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Abstract

This paper presents the generation of the 3D national geo-data model of Turkey, which is compatible with the international OGC CityGML Encoding Standard. We prepare an ADE named CityGML-TRKBIS that is produced by extending existing thematic modules of CityGML according to TRKBIS needs. All thematic data groups in TRKBIS geo-data model have been remodeled in order to generate the national large scale 3D geo-data model for Turkey. Within the concept of reference model-driven framework for modelling CityGML ADEs in UML, the first step is conceptual mapping between CityGML and national information model. To test all stages of the framework for Urban GIS Turkey, Building data theme is mapped with CityGML-Building thematic model. All classes, attributes, code lists and code list values of the TRKBIS is tried to be mapped with related CityGML concept. New classes, attributes and code list values that will be added to CityGML Building model are determined based on this conceptual mapping. Finally the new model for CityGML-TRKBIS.BI is established in UML with subclassing of the related CityGML classes. This study provides new insights into 3D applications in Turkey. The generated 3D geo-data model for building thematic class will be used as a common exchange format that meets 2D, 2.5D and 3D implementation needs at national level.

Keywords: CityGML, 3D Building Model, 3D Data Modeling, 3D Geo-Information, 3D Standards, 2D/3D Geo-Data Integration

Introduction

In recent years considerable progresses have been realized in modelling 3D geo-data as CityGML ADE for different domains such as noise mapping (Czerwinski et al. 2007; Wilson 2011; OGC 2012), utility networks (Becker et al. 2011; Becker et al. 2013); immovable property taxation (Çağdaş 2012); time dependent variables (Wilson et al. 2011); inclusive routing (Prandi et al. 2013; Kaya and Gazioğlu, 2015); energy potential assessment (Wate and Saran 2015; Bahu and Nouvel 2015; Krüger and Kolbe 2012; Kaden and Kolbe 2014; Nouvel et al. 2015), ubiquitous network robots services (OGC 2012), planning and management (Büyüksalih et al., 2017) etc. Most of the above mentioned studies were carried out based on only CityGML specifications that are existing national geo-data models were not taken into account. The first study that is aligned to both CityGML and national 2D geo-data model was realized in Netherlands in project named 3D Pilot (Stoter et al. 2013; Stoter et al. 2011). The resulting model is called IMGeo: Information Model Geography. As a general policy, it would be more efficient to draw the general principles of plans to be applied according to the natural properties of each type of zone which uncovered at present by the provisions of the governance (Gazioğlu et al., 2010).

Due to fact that in CityGML specifications ADE generation is described only in XML, the approach that is described in OGC 12-066 referenced numbered (OGC, 2014) "Modeling an ADE of CityGML in UML"-best practice paper is selected as guidance to establish the CityGML-TRKBIS.BI ADE in UML, as

purpose of the research presented in this paper. This approach was selected as best alternative for IMGeo version 2.0 among several approaches after discussions within the SIG3D modelling subgroup and other participants (van den Brink, Stoter and Zlatanova, 2013).

Within the concept of reference model-driven framework for modelling CityGML ADEs in UML, the first step is conceptual mapping between CityGML and national information model. To test all stages of the framework for Urban GIS Turkey, Building data theme is mapped with CityGML-Building thematic model. All classes, attributes, code lists and code list values of the TRKBIS are tried to be mapped with related CityGML concept. New classes, attributes and code list values that will be added to CityGML Building model are determined based on this conceptual mapping. Finally, the new model for CityGML-TRKBIS.BI is established in UML with subclassing of the related CityGML classes.

The overall structure of this paper is as follows. Section 2 begins with general description of the existing large scale geo-data model of Turkey (TRKBIS). Section 3 is concerned with the methodology used for extending existing

building and transportation models as CityGML ADE and proposed 3D building and transportation geo-data models are presented. Section 4 analyses the results and focus on the future developments.

Existing Urban Information System Standards in Turkey

TRKBIS (UrbanGIS) is a standard for large scale geo-data (1:5000 and larger) which describes definition of object-based, large-scale topographic features. Version 1.0 of the national 2D urban information standard (TRKBIS 1.0) was published in 2012 by General Directorate of GIS. The aim of the conceptual model components of TRGIS is to establish interoperable geo-data models that can be used from local to national level (Figure 1). Whole thematic geo-data classes are modelled compatible with both ISO/TC211 and INSPIRE standards. They are also determined based on TRGIS expectations and data requirement analysis (GD-GIS, 2012b). The Unified Modeling Language (UML) is used as a modelling language for all TRKBIS data themes.

