3D Description of Condominium Rights in Turkey: Improving the Integrated Model of LADM and IFC

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Key words: BIM, IFC, LADM, 3D Cadastre, 3D Land administration.

SUMMARY

Efficient management of land is vital for sustainable development. The growing densification in the built environment however makes difficult the job of administration. In addition, the built environment now contains a large number of buildings and facilities that are complex and multilayered. In this sense, Land Administration Systems (LASs) are of great importance to cope with emergent problems that should be paid attention for economic, social, and environmental aspects. It is for this reason that three-dimensional (3D) LASs that enable to unambiguously delineate the cadastral Rights, Restrictions, and Responsibilities (RRRs) with their physical counterparts are the current topic. On the other hand, digitalization has gained a lot of attention all around the world for improving and facilitating the processes regarding both public services and different sectors such as Architecture, Engineering, and Construction (AEC) industry. Considering the AEC industry is one of the primal sectors that implement the alterations in the built environment, there exists a close relationship between this industry and the land administration sector that deals with efficient management of the built environment. Today's AEC industry is performing a vast amount of effort for adaptation of Building Information Modeling (BIM) that allows to create highly detailed models of buildings and their immediate surroundings with semantically and spatially rich information. Whereas the Land Administration Domain Model (LADM) provides a conceptual model for land administration practices, Industry Foundation Classes (IFC) enables the interoperability in terms of modeling through its comprehensive schema that contains a great number of entities. It is thus important to benefit from the as-built building models for registration and depiction of condominium rights in Turkey. This paper, therefore, improves the previous conceptual model that links the classes of LADM and entities of IFC schema such that it covers detailed delineation of condominium rights. The models that cover packages of LADM and the related code lists are presented. This study contributes to 3D LASs transition in Turkey by providing a significant basis for IFC-based modeling of condominium rights.

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1. INTRODUCTION

Information regarding the land is highly important for countries since it contributes to development in terms of various aspects such as economic, cultural, legal, and social. Land registry and cadastre is the paramount issue that provides and preserves this kind of information completely (Yomralioglu and McLaughlin, 2017). Land administration aims to benefit from the information with respect to land and water, and Rights, Restrictions, and Responsibilities (RRRs) that are subject to it. The importance of land administration also appears in the sustainable development goals and targets, for example, goal 11, which is to make cities and human settlements inclusive, safe, resilient, and sustainable (United Nations, 2015). Land Administration Systems (LASs) that enable the management of the ownership information with their spatial components together are implemented such that they focus on two-dimensional (2D) data (Kalogianni et al., 2020b). However, ownerships regarding underground and aboveground of land should be considered and integrated into LASs.

In addition, the built environment is now more complex and denser than ever before globally. The challenges for the registration of RRRs on building and facilities in land are therefore notably increasing (van Oosterom, 2018; Williamson et al., 2010). Evolving the LASs in a way that they have the capabilities to manage, store, analyze, visualize, and disseminate ownership rights in three-dimensional (3D) is considered an important solution to cope with these challenges (van Oosterom et al., 2020). Countries around the world thus pay attention to transforming their cadastral and land registry system in the context of 3D cadastre, for example, The Netherlands (Stoter et al., 2017). It is important to mention that 3D land administration is taking the place of the 3D cadastre notion because it encompasses the cadastral and land registry activities as a whole (Kalogianni et al., 2020b).

The need for the conceptual basis that facilitates the 3D land administration is fulfilled with publishing the Land Administration Domain Model (LADM) Edition I as an International Organization for Standardization (ISO) (ISO, 2012). Countries concentrate to develop their models that are modified by taking as a reference the LADM (Kalogianni et al., 2021). Modification of the LADM is of significance since the legal basis and implementation approach with respect to land administration differs within countries and jurisdictions. Condominium ownership that can be formed in the units of the building that are suitable to exploit independently is a special type of ownership. In the context of 3D land administration, there is a need for the registration and representation of condominium rights in great detail.

Spatial data standards that enable to model of objects in the built environment in 3D are of importance to delineate the condominium rights in buildings or facilities. CityGML, as an Open Geospatial Consortium (OGC) standard, provides Geography Markup Language (GML)-based model for creating 3D models in different themes such as building, land use, and transportation (OGC, 2021). It is thus practiced by a large number of scholars to model legal rights with physical counterparts within buildings. Whereas some studies developed an Application Domain Extension (ADE) extension for defining cadastral rights (Góźdź et al., 2014), some of them proposed to add new classes to the CityGML model that correspond to classes in the LADM (Li et al., 2016). Most of the efforts utilized the CityGML 2.0. However, the new version of the CityGML, which has been approved as an OGC standard recently, includes a new modeling concept as spaces. It is therefore able to model ownership rights within buildings through provided classes in building theme such as BuildingUnit, Storey, and BuildingRoom (Kutzner et al., 2020). In this regard, Sun et al. (2019) presented an example to use the CityGML 3.0 for 3D cadastre purposes. Geoinformation that constitutes the vital basis for Geographic Information Systems (GIS) is exploited considerably in the land administration domain and its related fields such as spatial planning (Indrajit et al., 2020), urban management (Lemmen et al., 2015), and real estate valuation (Mete and Yomralioglu, 2021).

The Architecture, Engineering, and Construction (AEC) industry is notably significant for sustainable development of the built environment and economic stability of the countries. This industry intersects with the land administration sector because it should be conformed to decisions on how land should be used before constructing a completely new building or transforming an existing building. In the AEC industry, Building Information Modeling (BIM) that provides to create 3D models of buildings and immediate surroundings detailedly through object-based modeling techniques that allow storing spatial information and semantic information is taking place of traditional Computer-Aided Design (CAD) (Teicholz et al., 2018). Statistics show that the use of BIM has become widespread in many countries (BIMgenius, 2020; McGraw Hill Construction, 2014; NBC, 2020).

