# The Development of a Prototype SDI Compliant
# 2D Cadastral Parcels Model to Produce a Cadastral Dataset for Oman

**Salim Al Najashi, Oman**

**Key words**: Cadaster, 2D Cadastral Parcels Model, Land Administration, Spatial Data Infrastructure, Land Administration Domain Model

## SUMMARY

The National Centre for Statistics & Information (NCSI) is the leading body responsible for the Oman National Spatial Data Infrastructure (ONSDI). In the absence of a national cadaster system for land management, research was undertaken to develop a 2D cadastral parcels model for Oman which is compliant with spatial data infrastructures (SDIs) and in line with the International Standard ISO 19152 Land Administration Domain Model (LADM).

INSPIRE and FGDC standard practices together with the existing cadaster dataset at the Ministry of Housing were used to develop the new model which may be used for both SDI and by local authorities for land management.

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## 1. INTRODUCTION

In April 2015, the Oman government appointed the National Centre for Statistics & Information (NCSI) as the leading body responsible for the Oman National Spatial Data Infrastructure (ONSDI) (NCSI 2015). A Technical Committee was formed from different organizations to prepare a data content standard framework. The ONSDI regards Cadastral Parcels as a core theme, central to its mission. The Ministry of Housing, are responsible for cadastre maps, land distribution and land registration in Oman. The country does not have a cadastre system, but it does have a system of compulsory land registration.

The research aims to provide Oman with a 2D cadastral parcels model that is fully compliant with international standards and will serve local authorities well in their management of land resources.

### 1.1 2D Cadastral Parcels Model

The development of a 2D cadastral parcels data model is essential in order to produce a very high accuracy, large-scale vector database (surveyed at 1:2,500 in urban areas and 1:5000 in rural areas). This seamless database (base map) will be employed to create coherent mapping so that local authorities can use it for land management. The same datasets can be utilized by the SDI authority to generate SDI framework data themes. A cadastral parcels dataset for SDI and a land management system can be created easily because their feature objects (points, lines and polygons) were would have been taken into consideration while producing the base map.

Cadastral datasets encompass a wide range of spatial data entities that are fundamental to many GIS applications. Cadastral data is normally considered a key element of base maps and serves as essential reference data in this context (FGDC 2012). Both FGDC and INSPIRE, have in their reference documents and guidelines, considered cadastral spatial information as reference data for SDI at a national level.

### 1.2 Land Administration Domain Model

The Land Administration Domain Model (LADM) was published on 1st December 2012 as an international standard (IS) by the International Organization for Standardization as ISO 19152 (ISO 2012). LADM is a descriptive conceptual model which focuses not only on the description of rights to land, but also on the representation of restrictions and responsibilities (RRR) affecting land and the spatial representations of their associated "legal space" (Acinelli, 2014).

The Land Administration Domain Model (LADM) aims to support 'an extensible basis for efficient and effective cadastral system development based on a Model Driven Architecture (MDA)', (EC INSPIRE, 2014). In addition, it allows 'involved parties, both within one country and between

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different countries, to communicate based on the shared ontology implied by the model' (EC INSPIRE, 2014).

The core LADM consists of four basic classes (see Figure 1):

1. Class **LA_Party**. Instances of this class are parties. The definition of 'party' implies that a party may be a natural person (owner), or a group of natural persons, or a non-natural person (Lemmen, Van Oosterom, Eisenhut & Uitermark 2010) (see Figure 2).
2. Class **LA_RRR**. Instances of subclasses of LA_RRR are rights, restrictions or responsibilities.
3. Class **LA_BAUnit**. Instances of this class are basic administrative units (Basic Property Unit). A "Basic Property Unit" *(BPU)* is defined by UN/ECE, 1996 as "*the extent of land that is one unit of ownership. It may consist of one or more adjacent or geographically separate parcels. A farm, for example, may have a number of fields that are in different locations but together they constitute one BPU. Likewise, a house may have a garage on a separate piece of land* (Lemmen, Van Oosterom, Eisenhut & Uitermark 2010).
4. Class **LA_SpatialUnit**. Instances of this class are spatial units (parcels and the legal space of the building and utility networks).
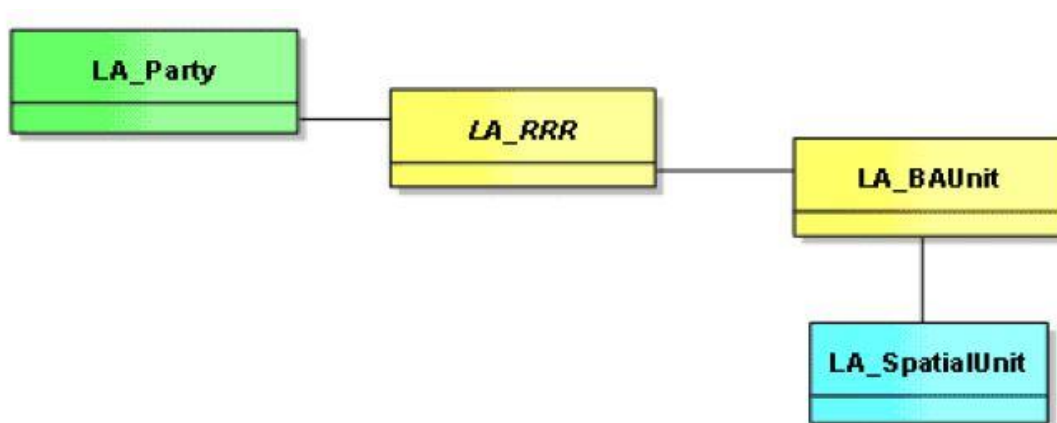