Fig 1. Standardization pyramid of Turkey (GD-GIS, 2012a)

TRKBIS objects have 2D geometry that is defined with GML 3 geometry types. Scale and resolution properties of the standard are defined based on Large Scale Map Information Production Regulation (BOHHBUY in

Turkish). In Urban GIS data model, maps that have scale larger than 1:5000 are defined as large scale maps according to the regulation. The use of geo-data is determined with 5 level of detail from district (level4), county (level3), province (level2), region (level1), to country

(level0). County level (Level3-Large Scale) is the most effective level for GIS applications in Turkey. Therefore it is accepted as base geo-database level (Aydinoglu 2009). TRKBIS is related with county level and involves geo-data larger than 1:5000 scale. Municipalities and provincial administrations produce and update geo-data from county level to district level.

Building data theme comprises data about cadastral parcel, related buildings and building units. INSPIRE initiative aims to develop a common standard for cadastral parcel and building geo-data themes that meets requirements of all European countries (INSPIRE 2013). In Turkey, cadastral data and building data are independent from each other. However, the relation of cadastre and building is provided with parcel number on parcels that have construction ownership. In addition, address information of the building is independent from parcel.

TRKBIS Building (TRKBIS.BI) data theme contains basic required properties of the building and has detaily identified relationships between cadastre and address data themes. It involves buildings, building parts; additional feature types (building unit, installation and other construction) and additional properties, such as official information and more detailed physical description. Feature types of the building data theme are determined according to analyses, discussions with stakeholders and findings of the questionnaires that was realised in TRKBISS project. International standards INSPIRE and ISO/TC211 were also taken into account while determining feature types of the building. TRKBIS Building (TRKBIS.BI) data theme provides data about building, building part, building installations, other constructions, etc. for different applications. Information about building and building parts are represented with area geometry and covers extended 2D properties of INSPIRE building thematic data group.

Modelling TRKBIS as CityGML ADE in UML

Since CityGML specifications do not provide information about generating ADEs with UML,

the procedure to obtain the 3D geo-data model from TRKBIS.BI builds on the work of Van den Brink et al. (2013). The model driven framework proposed by 3D Pilot in the Netherlands is the best practice for applying CityGML ADE mechanism in UML. However, there were structural differences in both data models; Dutch case IMGeo and Turkey case TRKBIS. As distinct from IMGEO data model, TRKBIS has much more similarities with INSPIRE building model. That is why mapping process between TRKBIS and CityGML was complicated. New model for buildings has different class structure and geometry definitions in LoD concept.

The main principle of the process is to retain CityGML concept while extending CityGML with domain specific needs. Five steps that are determined by proposed framework can be summarized as follows (Van Den Brink et al. 2011; 2012; 2013);

- Selecting a formal modelling language
- Defining correspondences between semantic classes of the application and CityGML generic classes
- Deciding which subclasses should be extended
- Defining application code lists
- Defining a geometry representation for each class for each applicable level of detail
- Defining topologically correct LOD

In this concept, corresponding classes, attributes, code lists and code list values are determined between CityGML Building model and TRKBIS.BI data themes (Table 1). Mapping is the base of CityGML-TRKBIS.BI ADE. However, there is no one to one mappings for all TRKBIS.BI classes. In this case there are two approaches that can be used;

- Remodelling TRKBIS concept to find complementary classes with CityGML. This method is used at "OzetBina" class in TRKBIS.
- Extending CityGML with a new class which is defined as subclass of related CityGML class. This method is used for "EkYapi (OtherConstruction)" and

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"BinaBagimsizBolum (BuildingUnit)" feature types in TRKBIS (In TRKBIS BuildingUnit represents independent subdivisions of building which can be separately sold or rented out. There is no equivalent CityGML class.)