Building Information Models (BIMs) are also significant for digital transformation that should be paid attention by administrations for facilitating and improving the public services such as building/construction permitting (Guler and Yomralioglu, 2021a; Noardo et al., 2020b). Several countries, for example Singapore, implement an approach that requests BIMs, specifically Industry Foundation Classes (IFC) (ISO, 2018) models, of buildings in building permit submission (Eastman et al., 2009). It is also mentioned in the “2020-2023 National Smart Cities Strategy and Action Plan” of Turkey that BIMs will be used in digital building permitting and facility management. Considering the as-built BIMs of buildings will be existing, there is a highly promising opportunity to use these BIMs for implementing 3D LASs (Atazadeh et al., 2017b; Rajabifard et al., 2019). Researchers from different countries thus focus on the modeling of RRRs in the buildings and immediate surroundings using BIMs (Alattas et al., 2021; Barzegar et al., 2021; Hajji et al., 2021; Petronijević et al., 2021; Ying et al., 2021). This paper aims to improve the conceptual model (Guler and Yomralioglu, 2021b) that integrates LADM and IFC in a way that it allows for thoroughly representing the condominium rights in Turkey.

2. BACKGROUND

2.1 Standards

2.1.1 Land Administration Domain Model (LADM)

LADM is an ISO standard that provides a conceptual model for land administration practices. The main aim of the standard is to ease the transition to an efficient land administration system by benefiting from the standardized model that encompasses a wide range of components involving land administration. The conceptual schema of the LADM includes three main packages namely *Party*, *Administrative*, *Spatial Unit*, and one sub package of *Spatial Unit* as *Surveying and Representation*. Whereas the *Party* package allows to model different types of parties that involve land administration practices, the *Administrative* package provides classes that can be used to detailedly represent specific occasions and elements with respect to RRRs. The *Spatial Unit* package of the schema describes how to model features that should be delineated spatially. The land parcel, buildings, and infrastructure facilities are examples of features that can be modeled within this package. The goal of the *Surveying and Representation* package is to provide an efficient spatial modeling concept for features in the *Spatial Unit* package. *LA_BoundaryFaceString*, *LA_Point*, and *LA_BoundaryFace* are the classes that are created to represent *LA_SpatialUnit* instances. The geometries of these classes are *GM_MultiCurve*, *GM_Point*, and *GM_MultiSurface*, respectively. It is significant to note that LADM benefits from ISO 19107 (ISO, 2019) standard that provides a spatial schema for geographic information, in order to obtain geometry specifications in the conceptual model. There is an ongoing study on preparing the next version of LADM and hence the second version of it will be released next year, probably. The updated version of LADM will contain two new packages, namely Valuation Information and Spatial Planning, so as to cover all main components of land administration. It is also aimed to improve the modeling of 3D spatial units. There is additionally an ambition to provide fundamental steps for the transition to the implementation from conceptualization in the context of the revision of LADM (Kalogianni et al., 2020a).

2.1.2 Industry Foundation Classes (IFC)

IFC is the primary, open standard for BIM data (buildingSMART, 2021a). This standard is developed by buildingSMART to provide interoperability regarding data exchange between different stakeholders and software in construction or facility management. IFC provides a comprehensive schema that enables to digitally represent the whole lifecycle of buildings and facilities. IFC contains four main data schemas namely core, shared element, domain-specific, and resource definition. These data schemas include a great number of defined types, enumeration types, select types, entities, functions, rules, property sets, quantity sets, and individual properties (buildingSMART, 2021b). Figure 1 shows the IFC schema representation that encapsulates several entities that can be used to delineate condominium rights. As can be seen from Figure 1, *IfcRoot* is the root entity in the IFC schema. *IfcProject* is the main entity that enables to store of information about the project. *IfcActor*, as a subtype from the *IfcObject* entity, enables to record information with regards to actors involved in a project lifecycle.

