An Application Domain Extension to CityGML for immovable property taxation: A Turkish case study
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ABSTRACT
It is generally acknowledged that immovable property taxes are one of the main revenue sources for local government. The literature emphasizes that the administration of property taxes needs well-developed inventories or registers that provide complete and accurate records of the taxed properties and their legal-economic attributes. This requirement is generally fulfilled by Spatial Data Infrastructures (SDIs) in which the coordinate exchange and sharing of geo-spatial data is provided by separate registers/information systems such as: cadastral systems, building and address registers. Recently, the Open Geospatial Consortium presented a core component of a 3D SDI in the form of an international domain standard for representing, storing and exchanging 3D city models. The CityGML allows the semantic and 3D geometrical representation of physical objects but does not deal with the legal and administrative aspects of the city objects which are required for the process of property taxation. This paper outlines the development of an Application Domain Extension (ADE) for the immovable property taxation domain that expands the CityGML data model with the legal and administrative concepts defined in Turkish Law. The study shows that this ADE could be a 3D national data model for municipal information systems and facilitate a more efficient taxation process, as well as providing data for urban planning, facility management and other municipal services.

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1. Introduction
This paper presents an Application Domain Extension (ADE) to the CityGML which can be used for the storage and exchange of immovable property tax records. The extension has been prepared based on the legal and administrative concepts defined in Turkish Law.

Immovable property taxes, or more specifically ‘recurrent taxes on immovable property’, according to the OECD (2010) refer to those “taxes levied regularly in respect of the use or ownership of immovable property. They are levied on land and buildings, in the form of a percentage of the assessed value of a property or in terms of other characteristics of real property, such as size, location, and so on, from which are derived a presumed rent or capital value” (p. 295). Generally, the following three main stages are involved in the administration of property taxation: (i) identification of the property being taxed; (ii) assessment of the property; and (iii) tax collection and dealing with arrears (Bird and Slack, 2002). The objective of the identification process is, according to Dillinger (1991) “to find all the properties subject to taxation and obtain the information needed” (p. 11). Then for the assessment of the properties single-property appraisal or mass appraisal techniques are applied. The last stage covers collecting the taxes, ensuring payments, and dealing with appeals (Bird and Slack, 2002).

The literature emphasizes that efficient administration of the above-mentioned procedures needs well-functioning tax inventories. For instance, Dillinger (1991) points out that a property tax system requires a complete and accurate inventory which enables the discovery of all the properties subject to taxation. Similarly, Tang et al. (2011) state that an integrated property database is the fundamental element underpinning the taxation of immovable property. In addition the Land Administration Guidelines determine that “tax inventories should enable (i) the identification and mapping of all properties; (ii) the classification of each property in accordance with an agreed set of characteristics; (iii) the analysis of relevant market data; and (iv) the identification of the person(s) who will be responsible for paying the tax” (UNECE, 1996, p. 39).

In some countries property databases or inventories exist in terms of cadastral systems consisting of cadastre and land registers, Silva and Stubkjær (2002) state that “a cadastre refers a systematic and official description of land parcels, which for each parcel includes a unique identifier. The description includes the text...
records about the attributes of each parcel. The prototypical means of identification is a large-scale map that provides the information about the parcel boundaries” (p. 410). The second component of a cadastral system is the land register or the land book which is the official record of the rights on immovable properties. A well-functioning cadastral system provides the basis for the property tax inventories. However, the property tax administration also needs the following information which is not generally provided by the traditional cadastral systems: (1) physical, economic, environmental data regarding property units with their buildings which is particularly needed for appraisal processes, and (2) a spatial representation of 3D property units which allows the tax administration to verify that all taxable objects have been included in the tax inventories.

In the last decade, these requirements were fulfilled by two paradigms within the geo-spatial domain, namely: the land administration and Spatial Data Infrastructures (SDIs). The notion of land administration refers to the “management of information about the ownership, value and use of land and its associated resources” (UNECE, 2004, p. 5). In many countries, this information management function is provided by separate registers/information systems (i.e., a cadastral system, address, building, planning, tax, and valuation registers) which are maintained by different organizations. According to Steudler (2003), “this creates problems such as datasets not being compatible and data not being shared across organizations, and therefore, leads to inefficiency and duplication of effort” (p. 236). Rajabifard et al. (2006), describe a SDI as a “platform that can overcome these shortcomings by facilitating and coordinating the exchange and sharing of spatial data between stakeholders in the spatial data community. It allows users to save resources, time, and effort when acquiring new datasets by avoiding the duplication of expenses associated with the generation and maintenance of data and their integration into other datasets” (pp. 726–728). As generally accepted in the SDI literature, the technical standards are one of the main components of the SDI that enables the integration of geo-spatial information from different sources.