Figure 1 The LADM four basic classes

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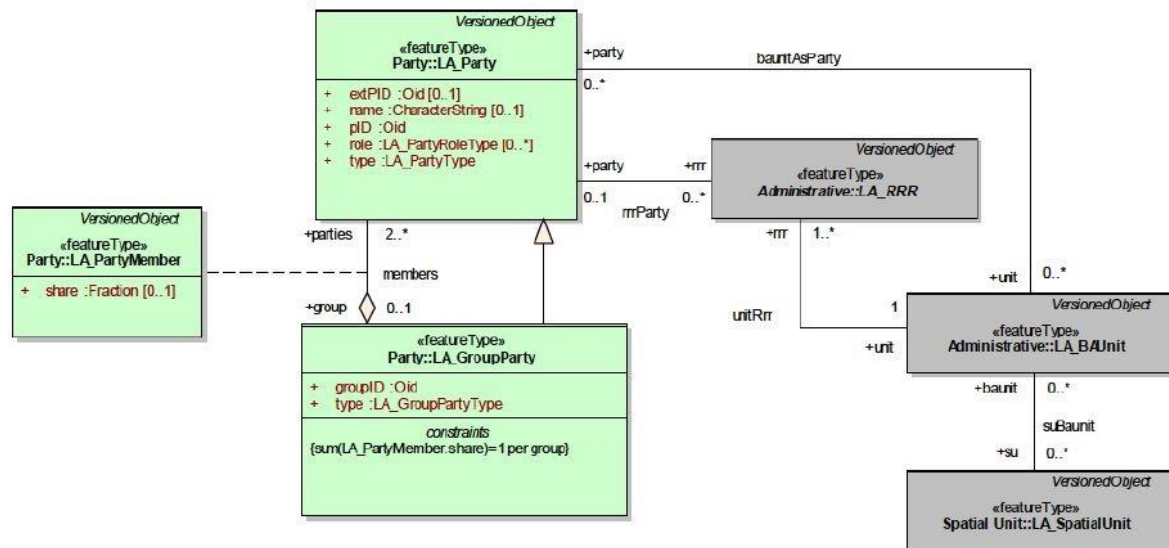Helsinki, Finland, May 29–June 2, 2017

Figure 2 Content of Party Package and association to other basic classes

## 2. METHODOLOGY

To accomplish the research objectives, a study of standard practices related to the development of a cadastral data model was carried out. The following two cadastral documents were utilized in the development of a new 2D cadastral parcels model for SDI and local authorities in Oman:

1. Infrastructure for Spatial Information in Europe (INSPIRE), D2.8.I.6 Data Specification on Cadastral Parcels – Technical Guidelines.
2. Federal Geographic Data Committee (FGDC), FGDC-STD-014.1-2008 Geographic Information Framework Data Content Standard – Part 1: cadastral documents.

The focus of the study was on the framework data content and technical specifications.

An examination of the existing situation regarding the cadastral and land registration in Oman was conducted to determine a base maps and databases used for cadastral mapping and land registration. Emphasis was placed in this context on the content of the database tables. To ascertain the prevailing situation, interviews were held with Ministry of Housing officials in the General Directorate of Town Planning and Survey (GDTPS), as well as the General Directorate of Lands (GDL) and Land Registry Secretariat (LRS).

### 2.1 Standard Practice of 2D Cadastral Parcels Model

2.1.1 INSPIRE – Cadastral Parcel

In 2014, INSPIRE issued the Data Specification on Cadastral Parcels – Technical Guidelines document which described the main geographic feature types of the cadastral parcel dataset. INSPIRE includes four feature type classes, CadastralParcel (areas defined by cadastral registers or

equivalent), CadastralZoning (intermediary areas (such as municipalities, sections, blocks, …) used in order to divide national territory into cadastral parcels.), CadastralBoundary (absolute positional accuracy information for the cadastral boundary) and BasicPropertyUnit (basic units of ownership that are recorded in the land books, land registers or equivalent) (EC INSPIRE, 2014). Figure 3 shows the Application Schema of the cadastral parcel with four feature type classes.

The LADM-based version of INSPIRE cadastral parcels, shows that the INSPIRE development fits within the LADM and that there are no inconsistencies. In the INSPIRE context, four classes are relevant to LADM (EC INSPIRE, 2014):
- LA_Parcel as a basis for CadastralParcel,
- LA_LAUnit as a basis for BasicPropertyUnit,
- LA_FaceString as a basis for CadastralBoundary,
- LA_SpatialUnitSet as a basis for CadastralZoning.

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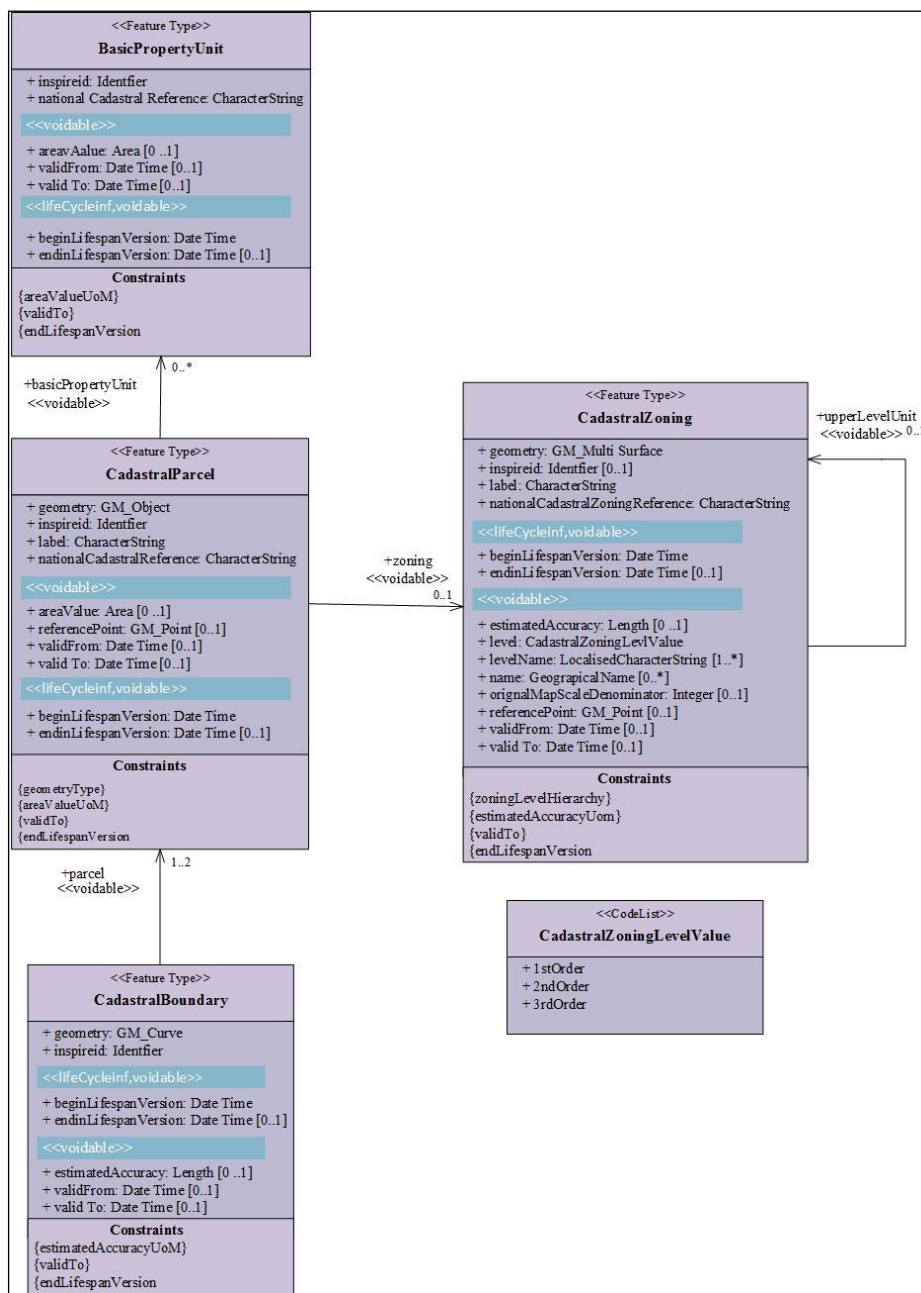Helsinki, Finland, May 29–June 2, 2017