Modelling Building Geo-data Theme

TRKBIS.BI application schema is composed of feature types, data types, code list values and relationships between classes. OzetYapi (AbstractConstruction),OzetBina, (AbstractBuilding),EkYapi,(BuildingInstallatio n),DigerYapi(OtherConstruction),Genişletilmiş Bina(ExtendedBuilding),YapiBelge(Document ationOfStructure), BinaBlok (BuildingPart) and BinaBagımsızBolum(BuildingUnit). Feature types are defined in Bina (Building) package. AbstractConstruction is the central class of the Building data theme. AbstractBuilding, BuildingInstallation, Building and BuildingPart feature types are associated with AbstractConstruction with inheritance relationship. As a result, all features of AbstractConstruction are inherited by related data themes. BuildingUnit is designed with distinctive structure and attribute named kbsNo is reused in this feature type to provide relation with other tables. Building and BuildingPart are related with each other and multiplicity property is defined for this relationship that means building or a building part can related with more than one building units. According to aggregation relationship defined between Building and BuildingPart, BuildingPart cannot exist without Building feature type (Figure 3).

"OzetYapi (AbstractConstruction)" is the top level feature type in TRKBIS.BI data theme and encompasses basic attributes of the construction. Common semantic properties of OzetBina (AbstractBuilding),DigerYapi(OtherConstructi on) and EkYapi (BuildingInstallation) are grouped in this feature type. Attribute kbsNo (identification number) is an object identifier that is defined to relate tables with each other. Temporal data is stored with; "versiyonBaslangicTarihi(creationDate)", "versiyonBitisTarihi(terminationDate)" and "versiyonNo (versionNumber)". These attributes are the same for the other themes. In addition, "insaatTarihi (yearOfConstruction)", "yapiAdi (name)" and "yapiDurumu (conditionOfConstruction)" are defined as priority attributes. In "OzetBina (AbstractBuilding)" feature type, other required attributes of the building are defined detaily. Common properties of Bina (Building) and BinaBlok (BuildingPart) are grouped in this feature type. "EkYapi (BuildingInstallation)" represents building elements that are not defined in OzetBina (AbstractBuilding) such as; pedway between buildings, balconies, antennas, etc. "DigerYapi (OtherConstruction)" encompasses self-standing constructions that are related with building data theme and not considered as buildings as it is defined in INSPIRE. The main difference between Bina (Building) and DigerYapi (OtherConstruction) themes is that objects defined in DigerYapi (OtherConstruction) does not need to be enclosed such as; acustic fence, city wall, etc. "Bina (Building)" feature type represents Bina (Building) feature type defined in Address data theme. "BinaBlok (BuildingPart)" represents other sub-divisions of the building that are not defined as another feature type. "BinaBagimsizBolum (BuildingUnit)" represents administrative aspect of building part or whole building. Building unit has its own access from the outside and functionally independed such as; flat, garage, celler, etc. TRKBIS.BI classes are determined as subclasses of related CityGML classes with their Turkish names. The stereotype of the subclass is no longer a <<featureType>>, it is marked as <<ADEElement>>. Using English names of the classes makes it clearly visible to understand which TRKBIS class is mapped to which CityGML class. Turkish name of the class is added as an alias for documentation purposes. <<ADEElemet>> stereotype provides only the possibility of adding attributes to current CityGML classes and the classes marked with this stereotype cannot be seen in GML application schemas that is generated automatically from UML models. In addition, the relationship between CityGML class and related subclass is marked with <<ADE>> stereotype.

Conceptual mapping between CityGML and TRKBIS building data themes is summarized in Table 1. According to this, all attributes of

"OzetYapi(AbstractConstruction)",
"GenisletilmisBina(ExtendedBuilding)",
"YapiBelge (DocumentationOfStructure)" and
many attributes of the "OzetBina
(AbstractBuilding)" are added to CityGML
"AbstractBuilding" feature type (Figure 3).
Although many attributes of the TRKBIS
"OzetBina (AbstractBuilding)" class are related
with CityGML "AbstractBuilding" class, there
are attributes related with other CityGML class
such as; "catiMalzemesi (materialOfRoof)" is
added to CityGML "RoofSurface" class;
"cepheMalzemesi (materialOfFacade)" is added
to CityGML "WallSurface" class; "zeminSinifi
(groundType)", "yerelZemin (localGround)"

and "zeminGrubu (groundGroup)" are added to
CityGML "GroundSurface" class. The concept
of "OzetBina (AbstractBuilding)" is divided
into many parts to integrate it with CityGML
(Figure 3).