The Open Geospatial Consortium (OGC) developed the Geographic Markup Language (GML) as an international geo-spatial data encoding and storage format which is a form of the Extensible Markup Language (XML). Several countries have developed a 2D national data exchange format based on GML encoding. The framework presented with the GML has enabled the development several thematic geo-spatial standards, i.e. OGC CityGML for 3D city models (http://citygml.org), OGC GeoSciML for geoscience (http://geosciml.org), and XPlaNGML for land use planning domains (http://www.iai.fzk.de/www-extern/index.php?id=679). Among these domain standards, CityGML provides a semantic information model for the representation of 3D urban objects. It is a conceptual model represented by the Unified Modeling Language (UML), and also an application schema based on GML (OGC, 2012). In the recent years, there has been growing interest to adopt CityGML as a national standard for 3D geo-information (cf. Stoter et al., 2010, 2011; v/d Brink et al., 2012a,b). CityGML defines classes and relations for the city objects including; buildings, land use, vegetation, water bodies and city furniture. Moreover, it is also extendable to include the requirements of specific applications such as the taxation of immovable properties and municipal information systems, as discussed in this paper with reference to a Turkish case study.

In Turkey, there is a standardized data model requirement for the immovable taxation system which enables the storage and exchange geo-spatial and non-spatial information and therefore allowing interoperability between different information systems. Such a standardized data model should facilitate the representation of property units in 3D. CityGML as an international 3D standard has the potential to respond to these requirements: condominium units can be represented in CityGML based on floor plans. Furthermore, the legal and economic characteristics of property units required for immovable property taxation can be added to the CityGML data model. This adaptation can be achieved by the Application Domain Extension (ADE) expanding the existing CityGML feature types and attributes (OGC, 2012). To model the subjects of the immovable property taxes and their properties, this paper presents an Immovable Property Taxation ADE which extends the CityGML feature classes within the terms of the legal and administrative concepts defined in Turkish Law.

The remainder of this article is organized as follows: Section 2 summarizes the Turkish property taxation system; Section 3 introduces the CityGML data model and ADE development methods; Section 4 presents the developed Immovable Property Taxation ADE. The last section presents the concluding remarks.

2. An overview of immovable property taxation in Turkey

2.1. General concepts

There are two types of annually levied recurrent taxes on immovable property in Turkey, namely building tax and land tax. The main principles regarding these taxes are given in the Real Estate Tax Law, dated 1970. Furthermore, the Tax Procedure Law (1961) and the Tax Assessment Statute (1972) contain the rules regarding assessment procedures.

The subject of the property tax is the immovable property specified in Turkish Civil Law as a cadastral parcel and a condominium unit. Land tax is levied from cadastral parcels in municipal areas, whereas the subject of the building tax covers all permanent buildings built on land and sea. Both ‘legal buildings’ and ‘illegal buildings’ are subject to building tax. Legal buildings refer to buildings that have certificate of occupancy which legally documents that the building is suitable for occupancy. Illegal buildings cover those structures that were not constructed in compliance with the law.

According to Turkish Condominium Ownership Law, a part of a (legal) building such as an apartment, office, shop, store, cellar or warehouse which is available for use separately and independently can be registered as condominium unit. The ownership right on a condominium unit is a type of co-ownership on buildings where each condominium is privately owned, and joint facilities are owned in shares held by owner of each condominium unit. In the law joint facilities include: the plot of land under the building(s), the structural components of building (e.g., foundations, load bearing system, external walls, doors and windows), common spaces (e.g., yards, laundries, garages and cellars), central utilities (e.g., heating rooms, wells, cisterns and common water tanks), and technical installations (e.g., heating, water, gas, electric and telecommunication installations). In condominium ownership, the share of the joint facilities belonging to each unit owner is specific to their unit and is called the ‘ownership fraction’ according to UNECE terminology (2005). Turkish Condominium Ownership Law states that the ownership fraction for a specific condominium unit is calculated by dividing its value by sum of the values of all the condominium units in the building. In addition, the law allows the allocation of places such as coal cellars, water tanks and garages to specific condominium units. These places, called ‘annexes’ are complementary parts of specific condominium units, therefore, the owner of specific condominium unit is also the owner of ‘annexes’ allocated to the condominium unit.

Property taxes have to be paid by the owner or the owner of the usufruct right of the immovable property. When a person has the usufruct right to a property the tax is paid by the right holder, otherwise it must be paid by the owners of property. Two

types of ownership are defined in Turkish Civil Law: (i) individual ownership, and (ii) collective ownership. The former refers to the ownership right that belongs to only one person, whereas the latter indicates ownership held by a group of people for either shared or co-operated properties. A shared property is a physically undivided property that belongs to more than one person. In this situation, each owner is responsible for paying the tax on their share. A co-operated property is owned by a community such as a group consisting of successors of a testator, or partners of a family company. Since there is no specific share of owners the tax levied has to be paid by the owners of co-operated property collectively.

Land and building taxes are levied according to the ‘tax values’ of the properties which are assessed by the municipality every four years. These values are updated between the assessment periods by the half of the revaluation rate which indicates annual changing rate in the Wholesale Price Indices computed by Ministry of Finance. The tax values for urban and rural parcels are assessed on the basis of unit land values determined by the local valuation commissions for each street in urban areas and each district in rural areas. The building tax values are assessed with a cost approach based on ‘cost of building per square meter’ determined by the Ministry of Finance and the Ministry of Public Works and Settlement.