Figure 3 Cadastral Parcel UML class diagram

## 2.1.2 FGDC – Cadastral

In 2008, the FGDC published the Geographic Information Framework Data Content Standard – Part 1: Cadastral document which identified the Parcel as the primary class for the Cadastral part The five Cadastral classes are, Parcel Class (the main class that conveys cadastral information), Owner Type Class (is a code list of valid values that classify the owner type), Parcel Source Class (groups elements regarding each parcel and its source information), Parcel Geometry Class (represents a choice between a centroid or polygon representation of the parcel) and Parcel Collection Class

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(introduced for conformance with the other geographic information framework data content standard parts in SDI) (FGDC 2008). Figure 4 shows the Application Schema of the five cadastral classes.
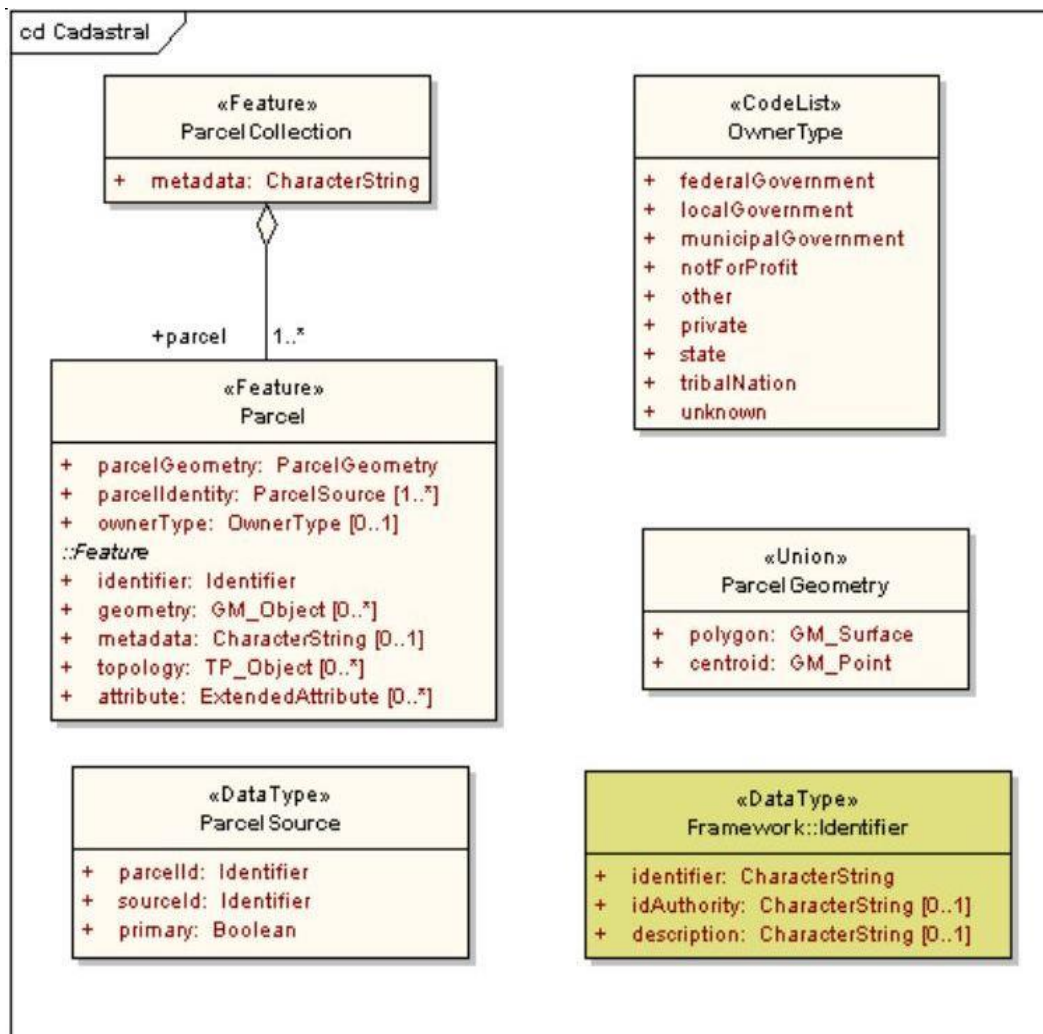


Figure 4 Cadastral UML model

## 2.2 Cadastral System in Oman

Oman does not have a cadastre system, but it does have a system of compulsory land registration. The General Directorate of Town Planning and Survey (GDTPS), General Directorate of Lands (GDL) and Land Registry Secretariat (LRS), under the Ministry of Housing, are responsible for the cadastre maps, land distribution and land registration (Ministry of Legal Affairs 2015).

The land registration in Oman uses fixed boundary system, where the precise line of the boundary is determined by land surveys, which are, in turn, expressed by co-ordinates (O'Brien and Prendergast 2011). According to Article 14 of the Royal Decree no.2/98, "Registration in accordance with the provisions of this System shall be based on accurate geometrical surveying works on which the

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identification of the landed unit, its location, its geometrical shape and whatever it includes shall be performed accordingly".

An Oracle database (non-spatial) used by the LRS and GDL is available. The LRS database contains 24 main attributes (Table 1). The survey departments (Cadaster) use a Spatial SQL Server database to produce the title site plan (a printed "krookie") for the planned areas (Press 1997). The GDL (Cadaster) database contains four main tables of attributes used to store data related to site plans (see Tables 4 – 5). Figure 6 shows the title/site plan and the related SQL server database table attributes.

The two databases work separately. They are linked in such a way (partially integrated) that the Survey Department can gain the auxiliary information that is required to issue the title site plan document for the land parcel. At the same time, it enables the LRS and Land Department to obtain the plot number (Parcel Id) and the national cadastral serial reference number.