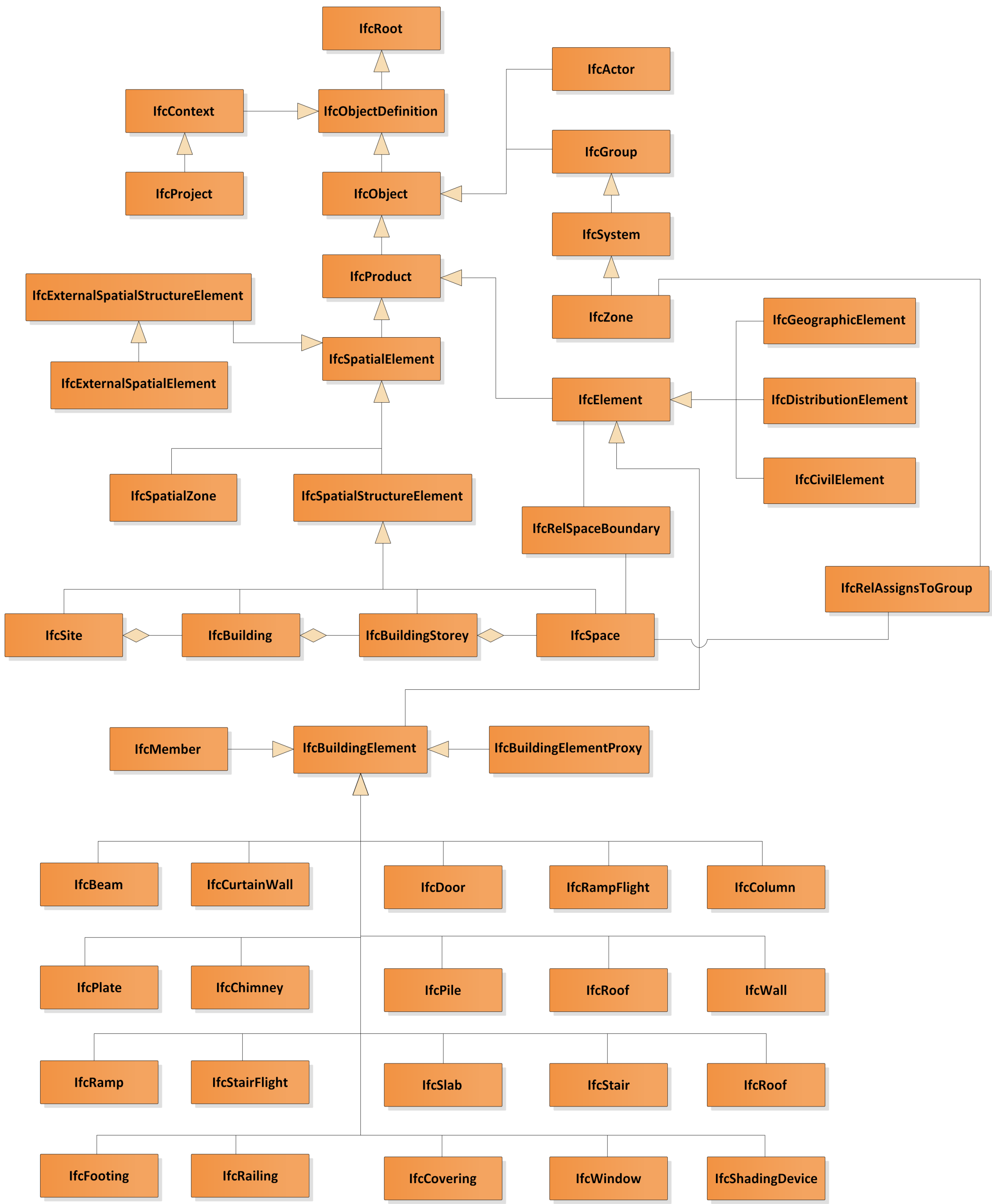

Figure 1. Summarized representation of IFC schema.

The actors can be a person or organization. *IfcSpatialElement* and *IfcElement* are two of the subtypes of the *IfcProduct* entity. *IfcElement* has several subtypes such as *IfcGeographicElement*, *IfcDistributionElement*, *IfcCivilElement*, and *IfcBuildingElement*. These entities provide modeling specifications for the different elements that might be in building or facility projects. For example, *IfcGeographicElement* can be used to model a different kind of features related to landscape. *IfcBuildingElement* is the primal entity that is used to store a wide range of elements regarding buildings. Doors, beams, columns, stairs, walls, windows are examples of these elements. *IfcSpatialElement* has three subtypes as *IfcExternalSpatialStructureElement*, *IfcSpatialStructureElement*, and *IfcSpatialZone*. *IfcExternalSpatialElement*, as a subtype of *IfcExternalSpatialStructureElement*, enables to model the external regions of the building site logically or physically. *IfcSpatialStructureElement* has four subtypes namely *IfcSite*, *IfcBuilding*, *IfcBuildingStorey*, and *IfcSpace* in order to define the possible spatial elements for different structure levels of buildings. There exists the aggregation relationship between these subtypes through the *IfcRelAggregates* entity. The current version of IFC is IFC4 ADD2 TC1 however there is an ongoing process for developing the IFC. The next version (IFC 4.3) will probably be published in 2023 as an ISO standard. Model View Definition (MVD) (buildingSMART, 2021c) is another important data standard that provides the exchange of the IFC models through focusing and extracting the required parts of these models for specific applications or parties. In addition to data standards, buildingSMART develops workflow standards that enable efficient information flow within the lifecycle of a building or facility. Information Delivery Manual (IDM) and BIM Collaboration Format (BCF) are examples of these standards (ISO, 2016).

3. CURRENT SITUATION IN TURKEY

3.1 Legislative Background

There are several laws and legislative documents regarding land administration and cadastral registration in Turkey. Turkish Civil Code No.4721 (Official Gazette, 2001) is the main law that describes real estate ownership. It is stated in Article 704 of this law that the subjects of real estate ownership are land, independent and permanent rights that are recorded on the separate pages of the land register, and condominiums that are recorded to the condominium register. This article manifests the condominium rights officially. The Civil Code also contains a number of articles that describe a wide range of rights such as superficies, usufruct, and right of way. In addition to the Civil Code, Cadastre Law, Land Registry Law, and Zoning Law are the important legal references for cadastral registration.

The Condominium Law No.634 (Official Gazette, 1965) is the main legislative document that defines the RRRs with respect to condominiums. Article 1 of the Condominium Law states that independent ownership rights can be established by owner or joint owners on the different units such as storey, apartment, office, store, cellar, and storage of a constructed building that are suitable to be used independently and separately. Clause 1 of Article 2 of the same law states the definitions of the main real estate, main building, condominium, annex, condominium right, and condominium owner.

According to the law, a condominium owner can have the right to use on condominium itself and spaces that are in the outside of the condominium as well. Annexes can be coal cellar, water tank, garage, electric meter box, or toilet. The Condominium law also states that condominium owners have jointly right to use on shared facilities and spaces that are in the outside of the condominiums in real estate and serve for protection and exploitation. Main walls, beams, columns, curtain walls, floors, ceilings, patios, stairs, elevators, and corridors are examples of shared facilities and spaces. Noteworthy to mention that 2D representations might be insufficient to realistically delineate the condominium rights in multilayered buildings. Building permitting is another important issue for condominium rights because it is mandated in the Condominium Law that the condominium plans that are approved in the building permit procedure should be used for the registration of condominium rights after construction of the building.

3.2 Recent Advancements

3.2.1 Academic Works

First efforts with respect to 3D cadastre in Turkey started with academic studies. There are a couple of graduate theses regarding the establishment of a database for 3D cadastre (for example, (Döner, 2010)). Afterward, a CityGML ADE that covers the modeling and storing of the condominiums is proposed with the aim of taxation (Cagdas, 2013). Döner & Şirin (2020) examine the 3D cadastre approaches in Turkey in terms of legal, technical, and organizational aspects. With the publishing of the LADM as an ISO standard, a country profile for the management of 3D RRR is developed by researchers (Alkan et al., 2021). In addition, an ADE for 3D cadastre purposes in Turkey is created by benefiting from the integration of LADM and CityGML (Gürsoy Sürmeneli et al., 2021). Scholars use CityGML 2.0 in their studies. An implementation that focuses on the real estate valuation in the context of the developed LADM Valuation Information Model (VIM) is also shown (Kara et al., 2021). The VIM contains modeling of condominiums and their attributes so as to use for valuation purposes. Guler & Yomralioglu (2021c) underline that it can be exploited interrelation between digital building permitting and registration of condominium rights through exchanging 3D digital models such as BIMs. Celik Simsek and Uzun (2021) propose to use of BIMs to model condominium rights and to find the values of condominium units for calculating the land share. Recently, an initial conceptual model that benefits from IFC and LADM standards to delineate the condominium rights in Turkey is developed (Guler and Yomralioglu, 2021b).