In Turkish property taxation, the tax rates are determined by the law with different tax rates being imposed on properties according to usage and location. The current tax rate is 0.1% for residential buildings, 0.2% for non-residential buildings, 0.1% for rural land and 0.3% for urban land located outside metropolitan municipality boundaries. Land and buildings located within the determined boundaries of metropolitan municipalities are taxed at twice that of the above-mentioned tax rates; namely 0.2% for residential buildings, 0.4% for non-residential buildings, 0.2% for rural land and 0.6% for urban land.

Some properties are temporarily or permanently exempt from property tax. According to the law, land parcels located outside municipal areas and mostly used for agricultural purposes are exempt from land tax. Immoveable properties that belong to public organizations, and properties used for health, religious, transportation, infrastructure and other public services are also have given tax exemptions.

2.2. Property tax inventories

In Turkey, the legal information required for taxation purposes is maintained by the land registry and consists of a land book and a condominium book which records cadastral parcels and condominium units, respectively. It generally keeps data including cadastral identifiers of property units (e.g., parcel number, cadastral district, address), identifiers of right holders (e.g., name, date of birth, address), type of property right (e.g., ownership, mortgage, servitude, encumbrance), legal restrictions on the property unit (e.g., restrictions regarding subdivision, transaction or environmental protection), transactions details (e.g., type, price and date of transactions), and cross references to legal documents (e.g., contracts, cadastral plans). The land registry allows the identification of buildings and, in addition to the legal records, contains archives of the certificates of occupancy for the building. The certificate of occupancy is a legal document which certifies that the building was constructed according to the law and development regulations. It includes detailed information on the structural components of buildings. This certificate of occupancy is also archived by the municipality, and the Address Registration System which is a central database maintained by Ministry of Interior.

In general, a land registry provides a basis for property tax inventories. However, in Turkey, where the legal situation differs from the actual situation in regard to illegal settlements, tax inventories are created and updated with the information periodically declared by the property owners to the municipalities. This self-declaration approach enables the identification of illegal buildings which are not visible in the land registry. It also provides structural, environmental and economic data regarding these buildings which are not recorded in any other information system.

Table 1 shows the content of declaration which, in addition to taxation data, includes personal civil records, address records, and land registry records that were already registered in national information systems, namely the Central Civil Registration System, Address Registration System, and the Land Registry and Cadastre Information System, respectively. However, there is no connection between the national and municipal information systems. The accuracy of information declared by the owner of the property is verified with land registry records and fieldwork carried out by the municipality.

There is no standardized national geo-spatial data model for managing property tax inventories in Turkey. In general, tax records are kept in municipal databases or management information systems which have no geo-spatial base. However, some large municipalities have geographical information systems (GIS) which integrate tax records with topographical and cadastral maps. The national cadastral organization maintains 2D cadastral maps which show parcel boundaries and the position of legal buildings. Moreover, the topographical maps produced by municipalities also show the positions of illegal buildings in 2D. Thus, topographical maps are used as complementary source in order to identify illegal buildings.

Since a cadastral parcel is the basic unit in the Turkish Cadastre, individual condominium units cannot be identified with the traditional 2D cadastral maps. However, floor plans archived by the cadastral organization include 3D geo-spatial information for condominium units. Currently 3D geo-spatial information for buildings that are not under the condominium ownership is unavailable.

As mentioned above, there is a standardized 3D geo-spatial data model requirement for the Turkish immovable taxation system. Thus, CityGML, as an international 3D standard, could be adopted as a national 3D data model in Turkey. This adoption has the potential to overcome the above-mentioned taxation shortcomings in that condominium units can be spatially represented in 3D, also the legal and economic attributes of property units can be stored using the CityGML data model. Furthermore, where floor plans for buildings that are not under the condominium ownership are available CityGML has the potential to include them.

The next section briefly outlines the CityGML data model and its LandUse and Building modules based on the OGC (2012) specification, which are detailed in Section 4 with the classes and attributes of the proposed Immovable Property Taxation ADE.

3. A general overview of CityGML

CityGML is an open data model with an XML-based format for the storage and exchange of virtual 3D city models. It is an application schema for the GML version 3.1.1 (GML3), the extensible international standard for spatial data exchange. The CityGML data model consists of a core module and thematic extension modules. The core module comprises the basic concepts and components of the CityGML data model, whereas the extension modules cover specific thematic fields of the virtual 3D city model including Appearance, Bridge, Building, CityFurniture, CityObjectGroup, Generics, LandUse, Relief, Transportation, Tunnel, Vegetation, WaterBody, and TexturedSurface. Moreover, Application Domain Extensions (ADEs) can specify additions to the CityGML data model (OGC, 2012, pp. 10–12).