The survey department (Cadastre) uses digital large-scale maps (Arc/Info and AutoCAD formats 1:5000 tiles) produced by the National Survey Authority (NSA) between 1992 and 1996 for urban areas as base maps (Press 1997). Hard copy maps (mylar drawings) produced in 1982, are still used as legal references for validation after field work to avoid overlaps within property boundaries (land parcels) in congested areas.

AutoCAD software is used for developing new land parcel plans after conducting a detailed survey of the selected site (see Figure 5). New land parcels are generally staked out according to plans, with relative cm-level accuracy. The boundary points are temporarily marked by iron bars in the ground before being delivered to the Omani citizens, as per the coordinates are shown in the title site plan (Figure 6).

Table 1 Main Land Registration System attribute fields:

| ID | Field | Type | Description |
|---|---|---|---|
| 1 | REGN_CODE | varchar (255) | Region Name |
| 2 | WLYA_CODE | varchar (255) | Willayat Name |
| 3 | VILG_CODE | varchar (255) | Village Name |
| 4 | PLAN_NO | varchar 255) | Plan number |
| 5 | PLT1_NO | varchar (255) | Plot number1 |
| 7 | PLT2_NO | varchar (255) | Plot number2 |
| 6 | HOUS_NO | varchar (255) | House no for social affair |
| 7 | ZONE_NO | varchar (255) | Governorate |
| 8 | ROFC_NO | number (10) | Ministry of Housing office |
| 9 | PUSE | number (10) | Land use |
| 10 | PAR_PIN | nvarchar (255) | Serial number of the land |
| 11 | PAR_AREA | number (10) | Land area |
| 12 | PAR_VALUE | number (10) | Land value |

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| 13 | DOC_NO | number (10) | Document no |
| 14 | USER_NO | number (10) | User no |
| 15 | LST_UPD | date | Last update |
| 16 | CLAM_CODE | number (10) | Reasons of ownership |
| 17 | AGREMENT_NO | varchar 255) | Agreement no |
| 18 | SUB_PUSE_CODE | number (10) | Sub land use |

Table 2 - Land use attribute fields:

| ID | Field | Type | Description |
|---|---|---|---|
| 1 | ID | Int IDENTITY(11) NOT NULL | Primty Field - Auto-increment |
| 2 | Geo_ID | Int | Foreign key - Geometry Table (ID) |
| 3 | LandUse | nvarchar (255) | Landuse of the plot |
| 4 | Sub_LandUse | nvarchar (255) | Sub-Landuse of the plot |
| 5 | User | nvarchar (255) | UserID updated the data |
| 6 | In_Timer | datetime | Date and time of data insertion |
| 7 | Up_Timer | datetime | Date and time of data update |

Table 3 – Geometry attribute fields:

| ID | Field | Type | Description |
|---|---|---|---|
| 1 | ID | int IDENTITY(11) NOT NULL | Primty Field – Auto-increment |
| 2 | Status | nvarchar (255) | Status of the land (Active, Deleted) |
| 3 | PAIN | nvarchar (255) | Serial number of the land |
| 4 | REGION | nvarchar 255) | Arabic Region Name in printed krookie |
| 5 | E_REGION | nvarchar (255) | English Region Name in printed krookie |
| 7 | WILLAYAT | nvarchar (255) | Arabic Willayat Name in printed krookie |
| 6 | E_WILLAYAT | nvarchar (255) | English Willayat Name in printed krookie |
| 7 | VILLAGE | nvarchar (255) | Arabic Village Name in printed krookie |
| 8 | E_VILLAGE | nvarchar (255) | English Village Name in printed krookie |
| 9 | BLOCK | nvarchar (255) | Arabic Block Name in printed krookie |
| 10 | E_BLOCK | nvarchar (255) | English Block Name in printed krookie |
| 11 | Plot_Num | int | Plot number |
| 12 | AREA | float | Area of the land |
| 13 | CENTROID | nvarchar (255) | Centroid (X,Y) of the land |
| 14 | Users | nvarchar (255) | UserID updated the data |
| 15 | GIScoord | geometry | Coordinates of the land |
| 16 | Up_Timer | datetime | Date and time of data insertion |
| 17 | In_Timer | datetime | Date and time of data update |
| 18 | Parent | nvarchar (max) | ID/IDs of related plots (e.g. Merge, Split) |

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Table 4 Condition attribute fields:

| ID | Field | Type | Description |
|----|-------|------|-------------|
| 1 | ID | int IDENTITY(11) NOT NULL | Primty Field – Auto-increment |
| 2 | Geo_ID | int | Foreign key – Geometry Table (ID) |
| 3 | Floors | nvarchar(255) | Number of floors |
| 4 | Height | nvarchar(255) | Land permitted height |
| 5 | B_Area | nvarchar(255) | Permitted built area |
| 6 | SB_Front | nvarchar(255) | Set Backs – Front |
| 7 | SB_Back | nvarchar(255) | Set Backs – Back |
| 8 | SB_Side | nvarchar(255) | Set Backs – Sides |
| 9 | Parking | nvarchar(255) | Permitted parking type (Inside Land, Outside Plot) |
| 10 | Conditions | nvarchar(255) | Any other conditions to the plot |
| 11 | Users | nvarchar(255) | UserID updated the data |
| 12 | In_Timer | datetime | Date and time of data insertion |
| 13 | Up_Timer | datetime | Date and time of data update |

Table 5 Title/site plan attributes fields: (Ministry of Housing 2015b)

| ID | Field | Type | Description |
|----|-------|------|-------------|
| 1 | ID | int IDENTITY(11) NOT NULL | Primty Field - Auto-increment |
| 2 | Geo_ID | int | Foreign key - Geometry Table (ID) |
| 3 | LandUse_ID | int | Foreign key - Landuse Table |
| 4 | Condition_ID | int | Foreign key - Condition Table |
| 5 | PAIN | nvarchar(255) | Serial Number of the land |
| 6 | SCALE_IN | nvarchar(255) | The Inner scale of printed krookie |
| 7 | SCALE_OUT | nvarchar(255) | The Out scale of printed krookie |
| 8 | BATH | nvarchar(255) | Folder path where the krookie is stored |
| 9 | User | nvarchar(255) | UserID updated the data |
| 10 | In_Timer | datetime | Date and time of data insertion |
| 11 | Up_Timer | datetime | Date and time of data update |
| 12 | WILLAYAT | nvarchar(255) | Arabic Willayat Name in printed krookie |
| 13 | E_WILLAYAT | nvarchar(255) | English Willayat Name in printed krookie |
| 14 | VILLAGE | nvarchar(255) | Arabic Village Name in printed krookie |
| 15 | E_VILLAGE | nvarchar(255) | English Village Name in printed krookie |
| 16 | BLOCK | nvarchar(255) | Arabic Block Name in printed krookie |
| 17 | E_BLOCK | nvarchar(255) | English Block Name in printed krookie |