3.2.2 Governmental Projects and Strategies

The 11th Development Plan, which is the current plan, contains the completion of the multidimensional cadastre. It covers the publishing of the digital, up-to-date, and trustworthy cadastral data in order to create the basis for investments that are made by public and private sector organizations. The plan also underlines that ownership data will be transferred to the electronic environment. "2020-2023 National Smart Cities Strategy and Action Plan" is of significance because it highlights that BIMs will be used in building permitting procedures. This means that there will be an important opportunity to use of BIMs in cadastral registration.

Before 3D modeling of cadastral rights, it is aimed to create a national Spatial Data Infrastructure (SDI) for Turkey. Interoperable spatial data production by a wide range of public organizations is highly essential for establishing and maintaining SDI. For this reason, the Turkey National Geographic Information System (TNGIS) project is carried out by the General Directorate of Geographic Information Systems (GDoGIS). Within the project, the conceptual models and their application schemas for various themes such as building, cadastre, and land use are developed and shared. These conceptual models and application schemas are updated in specific periods. While the previous versions of the Building Theme contain only 2D-based building models, the new version of this theme will cover the 3D building models that are modeled as a CityGML ADE based on the latest version of the CityGML standard (MoEUCC, 2021). With the increasing international attention for 3D cadastre, the project titled "3D Urban Models and Cadastre" is started to carry out by the General Directorate of Land Registry and Cadastre (GDoLRC). Whereas one aim of the project is to create 3D digital models of cities, the other aim is to produce 3D building models that store and represent the cadastral rights. Within the project, 2D floor plans are digitized and labeled in CAD software. Afterward, these CAD files are converted to CityGML 2.0 files by populating cadastral rights in the buildings.

4. MODEL DEVELOPMENT

In this study, a conceptual model that is developed previously is improved such that it provides to model condominium rights in buildings more detailedly. Two ISO standards namely LADM and IFC that are widely accepted are used for developing the model. Figure 2 presents the *Party* and *Administrative* packages of the developed model. As can be seen from Figure 2, all features in the *Party* and *Administrative* packages of LADM are utilized in the model. *TR_Easement* feature is added to the model as a subclass of *TR_Restriction* in order to represent the easements that are described in the Turkish Civil Code. *TR_Party* has twelve attributes that are needed in cadastral registration. It has four attribute types as *TR_NationalityType*, *TR_PartyType*, *TR_IDType*, and *TR_PartyRoleType*. There are generalization and aggregation relationships between *TR_Party* and *TR_ GroupParty* classes. *TR_RRR* has three subclasses namely *TR_Responsibility*, *TR_ Right*, and *TR_Restriction*. *TR_Mortgage* has an association relationship with *TR_Right* and a generalization relationship with *TR_Restriction*. *TR_AdministrativeSource* class has four attributes that store the necessary information for source for cadastral registration. *TR_Right* has an attribute type namely *TR_RightType* that provides different types such as superficies, usufruct, and timeshare. *TR_BAUnit*, which represents the registration object in the Turkish land administration system, has an attribute type as *TR_BAUnitType* that enables to select parcel, building, or condominium.

There are several entities in the IFC schema to use in the representation of the classes in the developed model. *IfcActor* entity that expresses the persons or organizations involved in a project can be used to model *TR_Party*. More than one *IfcActor* instances can be modeled as *IfcGroup* through the *IfcRelAssignsToGroup* entity. By this way, *TR_GroupParty* class can be depicted by using *IfcGroup*. *IfcDocumentInformation* that is aimed to store metadata information for an external document can be utilized to represent the *TR_AdministrativeSource* class. *IfcZone* is an entity that enables to group of multiple spaces. It can be used to model different legal spaces that belong to a condominium. Furthermore, source information of cadastral registration can be linked to the registration object via the *IfcRelAssociatesDocument* entity.