An ADE is specified in order to adapt CityGML to the requirements of specific application domains. It allows the definition of new feature types, attributes, geometries, and associations. Also,
new attributes, geometries, and associations can be added to the existing feature types with the ADE. To date, different research communities have developed ADEs for their requirements such as; the Noise ADE for a noise mapping, the HydroADE for hydrographical applications, and the Standard Opening ADE and the URN ADE for indoor navigation and mobile robotics tasks (OGC, 2012; Groger and Plümer, 2012). The technical details regarding the development of the ADE are given in Section 3.3.

Another important concept in the CityGML is the 'external reference' which allows pointing to the identifier of the object in another information system. This reference is a link from a CityGML object to a corresponding object in another information systems, and provides consistency between the different information systems which store different data relating to the same object. The reference consists of the name of the external information system (URI) and the reference of the external object (string or URI) (OGC, 2012, pp. 15–16).

The CityGML data model enables the representation of the same city object in different degrees of resolution through the notion of level-of-detail (LOD). The following five levels are specified: LOD0 the coarsest level is the digital terrain model. LOD1 provides the block model, without any roof structures. LOD2 is the block model with roof structures, texture and larger building installations. LOD3 provides detailed architectural models. Finally, LOD4 enriches LOD3 by adding interior structure objects (OGC, 2012, pp. 12–13).

Concluding this summary, the reader is referred to Kolbe et al. (2005), Kolbe (2009), Groger and Plümer (2012), and OGC (2012) for more detailed information on the general notions of the CityGML. The following subsections summarize the details of the CityGML Building and LandUse modules which provide a basis for the Immovable Property Taxation ADE presented in Section 4.

### 3.1. The CityGML Building module

This module can represent the subject of building tax. As shown in Fig. 1, the main class in the Building module is AbstractBuilding, which is either a BuildingPart or a Building. The former is used to model a structural part of a building however, if a building consists of only one (homogeneous) part, the latter class is used. The BuildingPart and Building classes inherit the attributes of AbstractBuilding: the class of the building, function, usage, year of construction, year of demolition, roof type, measured height, and number and individual heights of the stories above and below ground. A building may have zero or more building installation objects such as chimneys, stairs, antennas, or balconies which are represented by the BuildingInstallation class. Moreover, a Building or BuildingPart consist of Rooms which also may have BuildingFurniture and IntBuildingInstallations. The BuildingFurniture refers to a movable part of a room, such as a chair or table, whereas an IntBuildingInstallation is used to model an object inside a building and permanently attached to the building structure, e.g. interior stairs, railings, radiators and pipes (OGC, 2012, pp. 67–82).

### 3.2. CityGML Land Use module

The CityGML specification states that the LandUse class should be employed to represent cadastral parcels in 3D. The land use and land cover are different concepts, but in the CityGML conceptualization they are interlinked and mixed in the LandUse feature class. However, according to our conceptualization, the term Land is a better fit than LandUse. Since OGC (2012) proposes to use this feature to define the ‘area of the earth’s surface’. In the CityGML specification, the LandUse class has the attributes class, function and usage (see Fig. 2). The class attribute is used to represent the classification of land use objects, such as settlement areas, industrial areas and farmland. The attribute function defines the purpose of the object, for example, a cornfield, while the attribute usage can be used, if the object is used in a way that differs from the function (OGC, 2012, p. 151).

As briefly introduced above, CityGML allows the semantic and geometrical representation of city objects, but does not model the legal and administrative objects, namely the property units and their legal and economic characteristics which are important in taxation practices, as well as cadastral and other administrative applications. Therefore, the CityGML model should be improved so that it can allow the modeling of the subjects of the immovable property tax (cadastral parcel and condominiums) and their properties. This can be achieved by an ADE the technical details of which are given below.

### 3.3. Previous research regarding ADE development

The technical principles regarding ADE development are explained by OGC (2012, pp. 162–164). Accordingly, an ADE is
defined with an XML schema definition file with its own namespace which must have a unique URI. Within the ADE namespace, a domain specific feature type can be created as a subclass of an existing CityGML feature type with a number of attributes and relations. The generalization relationship between the new and existing feature types indicates that the new feature type will inherit all attributes and relations from the corresponding CityGML feature type. It should be noted that inheriting properties from more than one superclass (multiple inheritance) is not supported by the GML; therefore, each feature class must have only one base class. In addition to generalization, the CityGML provides a 'hook' mechanism which allows the attachment of a number of application specific attributes to the existing feature type. The hook mechanism is implemented in the XML schema file with "GenericApplicationPropertyOf<Featuretypename>" element, where <Featuretypename> refers to the name of the feature type definition where it is included.

