message or by making suggested changes in an edited copy of this document.

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OWS-6 Testbed

OWS testbeds are part of OGC's Interoperability Program, a global, hands-on and collaborative prototyping program designed to rapidly develop, test and deliver Engineering Reports and Chnage Requests into the OGC Specification Program, where they are formalized for public release. In OGC's Interoperability Initiatives, international teams of technology providers work together to solve specific geoprocessing interoperability problems posed by the Initiative's sponsoring organizations. OGC Interoperability Initiatives include test beds, pilot projects, interoperability experiments and interoperability support services - all designed to encourage rapid development, testing, validation and adoption of OGC standards.

In April 2008, the OGC issued a call for sponsors for an OGC Web Services, Phase 6 (OWS-6) Testbed activity. The activity completed in June 2009. There is a series of on-line demonstrations available here: http://www.opengeospatial.org/pub/www/ows6/index.html

The OWS-6 sponsors are organizations seeking open standards for their interoperability requirements. After analyzing their requirements, the OGC Interoperability Team recommended to the sponsors that the content of the OWS-6 initiative be organized around the following threads:

1. Sensor Web Enablement (SWE)
2. Geo Processing Workflow (GPW)
3. Aeronautical Information Management (AIM)
4. Decision Support Services (DSS)
5. Compliance Testing (CITE)

The OWS-6 sponsoring organizations were:

- U.S. National Geospatial-Intelligence Agency (NGA)
- Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD)
- GeoConnections - Natural Resources Canada
- U.S. Federal Aviation Agency (FAA)
- EUROCONTROL
- EADS Defence and Communications Systems
- US Geological Survey
- Lockheed Martin

- BAE Systems
- ERDAS, Inc.

The OWS-6 participating organizations were:

52North, AM Consult, Carbon Project, Charles Roswell, Compusult, con terra, CubeWerx, ESRI, FedEx, Galdos, Geomatys, GIS.FCU, Taiwan, GMU CSISS, Hitachi Ltd., Hitachi Advanced Systems Corp, Hitachi Software Engineering Co., Ltd., iGSI, GmbH, interactive instruments, lat/lon, GmbH, LISAsoft, Luciad, Lufthansa, NOAA MDL, Northrop Grumman TASC, OSS Nokalva, PCAvionics, Snowflake, Spot Image/ESA/Spacebel, STFC, UK, UAB CREAF, Univ Bonn Karto, Univ Bonn IGG, Univ Bunderswehr, Univ Muenster IfGI, Vightel, Yumetech.

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1 Introduction

1.1 Scope

This OGC™ document specifies a CityGML-based application schema for a subset of an Urban Topographic Data Store (UTDS) as specified by the US National Geospatial-Intelligence Agency (NGA).

The particular focus of this implementation profile was to test the applicability of CityGML to UTDS data.

This document specifies the implementation profile as well as the findings.

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1.2 Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

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1.3 Revision history

Date	Release	Editor	Primary clauses modified	Description
04/17/2009	0.0.1	C. Portele	all	
05/10/2009	0.0.2	C. Portele	all	Revision based on comments

06/03/2009	0.0.3	C. Portele P. Birkel	all	Minor edits for consistency

1.4 Future work

See Annex B.

2 References

The following documents are referenced in this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

OpenGIS® City Geography Markup Language (CityGML) Encoding Standard, OGC document 08-007r1

Intelligence Community Information Security Marking (IC ISM) version 2.1, Office of the Director of National Intelligence

NOTE The schema is available at http://schemas.opengis.net/ic/2.1/IC-ISM-v2.1.xsd.

3 Terms and definitions

For the purposes of this report, the definitions specified in the CityGML standard and the NAS shall apply.

4 Conventions

4.1 Abbreviated terms

ADE	Application Domain Extension
IC ISM	Intelligence Community Information Security Marking
LoD	Level of Detail
NAS	NSG Application Schema
NEC	NSG Entity Catalog
NGA	National Geospatial-Intelligence Agency
NSG	National System for Geospatial-Intelligence
OWS	OGC Web Services
UTDS	Urban Topographic Data Store
XML	extensible Markup Language

4.2 UML notation

Diagrams that appear in this standard are presented using the Unified Modeling Language (UML) static structure diagram, as described in ISO/CD 19103.

5 Overview and general approach

The Urban Topographic Data Store (UTDS) data content specification of NGA specifies an application schema & entity catalog (see Bibliography) with a significant number of feature types, feature properties, data types and listed values. For each of the these, a definition exists that is captured in a feature concept dictionary.

In the current version of UTDS, spatial geometries are of dimensions 0, 1 or 2. Additional information about dimensional measures is optionally provided in attributes like "height above surface level", "highest elevation", "width", or "length or diameter".

CityGML specifies an application schema with a relatively small number of feature types typically used in city models. A large number of listed values is provided to express additional information to the features. A difference between CityGML and UTDS is that in the CityGML standard there is no definition for any feature type, property or listed value. The only hint at the semantics of a model element is its name. The UTDS specifies a complete definition (and optionally an additional description) for each element.

The two UTDS datasets used in OWS-6 (airport dataset and city dataset) use a restricted set of feature types (the columns in Table 1) and properties (the rows) from the complete UTDS application schema only.

Table 1 — Scope of the UTDS data used in OWS-6

Property		AIRCRAFT_HANGAR	APRON	BUILDING	CONTROL_TOWER	FENCE	FUEL_STORAGE_FACILITY	GATE	LIGHT_SUPPORT_STRUCTURE	NON_BUILDING_STRUCTURE	ROAD	RUNWAY	STOPWAY	STORAGE_TANK	SURFACE_BUNKER	TAXIWAY	TOWER	VEHICLE_BARRIER
Accessibility Status	ACS		X									X	X			X		
Aerodrome Pavement Information: Aerodrome Movement Surface Composition	ZI019_ASU1, ZI019_ASU2, ZI019_ASU3		X									X	X			X		
Apron Type	HAC		X															
Basic Encyclopedia (BE) Number	BEN											X						
Condition of Facility	FUN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Feature Function	FFN1, FFN2, FFN3			X	X		X		X									
Fence Type	FTI					X												

Gate Use	GTC							X										
Height Above Surface Level	HGT	X		X	X	X	X		X	X				X	X		X	X
Height Above Surface Level (height accuracy)	HGT_AHO	X		X	X	X	X		X	X				X	X		X	X
Highest Elevation	ZVH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Highest Elevation (absolute vertical accuracy)	ZVH_AVA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Length or Diameter	LEN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Located Underground	LUN						X							X				
Manufacturing Information : Product	ZI014_PPO1, ZI014_PPO2, ZI014_PPO3						X											
Product	PPO1, PPO2, PPO3													X				
Pylon Configuration	PYC								X									
Pylon Material	PYM								X									
Structure Shape	SSC													X				
Runway Direction (high end) : Runway Identifier	GB052_RIDH											X						
Runway Direction (low end) : Runway Identifier	GB052_RIDL											X						
Thickness	THI					X		X										
Tower Shape	TOS								X									
Tower Type	TTC1, TTC2, TTC3																X	
Track or Lane Count	LTN										X							
Transportation System Type	TRS1, TRS2, TRS3				X			X										X
Vertical Construction Material	VCM1, VCM2, VCM3	X		X														
Width	WID	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X
Geometry (Horizontal) : Absolute Horizontal Accuracy (90%)	ZI010_AHA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Geometry (Vertical) : Absolute Vertical Accuracy (90%)	ZI010_AVA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ICISM Security : Resource Classification	ZR115_RS0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ICISM Security : Resource Owner-Producer	ZR115_RX4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Note : Memorandum	ZI006_MEM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Source Information : Spatial Source Type	ZI001_SSY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Source Information : Vertical Source Category	ZI001_VSC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Since the definition of the model elements in CityGML is unclear, the mapping from UTDS to CityGML is somewhat arbitrary. In all cases where a mapping could be done in several ways, it is essential to understand the goals of the UTDS-in-CityGML representation, so that the resulting application schema meets the requirements as close as possible. The goals for the UTDS-in-CityGML-experiment in OWS-6 are as follows:

> Test whether CityGML is the right choice for encoding urban data with a particular focus on supporting movement within an urban area. Two use cases are relevant - encoding for the transfer of data and visualization. Of these two, at this time visualization is the more important one.

NOTE The lack of definitions for the concepts in CityGML would be an even bigger issue, if the intent was to take some existing CityGML data and transform it to UTDS data.

The UTDS-CityGML application schema has been created based on the following design decisions:

- Existing concepts in CityGML were used whenever possible. This includes all model elements (feature types, properties, listed values). For example, UTDS roads are mapped to CityGML roads (and not any of its supertypes) and "feature function" properties in UTDS are mapped to "usage" and "function" properties in CityGML - making reuse of existing code list values whenever possible.
- The UTDS-CityGML application schema is modeled as an Application Domain Extension (ADE). The concept of generic attributes is not used to attach additional properties to CityGML feature types.
    - The reason for this approach is mainly to express at least some of the schema constraints captured in UTDS within the CityGML-based application schema. This simplifies validation (see also 09-038 GML Profile Validation Tool Guidelines ER).
    - Another reason is that for some aspects, particularly the reuse of the ICISM schema for security tagging, there is no way around creating an ADE including new feature elements in a new XML namespace.
- CityGML has strict requirements on the contents of a data set depending on the intended level of detail (LoD)[1]. For example, it is stated that “in LOD1, the positional and height accuracy of points must be 5m or less, while all objects with a footprint of at least 6m by 6m have to be considered.” In general, these requirements are related to absolute geometric accuracy, spatial representation and data capturing rules. Based

[1] However, the language in the OGC CityGML standard is contradictory and other parts of the standard could be interpreted that there are no such requirements.

on the requirements, the UTDS data is on LoD 1 or lower. This is reflected in the application schema. Geometric accuracy requirements were ignored in this testbed.

- The rules for creating the geometry of the CityGML-based feature from the source data is based on the LoD (see above), the available data and the goal to provide geometry in the maximum dimensionality in this context.
- In UTDS, code lists and enumerations are typically feature type dependent prohibiting meaningless combinations. This is also the case in CityGML; however, since all building-like structures are mapped to the single feature type building class in CityGML, different code lists do not exist for subcategories of buildings. To mimic this approach in the ADE, only a single ConditionOfFacility code list is specified that is "shared" between the different feature types. Additional constraints could be specified (in OCL and Schematron), if needed. Also, they have been created as code lists instead of enumerations to follow the general approach taken by CityGML.
- Code list values that were added to the existing CityGML code lists have been specified as extensions. While it might be the intention of the standard to allow ignoring the listed values specified in the CityGML standard, this does not seem to be a viable approach for two reasons:
    - Code lists can only be extended according to ISO/TS 19103, but this also implies that the provided pre-defined values cannot be ignored.
    - The code list encoding in CityGML provides no mechanism to point to the dictionary with the used code list values. i.e., CityGML does not provide a capability to interpret any code list values without prior knowledge unless only the pre-defined values are used - and those aren't actually defined, either. They are often reused from the German specifications ALKIS and ATKIS, which includes definitions for some of the values, but only in German. This makes CityGML difficult to use in an International Standards setting.
- At least for now, the data types mostly reflect the types used in the actual data. For example, accuracy is expressed in a measure value and not a DQ element from ISO 19115.
- IC ISM security markings are mapped to the IC ISM specification.

6 ISO 19109 application schema in UML

6.1 Overview and feature types

This clause illustrates the application schema using UML diagrams. Figure 1 provides an overview of the packages and their dependencies.

The remaining figures show the features types and data types of the UTDS-CityGML ADE in detail. The definitions of the feature types and their properties defined by the ADE is documented in the UTDS Entity Catalogue of NGA (and not repeated here).