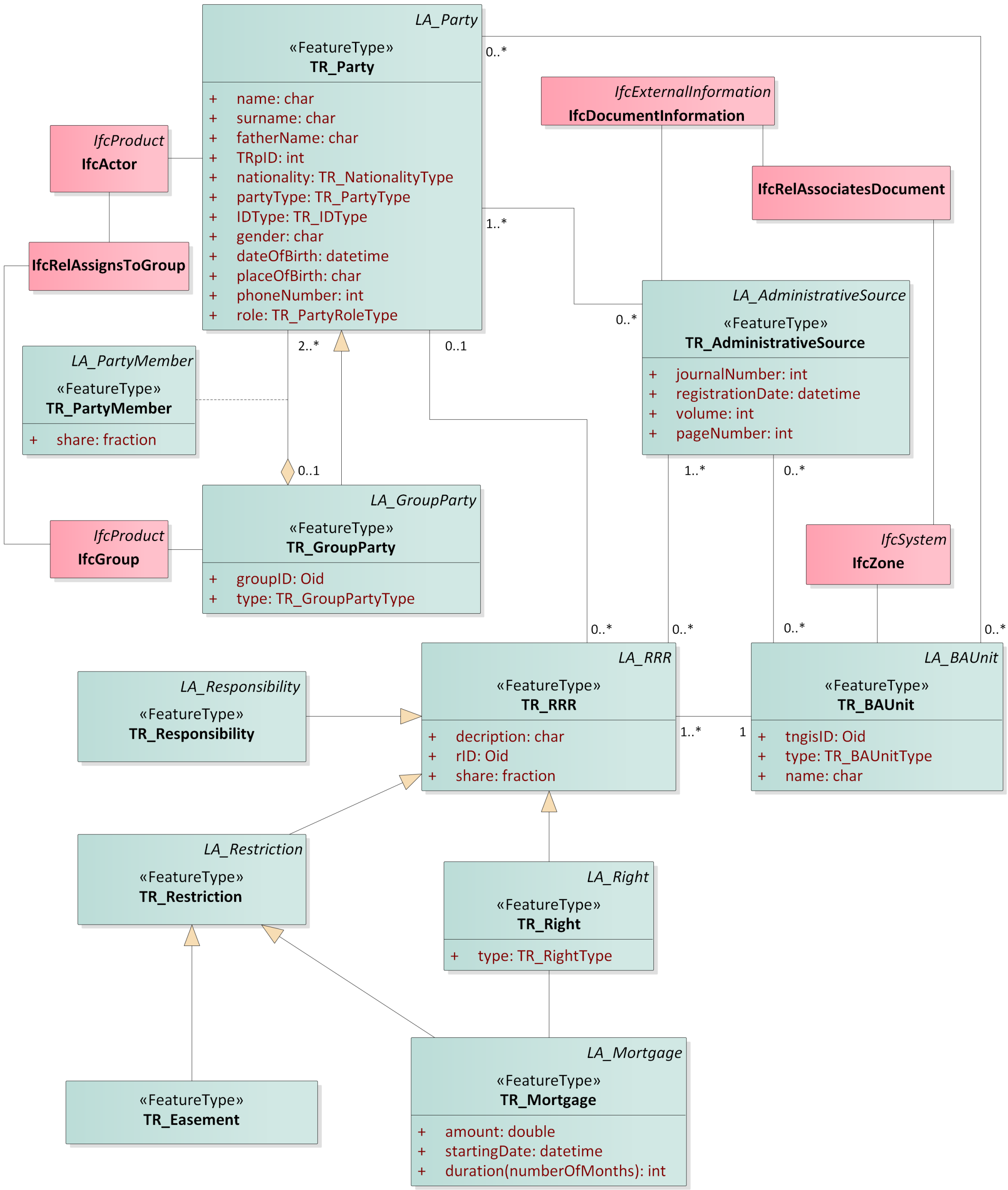

Figure 2. *Party* and *Administrative* packages of the developed model.

Figure 3 demonstrates the code lists that are prepared for attribute types of *Party* and *Administrative* packages. It is possible to add new property sets to IFC entities in a BIM authoring tool. Table A.1 itemizes the property set names, property names, property types, and data types that can be used to store the attributes of the classes in the *Party* and *Administrative* packages of the developed model.

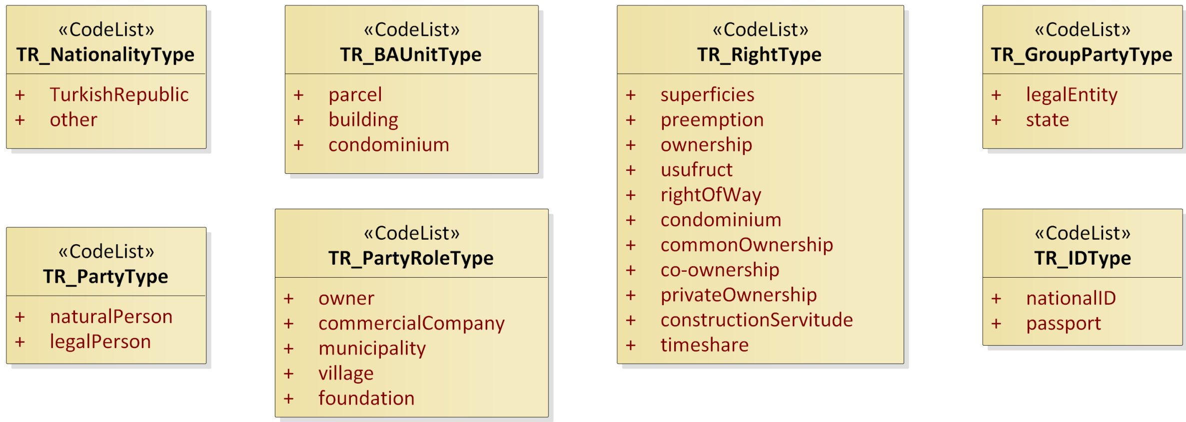

Figure 3. Code lists for the *Party* and *Administrative* package of the developed model.

The property sets related to *TR_BAUnit*, *TR_RRR*, *TR_Responsibility*, *TR_Restriction*, *TR_Right*, *TR_Mortgage*, and *TR_Easement* can be added to the *IfcZone* entity. Whereas *IfcActor* can be enhanced with the attributes of *TR_Party*, *IfcGroup* is suitable for being added attributes of *TR_GroupParty*. The property set pertaining to *TR_AdministrativeSource* can be included in *IfcDocumentInformation*. Figure 4 shows the S*patial* package and *Surveying and Representation* sub package of the developed model. Figure 5 demonstrates the code lists that are prepared for S*patial* package and *Surveying and Representation* sub package of the developed model. *TR_SpatialUnit* is an abstract class that has three subclasses namely *TR_Parcel*, *TR_Building*, and *TR_BuildingElement*. *TR_Parcel* class has seven attributes that are needed to store in the cadastral database. Two of them are attribute types namely *TR_ParcelType* and *TR_LandUseType*. *TR_Building* that has an association with *TR_Parcel* represents the buildings that can be constructed in a parcel. It has a great number of attributes that might be beneficial for different applications such as urban regeneration. *TR_CondominiumUnit* is one of the crucial classes that is utilized to condominium rights. It is an abstract class and has three subclasses as *TR_MainUnit*, *TR_Annex*, and *TR_SharedFacility*. There is a composition relationship between *TR_CondominiumUnit* and *TR_Building* classes since two condominium units should be existing at least to be composed condominium rights within a building. *TR_MainUnit* has a good number of attributes that can be benefited in real estate valuation. As mentioned before, a condominium can have different accessory parts such as a water tank, coal cellar, and storage according to the Condominium Law. This is why *TR_Annex* class has an attribute namely *relatedUnitNumber* in order to assign the external legal spaces to the related condominium. It has also the *TR_AnnexType* attribute type to enable the defining the particular accessory types.