Recently, a draft national 3D standard was developed in the Netherlands as an ADE which integrates the CityGML with the Dutch national Information Model for large scale topography.
The applied method for the IMGeo ADE enables the extension of the CityGML with the domain specific concepts by using UML class diagrams, also facilitates the automatic generation of application schemas from extended UML class diagrams. The main principles of this ADE development method supported by the SIG 3D and OGC (the founders of CityGML) is explained by v/d Brink et al. (2012a,b) as follows: Firstly, a conceptual mapping was performed to identify matching classes between the IMGeo and CityGML models. The IMGeo class which exactly matches the class in the CityGML is considered as subclass of the corresponding CityGML class. The IMGeo class which does not exactly match with the CityGML class is re-modeled in order to find an equivalent CityGML class. In the ADE, all original and re-modeled IMGeo classes are specified as subclasses of the related CityGML classes. As mentioned above, the created subclass inherits all the attributes and relations from the related CityGML superclass. However, it is emphasized that this was not the intention of the ADE developers, rather the aim was only to add the attributes of the IMGeo subclass to the relevant CityGML class. Therefore, the «ADEElement» stereotype is assigned to each subclass. This stereotype indicates that only attributes of the subclass will be added to the CityGML superclass using the ‘hook mechanism’ and no XML element for the subclass will be created in the XML schema definition file. In addition to the matched and the remodeled IMGeo concepts, for the other IMGeo concepts which are not addressed by the existing CityGML classes, the CityGML is extended with new classes, as a subclass of one of the CityGML classes. This is actually the extension of CityGML feature types with the inheritance mechanism, as described above. For more detailed information on ADE development using UML class diagrams, the reader can consult v/d Brink et al. (2012a,b).

An extension of CityGML for the cadastral/land administration domain was presented by Dsilva (2009). This research developed an ADE to CityGML for cadastral purposes which allow identification of apartments, and ownership rights for the apartments. As illustrated in Fig. 3, Dsilva (2009) designed a new class called KadasterApartment in order to store ownership rights on apartments, since the CityGML Building module does not allow the representation of apartments in a building. A set of attributes for the KadasterApartment was identified (e.g., number, floor number, owner, ownership type, and room count of the apartment). The KadasterApartment also includes detachedRoom and detachedRoomCount attributes which identify if the apartment has detached rooms with the same ownership rights (e.g., garage or storage). Finally, Dsilva
(2009) proposed a set of application specific attributes for the CityGML AbstractBuilding class such as parcel number and building owner (as shown in Fig. 3).

Dsilva’s research extended the CityGML Building module to represent apartments (condominium units) and some of their legal properties. However, it does not adequately consider the legal specifications of property units and their components, such as joint facilities and annexes as explained in Turkish case (see Section 2.1). In fact the detachedRoom attribute for the KadasterApartment allows the identification of annexes that belong to the owner of the apartment, but this is not sufficient to differentiate these annexes from joint facilities, and explicitly specify their legal characteristics. Also, the cadastral parcel which is conventionally one of the basic property units in Europe (see UNECE, 2004), is not specified by the ADE. As a contribution to this approach, the next section proposes an Immovable Property Taxation ADE in conjunction with the method proposed by v/d Brink et al. (2012a,b), and by adhering as much as possible to the legal and administrative regulations specified in Turkish Law. This paper extends the CityGML to fulfill the requirements of the immovable property taxation system in the case of Turkey. The main purpose here is to investigate whether the CityGML data model could be used to represent the property unit (i.e., cadastral parcel, condominium unit), their components (i.e., annex, joint facility), and their legal (e.g., property rights) and economic attributes (e.g., tax value, taxation period) as required for the process of property taxation, as well as for cadastral and other administrative processes.

4. An ADE to CityGML for immovable property taxation: a Turkish case study

This section describes the development of an Immovable Property Taxation ADE for Turkey through the addition of new classes and their attributes to the CityGML LandUse and AbstractBuilding feature classes, and defining new application specific attributes for the existing classes. The Immovable Property Taxation ADE is defined in an XML schema definition file (XSD) available online at http://cadastralvocabulary.org/citygml/tax/ade/1.0.

As mentioned above, the CityGML does not provide for the representation of property units which according to Turkish Civil Law comprise cadastral parcels and condominium units. In the developed ADE, three new feature classes: PropertyUnit, CadastralParcel and CondominiumUnit are created in order to model Turkish property units. Conceptually, the PropertyUnit is an abstract class with two concrete classes CadastralParcel and CondominiumUnit (see Fig. 4). However, as explained below, the CadastralParcel and CondominiumUnit have already been specified as the subclasses of the LandUse and BuildingUsePart classes, respectively. To avoid multiple inheritance, the PropertyUnit is now defined as a subclass of the CityObject, and the ADEElement stereotype is assigned to it, as proposed by v/d Brink et al. (2012a,b). This means that the PropertyUnit is no longer a feature type, and therefore, no element will be created for the PropertyUnit in the XML schema, rather only the attributes of PropertyUnit are attached to the CityObject class by the 'hook' mechanism. Fig. 4 and Table 2 show the attributes of PropertyUnit class which are attached to the CityObject as application specific properties and will be inherited by the CondominiumUnit and CadastralParcel classes, i.e. the name of the owner and taxpayer, ownership type, party share, tax type, exemption, taxation amount and period, acquisition date and price. Several data types are specified including: the OwnershipType specifying the ownership type as individual, associative or co-operative; the TaxType showing whether the object will attract building or land tax; and finally the Exemption which indicates the exemptions for the object. The external code lists for these data types are given in Table 3.