TRKBIS "Bina (Building)" is related with
CityGML "Building", "EkYapi
(BuildingInstallation)" is related with CityGML
"BuildingInstallation" class and "BinaBlok
(BuildingPart)" is related with CityGML
"BuildingPart" class by adding only new
properties to current CityGML classes.

Table 1. Summary of mapping CityGML and TRKBIS-Building data themes

TRKBIS.BI Feature Type	CityGML.BU Feature Type
OzetYapi (AbstractConstruction)	AbstractBuilding (most part) RoofSurface (materialOfRoof) WallSurface (materialOfacade) GroundSurface (groundClass, localGround, GroundClassType,groundGroup)
GenisletilmisBina (ExtendedBuilding)	AbstractBuilding
BinaBagimsizBolum (BuildingUnit)	-
BinaBlok (BuildingPart)	BuildingPart
Bina (Building)	Building
YapiBelge (DocumentationOfStructure)	AbstractBuilding
DigerYapi (OtherConstruction)	-
EkYapi (BuildingInstallation)	BuildingInstallation

Classes that are existing in TRKBIS model but
not in CityGML are added as new classes as a
subclasses of current CityGML classes.
TRKBIS "BinaBagimsizBolum
(BuildingUnit)" and "DigerYapi
(OtherConstruction)" classes are examples of
this situation (Figure 2). Properties of these new
classes are defined in the model too. These
classes may be visible in the GML application
schemas that are generated from UML models
automatically.

It is decided to use TRKBIS.BI code list values
instead of values determined in CityGML
specifications. According to CityGML
standard, code list values can be determined

outside of the model. In CityGML 2.0, the
mechanism is determined for extending and
replacement of code list values. In this concept,
all attribute values that use code list values
must be identified with "gml:CodeType"
attribute type. Optional code space is added to
values that are determined with
"gml:CodeType". CodeSpace provide
relationship between attribute and the
dictionary that include code list values of this
attribute with using URI (Unified Resource
Identifier). Although CityGML 2.0 proposes a
GML Dictionary Profile for encoding code list
values, it is deprecated in GML 3.3. New
standards are developed for this purpose such
as; SKOS, OWL and RDF. In the scope of this