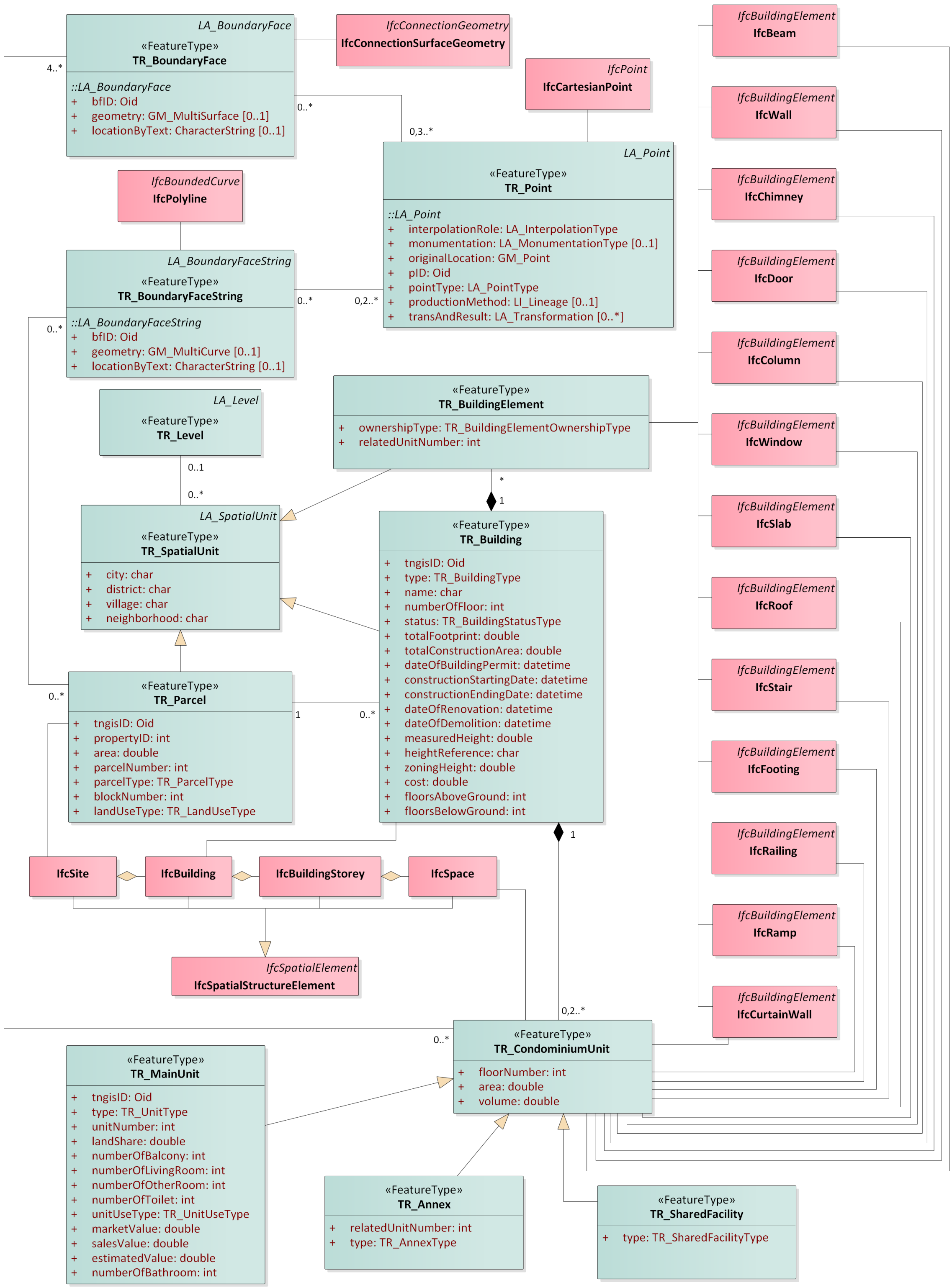

Figure 4. *Spatial* package and *Surveying and Representation* sub package of the developed model.

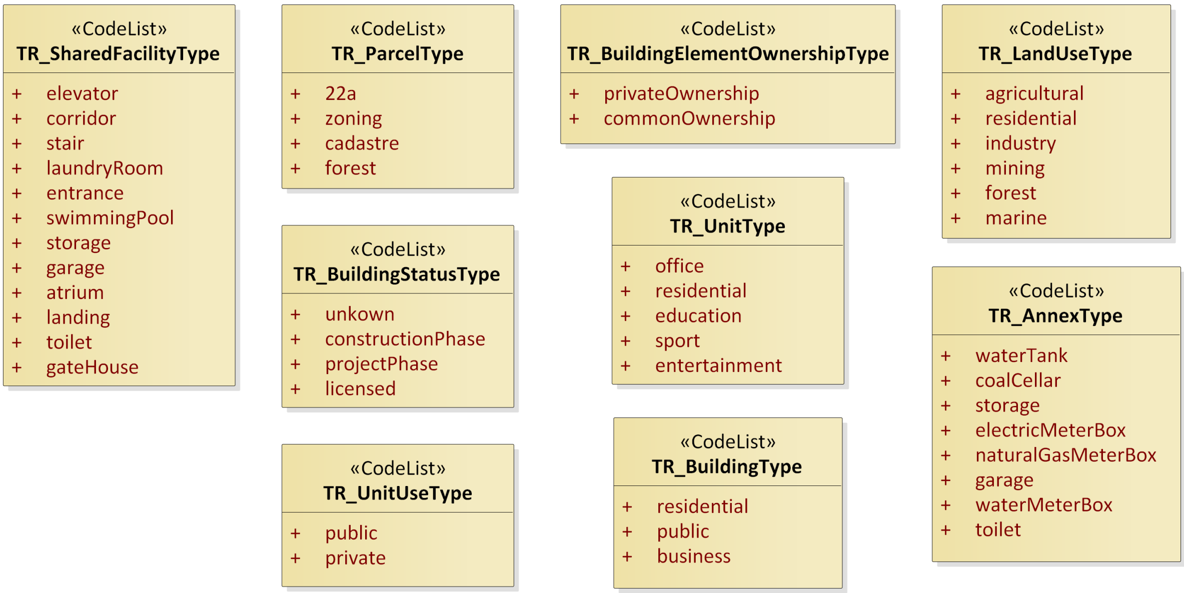

Figure 5. Code lists for *Spatial* package and *Surveying and Representation* sub package of the developed model.