According to Turkish Civil Law, the core component of a property unit is the cadastral parcel which is defined by UNECE (2004) as “a closed polygon on the surface of the Earth in unique ownership and with homogeneous real property rights” (p. 21). Turkish Civil Law (2001) specifies that the parcel extends from the center of the Earth to the sky, hence the ownership right on a parcel also covers everything above or under the ground below the parcel (e.g. building, mines, crops). The cadastral parcels are not clearly represented with CityGML, but the OGC specification states that the LandUse class be employed to represent cadastral parcels in 3D (2012, p. 151). Therefore, a new feature class is created: the CadastralParcel which is a subclass of the CityGML LandUse. The CadastralParcel inherits all attributes and relations from the CityGML LandUse. Also since the attributes of the PropertyUnit were attached to the CityObject via the 'hook mechanism', the CadastralParcel inherits these attributes from the CityObject. The CadastralParcel has a set of attributes including the number, area, value, and type of parcel as shown in Table 2. For the last attribute, a data type called ParcelType is defined in order to distinguish an urban parcel from a rural parcel which is required in accordance with Turkish tax regulations (see Table 3). An urban parcel refers to a parcel subdivided according to the zoning plan, whereas the rural parcel covers all un-subdivided parcels particularly those located in rural areas. However, according to the tax regulations a parcel which has not been subdivided according to a zoning plan, can still be considered as an urban parcel if it complies with the following conditions: (i) it has to be inside a master plan or a zoning plan, or (ii) it has to be located in a developed area, and benefit from transportation and utility services, even if it is not inside a planning area.

A cadastral parcel may or may not contain buildings. The CityGML AbstractBuilding can adequately represent buildings either with the specialized Building or the BuildingUnit classes introduced in Section 3. The AbstractBuilding feature class has predefined attributes and code lists for class, function, usage, construction and demolition years, roof type, stories and height of buildings above and underground. The CityGML provides a classification schema for buildings with the above mentioned class, function, and usage attributes. However, Turkish tax regulations present another schema for categorizing buildings according to their construction class (e.g., luxury, first class), usage (e.g., residential or commercial), and construction type (e.g., steel, wooden or concrete). In order to address this classification in CityGML, the proposed ADE uses predefined the class and usage attributes of the AbstractBuilding, but develops external code lists for these attributes (as shown in Table 3). Also a new application specific attribute, constructionType is created in order to specify construction type of buildings, such as steel or wood. Finally, in the developed ADE the AbstractBuilding class is extended with other application specific attributes concerning the legal and structural properties of buildings which are vital for taxation applications. These include: the building number, building permit number, building area, building value and legal status of the buildings (cf. Table 2). Table 3 shows the code lists that have been developed for class, usage and constructionType, legalStatusType attributes.

The second instance of a property unit according to Turkish Civil Law is the condominium. The CityGML includes the BuildingPart class to represent the structural parts of buildings, but does not have a class to identify the legal parts (i.e., condominium units, joint facilities, and annexes) of buildings required for tax purposes. This requirement is addressed in the developed ADE with the new abstract class; BuildingUsePart which is an extension of the abstract Site and represents condominium units, joint facilities and annexes (as shown in Fig. 4). In the developed ADE, a Building or
Fig. 4. UML diagram of the CityGML Immovable Property Taxation ADE (yellow: CityGML modules, green: proposed ADE). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)
Table 2
Description of the classes and their attributes of the Immovable Property Taxation ADE.