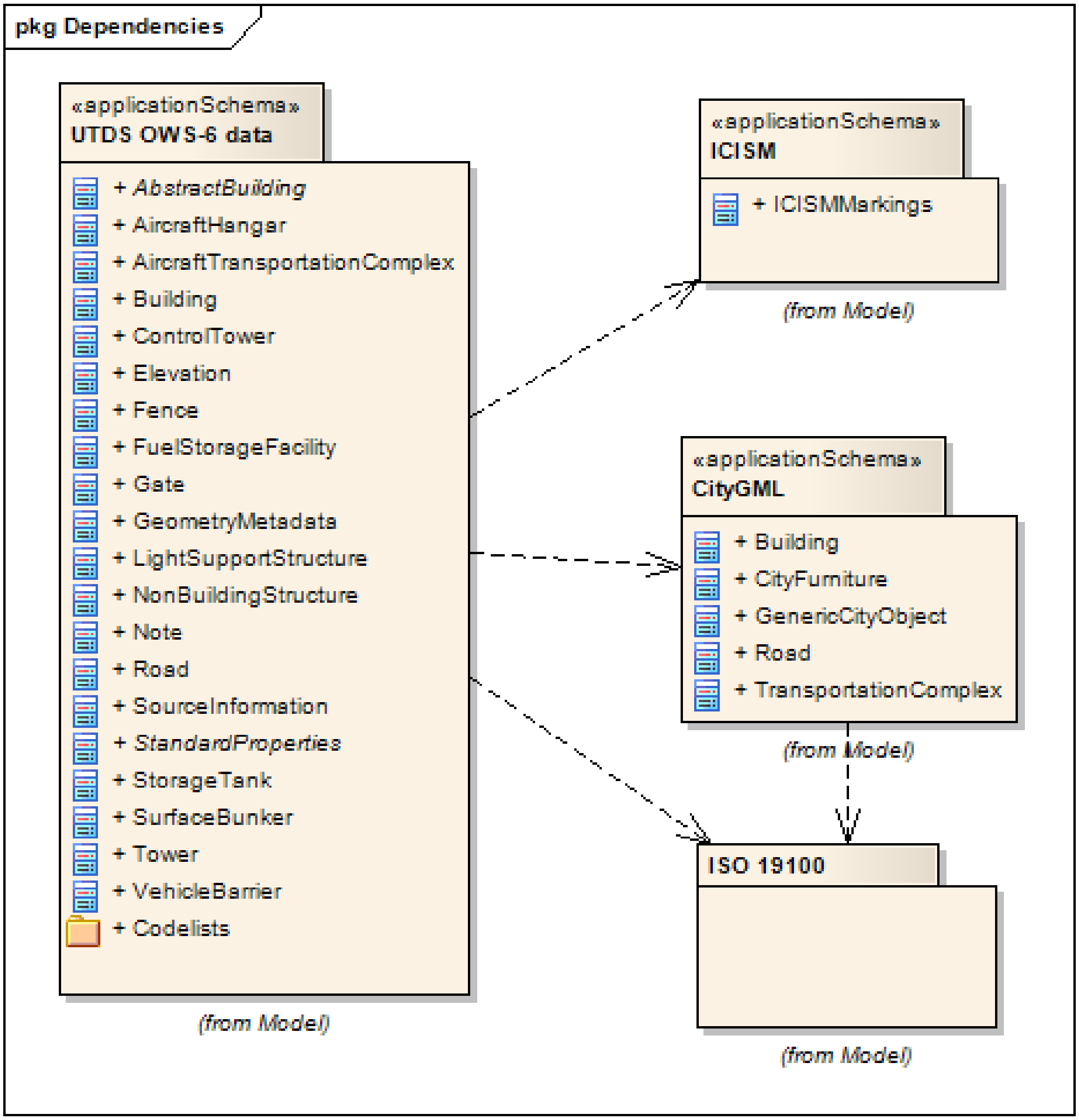

Figure 1 — Package overview of the UTDS-CityGML application schema

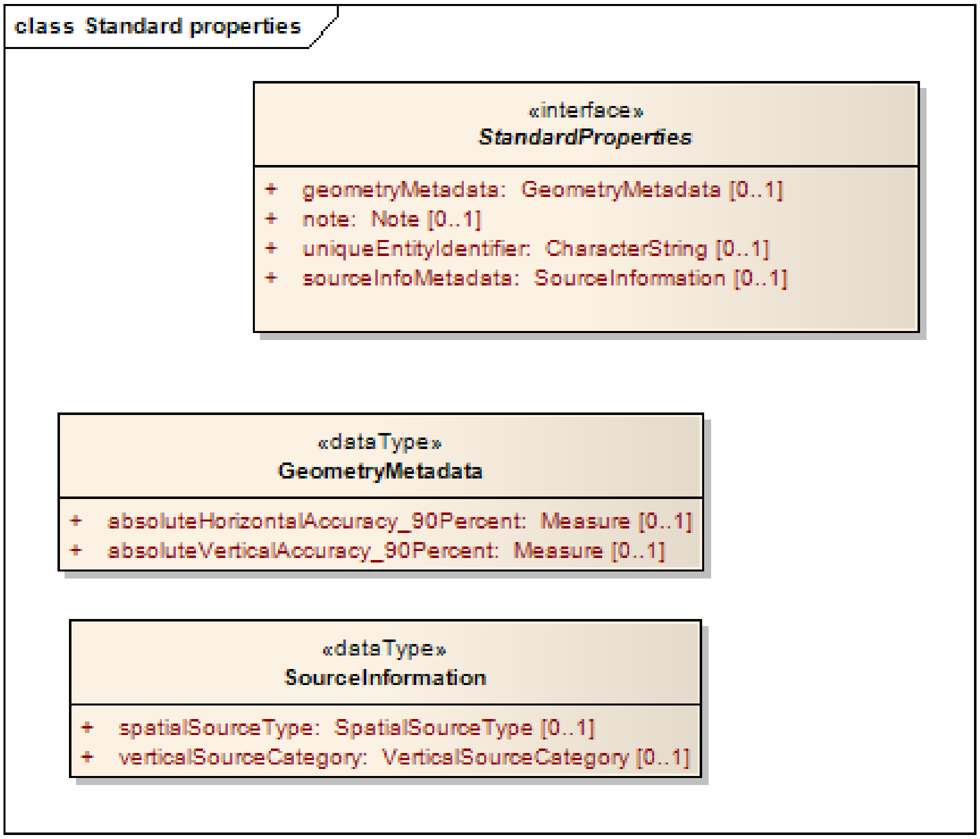

Figure 2 — Base type with properties applicable to any feature from a UTDS data set

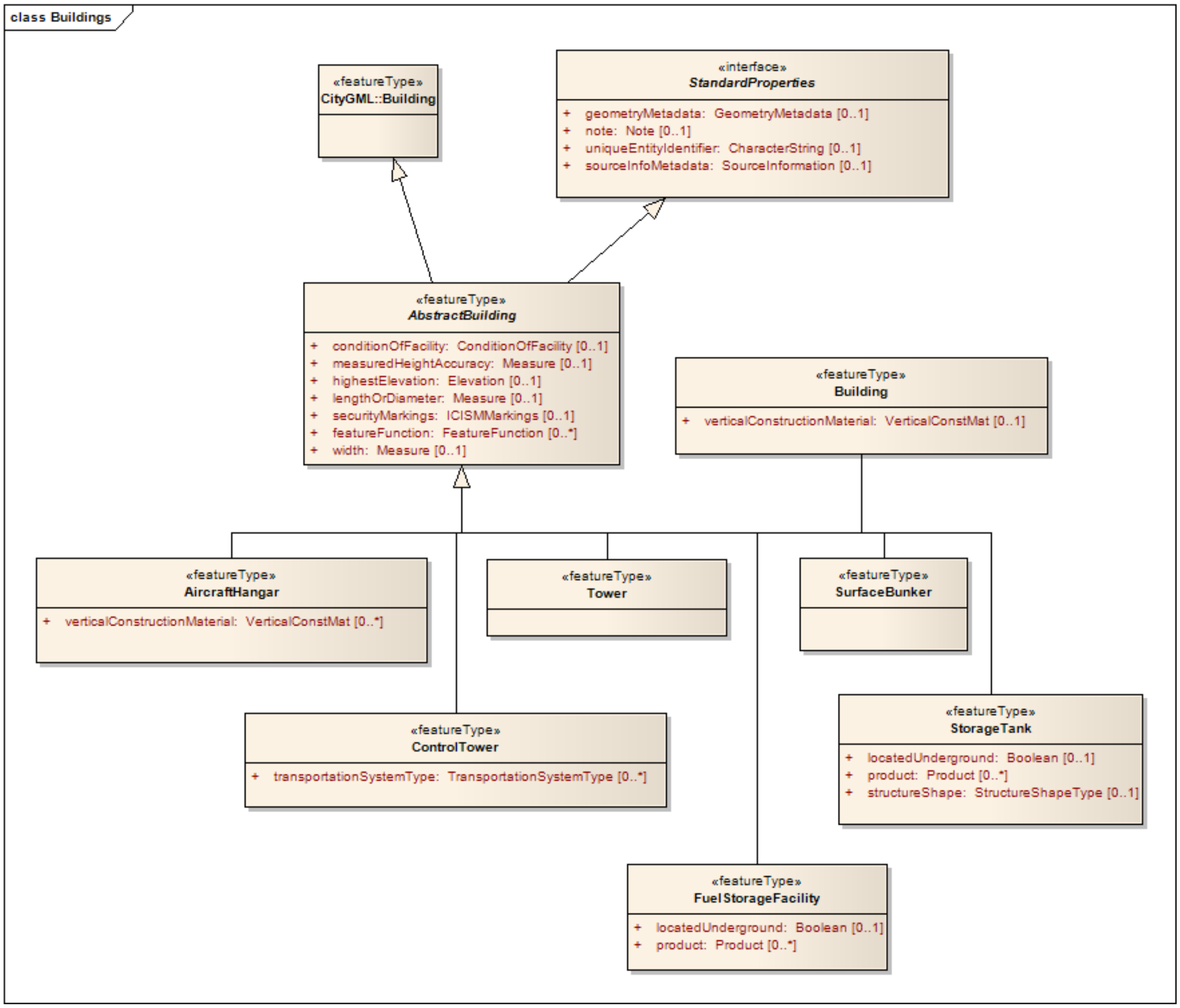

Figure 3 — Building features

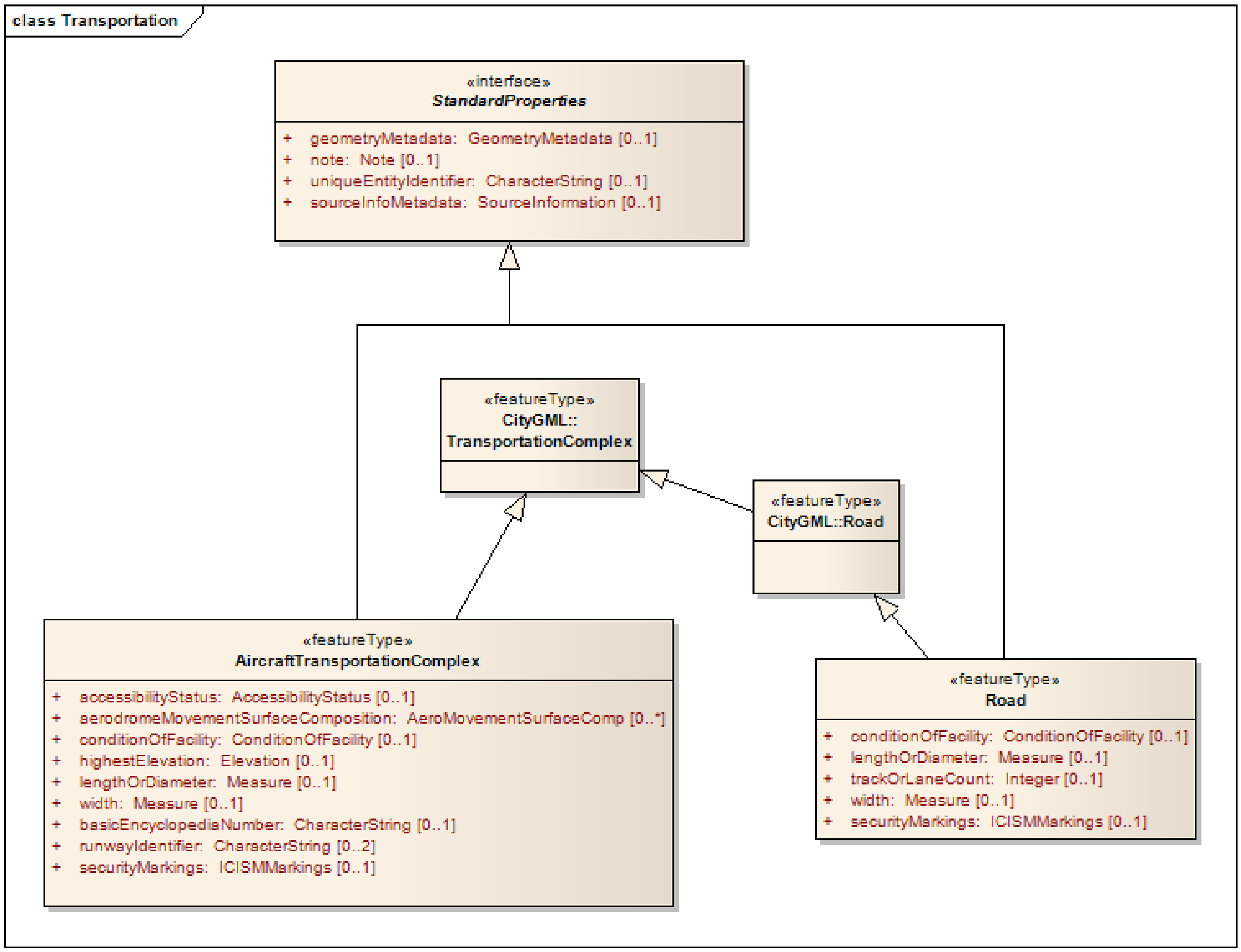

Figure 4 — Transportation features

Note that since several of the airport-related transportation features in UTDS have a similar pattern of properties, they are all represented by a single subtype of the CityGML feature type TransportationComplex, AircraftTransportationComplex. The function attribute specified for each CityGML transportation feature is used to distinguish the various types specified in UTDS; see 8.4 for details.