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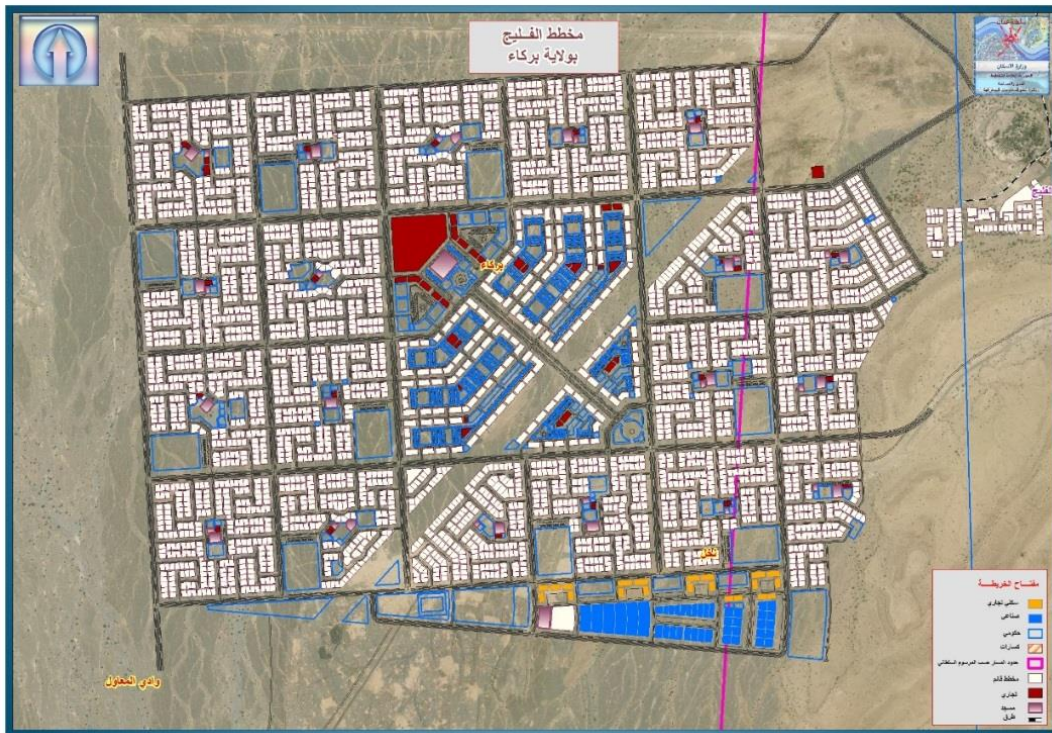Helsinki, Finland, May 29–June 2, 2017

Figure 5 New proposal plan for specific area

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Figure 6 Title site plan and related SQL server database tables

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# 3. RESULTS AND DISCUSSION

## 3.1 New 2D Cadastral Parcels Model

The study of the existing cadastral dataset in the Ministry of Housing along with the SDI cadastral parcels data content and (its) specification on the national reference framework in INSPIRE and FGDC revealed an absence of seamless data available at the national level in Oman. The available features were not structured according to a national hierarchical structure. The available features of cadastral parcels are exclusively represented by points and lines and do not include any unique feature identifier code.

The new 2D cadastral parcels model was developed to establish a common baseline for the semantic content of the cadastral databases which is compliant with the SDI and in line with LADM. The Basic Administrative Unit (LA_BAUnit class) will be called **Basic Property Unit** which is associated with LA_Party and Administrative LA_RRR. A natural person or owner will be represented as a separate object type (belonging to the LA_Party Class), see Figure 2.

The principles of design for the 2D cadastral parcels conceptual model are as follows:
1. It should be as simple as possible in order to be useful in practice.
2. It should cover the basic data related to the existing cadastral and land registration in the Ministry of Housing. It should also consider the requirements of international best practice available for 2D cadastral for SDI.
3. It should be compatible with Land Administration Domain Model (LADM).

The proposed 2D cadastral (parcel's) conceptual model, with full comprehensive of the attribute tables (6 – 14), was sent to the Ministry of Housing for comments. They were satisfied and believed that the overall model covered all cadastral features and registration requirements. However, they noticed that the attribute fields pertaining to planning conditions, shown in Table 4 were not included in the model as a feature type. Figure 7 shows a UML class diagram of the Cadastral Parcels first model application schema.

Table 6 – Cadastral Parcel attributes:

| Name | Domain | Definition |
|---|---|---|
| Geometry | | Geometry of the cadastral boundary. |
| Parcelid | | A unique parcel identifier for the parcel as defined by the response body. |
| Label | | Text commonly used to display the cadastral parcel identification. |
| National Cadastral Reference | | Thematic identifier at national level, generally the full national code of the basic property unit. |
| Area Parcel | | Registered area value giving quantification of the area projected on the horizontal plane of the cadastral parcels composing the basic property unit. |
| Reference Point | | A point within the cadastral parcel. Can be a parcel centroid. |
| Land Use Code | Land Use | Land use classification code. |
| Valid From | | Official date and time the basic property unit was/will be legally established. |
| Valid To | | Date and time at which the basic property unit legally ceased/will |

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| | | cease to be used. |
|---|---|---|
| Begin Life span Version | | Date and time at which this version of the spatial object was inserted or changed in the spatial dataset. |
| End Life span Version | | Date and time at which this version of the spatial object was superseded or retired in the spatial data set. |

Table 7 – CadastralZoning attributes:

| Name | Domain | Definition |
|---|---|---|
| Geometry | | Geometry for the cadastral zoning. |
| Parceled | | A unique parcel identifier for the parcel as defined by the response body. |
| Label | | Text commonly used to display the cadastral zoning identification. |
| National Cadastral Zoning Reference | | Thematic identifier at national level, generally the full national code of the cadastral zoning. |
| Begin Lifespan Version | | Date and time at which this version of the spatial object was inserted or changed in the spatial dataset. |
| End Lifespan Version | | Date and time at which this version of the spatial object was superseded or retired in the spatial data set. |
| Estimated Accuracy | | The estimated absolute positional accuracy of cadastral parcels within the cadastral zoning in the used SDI's coordinate reference system. |
| Level | Level Value | Level of the cadastral zoning in the national cadastral hierarchy. |
| Level Name | | Name of the level of the cadastral zoning in the national cadastral hierarchy. |
| Name | | Name of the cadastral zoning. |
| Original Map Scale Denominator | | The denominator in the scale of the original paper map (if any) to whose extent the cadastral zoning corresponds. |
| Reference Point | | A point within the cadastral zoning. |
| Valid To | | Date and time at which the basic property unit legally ceased/will cease to be used. |
| Valid From | | Official date and time the cadastral zoning was/will be legally established. |