research it is decided to use SKOS (Simple Knowledge Organisation System) for encoding code list values. This concept will be detailed in further research.
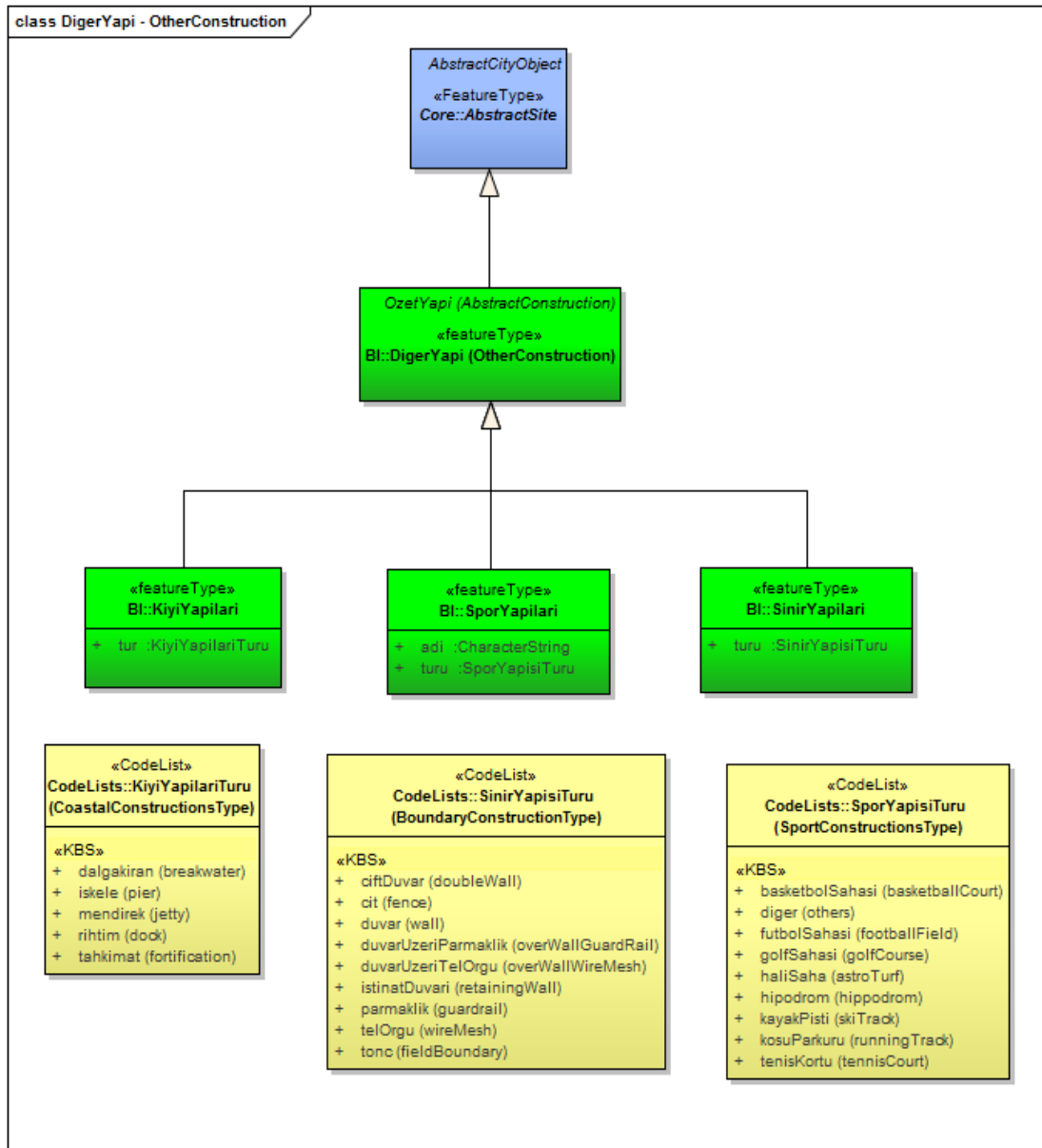