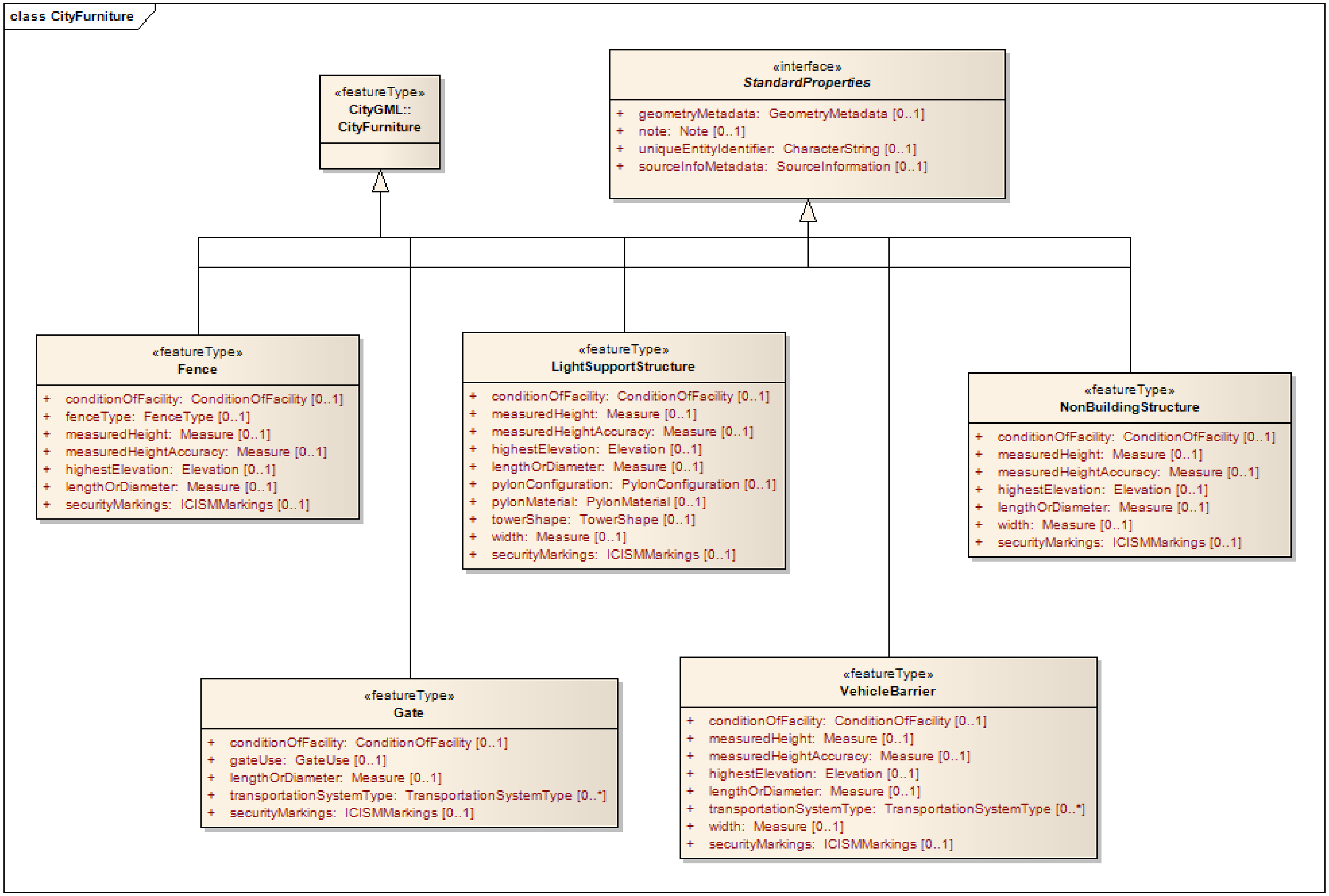

Figure 5 — City furniture features

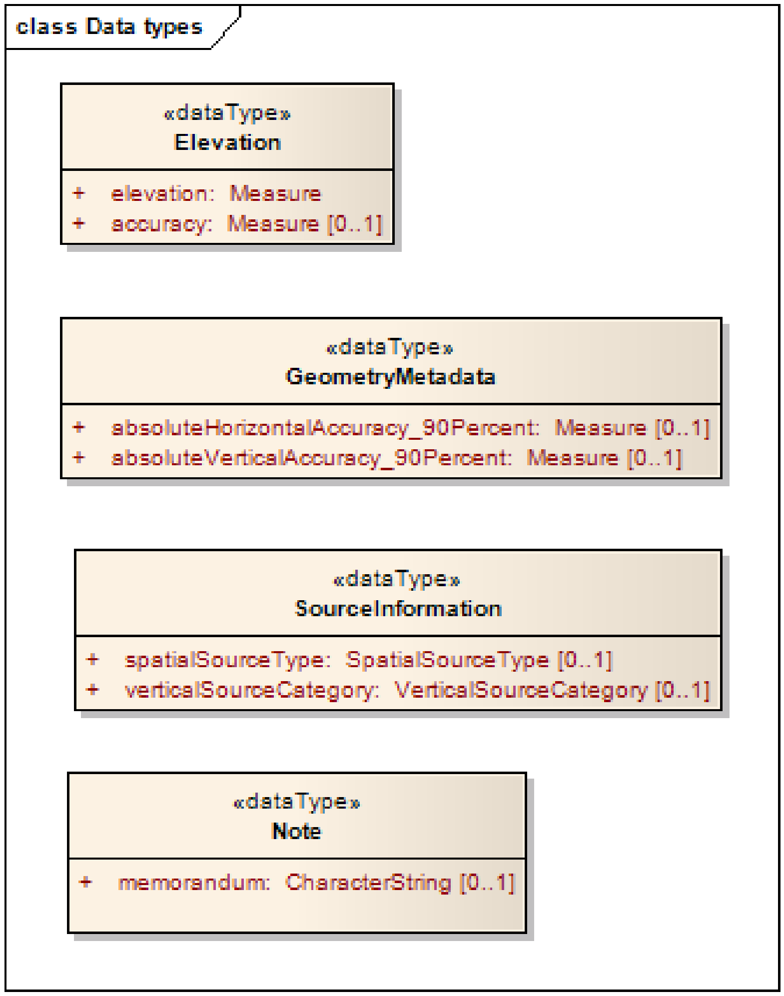

Figure 6 — Data types

6.2 Code lists

The relevant UTDS code lists are shown in the figures in this sub-clause. The lists contain all values specified by UTDS even though the city and airport datasets used in OWS-6 usually use only a small subset of the values.

Table 2 shows an overview how the code lists are represented in the UTDS-CityGML application schema. Details are provided in Clause 8.

Table 2 — Representation of UTDS code lists in UTDS-CityGML

UTDS code list	**UTDS-CityGML representation**
Accessibility Status	same
Aerodrome Movement Surface Composition	same
Apron Type	mapped to usage attribute
Condition of Facility	same
Feature Function	same, but also used to fill values of class, function and usage attributes
Fence Type	same
Gate Use	same
Located Underground	mapped to attribute with boolean value
Product	same
Pylon Configuration	same
Pylon Material	same
Structure Shape	same
Tower Shape	same
Tower Type	same
Transportation System Type	same
Vertical Construction Material	same
Spatial Source Type	same
Vertical Source Category	same

The definitions of the code list values are documented in the UTDS Entity Catalogue of NGA (and not repeated here).

NOTE: GML dictionary representations of the code lists with an associated XSLT script to view them in a web browser are packaged together with this document. They can also be accessed online at “http://services.interactive-instruments.de/ows6/data/codelists/*NameOfCodelist*.xml”.