Table 8 – CadastralBoundary attributes:

| Name | Domain | Definition |
|---|---|---|
| Parcelid | | A unique parcel identifier for the parcel as defined by the response body. |
| Geometry | | Geometry of the cadastral boundary. |
| Estimated Accuracy | | Estimated absolute positional accuracy of the cadastral boundary in the used SDI's coordinate reference system. |
| Valid From | | Official date and time the basic property unit was/will be legally established. |
| Valid To | | Date and time at which the basic property unit legally ceased/will cease to be used. |
| Begin Life span Version | | Date and time at which this version of the spatial object was inserted or changed in the spatial dataset. |
| End Life span Version | | Date and time at which this version of the spatial object was superseded or retired in the spatial data set. |

Table 9 – PropertyRight attributes:

| Name | Domain | Definition |
|---|---|---|
| Parceled | | A unique parcel identifier for the parcel as defined by the response body. |

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| | | |
|---|---|---|
| National Cadastral Reference | | Thematic identifier at national level, generally the full national code of the basic property unit. |
| Area Parcel | | Registered area value giving quantification of the area projected on the horizontal plane of the cadastral parcels composing the basic property unit. |
| Owner ID | | A unique identification number for Omani citizens and equivalent with other nations. |
| Owner Name | | Name of the parcels owners |
| Owner Type | Owner Type | Owner type is the classification of the owner. |
| Valid From | | Official date and time the basic property unit was/will be legally established. |
| Valid To | | Date and time at which the basic property unit legally ceased/will cease to be used. |
| Begin Lifespan Version | | Date and time at which this version of the spatial object was inserted or changed in the spatial dataset. |
| End Lifespan Version | | Date and time at which this version of the spatial object was superseded or retired in the spatial data set. |

Table 10 – LandUse Code table

| Name | Definition |
|---|---|
| residential. | Residential land use |
| Commercial | Commercial land use |
| Industrial | Industrial land use |
| Agriculture | Agriculture land use |
| Tourist | Tourist land use |
| governmental | Governmental land use |
| Diplomatic | Diplomatic land use |
| Other | Other lands use |

Table 11 – BasicPropertyUnit attributes:

| Name | Domain | Definition |
|---|---|---|
| Parcelid | | A unique parcel identifier for the parcel as defined by the response body. |
| National Cadastral Reference | | Thematic identifier at national level, generally the full national code of the basic property unit. |
| Area Parcel | | Registered area value giving quantification of the area projected on the horizontal plane of the cadastral parcels composing the basic property unit. |
| Owner Name | | Name of the parcels owners |
| Valid From | | Official date and time the basic property unit was/will be legally established. |
| Valid To | | Date and time at which the basic property unit legally ceased/will cease to be used. |
| beginLifespan Version | | Date and time at which this version of the spatial object was inserted or changed in the spatial dataset. |
| endLifespan Version | | Date and time at which this version of the spatial object was superseded or retired in the spatial data set. |

Table 12 – CadastralZoning Level Value table:

| Name | Definition |
|---|---|
| Governorate | Governorate zone where the parcels is a located |

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| Willayat | Willayat zone where the parcels is a located |
|---|---|
| Village | Village zone where the parcels is a located |
| Phase | Phase zone where the parcels is a located in the plan |

Table 13 – OwnerType table:

| Name | Definition |
|---|---|
| State Government | The Omani state government and its agencies and departments |
| Company | A company or multiple companies |
| Private | An individual, or group of individuals |
| Other | Any other organization |
| Unknown | The type of ownership is not known |

Table 14 – OwnerName table:

| Name | Definition |
|---|---|
| Owner Name | Owner name |
| Owner Address | Owner address |

The planning conditions are a part of the administrative package concerning the abstract class LA_RRR, Restriction in LADM. The planning conditions are very important because they act as a guide for land restriction it is therefore necessary to include the planning conditions in the proposed new 2D cadastral parcel model. The feature type Restriction Planning Condition will be added to the model.

*Restriction Planning Condition:*

This feature type is related to the land parcel's administrative restriction conditions. These conditions were set by the Ministry of Housing to encourage the owner of the land to refrain from making alterations within the parcels. The conditions cover land use and specify a maximum height, parking, the number of floors, the percentage of the built-up area of the ground and side defections from the parcel boundary when under construction. Table 15, shows the recommended attributes for the Restriction Planning Condition.

Table 15 – Restriction Planning Condition attributes.

| Name | Domain | Definition |
|---|---|---|
| Parcelid | | A unique parcel identifier for the parcel as defined by the response body. |
| nationalCadastralReference | | Thematic identifier at national level, generally the full national code of the basic property unit. |
| areaParcel | | Registered area value giving quantification of the area projected on the horizontal plane of the cadastral parcels composing the basic property unit. |
| landUse | | Type of parcels land use. |
| height | | Maximum height of the building within the parcel. |
| Floors | | Number of floors. |
| built-upArea | | Percentage of building area of ground of the parcels |
| setBacks | | Side defections from the parcel boundary when construction. |
| Parking | | Parking condition within the parcel. |
| Others | | Others special condition maybe require |
| validFrom | | Official date and time the basic property unit was/will be legally |

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| | | |
|---|---|---|
| | | established. |
| validTo | | Date and time at which the basic property unit legally ceased/will cease to be used. |
| beginLifespanVersion | | Date and time at which this version of the spatial object was inserted or changed in the spatial dataset. |
| endLifespanVersion | | Date and time at which this version of the spatial object was superseded or retired in the spatial data set. |

The UML in Figure 8 shows the class diagram of the cadastral parcel's revised model application schema after amendments made following the ministry's feedback. In the revised 2D cadastral parcel model, the two Administrative Packages, Right (PropertyRight) and Restriction (RestrictionPlanningCondition) of the LADM are presented. The third package (Responsibility) was not considered in the revised model, because it is a different system, which will be incorporated in another database.