<table>
<thead>
<tr>
<th>Class</th>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td>PropertyUnit (ADEElement)</td>
<td>ownershipType</td>
<td>describes property units with their attributes needed in property taxation.</td>
</tr>
<tr>
<td></td>
<td>ownerName</td>
<td>type of ownership as individual, associative, co-operated specified by OwnershipType.</td>
</tr>
<tr>
<td></td>
<td>partyShare</td>
<td>name of property unit owner.</td>
</tr>
<tr>
<td></td>
<td>taxType</td>
<td>ownership share of property unit owners.</td>
</tr>
<tr>
<td></td>
<td>taxpayerName</td>
<td>type of property tax as land tax or building tax enumerated by TaxType.</td>
</tr>
<tr>
<td></td>
<td>dateOfAcquisition</td>
<td>name of taxpayer.</td>
</tr>
<tr>
<td></td>
<td>priceOfAcquisition</td>
<td>acquisition date of property unit.</td>
</tr>
<tr>
<td></td>
<td>exemption</td>
<td>acquisition price of property unit.</td>
</tr>
<tr>
<td></td>
<td>startingDateOfExemption</td>
<td>type of exemption either temporary or permanent exemption enumerated by ExemptionType</td>
</tr>
<tr>
<td></td>
<td>endingDateOfExemption</td>
<td>starting date of tax exemption.</td>
</tr>
<tr>
<td></td>
<td>taxAmount</td>
<td>ending date of tax exemption.</td>
</tr>
<tr>
<td></td>
<td>taxPeriod</td>
<td>tax amount assessed by municipalities.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>taxation period.</td>
</tr>
<tr>
<td>CadastralParcel</td>
<td>parcelNumber</td>
<td>as a concrete class of PropertyUnit it describes cadastral parcels.</td>
</tr>
<tr>
<td></td>
<td>parcelArea</td>
<td>number of cadastral parcel.</td>
</tr>
<tr>
<td></td>
<td>parcelType</td>
<td>area of cadastral parcel.</td>
</tr>
<tr>
<td></td>
<td>parcelValue</td>
<td>type of parcel as urban parcel or rural parcel enumerated by ParcelType.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tax value of cadastral parcel assessed by municipalities.</td>
</tr>
<tr>
<td>BuildingUsePart</td>
<td>buildingUsePartType</td>
<td>as an abstract class it describes part of buildings from the legal point of view.</td>
</tr>
<tr>
<td>CondominiumUnit</td>
<td>condominiumUnitNumber</td>
<td>number of condominium unit.</td>
</tr>
<tr>
<td></td>
<td>floorNumber</td>
<td>number of floor where condominium unit located.</td>
</tr>
<tr>
<td></td>
<td>condominiumUnitArea</td>
<td>area of condominium unit.</td>
</tr>
<tr>
<td></td>
<td>ownershipFraction</td>
<td>ownership fraction of condominium unit.</td>
</tr>
<tr>
<td></td>
<td>condominiumUnitValue</td>
<td>tax value of condominium unit assessed by municipalities.</td>
</tr>
<tr>
<td>JointFacility</td>
<td>jointFacilityArea</td>
<td>describes commonly owned parts of buildings by condominium unit owners.</td>
</tr>
<tr>
<td></td>
<td>jointFacilityType</td>
<td>It is a concrete class of BuildingUsePart.</td>
</tr>
<tr>
<td>Annex</td>
<td>annexNumber</td>
<td>area of joint facility.</td>
</tr>
<tr>
<td></td>
<td>annexArea</td>
<td>type of joint facility enumerated by JointFacilityType (i.e., pool, laundry)</td>
</tr>
<tr>
<td>Annex</td>
<td>annexType</td>
<td>as a concrete class of BuildingUsePart it describes places allocated to use of specific</td>
</tr>
<tr>
<td></td>
<td></td>
<td>condominium unit.</td>
</tr>
<tr>
<td>AbstractBuilding</td>
<td>buildingNumber</td>
<td>number of building.</td>
</tr>
<tr>
<td></td>
<td>buildingPermitNumber</td>
<td>number of building permit document.</td>
</tr>
<tr>
<td></td>
<td>buildingArea</td>
<td>total gross area of building.</td>
</tr>
<tr>
<td></td>
<td>constructionType</td>
<td>type of construction enumerated by ConstructionType (i.e., steel, wooden).</td>
</tr>
<tr>
<td></td>
<td>legalStatus</td>
<td>type of legal status of buildings as legal or illegal building enumerated by LegalStatusType.</td>
</tr>
<tr>
<td></td>
<td>buildingValue</td>
<td>tax value of the building assessed by the municipalities.</td>
</tr>
<tr>
<td></td>
<td>class</td>
<td>construction class of buildings defined in Turkish Real Estate Tax Law, and enumerated by ConstructionClassType (i.e., luxury, first, second classes, etc.).</td>
</tr>
<tr>
<td></td>
<td>usage</td>
<td>type of building usage defined by Turkish Real Estate Tax Law, and enumerated by BuildingUsageType (i.e., residential, commercial).</td>
</tr>
</tbody>
</table>

BuildingUnit may have a BuildingUsePart which is a part of a building with homogenous use rights. The BuildingUsePart designates a subdivision of a building from an administrative/legal perspective (Çağdaş and Stubkjaer, submitted for publication). It covers the CondominiumUnit, JointFacility, and Annex concrete classes. The CondominiumUnit class represents individually owned building units and it has two composition relationships with JointFacility and Annex which relate one condominium unit with one or more annexes and joint facilities (see Fig. 4). The JointFacility includes cadastral parcel(s) and parts of building that are commonly owned by condominium units' owners, whereas Annex represents places allocated for the use of specific condominium units. These classes inherit all attributes and relations from their superclass BuildingUsePart.

One or more cadastral parcels contain zero or more buildings which may have a number of condominium units. These cadastral parcels are considered a part of joint places in the condominium ownership. This means that a condominium unit is related to a number of cadastral parcels through the joint facilities in the property. In the UML class diagram (Fig. 4), the composition relationship between the CadastralParcel and AbstractBuilding indicates that one or more CadastralParcel object includes zero or more AbstractBuilding objects; and the aggregation relationship between the JointFacility and CadastralParcel reflects that a CondominiumUnit object is related to a number of CadastralParcels through the JointFacility. In the developed ADE, the CondominiumUnit class has attributes such as: condominium unit number, floor number, area, ownership fraction, and value of the condominium. The remaining two classes, JointFacility and Annex have attributes which denote their number, area and type. Table 3 contains the code list developed for the buildingUsePartType, jointFacilityType and annexType attributes.