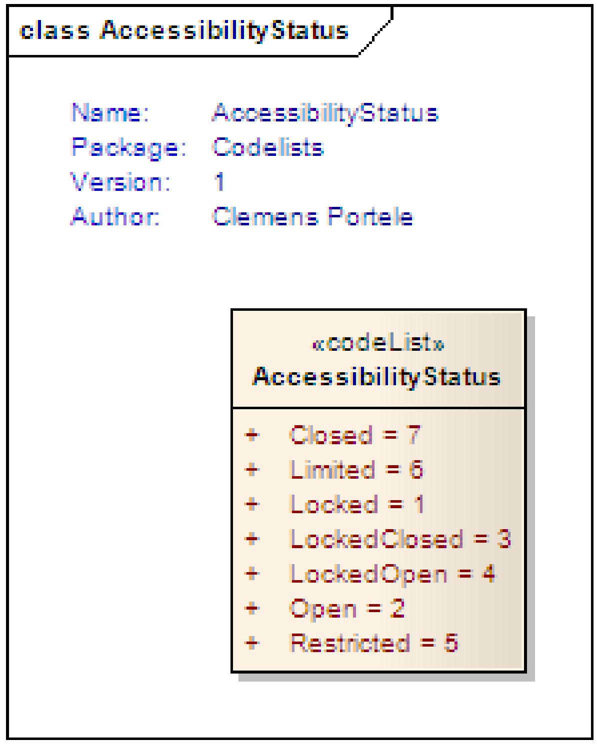

Figure 7 — Accessibility Status

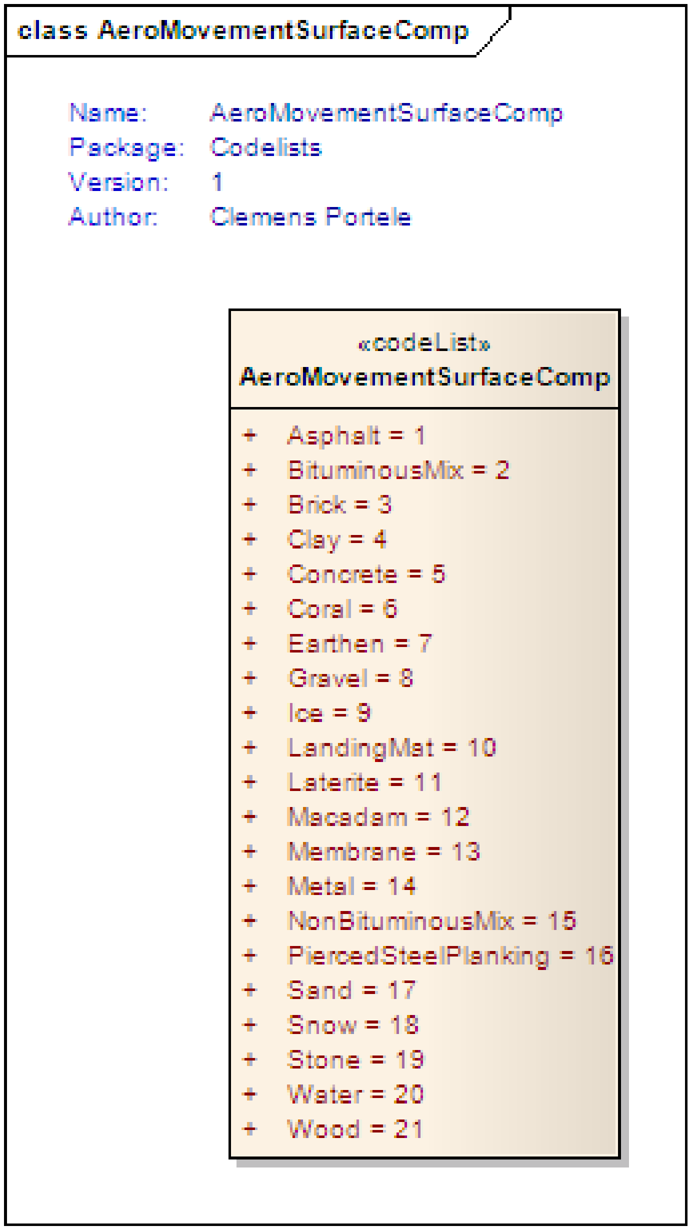

Figure 8 — Aerodrome Movement Surface Composition

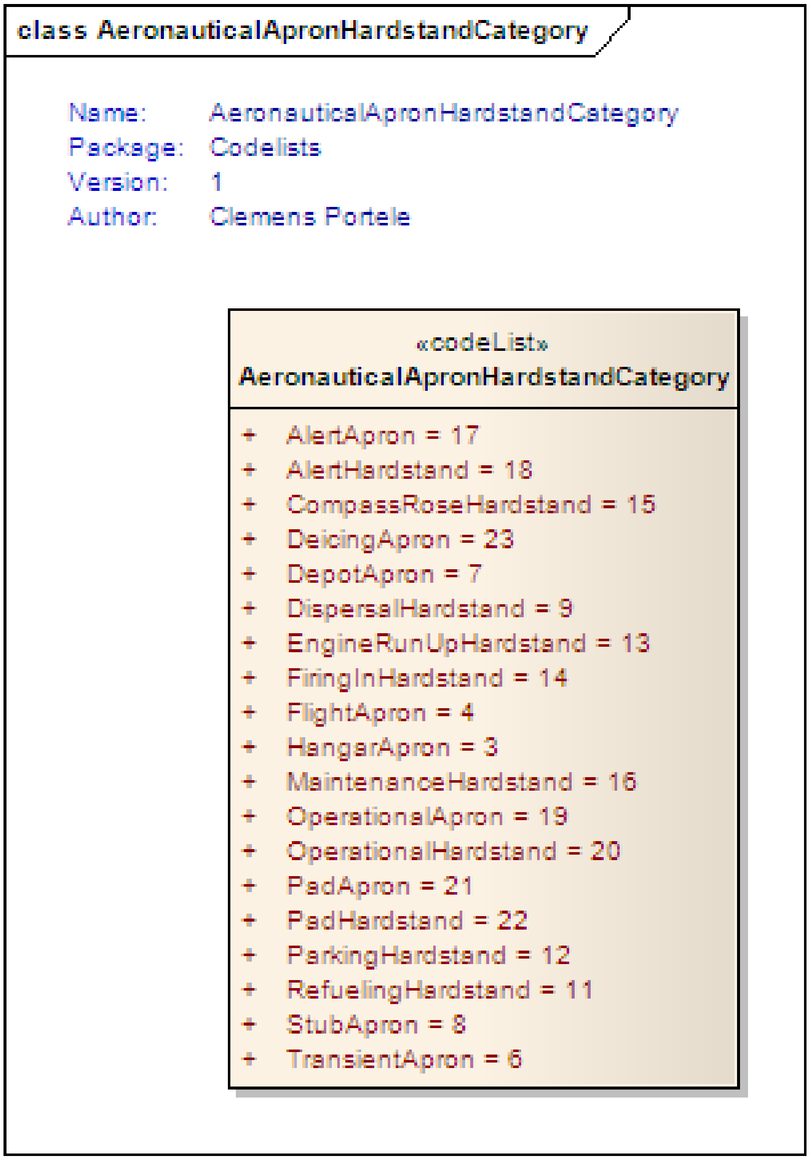

Figure 9 — Aeronautical Apron Hardstand Category

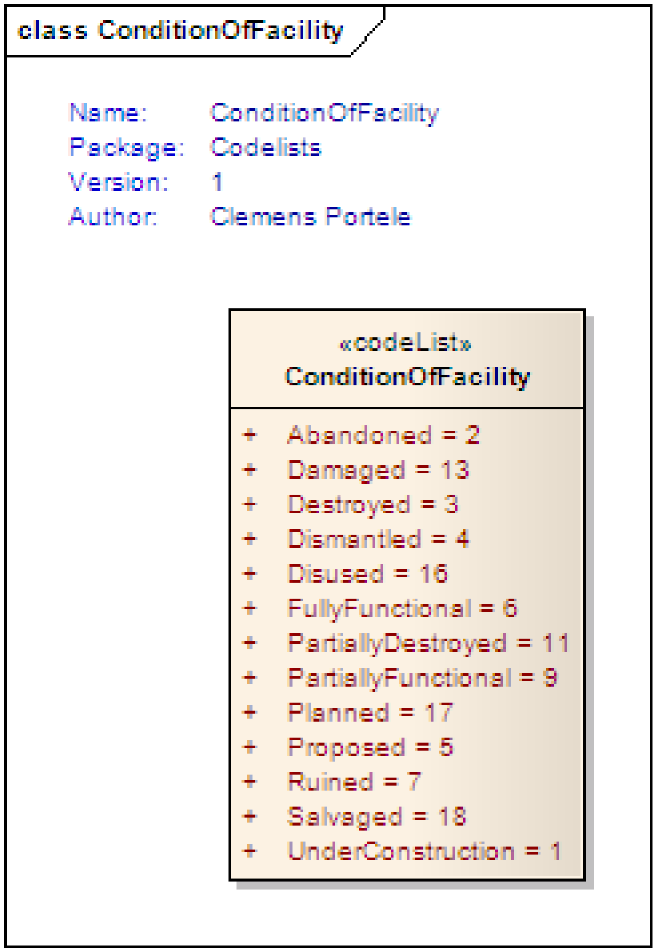

Figure 10 — Condition of Facility

The code list FeatureFunction is too large to be shown in this document. Please refer to the GML dictionary packaged with this document.

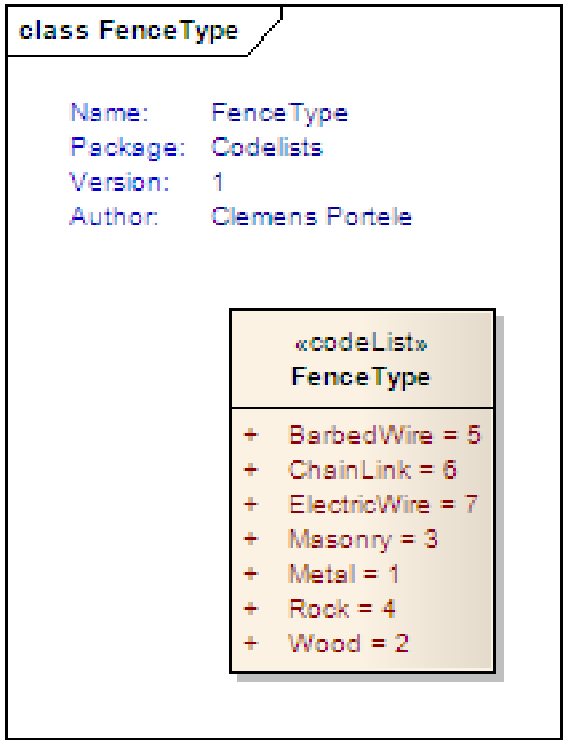

Figure 11 — FenceType

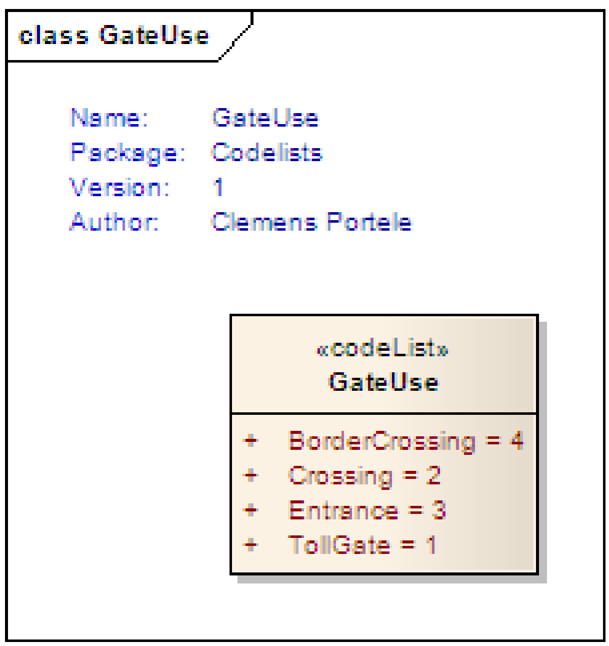

Figure 12 — GateUse

The code list Product is too large to be shown in this document. Please refer to the GML dictionary packaged with this document.