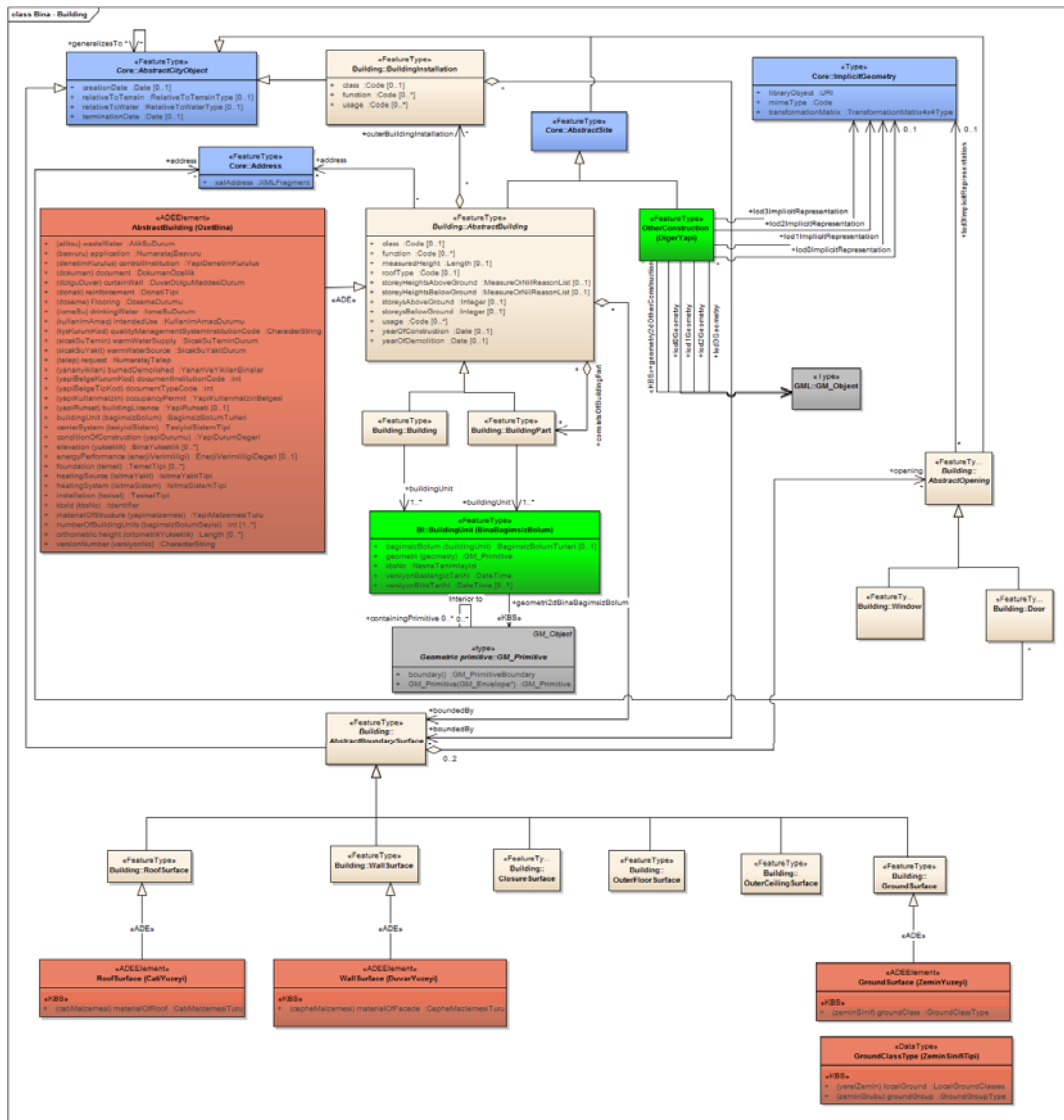Fig 2. CityGML-TRKBIS.BI ADE class "OtherConstruction"

Fig 3. CityGML-TRKBIS.BI ADE (classes with green colour shows TRKBIS feature types; classes with light pink shows CityGML feature types; classes with dark pink shows new ADE classes)