TR_SharedFacility class has an attribute type namely *TR_SharedFacilityType* that represents the different facilities and spaces that are exploited in common, for example, elevator, corridor, and swimming pool. *TR_BoundaryFace* has an association with *TR_CondominiumUnit* for delineating the faces of condominium units. *TR_BoundaryFaceString* is utilized to represent the boundaries of land parcels. *TR_Point* has associations with *TR_BoundaryFace* and *TR_BoundaryFaceString* as well. *TR_BuildingElement* class is used to express the building elements such as walls, doors, and columns that can be subject to condominium rights. There is a composition relationship between *TR_BuildingElement* and *TR_Building* classes. *TR_BuildingElement* class has two attributes namely *ownershipType* and *relatedUnitNumber*. *TR_BuildingElementOwnershipType* provides that a building element is associated with which type of ownership. One type is the common ownership stating that condominium owners are responsible for a building element together. Another type of ownership is private ownership that is utilized to express that a condominium has the right to use for a building element alone. *relatedUnitNumber* is used to specify what condominium has the right to use for a building element.

In the IFC schema, *IfcBuildingElement* has many subtypes to depict the different building elements. Figure 4 illustrates the selected entities that can be used to model condominium rights pertaining to building elements. These entities are associated with *TR_CondominiumUnit* because condominium units can have different building elements. As mentioned before *IfcSpatialStructureElement* has four subtypes. One of these subtypes is *IfcSite* can be used to represent land parcels. It can be noted that *IfcSite* is defined as an area of land in the IFC schema. Another subtype is the *IfcBuilding* entity that can be used to delineate *TR_Building* class in the model. *IfcSpace* is another subtype that is provided to model areal or volumetric spaces that are defined logically or physically. It is feasible to model legal spaces regarding condominium units. In this way, *TR_MainUnit*, *TR_Annex*, and *TR_SharedFacility* classes can be also represented via *IfcSpace*.

To delineate all spaces that the condominium has the right to use, the *IfcZone* entity that represents the group of spaces can be utilized. The space boundaries can be represented using *IfcRelSpaceBoundary* that allows expressing boundaries of spaces virtually or physically through *IfcConnectionSurfaceGeometry*. In this way, it can be depicted what condominium is responsible which faces of the wall. Whereas *IfcCartesianPoint*, as a subtype of *IfcPoint*, is feasible for describing *TR_Point*. *IfcPolyLine* can be used to model the *TR_BoundaryFaceString* class. The property sets regarding *TR_MainUnit*, *TR_Annex*, and *TR_SharedFacility* can be added to the *IfcSpace* entity. Whereas the property set of *TR_Parcel* is suitable for being added to *IfcSite*, *IfcBuilding* can be enhanced with the property sets of *TR_Building*. The property set of *TR_BuildingElement* can be added to subtypes of *IfcBuildingElement* that are included in the developed model. Table A.2 lists the property set names, property names, property types, and data types that can be used to store the attributes of the classes in the *Spatial* package and *Surveying and Representation* sub package of the developed model. While *IfcPropertySingleValue* can be used for the attributes that have a single value such as integer and string, *IfcPropertyEnumeratedValue* is suitable for attribute types that can be selected from a defined list.

5. DISCUSSION AND CONCLUSION

This paper presents the improved version of the conceptual model for delineating the condominium rights in Turkey. The model exploits LADM as a basis for modeling the semantically and spatially necessary classes in the representation of condominium rights in a realistic manner. To benefit from the opportunity that results from being designed the buildings using BIM, existing classes are linked to suitable entities in the IFC schema to depict the condominium rights. These entities enable to detailedly model the buildings and their immediate surroundings as well as the logical spaces that the condominium owner has the right to use. It is important to note that the use of specific entities and relationships between them might differ based on the legislative regulations of the countries or administrations regarding registration and definition of condominium rights. It is however shown in this paper that the reuse of as-built BIMs can be highly beneficial in registration and visualization of condominium rights with their physical counterparts in Turkey, as similarly demonstrated in the literature on various study regions (Atazadeh et al., 2017a).

Statistics, governmental visions, and literature together show a growing trend for digitalization in the AEC industry through the efficient and widespread use of BIM. This study therefore specifically focuses on the use of IFC models in the depiction of condominium rights in the context of 3D land administration evolvement. Another reason for concentrating the use of BIMs is due to challenges regarding the integration of GIS and BIM domains, the so-called GeoBIM. Recent studies point out that although there exists a vast amount of progress for integration between GIS and BIM-based models through being revised standards in terms of modeling approaches, the flowless transformation is not at the expected level in terms of accuracy and consistency (Noardo et al., 2020a). Accordingly, it should be paid attention to prospective conversions between GIS and BIM-based models within information flow regarding the registration of condominium rights.

The representation of the IFC models that current or prospective condominium owners can detailedly view and explore their cadastral rights as 3D is a crucial part of 3D LASs because in this way the probable misinterpretations that might cause problems within land administration practices can be hindered.