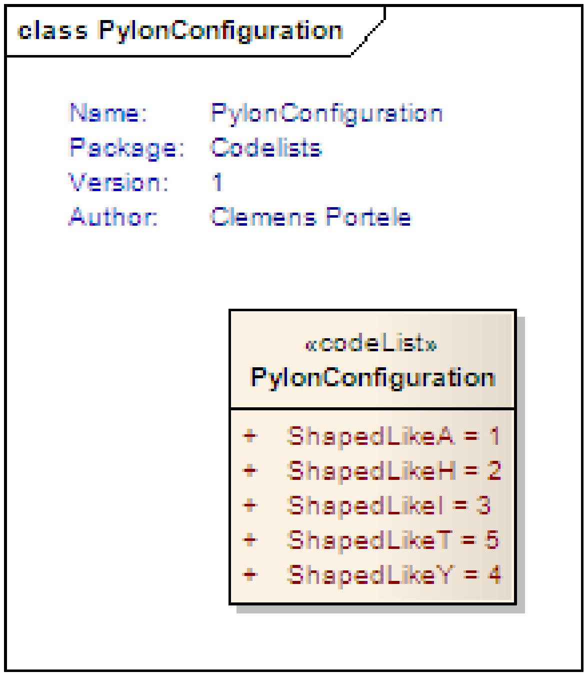

Figure 13 — Pylon Configuration

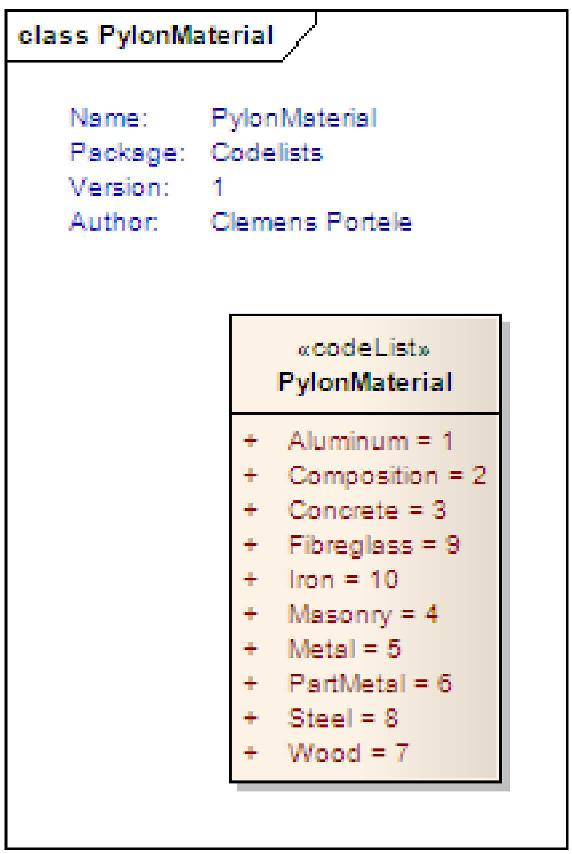

Figure 14 — Pylon Material

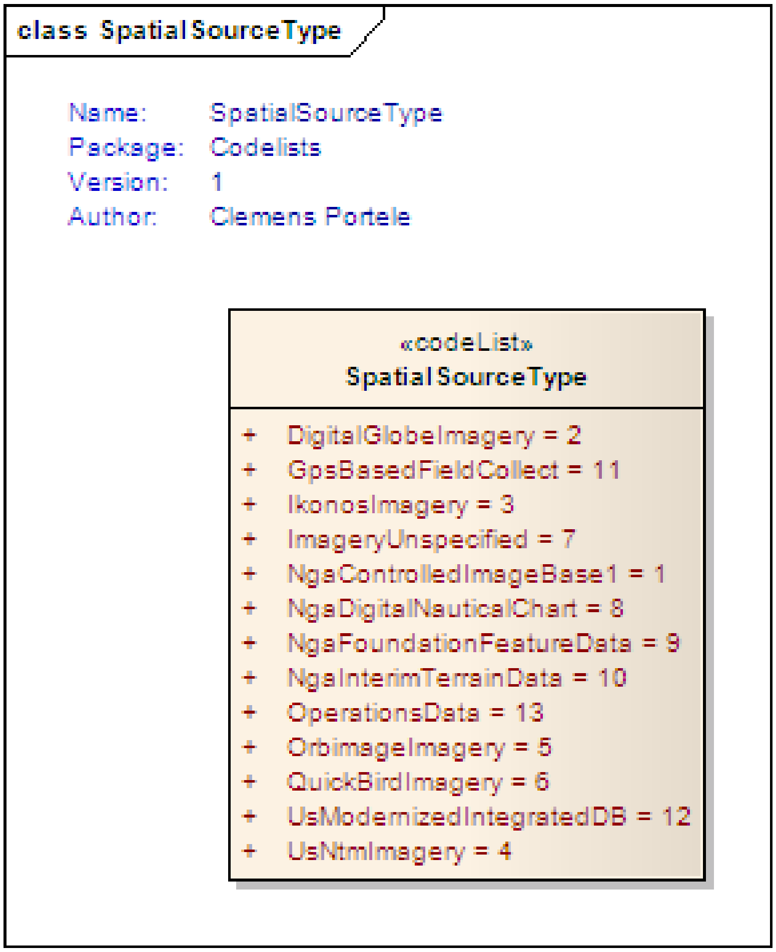

Figure 15 — Spatial Source Type

Figure 16 — Structure Shape

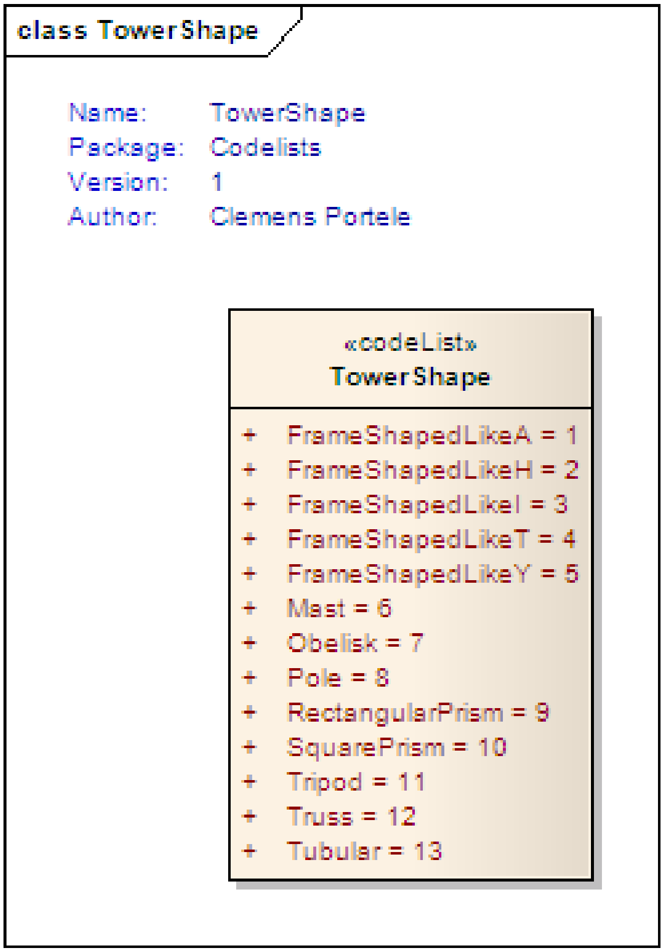

Figure 17 — Tower Shape

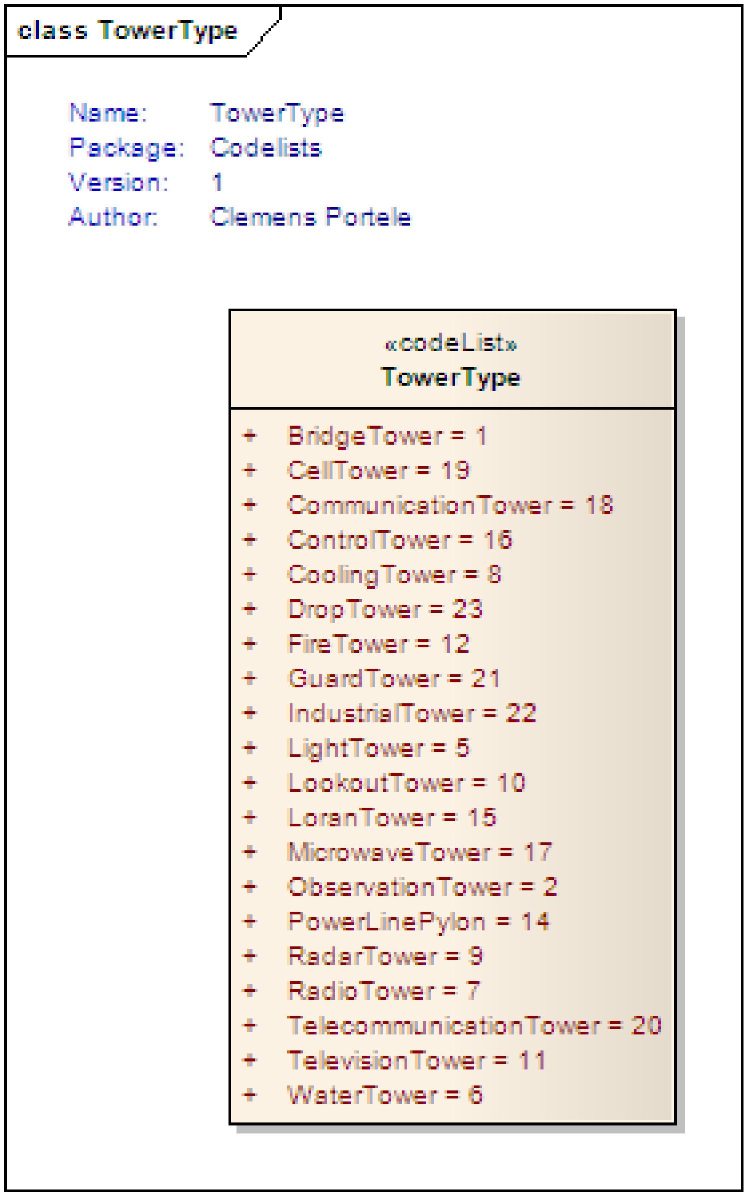

Figure 18 — Tower Type

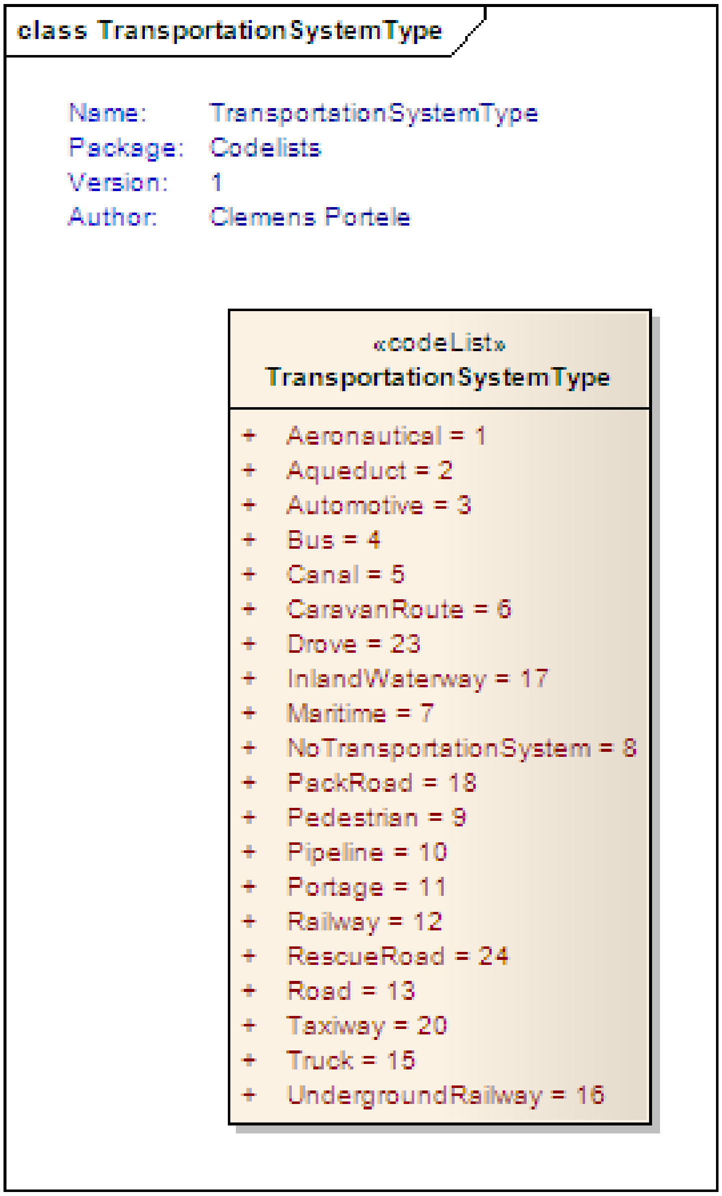

Figure 19 — Transportation System Type

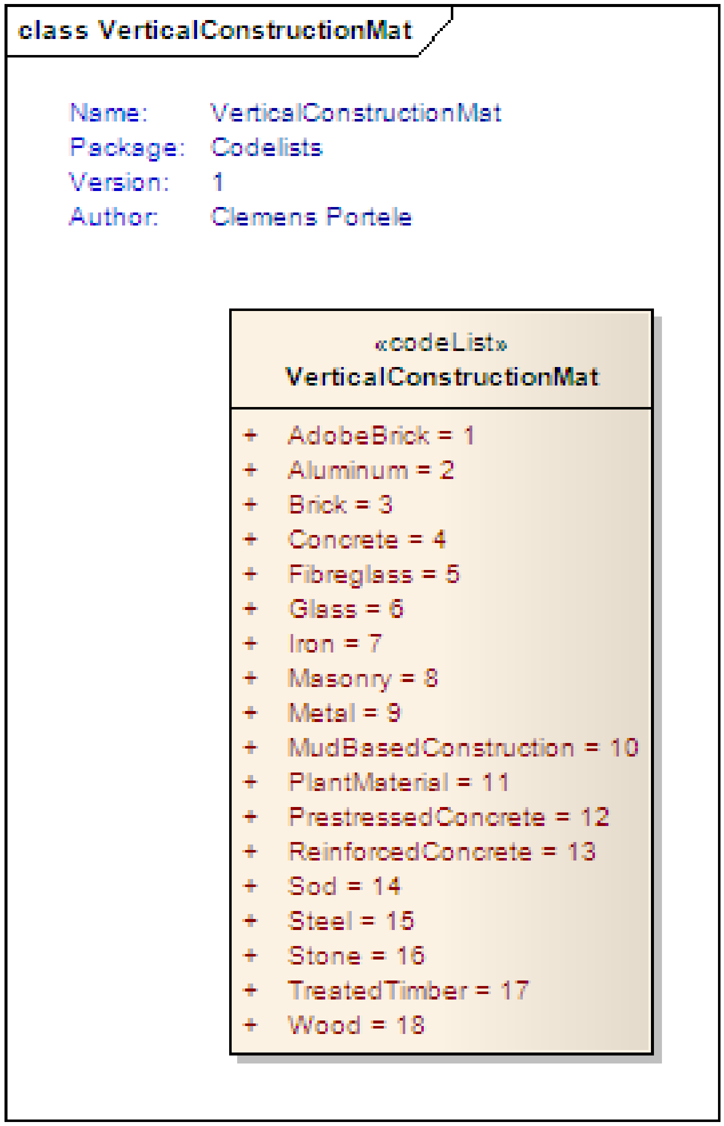

Figure 20 — Vertical Construction Material

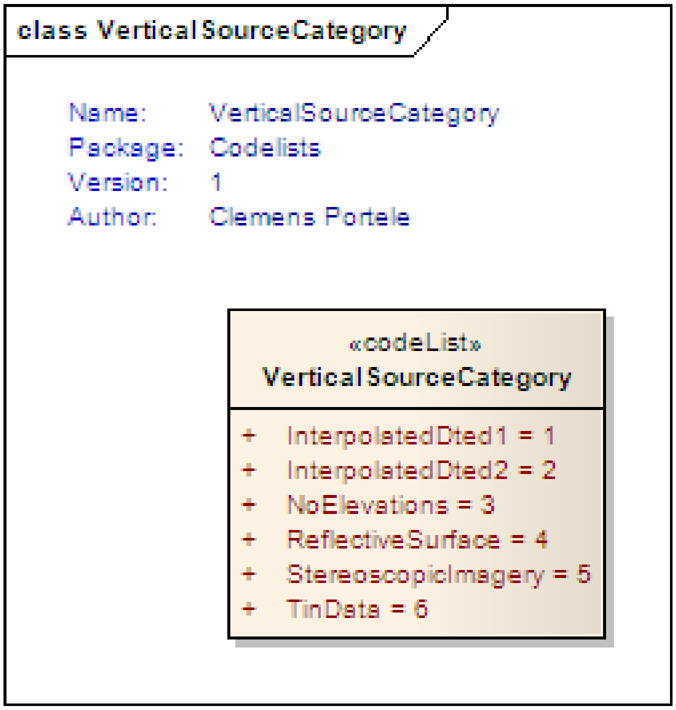

Figure 21 — Vertical Source Category

7 XML Schema with CityGML ADE

The XML schema components in UTDS-CityGML.xsd has been derived from the application schema above by ShapeChange and represent version 0.3 the UTDS CityGML ADE. This version has been the basis for the data used in OWS-6.

The XML Schema document UTDS-CityGML.xsd is packaged together with this document (i.e., in the same zip archive).

In addition to the XML Schema, the code lists of the ADE are encoded as GML dictionaries by ShapeChange. The dictionaries reference an XSLT script that styles that code list content as a HTML document. These files are also packaged with this document (i.e., in the same zip archive).

8 Mapping

8.1 General remarks

This clause describes the mapping from the features and fields in the UTDS datasets to UTDS-CityGML features.

Only code list values that actually occur in the city/airport data sets are mapped below.

8.2 For all Feature Types

Target property in UTDS-CityGML	**Field in source data**
geometryMetadata/GeometryMetadata/absoluteHorizontalAccuracy_90Percent	ZI010_AHA
geometryMetadata/GeometryMetadata/absoluteVerticalAccuracy_90Percent	ZI010_AVA
@icism:classification	ZR115_RS0
@icism:ownerProducer	ZR115_RX4
note/Note/memorandum	ZI006_MEM
sourceInfoMetadata/SourceInformation/spatialSourceType	ZI001_SSY
sourceInfoMetadata/SourceInformation/verticalSourceCategory	ZI001_VSC

8.3 Buildings

8.3.1 AIRCRAFT_HANGAR_S

Target Feature Type: AircraftHangar

Target property in UTDS-CityGML	**Source**
build:class	1170 (traffic)
build:function	1540 (hangar)
build:usage	1540 (hangar)
build:lod1Solid	solid from the given multi patch surface geometries in the source Shape file
conditionOfFacility	Field FUN
build:measuredHeight	Field HGT
verticalConstructionMaterial	Fields VCM1, VCM2, VCM3 NOTE To represent multiple values, the maximum multiplicity of the attributes in the UTDS-CityGML application has been set to unlimited. In case the values are ordered, such order is lost in the mapping.

	This same applies to other cases with multiple attributes in the UTDS-CityGML application schema.
width	Field WID

8.3.2 BUILDING_S

Target Feature Type: Building

Target property in UTDS-CityGML	Source
build:class	see featureFunction
build:function	see featureFunction
build:usage	see featureFunction
build:lod1Solid	solid from the given multi patch surface geometries in the source Shape file
featureFunction	Fields FFN1, FFN2, FFN3 810 (Administration) → class =1020 (administration); function =1970 (administration building); usage = 1970 (administration building) 520 (AirTransport) → class =1170 (traffic); function =3520 (AirTransport, NEW[2]) 536 (CargoHandling) → class =1170 (traffic); function =3536 (CargoHandling, NEW) 835 (DefenceActivities) → class =1140; function =3835 (DefenceActivities, NEW) 560 (DetachedHouse) → class =1000 (habitation); function =1000 (residential building) 850 (Education) → class =1100 (schools, education, research); function =2070 (building for education and research) 845 (Firefighting) → class =1020 (administration); function =2410 (fire station) 811 (Government) → class =1020 (administration)

[2] New values added to the CityGML code lists for the UTDS-CityGML application schema are marked as "NEW".

	781 (Guard) → class =1140 (security); function =3781 (Guard, NEW) 860 (HumanHealthActivities) → class =1120 (healthcare); function =3860 (HumanHealthActivities, NEW) 99 (Manufacturing) → class =1160 (industry); function =3099 (Manufacturing, NEW) 931 (PlaceOfWorship) → class =1080 (church institution); function =3931 (PlaceOfWorship, NEW) 495 (RoadTransport) → class =1170 (traffic); function =3495 (RoadTransport, NEW) 481 (Terminal) → class =1170 (traffic); function =3481 (Terminal, NEW) 530 (WarehousingStorage) → class =1150 (storage); function =3530 (WarehousingStorage, NEW) Remark: populate class only from FFN1
conditionOfFacility	Field FUN
build:measuredHeight	Field HGT
verticalConstructionMaterial	Fields VCM1, VCM2, VCM3
width	Field WID

8.3.3 BUILDING_P

See BUILDING_S, except:

Target property in UTDS-CityGML	**Source**
build:lod1Solid	box from surface geometry (as square around the point geometry with width WID) and height HGT; assumption: z coordinate value from the given geometry is the top height of the building; default width is 10m

8.3.4 CONTROL_TOWER_P

Target Feature Type: ControlTower

Target property in UTDS-CityGML	**Source**
build:class	see featureFunction - should generally be 1170 (traffic)
build:function	see featureFunction