Finally, as shown in Fig. 4, the CityGML allows the addition of the External References to each city object in order to link them with the corresponding objects in external information systems. Through the use of these External References, the instances of the CadastralParcel, CondominiumUnit, and Building classes can be linked with the corresponding objects recorded in the Turkish Land Registry and Cadastre Information System, and Address Registration System, respectively. This referencing facilitates the updating of tax records according to changes in the national

Table 3
Code lists specified by the Immovable Property Taxation ADE.

<table>
<thead>
<tr>
<th>Class</th>
<th>Attribute</th>
<th>Data type</th>
<th>Code list</th>
</tr>
</thead>
</table>
| PropertyUnit (ADEElement)  | ownershipType      | OwnershipType      | a. Individual ownership  
b. Associative ownership  
c. Co-operated ownership |
|                            | taxType            | TaxType            | a. Land tax  
b. Building tax |
|                            | exemption          | ExemptionType      | a. Temporary exemption  
b. Permanent exemption  
a. Urban parcel  
b. Rural parcel |
| CadastralParcel           | parcelType         | ParcelType         | a. Condominium unit  
b. Joint facility  
c. Annex |
| BuildingUsePart           | buildingUsePart    | BuildingUsePartType | a. Condominium unit  
b. Joint facility  
c. Annex |
| JointFacility             | jointFacilityType  | JointFacilityType  | a. Coal cellars  
b. Garage  
c. Terrace  
d. Laundry room  
e. Drying room  
f. Yard  
g. Central heating room |
| Annex                      | annexType          | AnnexType          | a. Coal cellar  
b. Water tank  
c. Garage |
| AbstractBuilding          | class              | ConstructionClassType | a. Luxury construction  
b. First class construction  
c. Second class construction  
d. Third class construction  
e. Simple construction |
|                           | usage              | BuildingUsageType  | a. Residential building  
b. Commercial building  
c. Factory building  
d. Hotel building  
e. Cinema-theatre building  
f. Hospital building  
g. Banking and insurance building  
h. Administrative building  
i. Filling station building  
j. Garage building  
k. Dormitory building  
l. School building  
m. Swimming pool  
n. Public bath building  
o. Exposition-fair building  
p. Warehouse building |
|                           | legalStatus        | LegalStatusType    | a. Legal building  
b. Illegal building |
|                           | constructionType   | ConstructionType   | a. Wooden construction  
b. Loadbearing wall construction  
c. Reinforced concrete construction  
d. Steel construction  
e. Prefabricate construction |

databases which officially record the information concerning property units and their components (as explained in Section 2.2).

The formal encoding of the developed XML schema definition file is available at http://cadastralvocabulary.org/citygml/tax_aade/1.0/ which also provides external code lists for the attribute of the ownershipType, taxType, and exemption (for the PropertyUnit class); the parcelType (for the CadastralParcel class); the usage, class, constructionType and legalStatusType (for the AbstractBuilding class); the buildingUsePartType (for the BuildingUsePart class), jointFacilityType (for the JointFacility class) and annexType (for the Annex class).

This section has explained the development of an ADE to CityGML for immovable property taxation in Turkish case, as well as demonstrating how the legal and administrative concepts are integrated with the physical objects specified in the CityGML. The CityGML provides a quite robust and flexible conceptual model which can easily be adapted to administrative requirements. The research reveals that the CityGML data model which is supported with legal concepts defined in Turkish Law has the potential to be a national data model for municipal information systems. Further research includes extending developed ADE according to the other requirements of municipalities to enable better utility management, urban planning, real estate valuation, and other administrative services. There is also a need to research the interrelation of CityGML with other international standardization and development initiatives in the cadastral domain, i.e. ISO/DIS 19152 Land Administration Domain Model; INSPIRE Data Specification on Cadastral Parcel, Building and Addresses; 3D Cadastre.

5. Conclusion

Municipalities which are responsible for the administration of immovable property taxation need standardized information systems that enable the identification of all taxable objects and their legal, economic and environmental attributes. The CityGML developed by the Open Geospatial Consortium presents both a semantic model that represents 3D city objects and a data exchange format.
based on Geographic Markup Language. It was basically developed to represent physical objects, but since it is a flexible model it was thought that the CityGML could be modified to support the legal and administrative concepts required for immovable property taxation. Thus, an Application Domain Extension was developed to be used as a data model for the storage and exchange of information regarding immovable property taxation in case of Turkey where a standardized national data model is needed. The developed ADE might also be of value to urban planning, facility management, property valuation, and other services undertaken by municipalities. It could also be used as a basis of a 3D national data standard for municipality information systems. The developed model is mainly based on legal concepts specified by Turkish Law however; it could be adapted to other jurisdictions, especially in Civil Law countries where similar legal concepts exist.

References