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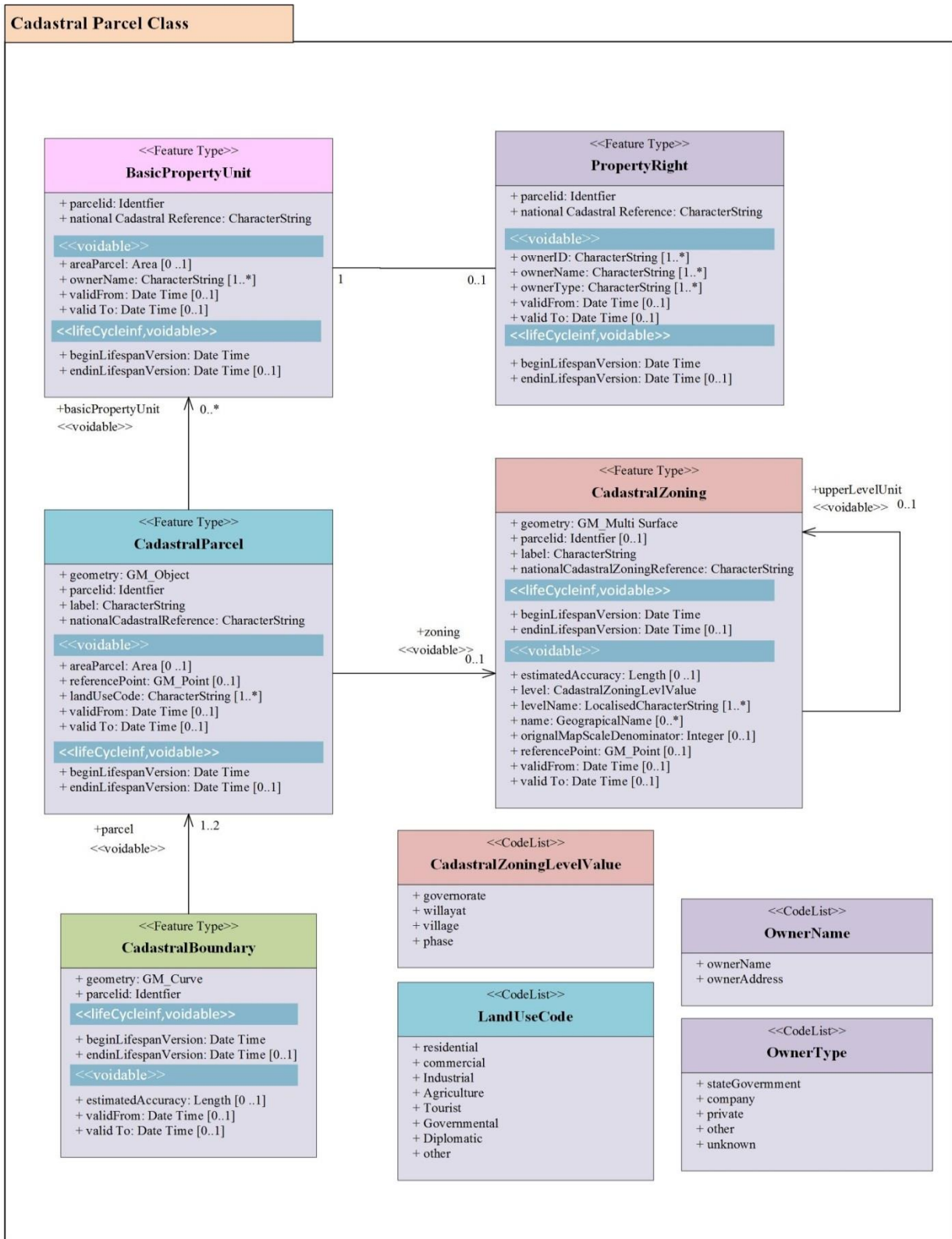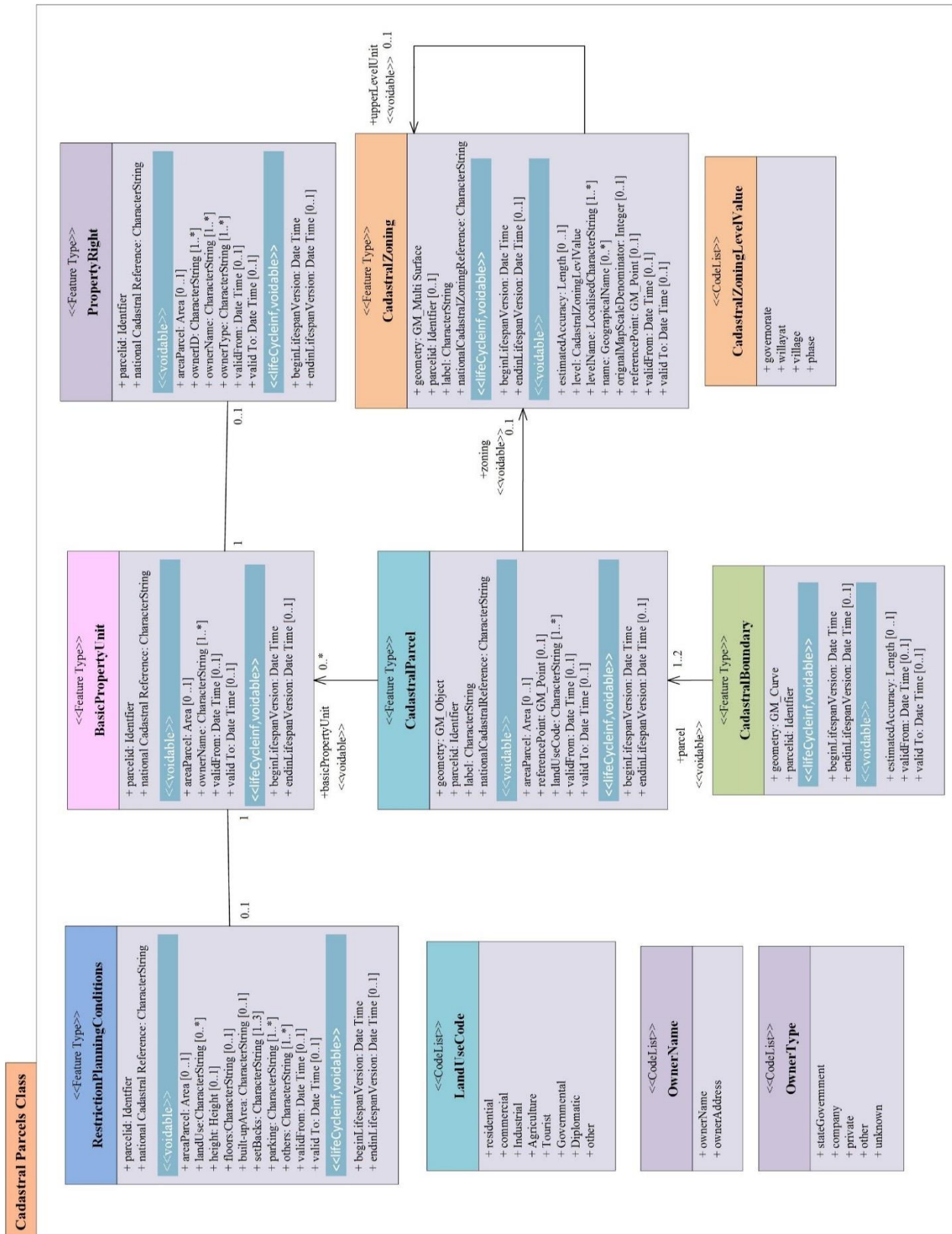Helsinki, Finland, May 29–June 2, 2017