build:usage	see featureFunction
build:lod1Solid	box from surface geometry (as square around the point geometry with width WID) and height HGT; assumption: z coordinate value from the given geometry is the top height of the tower; default width is 10m
featureFunction	Fields FFN1, FFN2, FFN3 mapping see BUILDING_S Remark: populate class only from FFN1
conditionOfFacility	Field FUN
build:measuredHeight	Field HGT
transportationSystemType	Fields TRS1, TRS2, TRS3
width	Field WID

8.3.5 TOWER_P

Target Feature Type: Tower

Target property in UTDS-CityGML	**Sourc**
build:class	see towerType
build:function	see towerType
build:lod1Solid	box from surface geometry (as square around the point geometry with width WID) and height HGT; assumption: z coordinate value from the given geometry is the top height of the tower; default width is 10m
towerType	Fields TTC1, TTC2, TTC3

	20 (TelecommunicationTower) → class =1130 (communicating); function =3020 (TelecommunicationTower, NEW) 21 (GuardTower) → class =1140 (security); function =3021 (GuardTower, NEW) Remark: populate class only from TTC1
conditionOfFacility	Field FUN
build:measuredHeight	Field HGT
width	Field WID

8.3.6 FUEL_STORAGE_FACILITY_S

Target Feature Type: FuelStorageFacility

Target property in UTDS-CityGML	**Source**
build:class	see featureFunction - should generally be 1150 (storage)
build:function	see featureFunction
build:usage	see featureFunction
build:lod1Solid	box from surface geometry as base surface and height HGT
featureFunction	Fields FFN1, FFN2, FFN3 mapping see BUILDING_S Remark: populate class only from FFN1
conditionOfFacility	Field FUN
build:measuredHeight	Field HGT
locatedUnderground	Field LUN 1000 → “false” 1001 → “true”
width	Field WID

product	Fields ZI014_PPO1, ZI014_PPO2, ZI014_PPO3

8.3.7 STORAGE_TANK_S

Target Feature Type: StorageTank

Target property in UTDS-CityGML	**Source**
build:class	1150 (storage)
build:lod1Solid	solid from the given multi patch surface geometries in the source Shape file
conditionOfFacility	Field FUN
build:measuredHeight	Field HGT
locatedUnderground	Field LUN 1000 → "false" 1001 → "true"
width	Field WID
product	Fields PPO1, PPO2, PPO3
structureShape	Field SSC

8.3.8 SURFACE_BUNKER_S

Target Feature Type: SurfaceBunker

Target property in UTDS-CityGML	**Source**
build:class	1140 (security)
build:function	2430 (bunker)
build:lod1Solid	solid from the given multi patch surface geometries in the source Shape file
conditionOfFacility	Field FUN
build:measuredHeight	Field HGT

width	Field WID

8.4 Transportation

8.4.1 APRON_S

see STOPWAY_S, except:

Target property in UTDS-CityGML	**Source**
trans:function	2180 (apron)
trans:usage	Field HAC 3 (HangarApron) → usage = 3003 (HangarApron, NEW) 7 (DepotApron) → usage = 3007 (DepotApron, NEW) 21 (PadApron) → usage = 3021 (PadApron , NEW)

8.4.2 ROAD_C

Target Feature Type: Road

Target property in UTDS-CityGML	**Source**
trans:function	1000 (road)
trans:lod0Network	curve geometry as composite curve
trans:lod1MultiSurface	multi surface with curve geometry segments as centerline and width WID
conditionOfFacility	Field FUN
lengthOrDiameter	Field LEN
trackOrLaneCount	Field LTN
width	Field WID

8.4.3 RUNWAY_S

see STOPWAY_S, except:

Target property in UTDS-CityGML	Source
trans:function	2190 (runway)
basicEncyclopediaNumber	Field BEN
runwayIdentifier	Fields GB052_RIDH, GB052_RIDL NOTE Both fields are mapped to the multiple-occuring property. However, it is not clear if the high/low identifiers can still be clearly distinguished from their specified values.

8.4.4 STOPWAY_S

Target Feature Type: AircraftTransportationComplex

Target property in UTDS-CityGML	Source
trans:function	2191 (stopway, NEW)
trans:lod1MultiSurface	surface geometry
conditionOfFacility	Field FUN
lengthOrDiameter	Field LEN
accessibilityStatus	Field ACS
width	Field WID
highestElevation	Field ZVH
aerodromeMovementSurfaceComposition	Fields ZI019_ASU1, ZI019_ASU2, ZI019_ASU3

8.4.5 TAXIWAY_S

see STOPWAY_S, except:

Target property in UTDS-CityGML	Source
trans:function	2170 (taxiway)

8.5 City Furniture

8.5.1 FENCE_C

Target Feature Type: Fence

Target property in UTDS-CityGML	Source
cfurn:class	1020 (others)
cfurn:function	1440 (fence)
cfurn:lod1Geometry	the geometry depends on the existence of HGT and THI; if none is specified, the geometry is the curve; if only HGT is specified, a vertical surface is created; if only THI is specified, a horizontal surface is specified; if both are specified, a solid is created
conditionOfFacility	Field FUN
lengthOrDiameter	Field LEN
measuredHeight	Field HGT
measuredHeightAccuracy	Field HGT_AHO
highestElevation	Field ZVH

8.5.2 GATE_P

Target Feature Type: Gate

Target property in UTDS-CityGML	Source
cfurn:class	1020 (others)
cfurn:function	1140 (gate)

cfurn:lod1Geometry	the geometry depends on the existence of THI; if not specified, the geometry is a vertical surface with 2m height and 10m length; if THI is specified, a horizontal surface is specified
conditionOfFacility	Field FUN
lengthOrDiameter	Field LEN
highestElevation	Field ZVH
gateUse	Field GTC
transportationSystemType	Fields TRS1, TRS2, TRS3