In the first process Building data theme is remodelled according to CityGML geo-data model. Based on experiments gained from building example, other data themes of the TRKBIS model are remodelled competible with CityGML. Generated application schema of TRKBIS transportation data theme is shown in Figure 4.
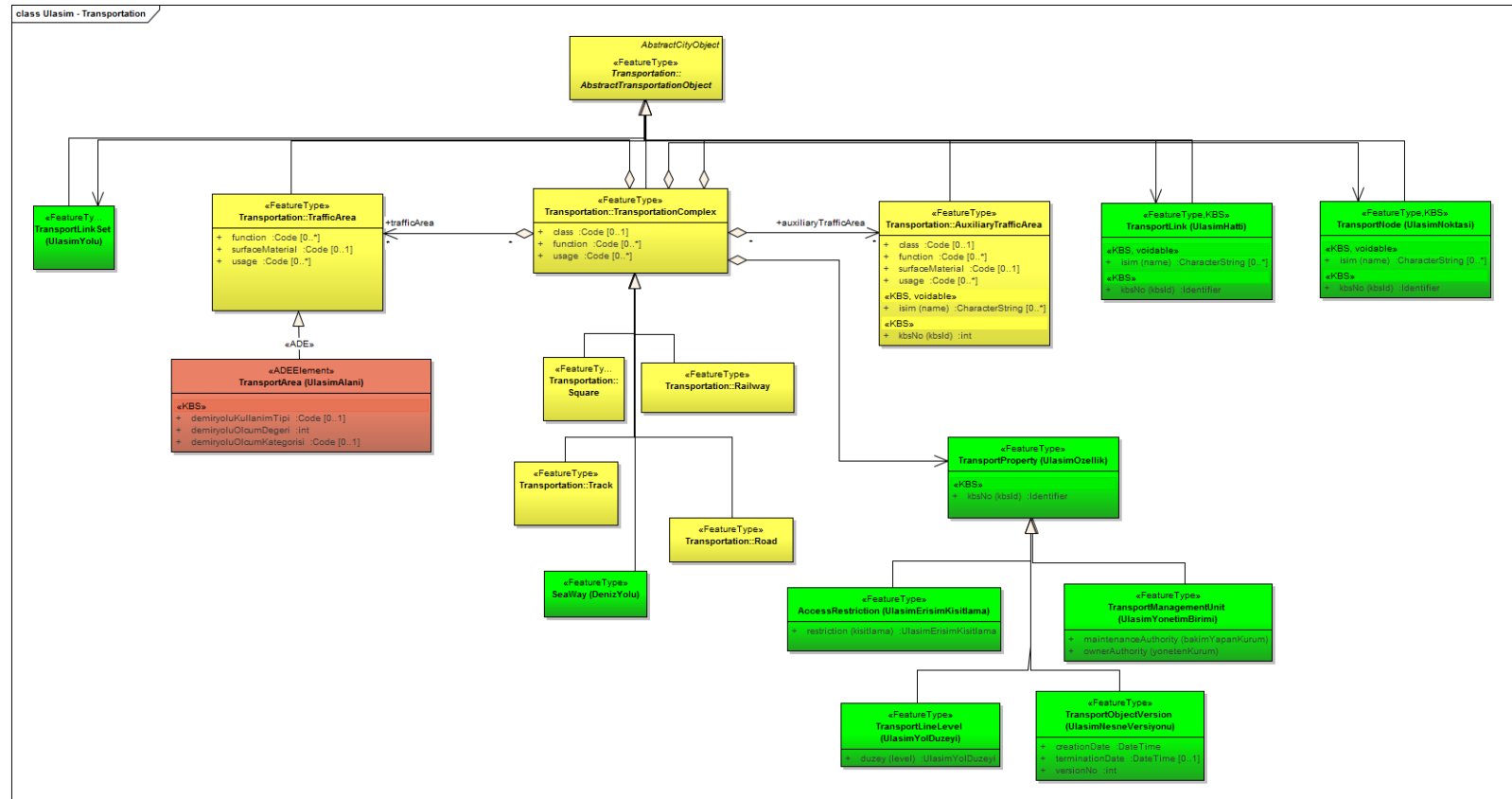
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Modelling Transportation Geo-data Theme

Fig 4. CityGML-TRKBIS.Transportation ADE

Conclusions and Further Research

In this paper a new geo-data model for two data theme (TRKBIS.BU and TRKBIS.TP) of Urban GIS Turkey has been proposed to be used as a common 3D geo-data model for storage and exchange of information about large-scale applications. This is the first study on extending CityGML data model according to Turkey national large-scale geo-data model for 3D applications. The developed models are mainly based on ADE mechanism of CityGML and provides integration between national data models and international CityGML standard.

The developed ADE's might be used as examples for developing CityGML compatible data models for other domains. The follow-up research will look at a generic approach to 3D geo-data model for Turkey. In this concept, all other data themes in Urban Geo-Data Model of Turkey (TRKBIS) will be remodelled according to CityGML data model with the help of experiences gained from CityGML-TRKBIS.BI application. Currently the research on mapping other data themes of TRKBIS is running in parallel and as a result; a Turkey national large-scale 3D information model that covers all classes of existing 2D urban geo-data model (TRKBIS) and that is based on OGC CityGML standard will be developed.

Many further research topics are also identified during developing process of the CityGML-TRKBIS.BI ADE. Firstly, we have to do more research to identify how the new model works with real data. For this purpose, example 3D TRKBIS data is required at different levels of detail. Secondly, further work is needed for generating GML application schemas from identified UML models. In addition, encoding code list values with appropriate structure (SKOS, OWL, etc.) needs further attention.

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References

Aydinoglu, A.C., 2009. Developing geo-data exchange model for Turkey. Ph.D. Thesis. Karadeniz Technical University, Applied Sciences Institute,Trabzon, Turkey.

Bahu, J.-M. and Nouvel, R., 2015. Development of the CityGML ADE Energy. In INSPIRE Geospatial World Forum (GWF) 2015.

Becker, T., Nagel, C. and Kolbe, T.H., 2011. Integrated 3D Modeling of Multi-utility Networks and Their Interdependencies for Critical Infrastructure Analysis. Archives, XXXVIII, pp.1–20.