Figure 7 UML class diagram of the Cadastral Parcels first model application schema

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Figure 8 UML class diagram of the Cadastral Parcels revised model application schema

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The newly- developed 2D cadastral parcels main four feature type classes (CadastralParcel, BasicPropertyUnit, CadastralBoundary, CadastralZoning) are all relevant to LADM and can be used for ONDSI cadastral parcels as shown in Figure 9 (EC INSPIRE, 2014).
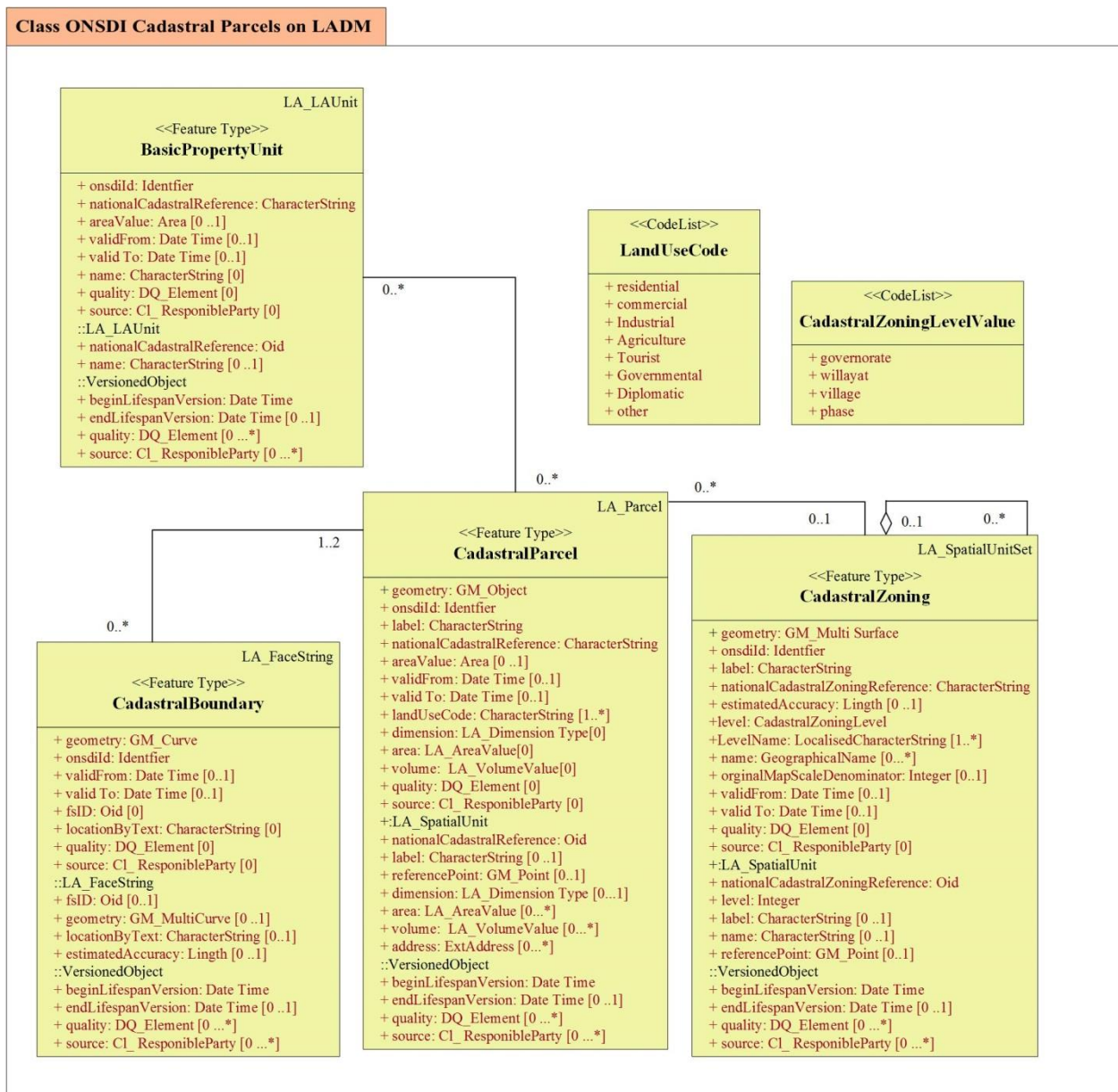


Figure 9 The ONSDI proposed cadastral parcels model derived from ISO LADM

## 4. CONCLUSIONS

The results obtained from the standard practices of INSPIRE and FGDC and the cadaster features attribute tables from the Ministry of Housing, contributed towards the development of a 2D cadastral parcels model for Oman. The proposed model includes the Ministry of Housing cadaster

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features attribute tables and is compliant as far as possible with SDI requirements at a national level. The model is in line with ISO 19152 LADM.

To utilize the new 2D cadastral parcels model, the Ministry of Housing and National Centre for Statistics & Information (NCSI) can discuss the possibility of using the model to generate a Digital Cadastral Database (DCDB) with the National Survey Authority (NSA). The latest high-resolution survey aerial photos can be used to produce DCDB. The captured cadastral parcel feature objects (points, lines and polygons) can then be checked and updated against the Ministry of Housing cadastral mapping (digitizing) and survey data to correct boundary deficiencies before the final issue of the cadastral geo-database. This process will create accurate data for the cadastral parcels at a national level.

Other regional and local authorities in Oman, such as municipalities and electricity and water utility companies can also avail of this model in future when they develop their land management services' framework. It is expected that part of the data model will be modified during testing and the data gathering approach will be used to populate the DB (e.g. the imagery and digitizing) to suit the fulfil the requirements of different authorities.


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## BIOGRAPHICAL NOTES

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