8.5.3 LIGHT_SUPPORT_STRUCTURE_P

Target Feature Type: LightSupportStructure

Target property in UTDS-CityGML	**Source**
cfurn:class	see featureFunction
cfurn:function	see featureFunction
cfurn:lod1Geometry	box from surface geometry (as square around the point geometry with 0.4m width) and height HGT: assumption: z coordinate value from the given geometry is the top height of the building/structure
featureFunction	Fields FFN1, FFN2, FFN3 495 (RoadTransport) → class = 1000 (traffic); function = 1170 (lamp post) Remark: populate class only from FFN1
conditionOfFacility	Field FUN
lengthOrDiameter	Field LEN
measuredHeight	Field HGT
measuredHeightAccuracy	Field HGT_AHO

highestElevation	Field ZVH
width	Field WID
pylonConfiguration	Field PYC
pylonMaterial	Field PYM
towerShape	Field TOS

8.5.4 NON_BUILDING_STRUCTURE_P

Target Feature Type: NonBuildingStructure

Target property in UTDS-CityGML	**Source**
cfurn:class	1020 (others)
cfurn:function	3010 (NonBuildingStructure, NEW)
cfurn:lod1Geometry	box from surface geometry (as square around the point geometry with 0.2m width) and height HGT; assumption: z coordinate value from the given geometry is the top height of the building/structure NOTE Given only a point and no "angle", the "box" was oriented arbitrarily. This seems acceptable as it is a relatively small base square and the width is arbitrary without a WID value anyhow. It was originally planned to use a cylinder, but this was not possible using the geometry operations of the geometry tools used (see Annex A). As a result, boxes were used as fallback.
conditionOfFacility	Field FUN
lengthOrDiameter	Field LEN
measuredHeight	Field HGT
measuredHeightAccuracy	Field HGT_AHO
highestElevation	Field ZVH

width	Field WID

8.5.5 VEHICLE_BARRIER_C

Target Feature Type: VehicleBarrier

Target property in UTDS-CityGML	**Source**
cfurn:class	1000 (traffic)
cfurn:function	3020 (VehicleBarrier, NEW)
cfurn:lod1Geometry	curve geometry
conditionOfFacility	Field FUN
lengthOrDiameter	Field LEN
measuredHeight	Field HGT
measuredHeightAccuracy	Field HGT_AHO
highestElevation	Field ZVH
width	Field WID
transportationSystemType	Fields TRS1, TRS2, TRS3

8.6 Summary of additions to the CityGML code lists

8.6.1 BuildingFunctionType / BuildingUsageType

3020 TelecommunicationTower

3021 GuardTower

3099 Manufacturing

3481 Terminal

3495 RoadTransport

3520 AirTransport

3530 WarehousingStorage

3536 CargoHandling

3781 Guard

3835 DefenceActivities

3860 HumanHealthActivities

3931 PlaceOfWorship

8.6.2 TransportationComplexFunction

2191 Stopway

8.6.3 TransportationUsageType

3003 HangarApron

3007 DepotApron

3021 PadApron

8.6.4 CityFurnitureFunctionType

3010 NonBuildingStructure

3020 VehicleBarrier

9 XML instances

All instances shall be encoded in conformance with the CityGML standard (see Clause 2 of 08-007r1).

In addition, all references to code lists that are ADE specific shall use a URL that resolves to a GML dictionary for the code list.

EXAMPLE 1 <utds:conditionOfFacility **codeSpace="http://services.interactive-instruments.de/ows6/data/codelists/ConditionOfFacility.xml"**>6</utds:conditionOfFacility>

Unit references shall be encoded using the commonly used symbol for the unit. The unit shall conform to the unit mandated by UTDS for the particular attribute.

EXAMPLE 2 <utds:width **uom="m"**>100.41</utds:width>

Finally, if hosted via a WFS, the default CRS for UTDS-CityGML-data shall be urn:ogc:def:crs:EPSG::4979 (latitude/longitude geodetic using the WGS-84 ellipsoid).

The following XML document includes the building feature shown in Figure 2 with data according to the UTDS entity catalogue, mapped to CityGML.