Becker, T., Nagel, C. and Kolbe, T.H., 2013. Semantic 3D modeling of multi-utility networks in cities for analysis and 3D visualization. Lecture Notes in Geoinformation and Cartography, pp.41–62.

Büyüksalih, İ., Alkan, M. and Gazioğlu, C. (2017). Design for 3D city model management using remote sensing and GIS: A case study for the Golden Horn in Istanbul, Turkey, Journal of Coastal Conservation (in Press).

Czerwinski, A. et al., 2007. Sustainable SDI for EU noise mapping in NRW – best practice for INSPIRE *. International Journal of Spatial Data Infrastructures Research, 2(July), pp.90–111.

Çağdaş, V., 2012. An application domain extension to citygml for immovable property taxation: A Turkish case study. International Journal of Applied Earth Observation and Geoinformation, 21(1), pp.545–555.

Gazioğlu, C. Burak, S.Z., Alpar, B., Türker, A. and Barut I.F. 2010 Foreseeable impacts of sea level rise on the southern coast of the Marmara Sea (Turkey), Water Policy 12 (6), 932-943

GD-GIS, 2012a. TRKBISS conceptual model components: concept, application and technical components, Ankara.

GD-GIS, 2012b. TRKBISS data themes descriptive document, Ankara.

INSPIRE, 2013. D2.8.III.2 Data specification on buildings-technical guidelines, INSPIRE Thematic Working Group Buildings, European Comission Joint Research Center.

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Kaden, R. and Kolbe, T.H., 2014. Simulation-Based Total Energy Demand Estimation of Buildings using Semantic {3D} City Models. International Journal of 3-D Information Modeling, 3(2), pp.35–53.

Kaya., H. and Gazioğlu, C. 2015. Real Estate Development at Landslides, International Journal of Environment and Geoinformatics Vol:2(1), 62-71.

Krüger, T. and Kolbe, T., 2012. Building analysis for urban energy planning using key indicators on virtual 3D city models—the energy atlas of Berlin, XXII ISPRS Congress. Melbourne, pp. 145–150.

Müller, P. et al., 2006. Procedural modeling of buildings. ACM Trans. Graph.,25, 614–623.

Nouvel, R. et al., 2015. Genesis of the CityGML energy ade. In CISBAT 2015. Lausanne, Switzerland, pp. 931–936.

OGC, 2014. Modelling an application domain extension of citygml in UML: OGC Best Practice Paper L. Van den Brink, J. Stoter, and S. Zlatanova, eds.

OGC, 2012. Open Geospatial Consortium City Geography Markup Language (CityGML) Encoding Standard Version 2.0.

Prandi, F. et al., 2013. Using citygml to deploy smart-city services for urban ecosystems. In International Archieves of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 29th Urban Data Management Symposium. pp. 29–31.

Stoter, J. et al., 2011. A generic approach for 3D SDI in the Netherlands. In Joint ISPRS Workshop on 3D City Modelling and Applications and 6th 3D GeoInfo. Wuhan, China, pp. 1–22.

Stoter, J. et al., 2013. Establishing and implementing a national 3D standard in The Netherlands. Photogramm.—Fernerkund.—Geoinf. 2013, 381–392

Wate, P. and Saran, S., 2015. Implementation of CityGML energy application domain extension (ADE) for integration of urban solar potential indicators using object-oriented modelling approach. Geocarto International, 6049(May), pp.1–19.

Wilson, D., 2011. Noise Domain Model: Measurements, Modelling and Mapping.

Wilson, D., Parslow, P. and Kraut, V., 2011. CityGML– Time Dependent Variables ADE.

Van Den Brink, L., Stoter, J. and Zlatanova, S., 2011. Establishing a National 3D Standard Compliant to CityGML : good practice of a national 3D SDI. , (June).

Van den Brink, L., Stoter, J. and Zlatanova, S., 2012. Establishing a national standard for 3D topographic data compliant to CityGML. International Journal of Geographical Information Science, pp.1–22.

Van den Brink, L., Stoter, J. and Zlatanova, S., 2013. UML-Based approach to developing a citygml application domain extension. Transactions in GIS, 17(6), pp.920–942.