As it is known, land valuation and land development are significant elements of the land administration paradigm, and hence LADM Edition II will cover these elements by adding two new packages namely VIM and Spatial Planning. It is thus important to first highlight that there is a huge potential to estimate values of condominium units by means of IFC models that provide a large amount of information regarding attributes that affect the value. A few studies (e.g., (El Yamani et al., 2021; Radulović et al., 2021)) focus on the likely use of IFC models for valuation and/or taxation but this can be enhanced in future studies. Secondly, it is vital to investigate the usability of IFC models for spatial planning purposes since the urban planning checks that restrictions are specified in approved zoning plans are one of the first processes within building permitting (Noardo et al., 2022). In this sense, the conceptual model that can benefit from IFC schema, and related property sets can be extended by taking valuation and spatial planning paradigms into account. By doing so, the conceptual model that encompasses all components of 3D land administration can be achieved.

ACKNOWLEDGEMENTS

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APPENDICES

Table A.1. Property set names, property names, property types, and data types for attributes of *Party* and *Administrative* packages of the developed model.

Property Set Name	Property Name	Property Type	Data Type
TR_Party	name	IfcPropertySingleValue	IfcLable
	surname	IfcPropertySingleValue	IfcLable
	fatherName	IfcPropertySingleValue	IfcLable
	TRpID	IfcPropertySingleValue	IfcInteger
	nationality	IfcPropertyEnumeratedValue	IfcLable
	partyType	IfcPropertyEnumeratedValue	IfcLable

	IDType	IfcPropertyEnumeratedValue	IfcLable
	gender	IfcPropertySingleValue	IfcLable
	dateOfBirth	IfcPropertySingleValue	IfcDate
	placeOfBirth	IfcPropertySingleValue	IfcLable
	phoneNumber	IfcPropertySingleValue	IfcInteger
	role	IfcPropertyEnumeratedValue	IfcLable
TR_GroupParty	groupID	IfcPropertySingleValue	IfcIdentifier
	type	IfcPropertyEnumeratedValue	IfcLable
TR_Administrative Source	journalNumber	IfcPropertySingleValue	IfcInteger
	registrationDate	IfcPropertySingleValue	IfcDateTime
	volume	IfcPropertySingleValue	IfcVolumeMeasure
	pageNumber	IfcPropertySingleValue	IfcInteger
TR_RRR	decription	IfcPropertySingleValue	IfcText
	rID	IfcPropertySingleValue	IfcIdentifier
	share	IfcPropertySingleValue	IfcReal
TR_Right	type	IfcPropertyEnumeratedValue	IfcLable
TR_Mortgage	amount	IfcPropertySingleValue	IfcReal
	startingDate	IfcPropertySingleValue	IfcDateTime
	duration(numberOfMonths)	IfcPropertySingleValue	IfcInteger
TR_BAUnit	tngisID	IfcPropertySingleValue	IfcIdentifier
	type	IfcPropertyEnumeratedValue	IfcLable
	name	IfcPropertySingleValue	IfcLable

Table A2. Property set names, property names, property types, and data types for attributes of *Spatial* package and *Surveying and Representation* sub package of the developed model.

Property Set	Property Name	Property Type	Data Type
TR_Parcel	tngisID	IfcPropertySingleValue	IfcIdentifier
	propertyID	IfcPropertySingleValue	IfcInteger
	area	IfcPropertySingleValue	IfcAreaMeasure
	parcelNumber	IfcPropertySingleValue	IfcInteger
	parcelType	IfcPropertyEnumeratedValue	IfcLable
	blockNumber	IfcPropertySingleValue	IfcInteger
	landUseType	IfcPropertyEnumeratedValue	IfcLable
TR_Building	tngisID	IfcPropertySingleValue	IfcIdentifier
	type	IfcPropertyEnumeratedValue	IfcLable
	name	IfcPropertySingleValue	IfcLable

	numberOfFloor	IfcPropertySingleValue	IfcInteger
	status	IfcPropertyEnumeratedValue	IfcLable
	totalFootprint	IfcPropertySingleValue	IfcInteger
	totalConstructionArea	IfcPropertySingleValue	IfcAreaMeasure
	dateOfBuildingPermit	IfcPropertySingleValue	IfcDateTime
	constructionStartingDate	IfcPropertySingleValue	IfcDate
	constructionEndingDate	IfcPropertySingleValue	IfcDate
	dateOfRenovation	IfcPropertySingleValue	IfcDate
	dateOfDemolition	IfcPropertySingleValue	IfcDate
	measuredHeight	IfcPropertySingleValue	IfcReal
	heightReference	IfcPropertySingleValue	IfcLable
	zoningHeight	IfcPropertySingleValue	IfcReal
	cost	IfcPropertySingleValue	IfcReal
	floorsAboveGround	IfcPropertySingleValue	IfcInteger
	floorsBelowGround	IfcPropertySingleValue	IfcInteger
TR_BuildingElement	ownershipType	IfcPropertyEnumeratedValue	IfcLable
	relatedUnitNumber	IfcPropertySingleValue	IfcInteger
TR_MainUnit	floorNumber	IfcPropertySingleValue	IfcInteger
	area	IfcPropertySingleValue	IfcAreaMeasure
	volume	IfcPropertySingleValue	IfcVolumeMeasure
	tngisID	IfcPropertySingleValue	IfcIdentifier
	type	IfcPropertyEnumeratedValue	IfcLable
	unitNumber	IfcPropertySingleValue	IfcInteger
	landShare	IfcPropertySingleValue	IfcReal
	numberOfBalcony	IfcPropertySingleValue	IfcInteger
	numberOfLivingRoom	IfcPropertySingleValue	IfcInteger
	numberOfOtherRoom	IfcPropertySingleValue	IfcInteger
	numberOfToilet	IfcPropertySingleValue	IfcInteger
	unitUseType	IfcPropertySingleValue	IfcLable
	marketValue	IfcPropertySingleValue	IfcReal
	salesValue	IfcPropertySingleValue	IfcReal
	estimatedValue	IfcPropertySingleValue	IfcReal
	numberOfBathroom	IfcPropertySingleValue	IfcInteger
TR_Annex	relatedUnitNumber	IfcPropertySingleValue	IfcInteger
	type	IfcPropertyEnumeratedValue	IfcLable
TR_SharedFacility	type	IfcPropertyEnumeratedValue	IfcLable

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