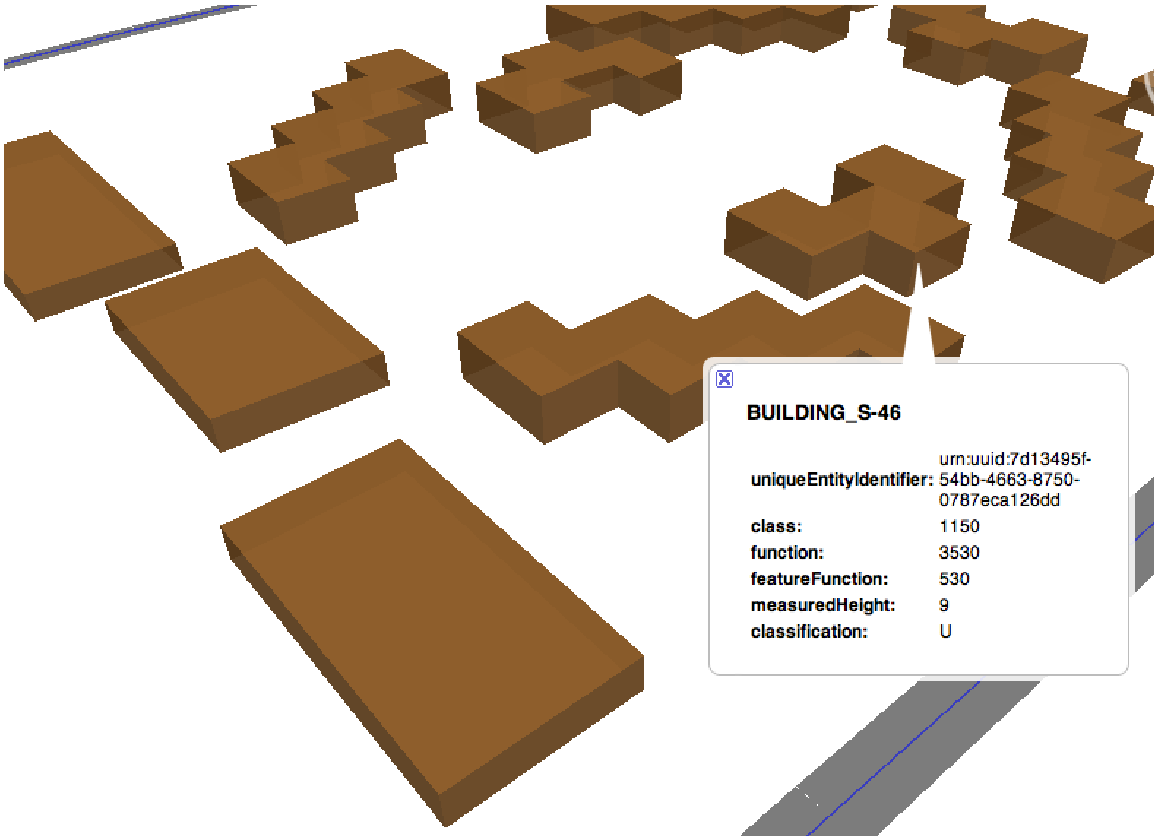

Figure 22 — Building example

```
<core:CityModel xmlns:build="http://www.opengis.net/citygml/building/1.0"
xmlns:core="http://www.opengis.net/citygml/1.0"
xmlns:gml="http://www.opengis.net/gml" xmlns:icism="urn:us:gov:ic:ism:v2"
xmlns:utds="http://www.opengis.net/ows-6/utds/0.3"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/ows-6/utds/0.3
http://services.interactive-instruments.de/ows6/data/schema/UTDS-CityGML.xsd
http://www.opengis.net/wfs http://schemas.opengis.net/wfs/1.1.0/wfs.xsd
http://www.opengis.net/citygml/1.0
http://schemas.opengis.net/citygml/1.0/cityGMLBase.xsd">
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<gml:Envelope srsDimension="3" srsName="urn:ogc:def:crs:EPSG::4979">
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icism:ownerProducer="USA">
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```



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10 Conclusions

The aim of the activity in OWS-6 to represent UTDS data using CityGML was to test whether CityGML is the right choice for encoding urban data with a particular focus on supporting movement within an urban area. Two use cases were identified as relevant - encoding for the transfer of data and visualization. Based on the results, the following general conclusions can be drawn:

- Encoding the data using CityGML made the data available to CityGML clients, in particular visualization clients, without any significant problems. CityGML clients used in OWS-6 were able to visualize/process the data without the need for any changes to the UTDS-CityGML schema or data.

- However, based on issues identified in B.1, which are submitted as Change Requests to CityGML, the use of CityGML in its current form is somewhat limited in particular due to the semantic issues. Without resolving these issues UTDS-CityGML data will probably be largely useful only to UTDS-aware software – at least beyond visualization use cases.

- In addition, the issues documented in B.2 to B.6 will require additional work, if the representation of UTDS data in a CityGML ADE is investigated further. In particular issues related to the generation of appropriate 3D geometries from 1D or 2D geometries in the source data will require further investigation. Clause 8 specifies rules for the generation of such “higher dimension geometries” for most feature types, Annex A documents the tools used in OWS-6 and B.2 highlights the most important open issues that still need to be addressed.

Annex A

Providing access to UTDS data via a UTDS-CityGML WFS

A.1 General

This annex briefly describe how the UTDS sample datasets (city data, airport data) were imported into an Oracle database (v10.2), geometrically enriched and published as UTDS-CityGML data via a WFS. The WFS used is XtraServer from interactive instruments.

A.2 Step 1: FME

The shapefiles were imported with FME Desktop (Oracle Edition) 2008/2009.

The database uses the same database table for all Buildings (AircraftHangar, Building, Tower, etc). The source feature type is distinguished using an additional column storing the source feature type. The same applies to CityFurniture features.

The shapefiles contain 3D data but most geometries required further processing.

A.2 Step 2: Oracle SQL

The following data processing to implement some of the mapping aspects specified in clause 8 has been implemented in PL/SQL procedures and SQL scripts:

1. Converting geometries from one type into another (e.g. curve into surface, point into solid, etc.)
2. Creating envelope geometries
3. Some attribute mapping (in particular, FFN-to-class/function-mapping)

The following geometries had to be manipulated:

- All Building types: create solid from patches
- CityFurniture (FENCE_C, GATE_P, LIGHT_SUPPORT_STRUCTURE_P, NON_BUILDING_STRUCTURE_P): Increase dimension of geometry and create Curve or MultiSurface geometries from source geometry and other attribute values
- Road: create MultiSurface geometries from centerline and width

Since Oracle 10.2 cannot store 3D solids, Multipolygon geometries are used to store the solids.

A.3 Step 3: XtraServer

XtraServer has been configured to access the databases established in step 2 and to transform the data in accordance with the OWS-6 UTDS-CityGML application schema. The WFS converts the remaining mapping aspects specified in clause 8 that are not pre-processed in step 2.

Figure 23 shows UTDS-CityGML-airport-data accessed from the WFS by a CityGML client.

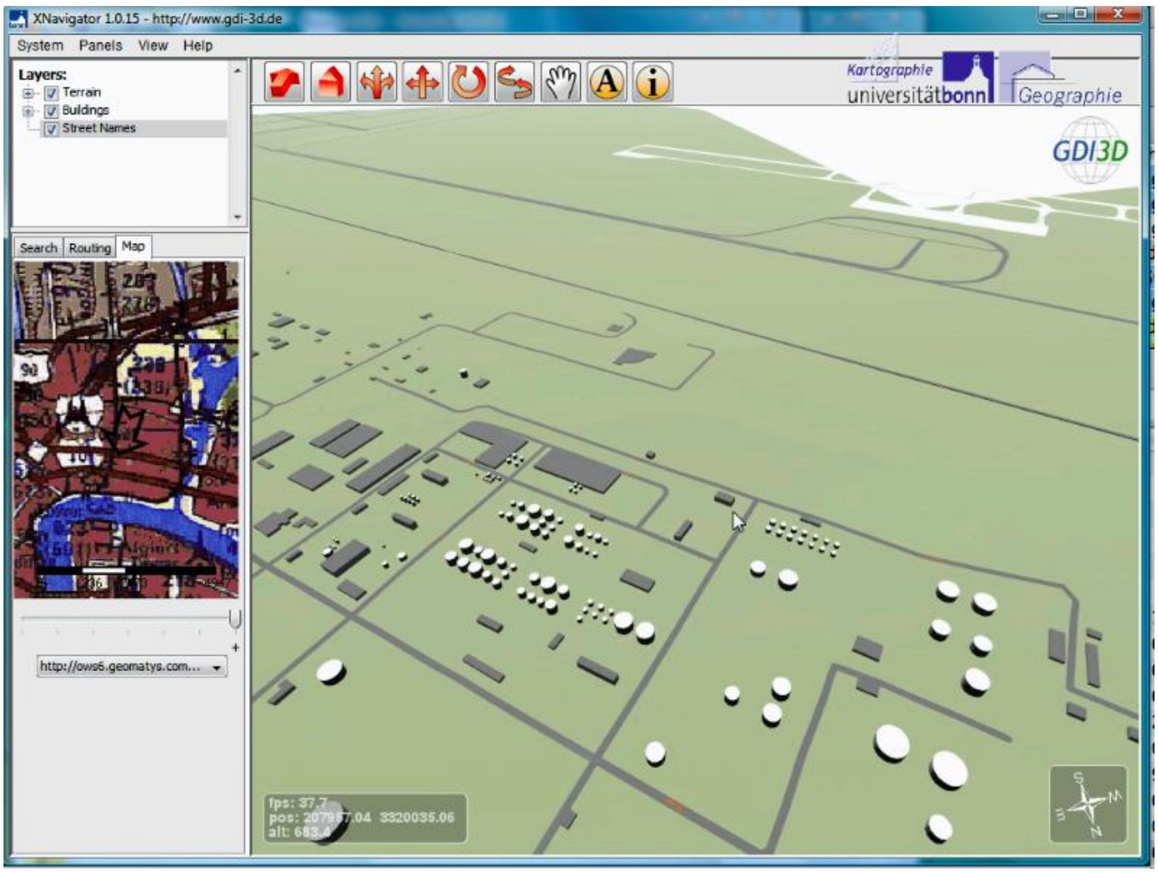

Figure 23 — UTDS-CityGML-data

Annex B

Summary of known issues

B.1 CityGML Change Request

A Change Request to the OGC CityGML standard will be submitted as OGC document 09-039 to initiate addressing any CityGML-related issues that have been identified.

The requested changes are:

- Lack of definitions

  There seem to be no definitions for any feature type, property or listed value in CityGML. The only hint at the semantics of a model element is its name.

  This is in conflict with ISO 19109 and due to the lack of semantics limits the use of CityGML across community-boundaries.

  Example: What is a building? In OWS-6 the source dataset uses the following definition for building “A free-standing self-supporting construction that is roofed, usually walled, and is intended for human occupancy (for example: a place of work or recreation) and/or habitation.” Is “a container used for the storage of liquids and/or gases that is not supported by a tower” a building in CityGML? Building class “storage” (1150) seems to indicate “yes”. I.e. the definition of Building in CityGML seems to differ from the UTDS definition, but this is hard to tell.

  This issue gets worse when trying to use the code lists as it is often not clear which listed value should be used due to overlapping concepts.

  Note: The lack of definitions for the concepts in CityGML would be even bigger, if it would be a goal to take existing CityGML data and transform it to another data specification as it would be unclear how to map CityGML features with their loosely defined semantics.

  It is understood that CityGML is intentionally vague. However, it would be still beneficial to have (even rather generic) definitions for feature types, properties and listed values.

- Use of code lists

  The mechanisms to extend the existing code lists specified in CityGML are broken:

  - Code lists can only be extended, i.e. the pre-defined values cannot be ignored (this would be in conflict with ISO 19103). However, without a definition it is often unclear when to reuse an existing value and when to extend them.

  - The code list encoding in CityGML provides no mechanism to point to the dictionary with the used code list values (and it does not use the GML mechanism) → no one can interpret the property values without prior knowledge unless only the pre-defined values are used. This could be corrected by using the GML mechanism for the encoding of code list values (gml:CodeType).

- Building.class multiplicity

  Attribute "class" in feature type "Building" has a maximum multiplicity of "1". In OWS-6, we would have needed multiple class values for the same building. Why can a building have a single class only (it may have multiple functions and usages)? Consider increasing the multiplicity to unbounded.

- LoD requirements inconsistent

  Examples from sub-clause 6.2:

  Clear requirements: "In LOD1, the positional and height accuracy of points must be 5m or less, while all objects with a footprint of at least 6m by 6m have to be considered. The positional and height accuracy of LOD2 must be 2m or better. In this LOD, all objects with a footprint of at least 4m × 4m have to be considered. ..."

  vs.

  No requirements: "The accuracy requirements given in this standard are debatable and should be considered as discussion proposals."

  The inconsistencies should be removed.

- ADE vs. generic objects/attributes

  Consider providing guidance when which extension mechanism should be used.

- Inline vs. by-reference

  The value of most feature-valued properties can be either embedded inline or referenced using Xlinks. Example: BuildingPart and Address in _Building. Our implementation experience is that allowing both encoding styles decreases performance in a WFS context. Mandating the use of Xlinks for such properties would be preferred.

B.2 3D Tool support

B.2 Generating 3D geometries

The conversion of 3D geometries based on 2D or 2.5D geometries and additional properties like height, length and/or width involves complex geometry operations. Several of such conversions are described in this document (see Clause 8 and Annex A), but some open issues remain:

- While tools like Oracle and FME support 3D geometries in general in their new releases, geometry operations are still limited and often do not support full 3D capabilities. However, this is expected to change in future releases of the products and this will simplify dealing with the following two issues.
- For the generation of solids from point geometries, ad-hoc assumptions about the orientation of buildings were made. It was not investigated in OWS-6 how reasonable these ad-hoc assumptions were and whether a different approach should have been taken in general. Within the usage of the data in the OWS-6 scenarios and visualizations, the assumptions did not trigger any issues.
- Converting centerline geometries to surface geometries in 3D involves complex geometry operations and could not be completed in OWS-6. At locations where line segments meet with a bend, surfaces created by applying the width attribute to the centerline geometry do have gaps and overlaps. While tools are generally available to create such surfaces in a plane, this is not yet commonly supported for surfaces in 3D space. Figures 24 and 25 illustrate this.

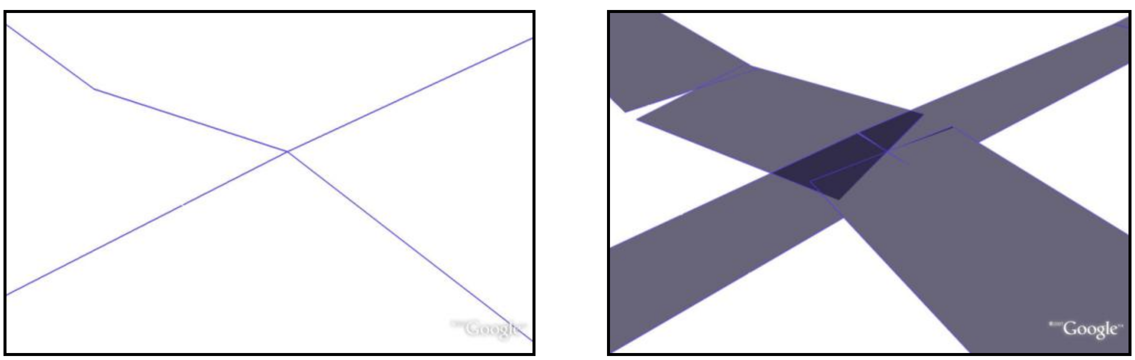

Figure 24 — Road junction (left lod0Network, right lod1MultiSurface created from the lod0Network and width attributes)

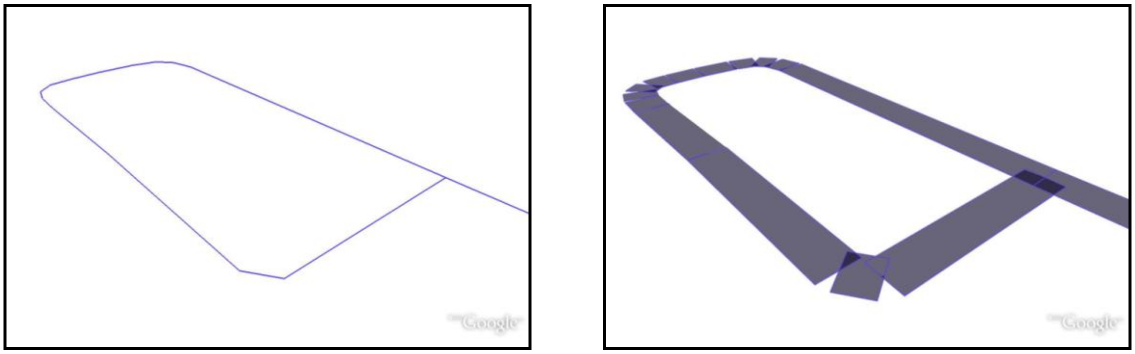

Figure 25 — Roads (left lod0Network, right lod1MultiSurface created from the lod0Network and width attributes)

B.3 Code list representations

UTDS (actually the NAS) specify several pieces of information for each entry in a code list:

- an integer code
- an alpha code
- a name/title
- a definition
- an optional description

In a UML representation there are (without using tagged values) three pieces:

- a code name (the initial value)
- a code value (the attribute name)
- a documentation

The definition and description are stored in the documentation field, separated by "[desc]".

Originally, the representation used was to map the name/title to the code value to have a value for humans and the integer code (which was used in the actual data) to the code name as a code for storage purposes; the alpha code was dropped in most cases unless there was no integer code known.

However, an analysis of ISO/CD 19103 finally lead to another representation. The sub-clauses 6.5.2, 6.5.3 and 6.12 are understood to imply that the code value should be without whitespace. Therefore, the alpha code is used as the code value in the code list shown in this document. The name/title has been moved to the beginning of the documentation field, separated from the definition by a colon.

The alpha codes use a camel case notation as recommended by 6.12 of ISO/CD 19103, however, based on the alpha codes used in the NAS, these are currently in UpperCamelCase, not lowerCamelCase as recommended.

Since the use of an alpha and an integer code seems to be for legacy reasons only, it should be considered in the future to drop the integer code and simply use the alpha code only. In UML, this means that no initial value would be specified.

B.4 WGS84 vs. projected coordinate reference systems

UTDS data is usually encoded in WGS84 geographic coordinates. However, CityGML viewers usually use projected coordinate reference systems which seems plausible in particular for visualization in large scales – like an urban environment.

For the preparation of the UTDS-CityGML data from the source UTDS data, the data also had to be converted to a projected, metric coordinate reference system since all spatial attributes like width, length or height are provided in meters.

This is not an issue per se, but it should be noted that while the NAS usually uses geographic coordinates, CityGML data is usually used in projected coordinate reference systems and thus coordinate conversions or transformations will usually be required.

B.5 Feature-type-specific code lists

As mentioned in Clause 5, the decision had been made for OWS-6 to follow the CityGML approach to use code lists applicable to a wide range of phenomena. However, the NAS approach is different and this results in the need for constraints to assess that only valid code list values are used for a particular feature (based on its feature type, an example is shown in document 09-038, OWS-6 GML Profile Validation Tool ER).

This is a general difference in the approaches of the NAS and CityGML that have to be considered if the approach described in this ER is continued.

B.6 Other modeling issues

- In accordance with the UTDS application schema, the two attributes of the data type GeometryMetadata should be named “absoluteHorizAccuracy90” and “absoluteVertAccuracy90”. For the UTDS-CityGML application schema, the property name, e.g. “Absolute Horizontal Accuracy (90%)”, from the sample datasets were used as the basis for the name.

- Both the high and low runway identifiers were mapped to the same property (runwayIdentifier), which may occur up to two times. However, in general the high/low identifiers cannot be distinguished in this representation. It would have been correct to represent these as two separate properties.

These issues were discovered only late in the process and as it would have affected the application schema and the instance data, they have not been changed, but are documented here. They should be addressed in any future version of a UTDS-CityGML application schema.

Bibliography

Specialized-Urban Topographic Data Store Entity Catalog (UTDS EC), Version 1.0 DRAFT, November 4, 2008

OGC® OWS-5 GSIP Schema Processing Engineering Report, OGC document 08-078r1 (OGC discussion paper)

ISO/CD 19103 Geographic Information – Conceptual Schema Language, ISO/TC 211 document N 2617

GEOINT Structure Implementation Profile (work in progress)

NOTE The GEOINT Structure Implementation Profile (GSIP) includes the NSG Application Schema (NAS), the NSG Feature Concept Dictionary (NFDD) and the NSG Entity Catalog (NEC).

